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Framing British Columbia's low-carbon future:

Identifying the skills and workforce needs of BC's growing mass timber sector

PLACE Centre
Smart Prosperity Institute

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Abbreviations

3D	Three-dimensional
AAC	Annual allowable cut
BC	British Columbia
BIM	Building information modelling
CAD	Computer-aided design
CAM	Computer-aided manufacturing
CLT	Cross-laminated timber
CNC	Computer numerical control
DfMA	Design for Manufacturing and Assembly
GLULAM	Glue-laminated timber
MEP	Mechanical, electrical, and plumbing
NAICS	North American Industry Classification System
NOC	National Occupational Classification
O*NET	Occupational Information Network
SME	Small and medium-sized enterprises

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Executive summary

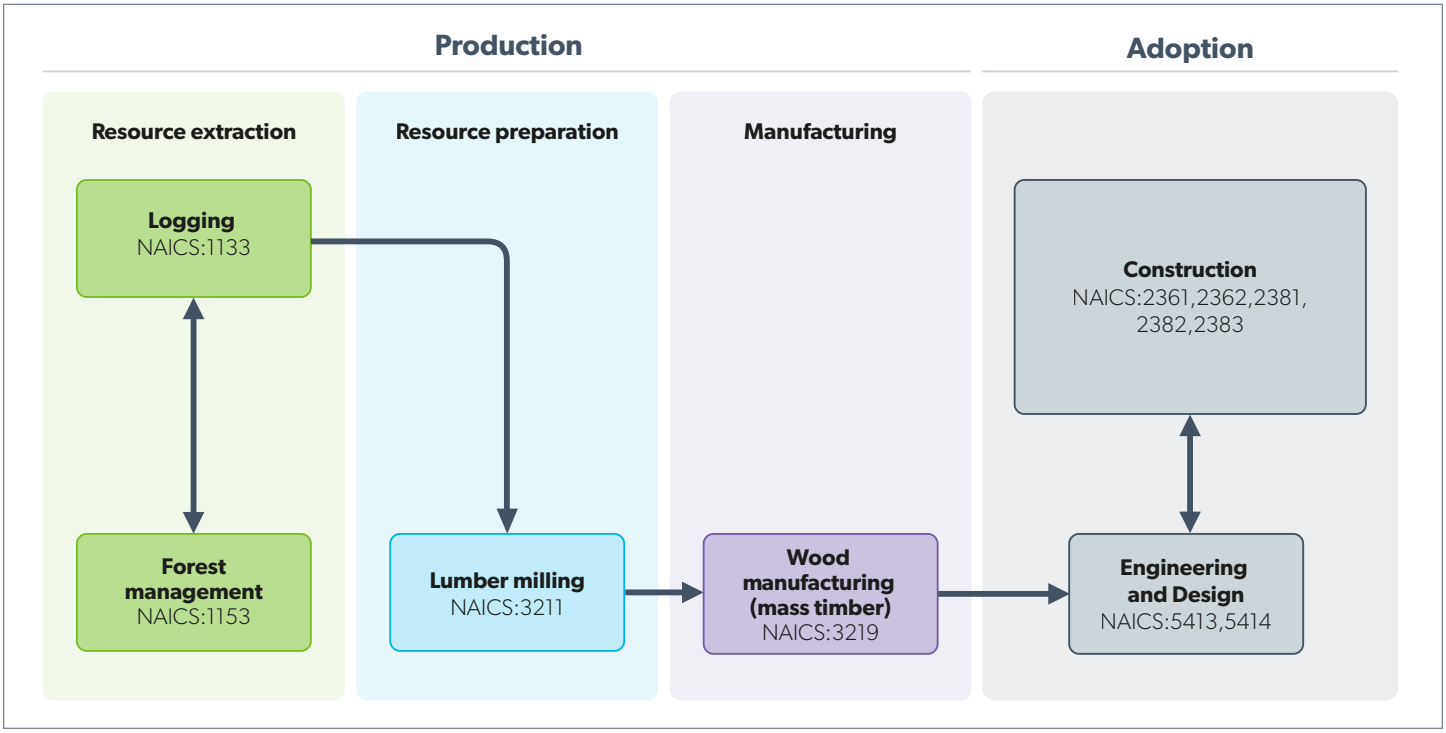
Stakeholders across British Columbia (BC) are exploring the potential of mass timber to support economic growth. Mass timber, an engineered wood product used as a building material, could offer economic benefits for many industries, from forestry to manufacturing to design to construction. Projections by the Government of British Columbia foresee the creation of roughly 4,000 direct and indirect jobs from mass timber by 2035. Despite this relatively modest overall potential, the opportunity has proven attractive to provincial stakeholders for two primary reasons. First, the solution's economic and environmental benefits could help tackle multiple challenges simultaneously.

Mass timber can be used to build more housing, reduce greenhouse gas emissions from new construction, and create jobs manufacturing value-added products in the province's forestry sector.

All three goals are stated objectives of the provincial government, and any solution that could further these goals simultaneously will attract attention. Second, even if mass timber production and adoption are unlikely to prove transformative for the province as a whole, they can still offer economic benefits to a number of communities. Rural and resource communities exploring avenues for future job creation, alongside companies designing and constructing sustainable buildings, could benefit from pursuing this opportunity. For these reasons, mass timber merits attention. Understanding how to support this opportunity will be key in achieving policy objectives and capturing its economic benefits for resource communities, as well as informative as a case study for unpacking how novel technologies will impact different industries in the years to come.

This report identifies what the growth of mass timber in BC means for workers. It details the emerging supply chain for mass timber, as seen in Figure 1, and divides the discussion into production (sectors involved in creating mass timber panels, including resource extraction, resource preparation, and manufacturing) and adoption (sectors involved in using mass timber panels in buildings, such as design and construction). These are two distinct supply chains, as one could grow without corresponding growth in the other (i.e., panels manufactured in BC could be exported to other markets, and panels manufactured elsewhere could be used in BC). However, both are relevant when discussing the future of mass timber within the province. This report then identifies how the growth of mass timber could change the skills needs of workers, provides an overview of existing training programs in the mass timber space in BC, and offers recommendations on how the province can best develop and support the workforce needed to seize this opportunity.

Figure 1: Supply chain for mass timber



Key findings

Mass timber does not represent a transformation for the forestry sector or any other industry involved in the supply chain. Rather, it is a small but growing opportunity that could offer the province and some of its forestry-dependent communities a rare chance to tackle some of their greatest issues simultaneously.

The BC government currently projects the potential for ten new mass timber facilities to be built in the province by 2035, creating an estimated 2,350 — 4,230 new jobs in forestry, manufacturing, technology and engineering, and design.[1] The province's forestry sector currently creates around 50,000 direct jobs and supports an additional 100,000 jobs. This highlights that mass timber's fully realized potential would still only represent a small percentage of jobs in all sectors involved in the supply chain across the province.[2] However, forestry-dependent communities affected by the downturn of the traditional forestry sector could leverage this growing opportunity to diversify their local economies.

Mass timber discussions should be divided into two separate opportunities: production and adoption.

Producing mass timber panels involves all activities ranging from logging to manufacturing panels and includes sectors like forestry, transportation, and manufacturing. There are currently nine active mass timber production facilities in BC. Adoption, on the other hand, involves all activities that install or use mass timber panels in construction projects, including some manufacturing activities (given mass timber panels' pre-fabricated nature), design, and construction. Two hundred eighty-four construction projects have been completed using mass timber in BC as of the end of 2020.[3]

These two sides of the supply chain may not grow at identical rates.

Panels produced in BC could be exported to other markets, while panels used for BC construction projects could be imported from elsewhere. Importantly, workforce impacts will be concentrated in sectors where growth occurs. For example, in scenarios with high production volumes but low adoption, we can expect substantial workforce impacts in resource extraction, resource preparation, and manufacturing but limited impacts in construction and design.

BC stakeholders identified three variables that would shape the outlook of the overall mass timber opportunity: timber supply, uncertainty around future demand, and a lack of coordination across production and adoption.

The supply of wood has been impacted by reductions in annual allowable cut (AAC) volumes, as well as the design of the quota system. Ensuring a predictable supply of high-quality wood fibre is critical for mass timber manufacturing. Additionally, while mass timber products can be used in a range of projects, it remains uncertain how large the end-use market is and where demand will be largest. Finally, a lack of coordination is a challenge. One example of this challenge is that manufacturing firms, who have

Key findings

traditionally been more engaged within the forestry sector, have cited a lack of familiarity with the vocabulary of the construction sector as an obstacle for growth.

Stakeholders expect mass timber to grow, but there is uncertainty around the growth trajectory.

Overall, there is great confidence amongst stakeholders that mass timber will experience further growth. However, there is uncertainty around the growth trajectory. A majority of survey respondents (57%) believe that mass timber will experience slow but steady growth in BC. The remaining (43%) believe that mass timber will quickly overcome the challenges limiting its growth.

Stakeholders identified that building codes and uncertainty from financiers are two key barriers preventing or slowing down the adoption of mass timber.

Stakeholders identified that one of the barriers to the adoption of mass timber includes current local government policies in BC, such as the slow adoption of building code changes required to permit the construction of taller mass timber buildings (>12 storeys). Others felt that uncertainties from financiers, such as banks and insurance companies, would prove a challenge for increasing the adoption of mass timber, as mass timber structures were typically seen as riskier and less safe than conventional alternatives.

Opportunities exist for upskilling workers from other industries to become more acquainted with the properties of wood manufacturing.

For example, while workers from other industries (such as metal or plastic processing) can operate computer numerically controlled (CNC) machines to produce prefabricated structures with precision dimensions, they lack experience working with wood as a production material as well as lack knowledge of construction and wood adhesion. This example of specialized knowledge requirements illustrates a clear need to upskill workers to become more acquainted with the properties of wood before mass timber manufacturers can employ individuals in similar roles from other sectors.

Stakeholders identified the majority of occupations discussed in this report would not need to fully retrain to work with mass timber. Rather, they would need to upskill, and the skills gaps can be plugged in a relatively small amount of time.

For trained engineers, stakeholders estimated around 60 hours of additional training was required to learn the knowledge needed to work with mass timber products. As such, stakeholders have noted that they prefer targeted, shorter programs, such as the University of British Columbia's regularly held Design for Manufacturing and Assembly (DfMA) workshop.

Additional training and education programs are needed to support workers in the production space, such as the forest management and manufacturing sectors.

Current training programs offered in the province focus on training for construction and engineering workers, or general professionals looking to better understand the challenges that accompany using mass timber solutions in buildings. However, there is little to support workers in sectors that will be impacted by the production (and potential export) of mass timber products.

Recommendations

1 Ensure training programs are available for all industries and occupations within the supply chain, distinguishing between production and adoption.

This includes upskilling workers in production in regions where increases in mass timber production capacity, either through new facilities or expansions to existing production lines, are anticipated. It also means that occupations involved in adoption receive training in communications, collaboration, and coordination between sectors.

2 Ensure training programs focus on upskilling for gaps (i.e., they should be short, targeted, and low-cost) rather than full retraining.

These programs should be designed to minimize the time and cost associated with retraining as well as designed for specific occupations looking to gain the knowledge needed to use mass timber in their occupation.

Table 1: Summary of occupations most impacted by the growth of mass timber throughout the supply chain

Occupation	Tasks traditionally performed	Expected changes due to increased production and use of mass timber	The geographical region of employment
Lumber graders and other wood processing inspectors and graders	Inspect wood products and classify according to industry specifications	New industry classification for mass timber products, specific focus on the moisture content of wood	Mainland/Southwest (36.4%), Cariboo (19.2%, Thompson-Okanagan (15.7%)
Other wood processing machine operators	Run drying kilns to reduce wood moisture	Increase amount or intensity of the drying cycles to reduce wood moisture	Mainland/Southwest (33.9%), Thompson-Okanagan (27.1%), Cariboo (16.8%)
Woodworking machine operators	Use CNC machines to produce furniture, use glueing machines to join pieces of wood	More extensive use of digital tools, produce precise building components	Mainland/Southwest (48.8%), Thompson-Okanagan (16.5%), Vancouver Island/Coast (11.0%)
Other wood processing machine operators	Glue layers of wood to produce veneer and plywood	Produce stronger, thicker layers of wood using adhesive	Mainland/Southwest (33.9%), Thompson-Okanagan (27.1%), Cariboo (16.8%)
Supervisors, wood product processing	Supervise and manage workflow	Align work schedule with construction, increased knowledge of construction and design processes	Mainland/Southwest (26.6%), Cariboo (26.0%), Thompson-Okanagan (13.0%)
Manufacturing managers	Plan plant activities to meet production targets, plan resource use	Increased communication with external stakeholders (i.e., designers, construction managers, etc.), plan resource use under a 'just-in-time' approach	Mainland/Southwest (69.0%), Thompson-Okanagan (12.4%), Vancouver Island/Coast (10.9%)
Architects	Prepare building design, prepare building plans	Engage with manufacturers and construction professionals, prepare building design according to wood's structural properties	Mainland/Southwest (84.04%), Vancouver Island/Coast (10.7%), Thompson-Okanagan (4.2%)
Mechanical engineers	Design building heating and cooling systems	Engage with manufacturers and construction professionals, design mechanical systems according to the thermal properties of wood	Mainland/Southwest (75.6%), Vancouver Island/Coast (11.4%), Thompson-Okanagan (6.0%)
Electrical and electronic engineers	Design building electrical and power systems	Engage with manufacturers and construction professionals, design electrical systems according to the properties of wood	Mainland/Southwest (82.6%), Vancouver Island/Coast (8.7%), Thompson-Okanagan (5.4%)
Construction managers	Plan construction projects according to building design, oversee construction activities	Involved in the design stages, use of building information modelling (BIM), coordinate with designers and manufacturers	Mainland/Southwest (66.6%), Vancouver Island/Coast (13.6%), Thompson-Okanagan (11.9%)
Carpenters	Form building foundation, install floor beams, walls, and roofs	Provide inputs in the design process, assemble building components on site, increased precision in work, knowledge about wood and connectors	Mainland/Southwest (52.6%), Vancouver Island/Coast (21.2%), Thompson-Okanagan (13.5%)
Construction trade helpers and labourers	Load and unload construction material, support tradespersons and heavy equipment operators, mix various materials	Support moisture management, manage construction site for on-site assembly	Mainland/Southwest (62.0%), Vancouver Island/Coast (14.5%), Thompson-Okanagan (12.8%)

Occupation	Tasks traditionally performed	Expected changes due to increased production and use of mass timber	The geographical region of employment
Plumbers	Install, maintain, and repair plumbing systems	Involved in design, coordination with engineers and manufacturers, precision in working with finished products	Mainland/Southwest (66.1%), Vancouver Island/Coast (14.8%), Thompson-Okanagan (10.6%),
Electricians	Install, maintain, and repair electrical and power systems	Involved in design, coordination with engineers and manufacturers, precision in working with finished products	Mainland/Southwest (60.1%), Vancouver Island/Coast (17.3%), Thompson-Okanagan (13.2%)
Heating, refrigeration and air conditioning mechanics	Install, maintain, and repair heating and cooling systems	Involved in design, coordination with engineers and manufacturers, precision in working with finished products	Mainland/Southwest (61.5%), Thompson-Okanagan (17.3%), Vancouver Island/Coast (13.8%)

Introduction

Accelerating climate action, fostering clean growth, promoting innovation, and creating new job opportunities are key priorities for the Government of British Columbia (BC).[4] Additionally, there is an urgent need for more housing in the province.[5] Given the intersecting nature of these social, environmental, and economic crises, provincial and municipal governments are looking for solutions that offer improvements on multiple measures. One such solution is mass timber, a term used to refer to a range of engineered wood products. Mass timber solutions provide opportunities to contribute to the decarbonization of buildings, speed up the construction of new housing, and create jobs in the province's forestry, manufacturing, and construction sectors.[6]

Beyond simply offering a chance to tackle multiple challenges, mass timber solutions also have implications for a number of existing debates in the province. In the forestry and manufacturing sectors, mass timber products are part of a broader discussion about the need to shift towards manufacturing more value-added forestry products. This discussion first emerged during the recession of the 1980s,[7] and it has since re-emerged as a stated policy objective by the Government of BC.[8] In communities that have historically been economically dependent on the forestry sector, value-added forestry products such as mass timber offer employment opportunities for an industry facing decline, where discussions of the need to diversify are common. These implications for communities underscore the importance of discussions around mass timber products.

There are anticipated economic benefits as a result of growth in mass timber. The BC government projects the potential for ten new mass timber facilities in the province by 2035, creating an estimated 2,350 — 4,230 new jobs in forestry, manufacturing, technology and engineering, and design.[9] While the job creation potential of mass timber appears to be relatively modest and is likely not transformational for the forestry sector on its own, it should be understood in the larger context of significant changes occurring in the sector. The province's forestry sector currently employs around 50,000 people directly,[10] a significant drop since the late 1990s when the sector directly employed over 100,000 people.[11] Meanwhile, employment in the value-added sector, which mass timber is part of, has increased steadily by around 35% since 2012, and employment numbers are expected to continue to rise.[12]

While mass timber might not represent a transformation for the forestry sector or any other industry, it is a small and growing opportunity that could offer the province a chance to tackle many of the intersecting challenges outlined above. Additionally, even if it remains small as an economic opportunity for BC, it will be impactful for some regions or sectors within the province. For example, resource communities in Northern BC are exploring mass timber, alongside other value-added products, as an opportunity to diversify their local economies and create jobs. Construction companies and design firms in Vancouver specializing in green buildings are looking to design leading sustainable buildings.

Advancing mass timber solutions offers an opportunity for those most interested in resource innovation to display sustainability leadership within the province.

While there are uncertainties expected to impact different aspects of the production and adoption of mass timber products in BC, such as fibre supply and demand for the technology, stakeholders generally expect growth in both the production (manufacturing panels, which involves forestry, transportation, and manufacturing) and adoption (using panels in buildings, which involves manufacturing, design, and construction) of mass timber products. As these two sides of the mass timber opportunity grow, there will be a role for both provincial and municipal governments to play in managing the regional changes this growth could bring about.

In an effort to understand these changes, this report identifies how the growth of mass timber manufacturing and increased use of mass timber products could impact the provincial workforce. Workers throughout the entire supply chain for mass timber will be impacted by trends such as the growing role of sustainable forest management practices; changes in manufacturing and design driven by highly integrated and coordinated project teams of manufacturers, designers, and construction managers; and the need for stronger coordination on construction sites. This report begins by providing an overview of mass timber solutions and the sectors that are implicated in mass timber's growing supply chain. This report then dives into each component of the supply chain, identifying how greater production and adoption of mass timber solutions could impact workers in a given sector by examining the current skills profile of the workforce and how skills needs are expected to change. This research is based on findings from quantitative analysis, foresight exercises, surveys, conversations, and a workshop that directly engaged stakeholders in BC. Many of these changes are not unique to mass timber, and this report does not presume that mass timber is the only solution that can achieve goals like decarbonizing the building sector or adding value to BC's forestry sector. However, given that mass timber is a part of each of these discussions, supporting the growth of its production and adoption could help equip the workforce with the skills needed to tackle many of the province's biggest challenges.

What is mass timber?

Mass timber is a term used to refer to a range of engineered wood products, typically comprised of thick, compressed layers of wood. The wood is typically fastened together using glue, wood, or dowels. These products are designed for high strength ratings, meaning they can be used as substitute materials for concrete and steel. Mass timber solutions are differentiated from dimensional lumber by a number of features, including the way the wood panels are fastened together. Products include cross-laminated timber (CLT), glue-laminated timber (GLULAM), nail-laminated timber, and dowel-laminated timber. Each product requires a different manufacturing process, can use different tree species as inputs, and is designed for different end-uses depending on their size and load-bearing qualities.[13] Many mass timber products are designed to be load-bearing, meaning their strength and lightweight nature make them useful building materials.[14] Their technical use ranges from individual homes to 18-storey commercial or residential buildings, the current height granted by the 2021 International Building Code.[15]

Mass timber solutions fall into the category of modular construction technologies, meaning increased adoption has implications for industries involved in construction and assembly. Mass timber panels, which are the products developed using the abovementioned manufacturing approaches, are manufactured off-site and then brought onto a construction site to be assembled.

Fabrication shops develop these panels to exact specifications, typically using various digital tools such as robotic and computer numerically controlled (CNC) machines. CNC machines also allow for pre-cutting openings, such as windows, staircases, and utilities. Most exterior and interior finishes can also be installed off-site, meaning that all mass timber components arrive at the construction site and require only minor adjustments. On-site, the different elements are hoisted into place and connected with fastening systems such as bolts, screws and nails, allowing for a fast and quiet construction process with only minimal disruption to the local area.[16] This shift away from most work being completed on-site to a controlled manufacturing setting increases efficiency on the job site. However, this shift requires greater collaboration and coordination within the design and manufacturing phase from architects, designers, manufacturers, and construction managers.[17]

In Canada, CLT and GLULAM are the two most frequently used mass timber products.[18] CLT is typically made from dimension lumber that is stacked in cross-directional layers and glued together. Canadian CLT is often made from Spruce-Pine Fir or Douglas-Fir-Larch, and it is frequently used for beams, columns, trusses, and headers due to its size and load-bearing qualities. Additionally, GLULAM can be manufactured with curved designs to create load-bearing arches and similar structures. In Canada, GLULAM is also typically made from Spruce-Pine-Fir and Douglas-Fir-Larch.[19] As of 2021, Canada manufactured mass timber products in 40 facilities across the country. The three most produced products are GLULAM (13 production facilities), CLT (8 production facilities), and laminated veneer lumber (7 facilities).

Supply chain for mass timber in British Columbia

When identifying what sectors are involved in the growing mass timber supply chain, it is important to distinguish between the two ways mass timber solutions could impact the provincial economy: production and adoption. Mass timber production focuses on manufacturing products, such as panels, within the province. It includes all activities upstream of construction, given that panels could be manufactured in the province and exported elsewhere. The first manufacturing plant in BC was opened in 2010, and there are currently nine active manufacturing facilities. The adoption of mass timber relates to the use of mass timber solutions in construction projects and does not necessitate that the panels used in construction be manufactured within the province. In BC, 284 construction projects using mass timber products have been completed, 28 are currently under construction, and an additional 29 projects are planned to be constructed. The majority of these projects are concentrated in and around the Greater Vancouver Area, as seen in Figure 2.

Based on completed projects and manufacturing capacities, BC is currently leading in both the production and adoption of mass timber in Canada.[20] With this in mind, this report details a mass timber supply chain that maps out both production and adoption for the province. This holistic supply chain can be broken down into four stages. The first three are resource extraction, preparation, and manufacturing, which combine to form the production part of the mass timber supply chain. The fourth stage is adoption. These stages include activities related to forest management, logging, lumber milling, mass timber production, design, and construction. It is important to emphasize that the industries relevant to mass timber's supply chain will experience different impacts depending on the degree of production and/or adoption within the province. For example, a scenario of high production but low adoption would impact the workforce in the first three stages as compared to construction and design.

Figure 2: Distribution of mass timber construction projects across British Columbia, 2021

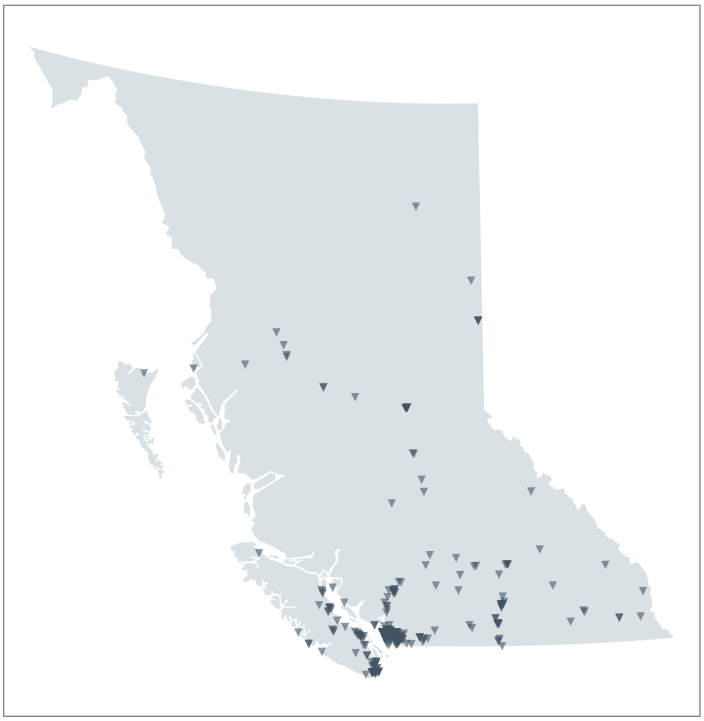
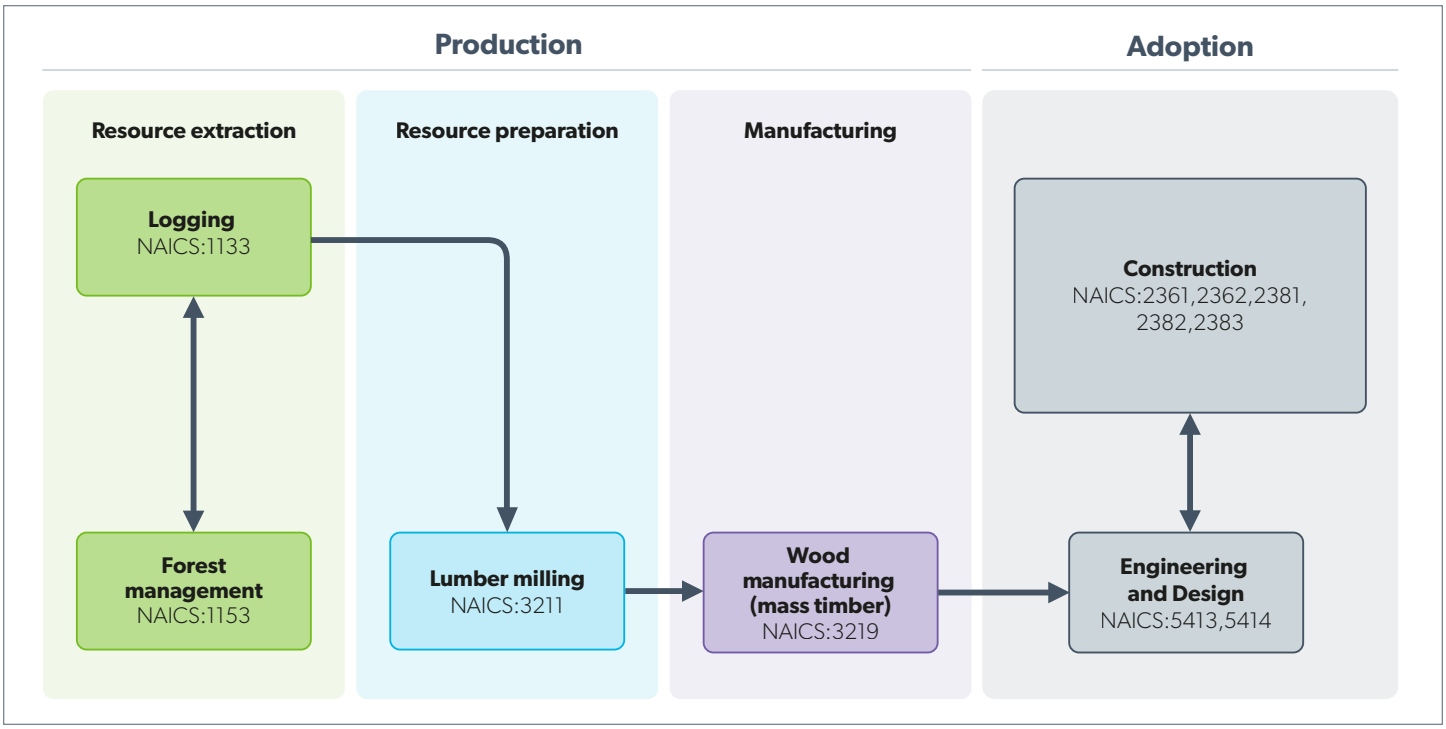


Figure 3: Supply chain for mass timber



Forest management (NAICS 1153): Forest management includes practices such as planning and research activities related to the harvesting of trees, forest health, and forest regeneration.[21] These practices ensure that forest growth exceeds harvests for forest products, natural ecosystems are protected, and the loss of tree species to wildfires or disease is minimized.[22] Mass timber products require a consistent supply of lumber, meaning forest management becomes integral to the growth of this technology.[23]

Logging (NAICS 1133): Logs, and lumber more broadly, are a critical input for mass timber products. The quality of fibre is essential for different forms of mass timber products, and manufacturers need to procure a supply of wood that meets the demand for products. Logging companies typically plan which trees will be harvested, carry out the safe felling of trees, delimb branches, and conduct the skidding and sorting of logs for transport to sawmills.[24] In 2021, the overall log consumption by BC's primary wood sector was 52.7 million cubic meters.[25] Table 2 shows BC's estimated log use and availability in 2020. While sawmills processed 69.4% of the harvested wood, chip mills and veneer mills accounted for the second and third highest use respectively.

Lumber milling (NAICS 3211): A critical step following resource extraction is preparing the lumber for use within a mass timber manufacturing facility through lumber milling. Lumber milling involves activities related to grading and sorting of the logs, debarking, sawing, trimming, and stacking. The lumber is then sent for kiln drying (a process that uses heat to remove moisture content from wood, which prevents warping and damage over time). These processes require experienced and skilled professionals for grading, sorting, inspection, stacking, and storing.

The lumber is then sold as is or transported to a mass timber manufacturing facility for further processing. The production of mass timber (GLULAM or CLT) requires a low moisture content of 12%±3%.[26] This is lower than what is required for dimensional lumber, which is typically allowed moisture content up to 19%.[27] Therefore, manufacturing mass timber requires additional drying. Some suppliers in BC provide kiln-dried lumber, saving manufacturers capital and energy costs associated with installing a dry kiln in-house. However, some mass timber manufacturers, such as Kalesnikoff, have integrated a kiln-drying process into their facility, as it can broaden the sources from where a company can obtain lumber.[28]

Table 2: Mills by type and volume of wood used in British Columbia, 2020[29]

Primary log use	Primary log use	Est volume used ('000 m^3)	Percentage
Lumber mills	111	35,276	69.4%
Veneer/ oriented strand board mills	16	4,918	9.7%
Chip mills & pulp mills	23	6,131	12.1%
Shake and shingle mills	34	495	1%
Other mills	52	1,324	2.6%
Log exports	–	2,722	5.4%
Total	**236**	**50,866**	**100%**

Wood manufacturing — mass timer (NAICS 3219): Manufacturing activities depend on the type of mass timber produced. CLT and GLULAM are the two most common types of mass timber products produced in Canada, and both go through the following process: preparation (re-surfacing and re-planing), finger-jointing, resin application, and pressing which are described in greater detail in Table 3. Depending on the facility, some of the next steps may include CNC machining and finishing. The final product is then prepared for transportation and typically transported directly to the construction site for a "just-in-time" delivery, meaning products are typically delivered and transported without the need for longer-term storage before reaching a job site. The planning behind the actual processing is typically completed in collaboration with the engineering, design, and construction teams.

Table 3: Overview of the steps in mass timber manufacturing and process[30]

Process	Description
Lumber preparation	Lumber is sorted and graded as per quality. In some facilities, computerized grading systems are used. Any defects are cut out.
Edge jointing/ Finger jointing/ End jointing	The ends of the boards are glued together using an edge-jointing machine.
Resin application	Layers of the CLT boards are stacked, and adhesive is applied.
Pressing	Assembled layers of CLT boards are pressed to create a solid panel.
CNC fabrication	CNC machines are used to precisely trim the edges and create openings for joints, connectors, and mechanical, electrical and plumbing components

Engineering and Design (NAICS: 5413, 5414): The design stage aims to plan the aesthetics, structural performance, acoustics, and cost-effectiveness of buildings and homes that use mass timber products. Given the pre-fabricated nature of mass timber panels, the design and planning of buildings that use mass timber products should commence at the pre-construction stage.[31] Architects, engineers, and designers must closely coordinate with mass timber manufacturers to design the most optimal structures. The specific activities completed in this sub-sector are relatively similar when working on structures that use mass timber products compared to traditional construction approaches. However, the shift towards modular assembly requires greater use of three-dimensional (3D) modelling, robotic programming, and CNC programming. Additionally, there is a need for greater familiarity with wood as a building material, knowledge of wooden construction, and understanding of how mass timber products influence considerations such as moisture, acoustics, and fire safety.[32]

Construction (NAICS: 2361, 2362, 2381, 2382, 2383): The final step is the assembly of the pre-fabricated mass timber elements at the construction site. Once delivered, the different elements are hoisted into the correct position and connected with fastening systems, such as bolts and screws.[33] Compared with concrete structures, on-site construction and subsequent installation of mechanical, electrical, and plumbing (MEP) services are faster and less resource-intensive.[34] Construction times are also lower for buildings that use mass timber products relative to steel and concrete alternatives. For example, the 18-storey Brock Commons Tallwood House was completed in just 66 days compared to a steel and concrete building that may take up to two years to build.[35] However, many buildings use a mix of mass timber products, concrete, and steel, which are referred to as hybrid structures.[36] For hybrid structures, a combination of traditional construction techniques and more specialized assembly approaches are required by construction crews.

Which factors will determine the growth of the mass timber supply chain?

There are a number of factors that will influence the growth of mass timber production and adoption in the province. These factors, which include public policies, commercial barriers, and environmental challenges, impact both the supply of materials to develop products and the demand for mass timber products. Through a foresight exercise conducted for this report, BC stakeholders identified three variables that would shape the outlook of this opportunity: timber supply, uncertainty around future demand, and a lack of coordination.

The first challenge is timber supply. The supply of wood in BC has been impacted by reductions in annual allowable cut (AAC) volumes, as well as the design of the quota system. Reductions in AAC have been implemented in recent years due to pine beetle infestations, wildfires, and new limitations on removing old-growth forests. While the former two challenges resulted in the destruction of available timber, the latter is a policy decision made to conserve critical habitat within the province, a necessary step to preserve biodiversity and sustainability.

> **"The volume of wood is just not there, and in the short term, the annual allowable cut will drop. We will need to focus more on forest management and stewardship."**
> — Forestry expert

Stakeholders have noted that the decline in the AAC requires renewed discussions around the distribution of the defined fibre basket (i.e., the wood fibre available as an input for different industries). Stakeholders have noted this reduction in the AAC is a particular concern for small and medium-sized enterprises (SMEs), in part due to the design of the quota system. Historically, BC's forestry sector has been characterized by stakeholders as a sector focused on producing low-value, standardized commodity products.[37] This characterization arises in part from a view that timber pricing, raw-material supply, and policies in BC have favoured large land tenure holders and

primary lumber manufacturers.[38] Many stakeholders working in value-added wood manufacturing and wood products sectors, which includes manufacturing mass timber panels, work in smaller and medium-sized firms that have faced challenges accessing high-quality raw materials. SMEs have noted that the design of the quota system has limited their ability to reliably source products for their businesses, which has proved (and may continue to prove) a barrier to further investment within the sector. Despite the fact that steps have been taken recently to improve access to fibre supply for SMEs, including the new British Columbia Timber Sales Value-Added Manufacturing Program (which sets aside 10% of total AAC for SMEs in higher value-add sectors), stakeholders within the sector have noted these amounts are not enough to meaningfully support the growth of more value-added manufacturing or processing opportunities in BC.[39]

"Each month, I have different requirements for my supply of wood, but I'm at the back of the list; everything goes to the big companies. There is often not enough of it [wood supply], the big guys take it all. It is volume-based rather than quality-based."
— Mass timber manufacturer

The second challenge is uncertainty surrounding future demand and where markets for products might appear. Global market research studies indicate significant growth potential for mass timber products globally, including North America.[40] This is particularly the case for CLT, where the global CLT market is estimated to triple by 2030. Despite this expected growth, it remains uncertain how large the end-use market will be and where demand will be largest. Furthermore, although demand for new construction is expected to grow in the coming years, especially for new housing, stakeholders have identified current barriers that may hold back the adoption of mass timber solutions, several of which are policy related.[41] For example, although steps have been taken in BC to change zoning by-laws and reform building codes to permit tall mass timber structures, adoption of mass timber in markets outside of BC requires these markets to adopt similar changes in building codes.

Many mass timber projects also struggle with insurance or experience slow approvals processes from municipalities due to a lack of familiarity with designs using this novel technology.[42] In some cases, approvals processes prove so slow that initial project designs are revised to substitute mass timber design elements with more conventional concrete and steel to increase the chance of project approvals and speed up municipal approval timelines.[43] Other frequently cited concerns during the approvals processes relate to acoustics, fire safety, and earthquake safety, despite credible research citing above-average performance in all categories on buildings using mass timber solutions.[44] There are however, promising signs that policy and uncertainty-related barriers are being addressed in leading jurisdictions. For instance, Quebec not only permitted the construction of tall timber buildings but also introduced a charter that requires public projects to consider mass timber or wood as a building material in lieu of steel or concrete.[45] Additionally, over 1,200 mass timber projects were under development in the United States in 2021, illustrating the growth of future markets for BC firms.[46]

The third challenge relates to the need for stronger coordination, familiarity, and experience working with mass timber products. As with any novel solution, a lack of experience with mass timber is slowing its growth across different components of the supply chain. This challenge is evident when considering the need for different occupations across sections of the supply chain — manufacturers, architects, designers, engineers, and construction managers — to collaborate on the design and installation of pre-fabricated components. Ensuring collaboration across sectors is no simple task, as it requires all stakeholders to be familiar with the processes, terminology, and technology of other members of the supply chain. For example, manufacturing firms, who have traditionally been more engaged within the forestry sector, have cited a lack of familiarity with the vocabulary of the construction sector as an obstacle for growth. While manufacturing firms are invested in bridging this gap, a steep learning curve remains.

"We brought our director of design on board as he is from the construction industry and can speak their language. This has helped us tremendously."
— Mass timber manufacturer

For individuals in construction, engineering, and design, mass timber is a new technology and engineers and architects are slowly gaining awareness about it. However, many architects and engineers are unfamiliar with wood construction techniques as colleges offer relatively fewer courses on wood construction and engineered wood product design.[47] In addition, uncertainties listed above about costs, acoustics, fire safety, and stability have prevented the architectural and engineering community from embracing mass timber solutions[48] While some stakeholders are trying to bridge this gap in education and familiarity, it is clear that more is needed to tackle this challenge.

Box 1

What do stakeholders believe about the future of mass timber in BC?

This report acknowledges that there is not a universally agreed-upon growth trajectory for the production or adoption of mass timber technologies within the province in the coming years. Given this uncertainty, no single credible future could be modelled to answer the questions posed in this report. Instead, stakeholders were asked at the beginning of the survey exercise to participate in a foresight exercise to identify which growth trajectory the industry might take, helping the researchers understand the perspective of each respondent. The skills analysis presented in this report represents the responses of stakeholders who participated in this foresight activity, many of whom had diverse perspectives about the potential growth of this technology in the coming decade. This foresight exercise is discussed in greater detail in Appendix 1 and outlines the following three scenarios:

Scenario 1: Best-case

The mass timber sector is able to quickly overcome the challenges limiting its growth. Manufacturers are able to procure the necessary amount of high-quality and sustainably sourced lumber to meet all their production needs rising from growing demand. Building codes allow mass timber products to be used more frequently in high-rise buildings. There are several incentives in place for the rapid adoption of mass timber products in Canada and internationally. An adequate number of skilled professionals are available across the supply chain (forestry, manufacturing, design, construction, etc.). There are ample training and upskilling opportunities available for workers across the supply chain to fill roles in this sector.

Scenario 2: Consistent, slower growth

The mass timber opportunity grows slowly and faces numerous challenges. Timber supply remains unpredictable and low, potentially because of poorer quality at a high price point. Existing manufacturers are less able to scale up to meet opportunities, and wait times for mass timber products remain long. However, policy changes support greater demand. Building codes allow mass timber to be used more freely in high-rise buildings. There are several incentives in place for the rapid adoption of mass timber, and demand remains high. For companies, hiring and training challenges remain. There are chronic labour shortages in the construction sector, with fewer people entering the skilled trades. There are not many training or re-skilling opportunities available for workers.

Scenario 3: Challenges to growth

In this future, the challenges faced in the production and adoption of mass timber products prove difficult to overcome. Timber supply remains unpredictable and low, potentially because of poorer quality at a high price point. Existing manufacturers are less able to scale up to meet opportunities, and wait times for products remain long. Jurisdictions delay changes in building codes, preferring traditional forms of construction. Developers do not invest in mass timber buildings as costs remain higher, and demand does not grow at expected rates. The use of mass timber panels in buildings and homes grows slower than expected or hovers around the current levels, representing a lower share of the construction industry than desired. Labour shortages persist within the construction sector, and growth in the skilled trades is slow. There are not many training or re-skilling opportunities available for workers.

The survey results found that the majority of respondents (57%) believe mass timber will experience slow yet steady growth in BC. The remaining (43%) believe that mass timber will quickly overcome the challenges limiting its growth. Many respondents felt that demand would rise as a result of the government's focus on sustainability considerations and emissions reduction targets. Another factor stakeholders thought would contribute to demand is new entrants into the mass timber space marketing the sustainability of their buildings. There was also a belief that improvements in manufacturing processes, product quality, and new investments would help grow production capacity within the province.

While survey respondents agreed that mass timber will experience growth in BC, there was less consensus on the key barriers slowing down the growth. Some respondents identified current local government policies in BC and building code changes required to permit mass timber buildings (>12 storeys) as slow to evolve:

> **"We can see the demand side growing from developers and owners, and the supply is slowly scaling up. In my opinion, supply will continue to rise to meet demand, and the biggest challenge will be municipal building codes being too slow to catch up with building methods."** — Survey respondent

Most respondents highlighted a combination of factors slowing down the growth, such as access to fibre, the lack of training opportunities, and skills shortages. Others felt that uncertainties from financiers, such as banks and insurance companies, would prove challenging for increasing the adoption of mass timber, as structures were seen as riskier and less safe than conventional alternatives. Additionally, respondents had concerns about broader market acceptance and the interest from the private sector and general public to drive demand.

> **"Numerous technical challenges need to be overcome, and access to fibre remains an issue. However, the biggest potential limiter is the lack of a trained workforce."** — Survey respondent

Skills analysis of the mass timber supply chain

This section details how the changes outlined above will change the skills needs of the workforce in all the sectors throughout the supply chain. This section contains two forms of analysis. The first is an overview of the current skills profile of the workforce in industries throughout the mass timber supply chain. This is completed through a quantitative assessment of the workforce's current technical, social, and emotional skills using Labour Force Survey data from Statistics Canada and the Occupational Information Network (O*NET) skills taxonomy from the United States federal government. Second, this report includes information about future skills needs collected through interviews, surveys, and a workshop that illustrate how skills needs are changing through the sector as a result of the growth of mass timber. These two forms of analysis are then compared to show where current skill sets are insufficient and which occupations will require additional skills training or education to adapt to a changing industry. For a full summary of the methodologies used to conduct this work, please see Appendices 1 and 2. Additionally, the limitations and assumptions used within this analysis are outlined in Appendix 3.

Methodology used in skills analysis

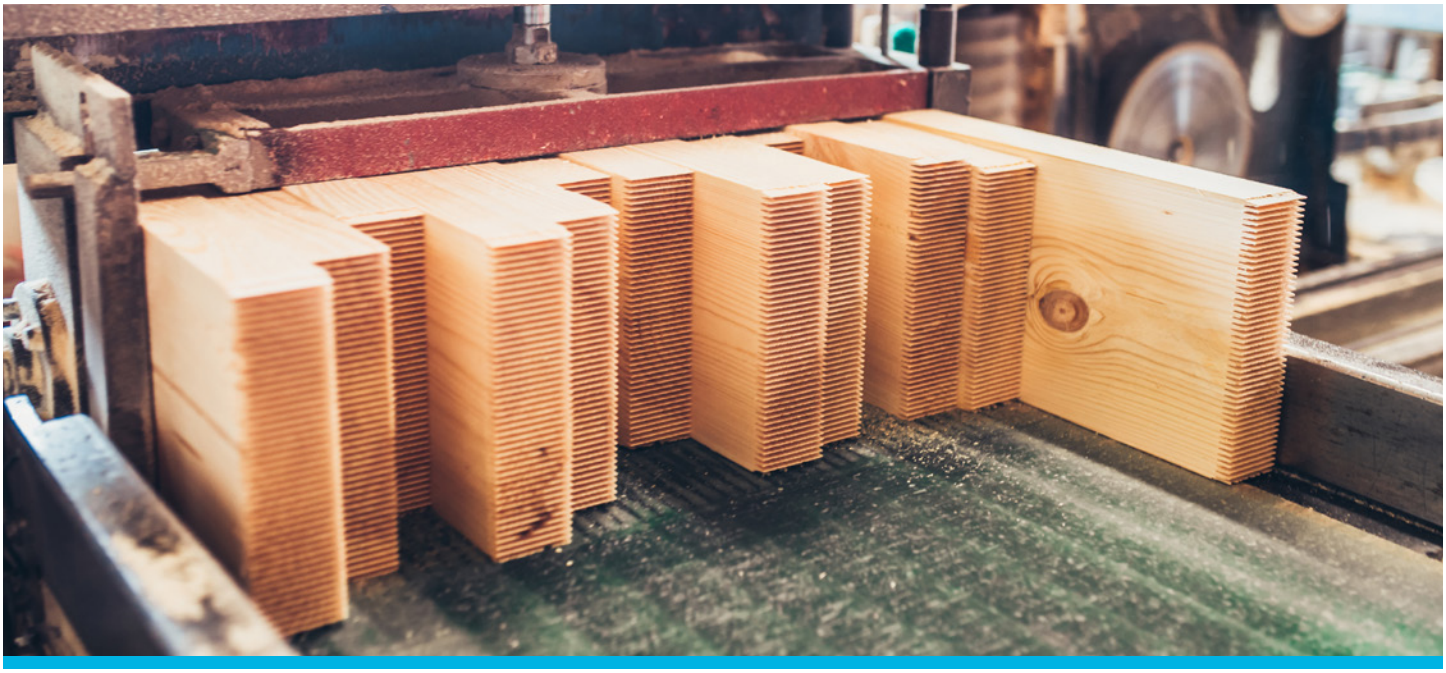
Each sector in the supply chain was defined using the North American Industry Classification (NAICS). This report uses NAICS industry groups at the 4-digit level to capture the extent of the mass timber supply chain. The relevant industries identified, along with the NAICS codes used to represent them in this report, can be seen in Table 4.

Table 4: North American Industry Classification System (NAICS) codes and industry groups used for this analysis

Industry in supply chain	NAICS code	Description
Logging	1133	Logging
Forest management	1153	Support activities for forestry
Lumber production	3211	Sawmills and wood preservation
Mass timber manufacturing	3212	Veneer, plywood, and engineered wood product manufacturing
Design	5413	Architectural, engineering and related services
Design	5414	Specialized design services
Construction	2361	Residential building construction
Construction	2362	Non-residential building construction
Construction	2381	Foundation, structure, and building exterior contractors
Construction	2382	Building equipment contractors
Construction	2383	Building finishing contractors

To understand the importance of skills and knowledge across the mass timber supply chain, this analysis compiled a comprehensive dataset linking the Canadian industry and occupational codes with their associated skills and knowledge profiles. This dataset links labour market information specifically related to skills and knowledge and the Canadian National Occupational Classification (NOC) system. For each industry, the top occupations in terms of employment and relevance to mass timber were selected from the NOC. The O*NET database was then used as a foundation for the skills and knowledge component. Developed by the U.S. Bureau of Labor Statistics, the O*NET database is one of the most widely used and comprehensive databases for occupational information, including information related to skills, knowledge, abilities, and tasks. This analysis focused on the 35 skills identified within the database as classified broadly within basic and cross-functional skills, and the 33 knowledge pieces identified within the database. Basic skills, which include both content and process skills, enable workers to develop capacities that further allow for learning and acquiring knowledge. These include active listening, reading, critical thinking, and monitoring. Cross-functional skills allow workers to undertake activities across tasks, including coordination, problem solving, operations monitoring, decision making, and management. Due to their fundamental nature, basic content skills have the highest importance scores across jobs and sectors. They have been excluded from the analysis because they offer little insight into skills demand beyond identifying that reading and writing will be in demand for all positions. However, basic process skills, such as critical thinking and monitoring, are included in this analysis. The O*NET assigns 'importance' scores to specific skills across different occupations, which identify how important it is for an individual to have a particular skill to perform in that occupation. This analysis emphasizes the importance of skills and knowledge profiles within occupations to illustrate what skills are needed most within a job.

As part of the foresight analysis conducted for this report, stakeholders throughout the supply chain in BC were interviewed or asked to complete a survey. Respondents answered questions specific to their professional expertise, focusing on the recruitment of workers, as well as the current context and future of the sector out to 2030. This foresight exercise provides an indication as to how the growth of mass timber will impact the skills and knowledge requirements of their workforce.



Sub-sector analysis

Resource extraction

Logging

Logging is the primary industry responsible for generating the necessary raw material (i.e., wood) for the production of mass timber. In this analysis, logging represents the Logging sector (NAICS 1133). Professionals in this sector are mainly involved in the cutting, harvesting, and transporting of wood, with key occupations detailed in Table 5.

In harvesting, key occupations are logging machinery operators, heavy-duty equipment mechanics, and chain saw and skidder operators. Logging machinery operators are responsible for setting up and operating machinery in forests to cut trees and prepare them into logs.[49] As such, they require a strong knowledge of operating and repairing technical equipment. Moreover, since the nature of the work entails working outdoors, in sometimes hazardous conditions, there is a key emphasis on abiding by safety rules.[50] Logging machinery operators typically require a secondary school diploma, with most of the job-related knowledge and skills acquired through on-the-job training. Chain saw and skidder operators perform functions similar to logging machinery operators and are responsible for using chain saws and skidders for cutting and moving trees.[51] Much like logging machinery operators, the nature of work involves outdoor labour in forests, requiring a stringent focus on safety. Chain saw and skidder operators also require a secondary school diploma, with training provided mostly on the job.[52] However, workers in this occupation might also need to complete safety and heavy equipment operator certifications.[53] The retirement of older workers and dwindling interest among youth have created a labour shortage in this sector. At the same time, mechanization and technological development might reduce labour demand in the future. Most of the labour demand for chainsaw and skidder operators is expected to come from the replacement of workers as opposed to the creation of new opportunities.[54]

Chain saw and skidder operators have similar requirements for skills and knowledge. In terms of skills, this occupation requires skills in the controlling and monitoring of machinery. Individuals in this occupation also require on-the-spot decision making, making critical thinking and problem solving skills important. In terms of knowledge, chain saw and skidder operators require knowledge of machine design and the ability to perform minor repairs to machinery. As mentioned above, the hazardous nature of work requires a strong knowledge of safety and security regulations and guidelines. Moreover, since the work involved includes the felling, processing, and transporting of trees, individuals in these roles also require knowledge of transportation methods and systems alongside the quality controls associated with the process. One of the possible paths of career progress for chain saw and skidder operators is to transition to a logging machinery operator, which is a higher-skilled occupation than chain saw and skidder operators given the need to use of a broader range of equipment and machinery.

Heavy-duty equipment mechanics are not directly involved in the harvesting process, however they provide support as they are responsible for repairing the heavy machinery used in harvesting.[55] Due to their skill set, they are employed across various industries, including transportation, construction, and forestry. In forestry, they are responsible for supporting operations through repairing machinery used in harvesting and transportation.[56] This occupation continues to generate strong demand from various industries, meaning that the forestry sector has to compete

Table 5: Occupations in logging, tasks performed in each occupation, which regions have the highest concentration of each occupation within British Columbia, and sources of future labour demand

Occupation	Task performed	Top 3 geographical areas of employment	Sources of labour demand	Number of people employed in BC
Logging machinery operators	Fell trees, prepare logs, transport logs	Vancouver Island/Coast (28.7%), Thompson-Okanagan (19.2%), Cariboo (19.2%)	Replacement of retiring workers	1,565
Chain saw and skidder operators	Operate chain saws to fell trees, operate skidder to transport felled trees	Vancouver Island/Coast (40.1%), Thompson-Okanagan (16.6%), Mainland/Southwest (13.3%)	Replacement of retiring workers	1,965
Heavy duty equipment mechanics	Troubleshoot, repair, and maintain heavy-duty equipment	Mainland/Southwest (30.1%), Thompson-Okanagan (19.3%), Vancouver Island/Coast (18.3%)	Replacement of retiring workers (74.6%) and economic growth (25.4%)	7,025
Supervisors, logging and forestry	Supervise and coordinate harvesting activities, train workers, monitor and solve bottlenecks	Vancouver Island/Coast (28.8%), Cariboo (17.6%), Mainland/Southwest (Thompson-Okanagan 15.0%)),	Replacement of retiring workers	1,615
Managers in natural resources production and fishing	Plan and monitor harvest operations, set production goals and plan activities to achieve them	Mainland/Southwest (34.0%), Vancouver Island/Coast (17.8%), Thompson-Okanagan (14.4%)	Replacement of retiring workers (93.2%) and economic growth (6.8%)	1,725

with other industries that also employ heavy-duty equipment mechanics.[57] Heavy-duty equipment mechanic is a rather highly skilled occupation. It requires a strong skill set in monitoring, troubleshooting, and repairing equipment and machinery, which also requires stronger problem solving and decision making skills. Moreover, as the occupation continues to evolve with the advent of newer technologies, individuals in these roles require strong knowledge of not only mechanical equipment, but also electronic technological tools and computers to perform the necessary diagnostics for repairing mechanical equipment.[58]

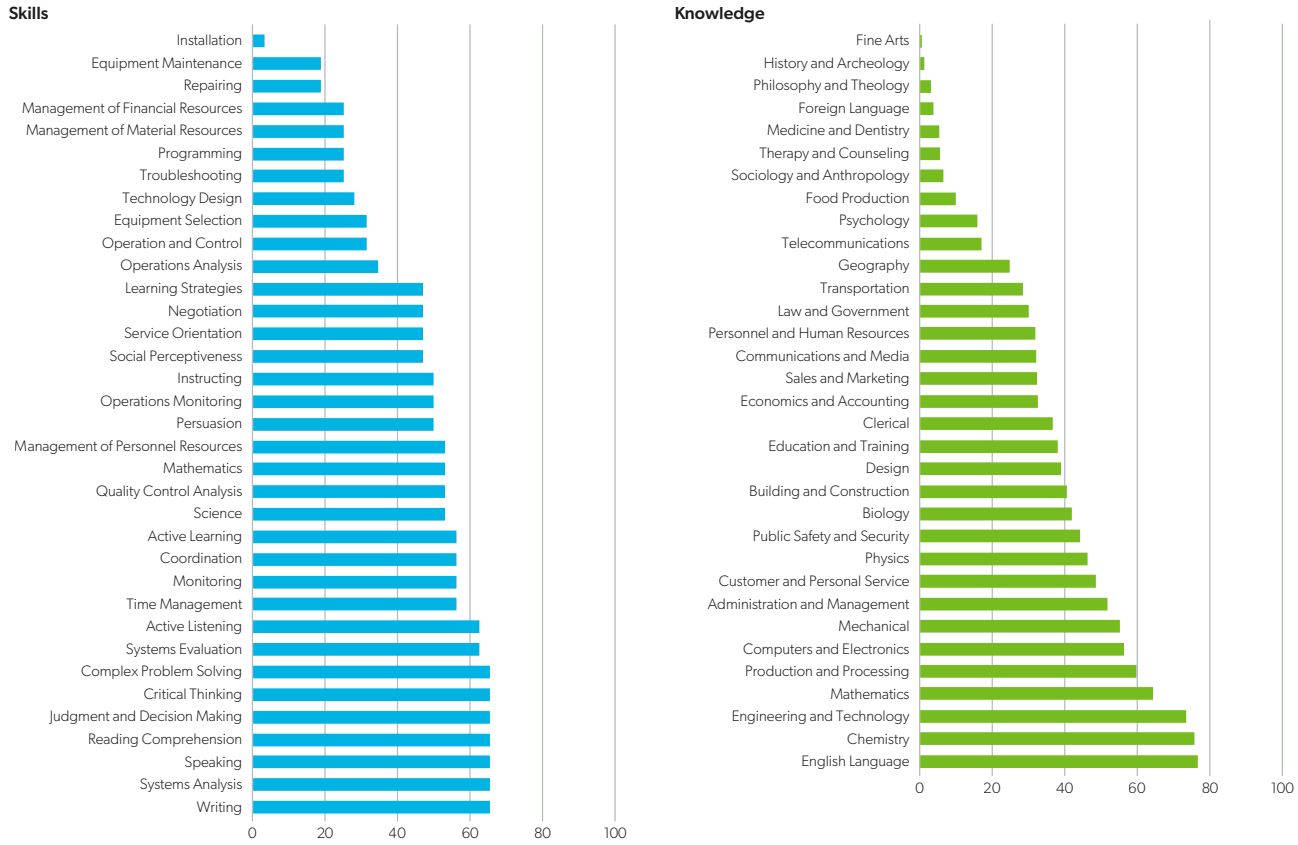
In management, the key occupations are supervisors, logging and forestry, and managers in natural resources production and fishing. Supervisors in logging and forestry are responsible for managing the crews that harvest wood in the forests.[59] As such, they are responsible for planning their crews' activities, troubleshooting bottlenecks in harvesting activities, and training new workers. They are also responsible for ensuring adherence to government regulations and coordinating their crews' activities with forest management professionals. Entry into this occupation usually requires work experience in logging and forestry-related educational credentials at the college level. On the other hand, managers in natural resources production and fishing are employed across a range of industries, including fishing, oil and gas, mining, and forestry.[60] Workers in this occupation are responsible for planning, monitoring, and evaluating the implementation of projects involving natural resource extraction.[61] They are responsible for ensuring that production goals are met and safety requirements are followed. They are also involved in hiring and training staff as well as communicating with various levels of management to meet production targets. Entry into this occupation requires work experience in the industry and a university qualification in forestry-related subjects.[62]

As shown in Figure 4, supervisors in logging and forestry require different skill sets and knowledge compared to managers in natural resource and fishing. Supervisors in logging and forestry usually require strong verbal communication, people management, and coordination skills as they directly manage logging crews operating in forests. Managers in natural resources production and fishing are usually more proficient in written and verbal communications skills. They are also quite proficient in critical thinking and problem solving as their work requires analytical thinking around setting and achieving production targets. In terms of knowledge, supervisors in forestry and logging are more proficient in diverse areas, ranging from management to mechanical equipment operations to interpersonal communications. Managers in natural resources production and fishing are more knowledgeable in interpersonal communications and possess specific scientific knowledge in areas such as chemistry, mathematics, and engineering. The difference between these knowledge requirements could be explained by the fact that supervisors in logging and forestry usually advance from working in logging, and the nature of their work entails more hands-on management of the crews. Meanwhile, managers in natural resources production and fishing have a university education in the sciences, and their work involves the overall planning, implementation, and evaluation of natural resource production projects.

Figure 4: Current skills and knowledge needs for workers in logging (absolute scores on the importance of a skill or knowledge area, 0-100)

Managers in natural resources production and fishing

Figure 4-1

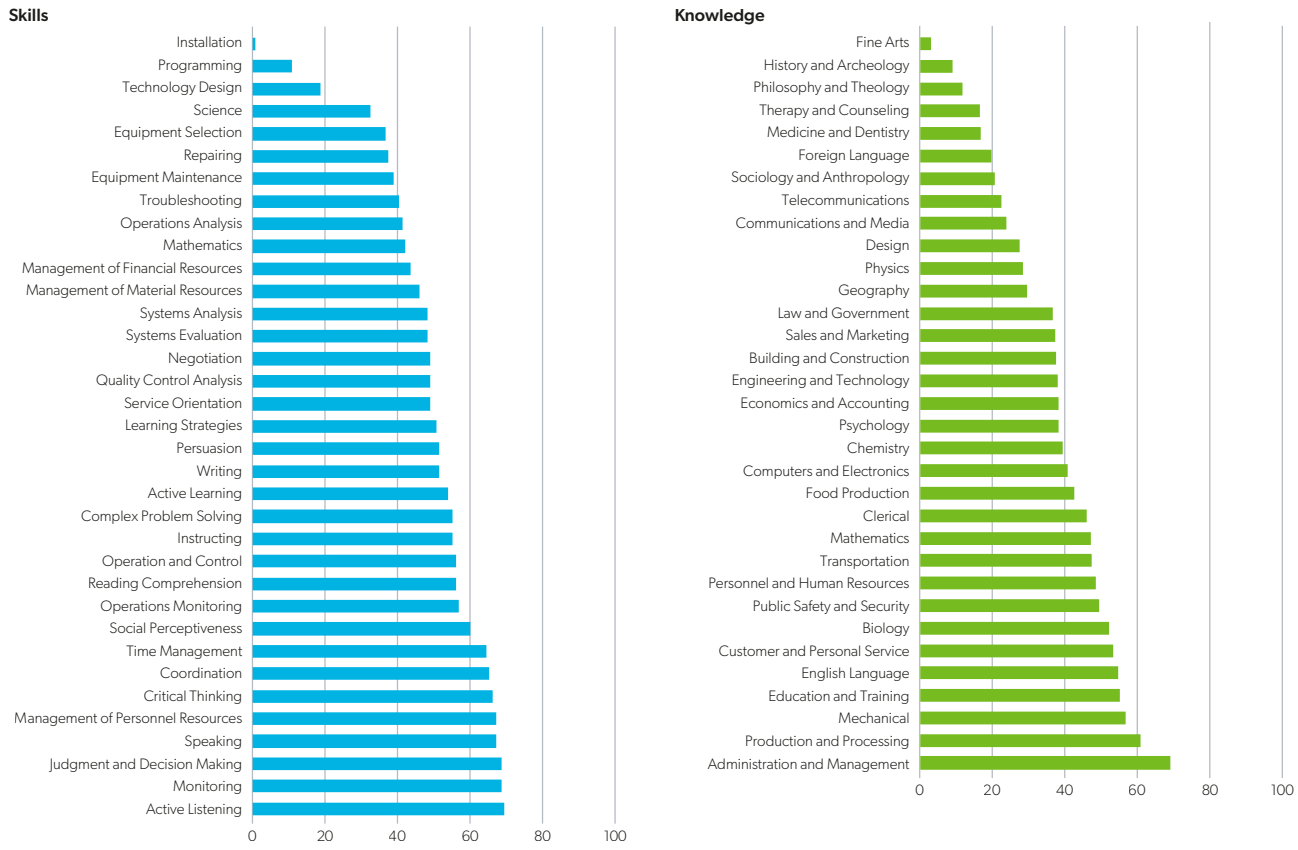


Logging machinery operators

Figure 4-2

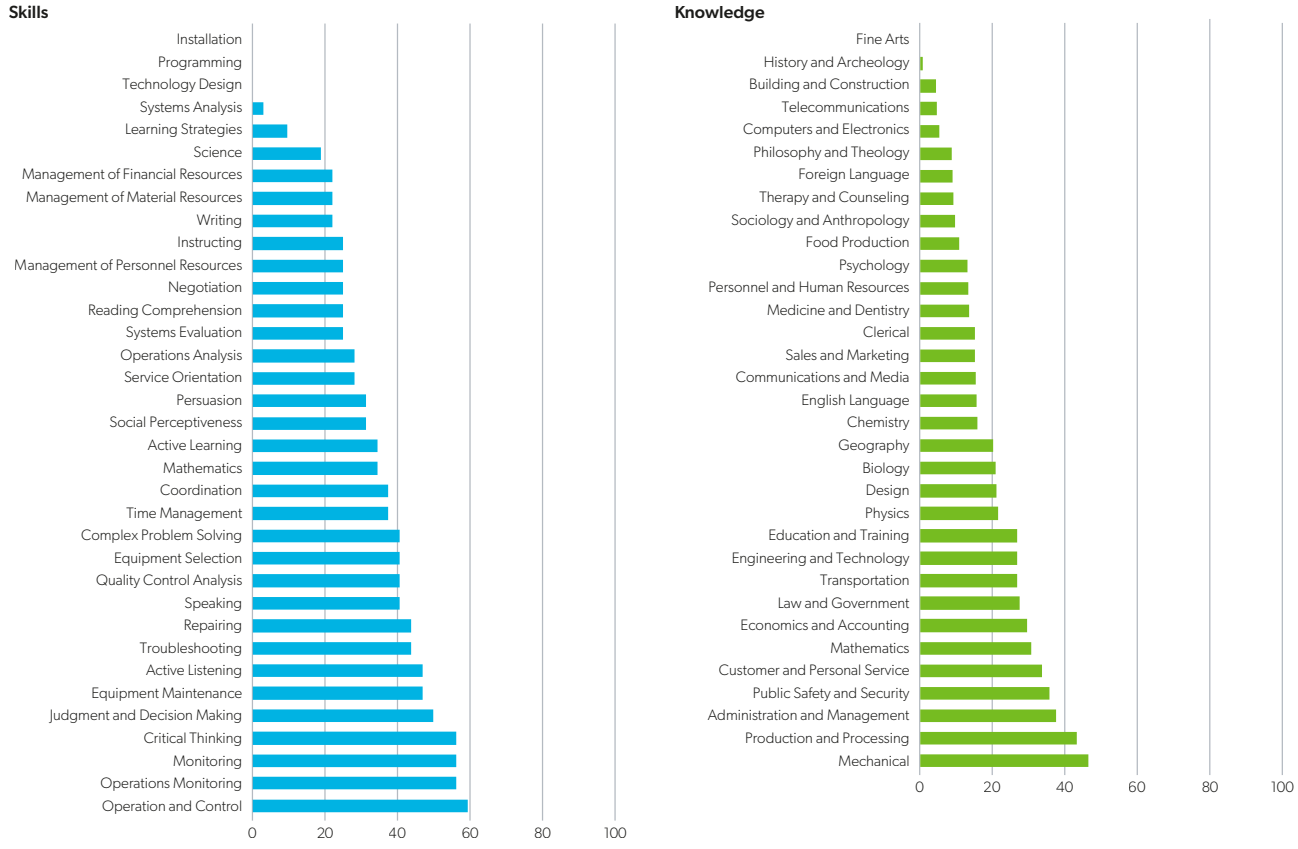
Supervisors, logging and forestry

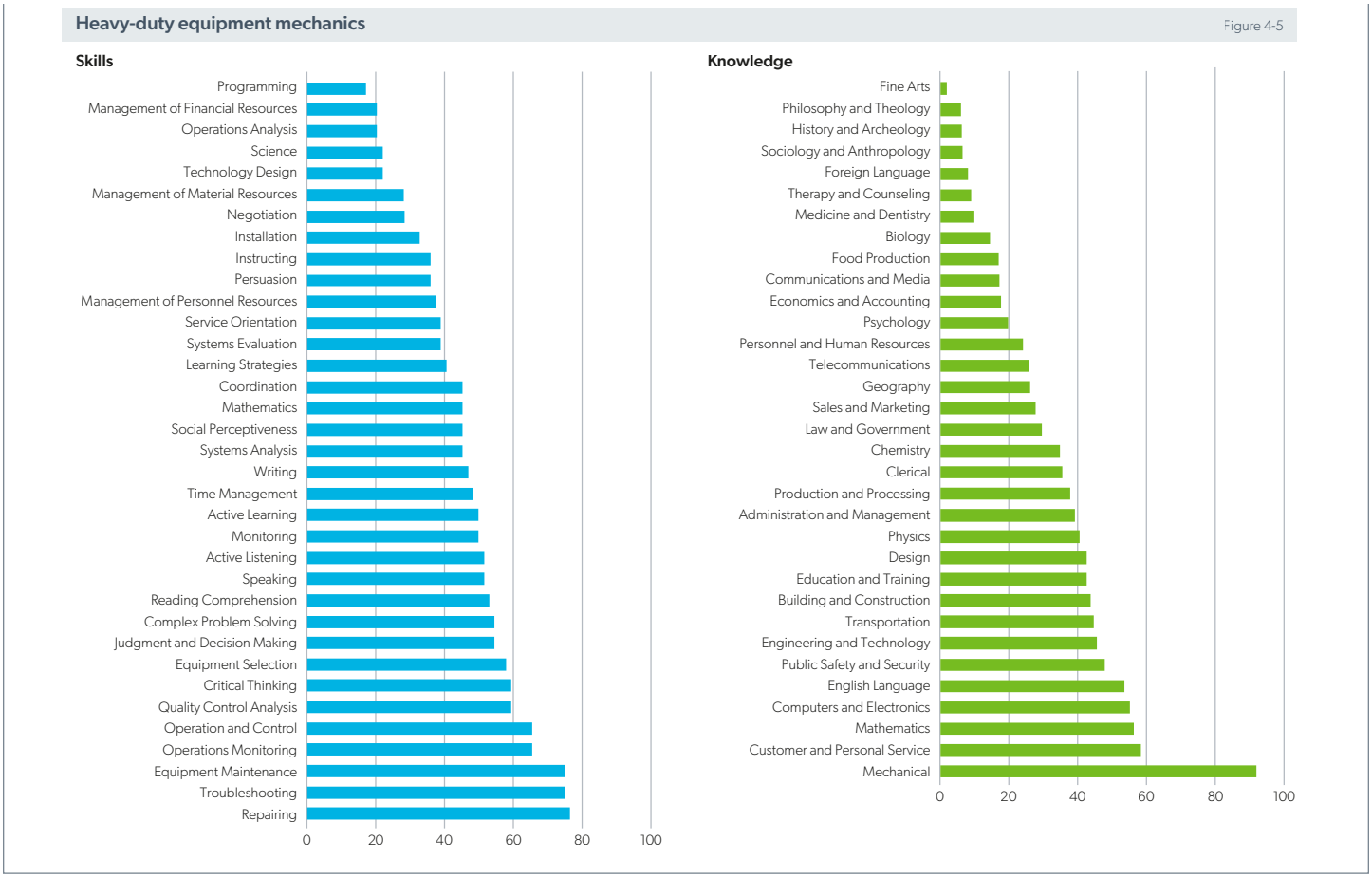
Figure 4-3



Chain saw and skidder operators

Figure 4-4





Forest management

The forest management sector is represented in this report by the Forestry and logging support activities sector (NAICS 1153). Key occupations in forestry management are forestry technologists and technicians, silviculture and forestry workers, forestry professionals, and conservation and fishery officers. Occupations in this sector could be divided into three categories based on the tasks carried out: reforestation, monitoring, and planning.

In reforestation, silviculture and forestry workers are responsible for planting new trees after the harvest.[63] They are responsible for preparing the sites to grow new trees and planting the seedlings.[64] Silviculture and forestry workers use machinery to thin forests to support the reforestation process. They also support firefighting operations. While there are no specific educational requirements for silviculture and forestry workers, workers in this occupation are required to have first aid knowledge and the capacity to operate vehicles.[65] Since the occupation involves performing a variety of tasks, the exact nature of the work and qualification requirements depend upon employers' specific needs. Training in this occupation is mostly provided by employers and industry associations, with certifications and training standards identified mainly by industry associations.[66] Recent reductions in logging activity have resulted in a lower demand for reforestation. However, the provincial government's focus on harvesting second-growth trees (trees grown as part of second-growth plantations, which are planted following the removal of the primary forest) and shorter harvest cycles have generated a stronger demand for silviculture and forestry workers.[67] Going forward, the demand for better forest management practices will lead to the need for an adjusted skill set amongst silviculture and forestry workers.[68] As seen in Figure 5, this is a relatively low-skilled occupation, with communications and problem solving skills being more critical in these roles. In terms of knowledge, this occupation requires a strong understanding of geography, biology, and safety standards and regulations.

In monitoring, conservation and fishery officers are mainly responsible for ensuring compliance with governmental regulations regarding wildlife and the environment. Workers in this occupation are almost exclusively hired by the government.[69] Conservation and fishery officers patrol forests and arrest offenders who violate environmental regulations.[70] They also issue licenses and collect royalties related to timber extraction. Individuals typically obtain a college diploma to enter the occupation, with some aspects of the work learned through on-the-job training.[71] In terms of skills, workers in this occupation mainly require communications and problem solving skills. These two skill areas are vital as these roles involves communicating with various stakeholders and responding to evolving situations. In terms of knowledge, workers require a strong understanding of a range of areas, such as geography, interpersonal communications, and governmental regulations. Since they are involved in implementing laws and regulations in a nature-based setting, workers in this occupation require both scientific and legal knowledge.[72]

Table 6: Occupations in forest management, tasks performed in each occupation, which regions have the highest concentration of each occupation within British Columbia, and source of future labour demand

Occupation	Tasks performed	Top 3 geographical regions of employment	Source of future labour demand	Number of people employed in BC
Silviculture and forestry workers	Conduct reforestation, support firefighting, conduct thinning of trees	Cariboo (21.0%), Mainland/Southwest (19.0%), Thompson-Okanagan (20.2%)	Replacement of retiring workers	1,395
Conservation and fishery officers	Patrol forests, issue licenses, collect royalties	Mainland/Southwest (26.2%), Vancouver Island/Coast (26.2%), Thompson-Okanagan (15.3%)	Replacement of retiring workers (66.7%) and economic growth (33.3%)	710
Forestry technologists and technicians	Conduct surveys, monitor harvest and reforestation operations, ensure legal compliance	Vancouver Island/Coast (24.1%), Cariboo (20.5%), Thompson-Okanagan (16.7%)	Replacement of retiring workers	2,225
Forestry professionals	Prepare forest management plans, plan surveys, manage harvest and reforestation activities	Vancouver Island/Coast (27.6%), Thompson-Okanagan (19.0%), Cariboo (18.4%)	Replacement of retiring workers (91.7%) and economic growth (8.3%)	2,225

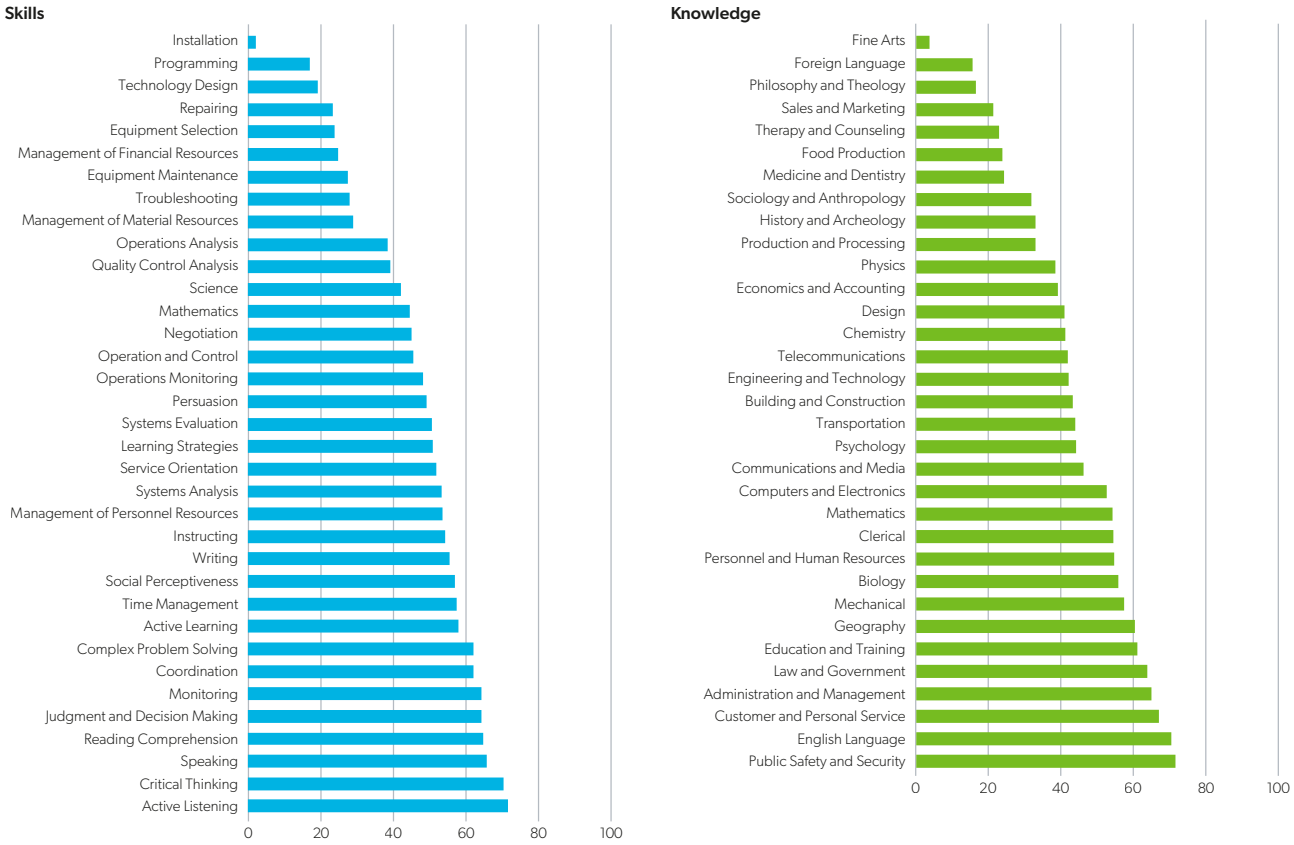
Forestry technologists and technicians, as well as forestry professionals, are mainly responsible for planning the forest management process. Forestry technologists and technicians are involved in a wide range of tasks.[73] They support the formation and implementation of forest harvesting and management plans by collecting information from surveys and information systems. They supervise and coordinate tree-planting operations.[74] They also support the coordination of activities such as fire suppression and insect control. Some technologists and technicians might be employed in a regulatory role where they monitor the activities of logging companies and ensure compliance with the relevant regulations. Entry into these roles is regulated and requires a college diploma in certain forestry-related subjects. Further professional certification requires a combination of work experience and professional examinations.[75] On the other hand, forestry professionals are mainly involved in carrying out research and preparing plans for forest management and harvesting.[76] Workers in this occupation prepare and administer research surveys and studies, as well as prepare forest resource management plans.[77] They are involved in planning and managing activities in areas ranging from reforestation to insect control to fire prevention.[78] Planning and implementing programs for environmental protection also fall within their domain. Furthermore, they are responsible for managing tree nursery operations. Entry into this occupation requires a university degree in forestry-related subjects, while professional certification requires work experience and successful completion of a professional examination.[79]

Due to the nature of work in these occupations, workers in these roles require communications and problem solving skills. Since forestry technicians require greater physical labour, knowledge in the areas of interpersonal communications and safety regulations is of higher importance. In contrast, forestry professionals are more well-versed in scientific knowledge and the operation of computer machinery.

Figure 5: Current skills and knowledge needs for workers in forest management (absolute scores on the importance of a skill or knowledge area, 0-100)

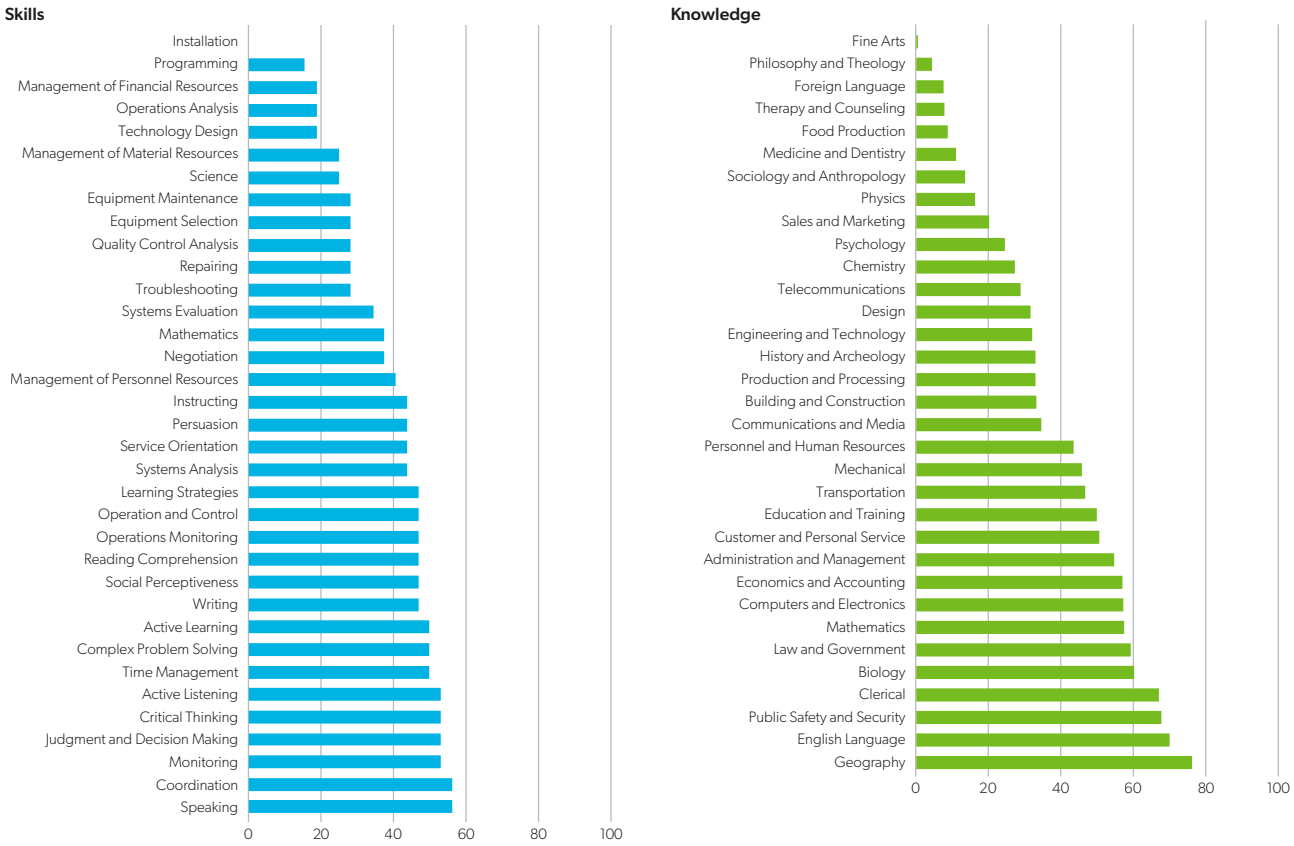
Forestry technologists and technicians

Figure 5-1



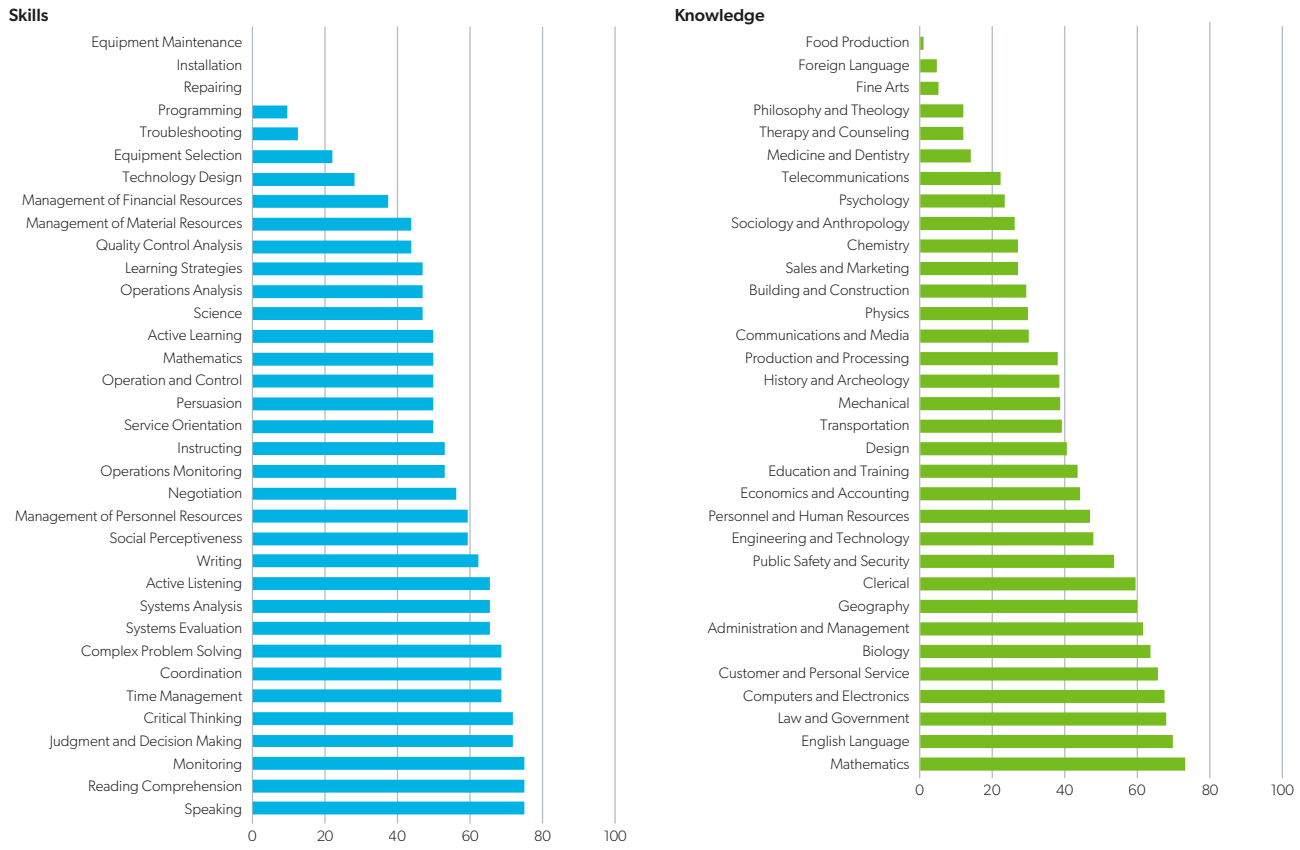
Silviculture and forestry workers

Figure 5-2



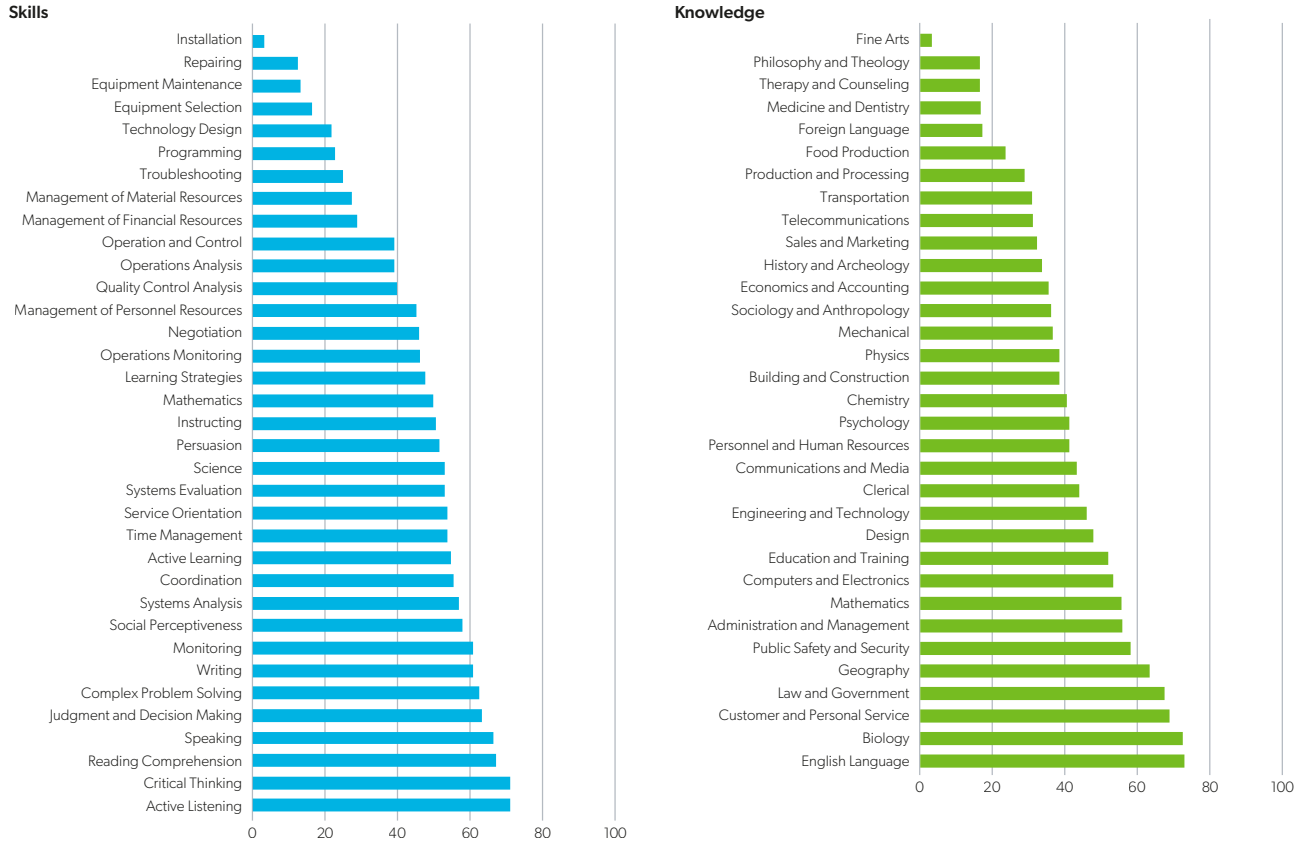
Forestry professionals

Figure 5-3



Conservation and fishery officers

Figure 5-4



Resource preparation

Lumber production

The lumber production process involves processing logs of wood into a wood product that can then be used to produce mass timber products. Activities in lumber production are represented in this report by the Sawmills and wood preservation sector (NAICS 3211). The tasks in this industry can be divided into wood and lumber handling, lumber production, sales, and management.

In lumber handling, material handlers are responsible for operating machinery and equipment to load and unload shipments of wood and wood products at sawmills.[80] They are primarily responsible for off-loading log shipments received at the sawmill. They also load sawmill products from the warehouse to trucks. Heavy equipment operators perform a similar function and are responsible for loading and unloading logs and finished wood products at the production site. There are no specific educational or training requirements to enter the material handlers occupation.[81] However, operating certain heavy equipment

Table 7: Occupations in lumber production, tasks performed in each occupation, which regions have the highest concentration of each occupation within British Columbia, and source of future labour demand

Occupation	Tasks performed	Top 3 geographical regions of employment	Source of future labour demand	Number of people employed in BC
Material handlers	Load and unload products at the sawmill	Mainland/Southwest (70.9%), Thompson-Okanagan (9.8%), Vancouver Island/Coast (8.9%)	Replacement of retiring workers (64.9%) and economic growth (35.1%)	27,805
Heavy equipment operators	Load and move products across the production site	Mainland/Southwest (33.0%), Thompson-Okanagan (20.7%), Vancouver Island/Coast (15.8%)	Replacement of retiring workers (74.6%) and economic growth (25.4%)	12,090
Lumber graders and other wood processing inspectors and graders	Inspect wood products for defects, grade products according to industry standards	Mainland/Southwest (36.4%), Cariboo (19.2%), Thompson-Okanagan (15.7%)	Replacement of retiring workers	790
Labourers in wood, pulp and paper processing	Feed logs in conveyer, move wood products across manufacturing stages	Mainland/Southwest (30.2%), Cariboo (20.05%), Thompson-Okanagan (20.2%)	Replacement of retiring workers	4,770
Sawmill machine operators	Operate lumber equipment, convert logs into wood products	Mainland/Southwest (28.7%), Thompson-Okanagan (17.2%), Cariboo (15.4%)	Replacement of retiring workers	1,820
Technical sales specialists — wholesale trade	Promote products to clients, negotiate contracts and agreements	Mainland/Southwest (77.6%), Vancouver Island/Coast (9.0%), Thompson-Okanagan (8.4%)	Replacement of retiring workers (61.4%) and economic growth (38.6%)	6,805
Sales and account representatives — wholesale trade (non-technical)	Identify and engage with clients, promote products, prepare contracts	Mainland/Southwest (75.7%), Vancouver Island/Coast (11.0%), Thompson-Okanagan (8.9%)	Replacement of retiring workers (67.3%) and economic growth (32.7%)	9,265
Supervisors, forest products processing	Oversee activities at the production site, monitor the performance of machinery, train new staff	Mainland/Southwest (26.6%), Cariboo (26.0%), Thompson-Okanagan (13.0%)	Replacement of retiring workers	1,175
Manufacturing managers	Plan and oversee the operations of the manufacturing plant, plan and oversee the optimal use of resources to meet the production targets	Mainland/Southwest (69.0%), Thompson-Okanagan (12.4%), Vancouver Island/Coast (10.9%)	Replacement of retiring workers (90.3%) and economic growth (9.7%)	9,265

requires completing an apprenticeship program.[82] Moreover, these occupations are not necessarily restricted to forest products manufacturing and face demand from multiple sectors and industries. In terms of skills, both heavy equipment operators and material handlers require operation and maintenance of machinery skills. In terms of knowledge areas, understanding safety guidelines is important for both occupations. For material handlers, understanding production processes is an important knowledge area as they are mostly employed in manufacturing industries. Meanwhile, for heavy equipment operators, knowledge of construction processes is more important as the occupation is in high demand in the construction industry.

Lumber graders, on the other hand, are involved in inspecting wood products and sorting them into different categories.[83] They inspect lumber produced by the sawmill for defects and ensure that the company's quality control measures are followed. Furthermore, they use tools to obtain different measurements on various characteristics of lumber, such as its thickness, wood type, and moisture content, and sort lumber into different categories according to industry standards.[84] In addition to taking a specialized course on lumber grading, most of the skills required in this occupation are acquired through work experience and on-the-job training.[85] In terms of soft skills, communications and problem solving skills are important in these roles, while knowledge of mathematics and production processes is quite critical. Entry into this occupation mostly requires previous work experience in a wood manufacturing role.

In lumber production, sawmill machine operators operate machinery and equipment to generate lumber from wood logs.[86] As the equipment used in this occupation is primarily automated, sawmill machine operators are usually involved in operating and adjusting the equipment to produce various types of lumber products in different sizes.[87] Entry into this occupation usually involves on-the-job training and some college education. Meanwhile, labourers in wood, pulp and paper processing are mostly involved in a supporting role as they feed wood logs into conveyors to process wood into lumber products.[88] They support the upkeep, maintenance, and repair of sawmill machinery. They also support the movement of lumber across the production site throughout the various stages of wood processing. Entry into this occupation does not require specific training or educational qualifications.[89] Both sawmill machine operators and labourers in wood, pulp and paper processing are relatively low-skilled occupations. For sawmill machine operators, the operation and maintenance of machines and equipment is a key skill for their work as they are responsible for operating automated equipment. For labourers in wood, pulp and paper processing, communications skills are more important as they support a variety of functions in a sawmill. In terms of knowledge areas, both occupations require expertise across similar areas, requiring understanding of mechanical equipment operation and repair, production processes, and safety guidelines.

In sales, both non-technical and technical sales specialists perform similar tasks. They are involved in engaging with both existing and potential clients. They promote company products to clients and prepare quotations and contracts.[90] Entry into these occupations sometimes requires a college diploma or university-level education and some technical knowledge of the products being sold.[91] In terms of skills, both occupations require verbal communication skills as speaking is a vital part of these roles. Meanwhile, knowledge of interpersonal communication, as well as sales and marketing knowledge, are important for performing these roles' tasks and responsibilities.

In management, supervisors in forest products processing coordinate and supervise the activities of workers involved in the processing of logs into lumber. They ensure the smooth operation and maintenance of plant machinery and equipment.[92] They are responsible for preparing activity plans for workers and navigating through any hindrances that appear in the operation of the mill. They are also involved in the hiring and training of staff, as well as ensuring staff adherence to the safety requirements.[93] Entry into this occupation usually requires a combination of on-the-job training and college education.[94] On the other hand, manufacturing managers are involved in planning and managing the sawmill's operations.[95] They maintain the inventory for both raw materials and wood products. They develop systems for production reporting and quality control. Manufacturing managers also plan the effective use of raw wood logs, machinery, and labour and are responsible for meeting the sawmill's production targets. Entry into this occupation requires a college or university-level education and previous experience in a supervisory capacity.[96] Both of these occupations require a similar set of skills. Supervisors of forest products processing have higher importance for the management of personnel skills as they have a hands-on role in managing employees. Meanwhile, manufacturing managers have higher importance for problem solving and communications skills as they are responsible for planning plant activities and communicating them to different stakeholders. In terms of knowledge, both occupations require management of personnel knowledge, as well as knowledge of production systems and processes.

Figure 6: Current skills and knowledge needs for workers in lumber production (absolute scores on the importance of a skill or knowledge area, 0-100)

Labourers in wood, pulp and paper processing

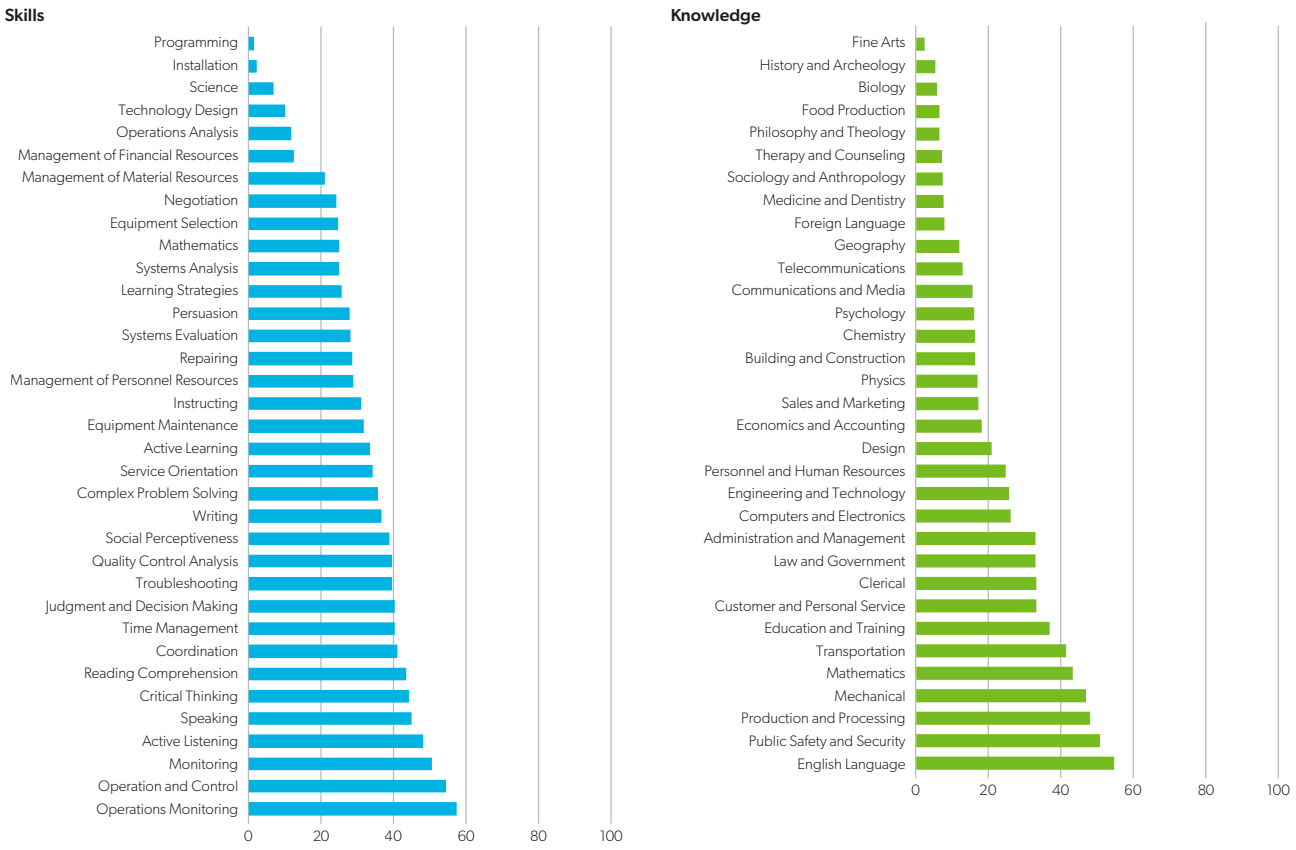
Figure 6-1

Sawmill machine operators

Figure 6-2

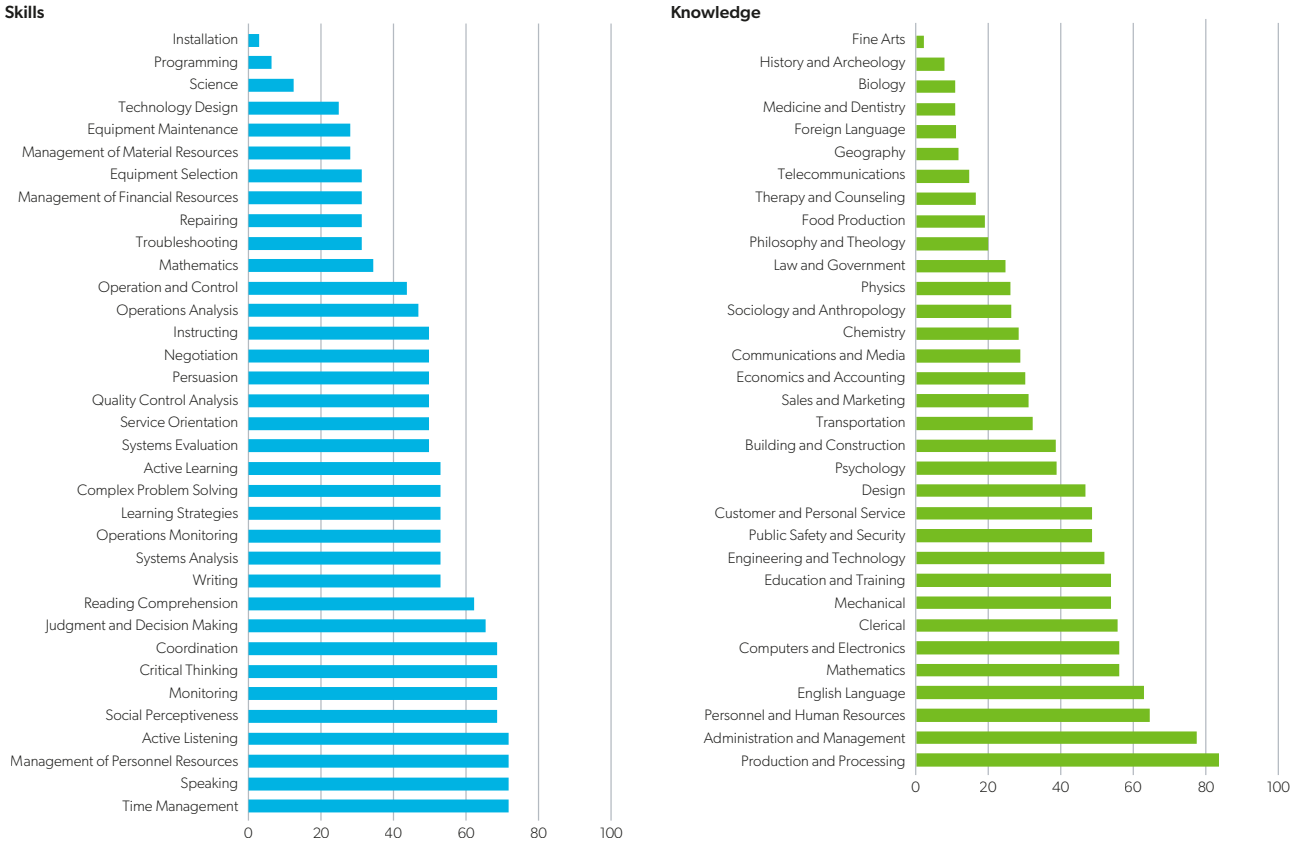
Material handlers

Figure 6-3



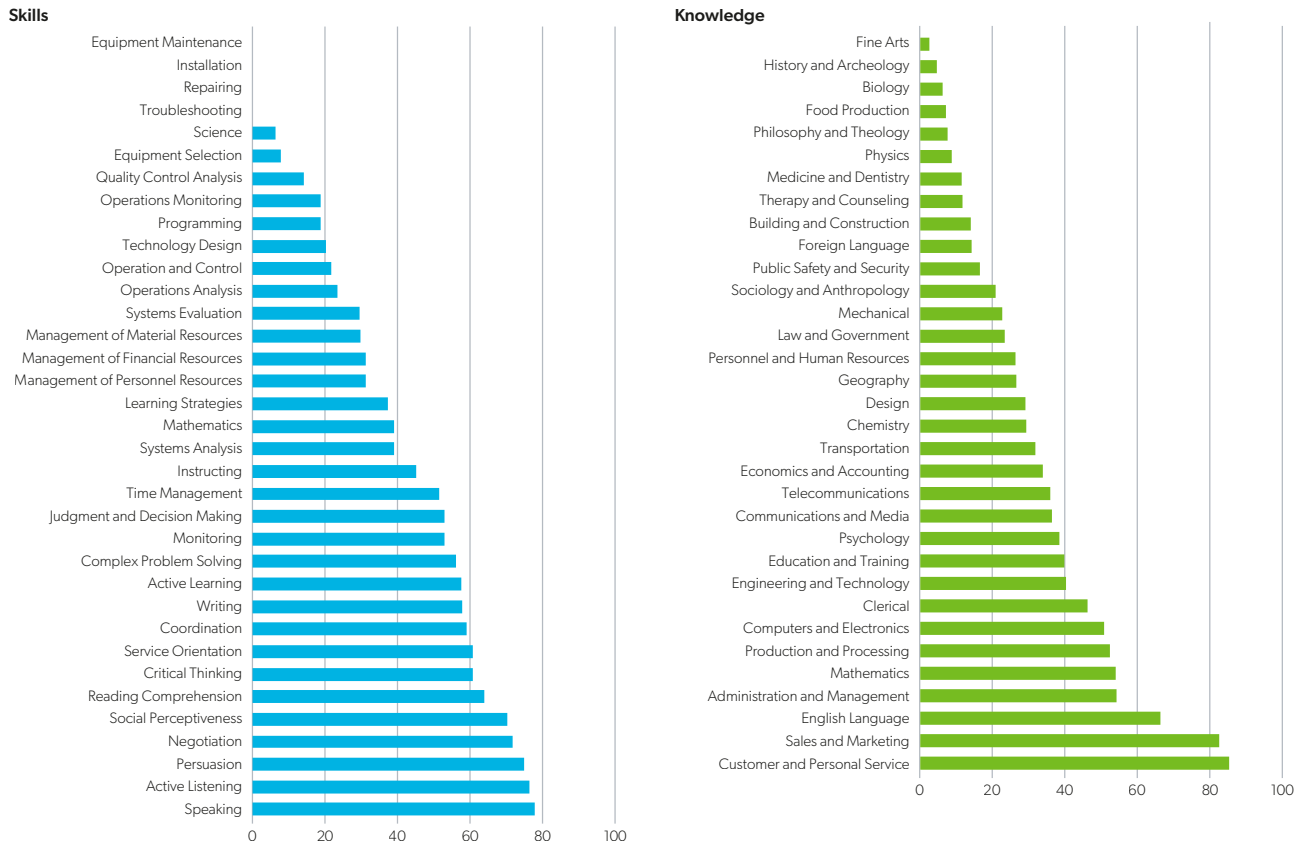
Supervisors, forest products processing

Figure 6-4



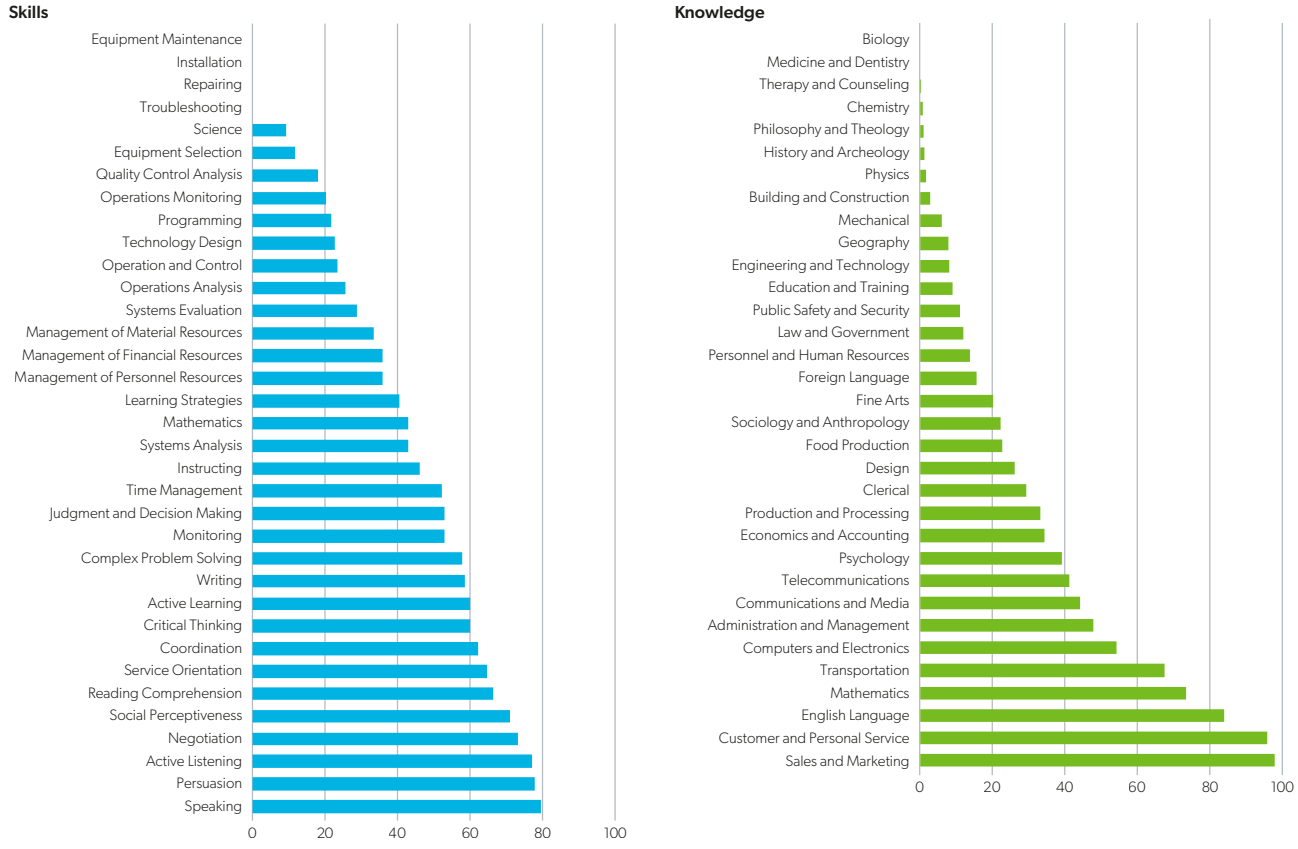
Technical sales specialists — wholesale trade

Figure 6-5



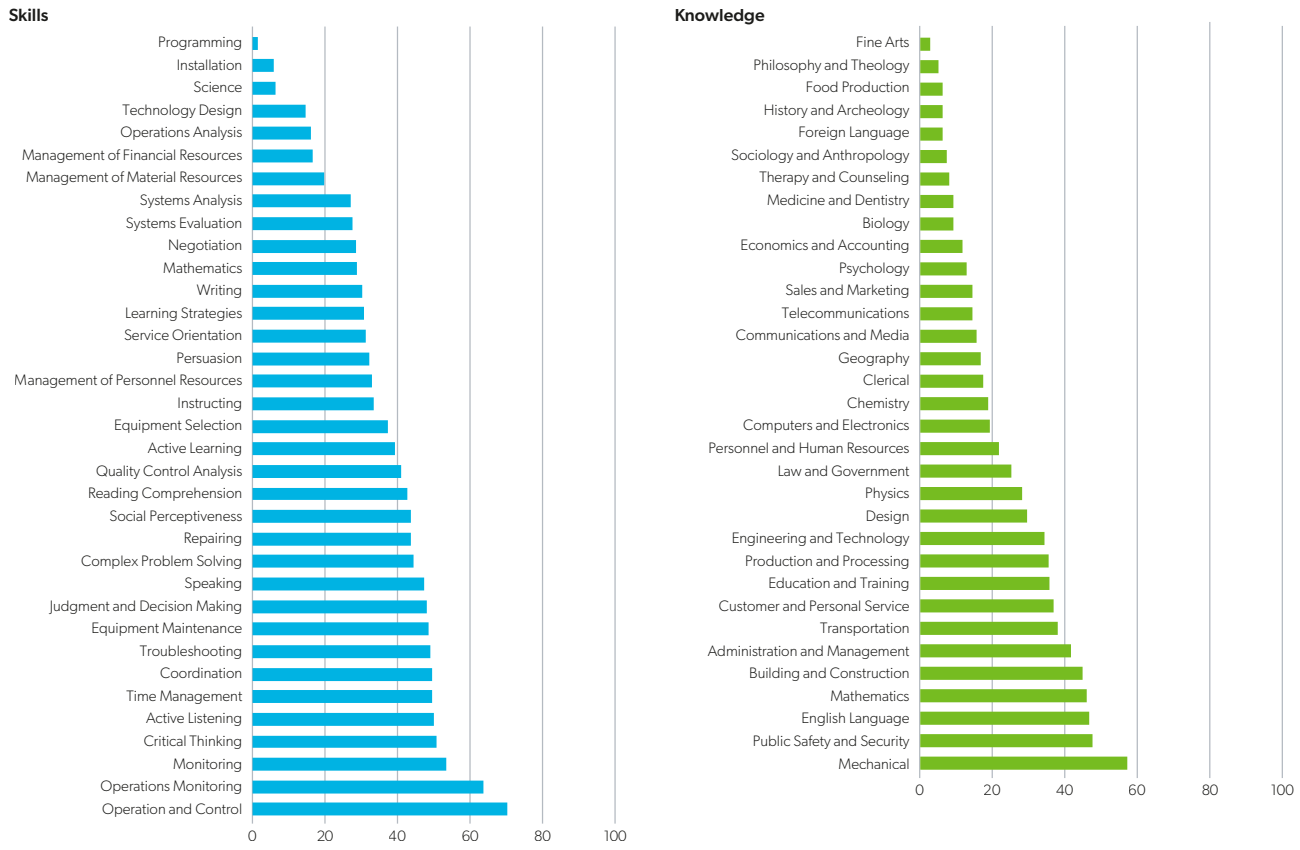
Sales and account representatives — wholesale trade (non-technical)

Figure 6-6



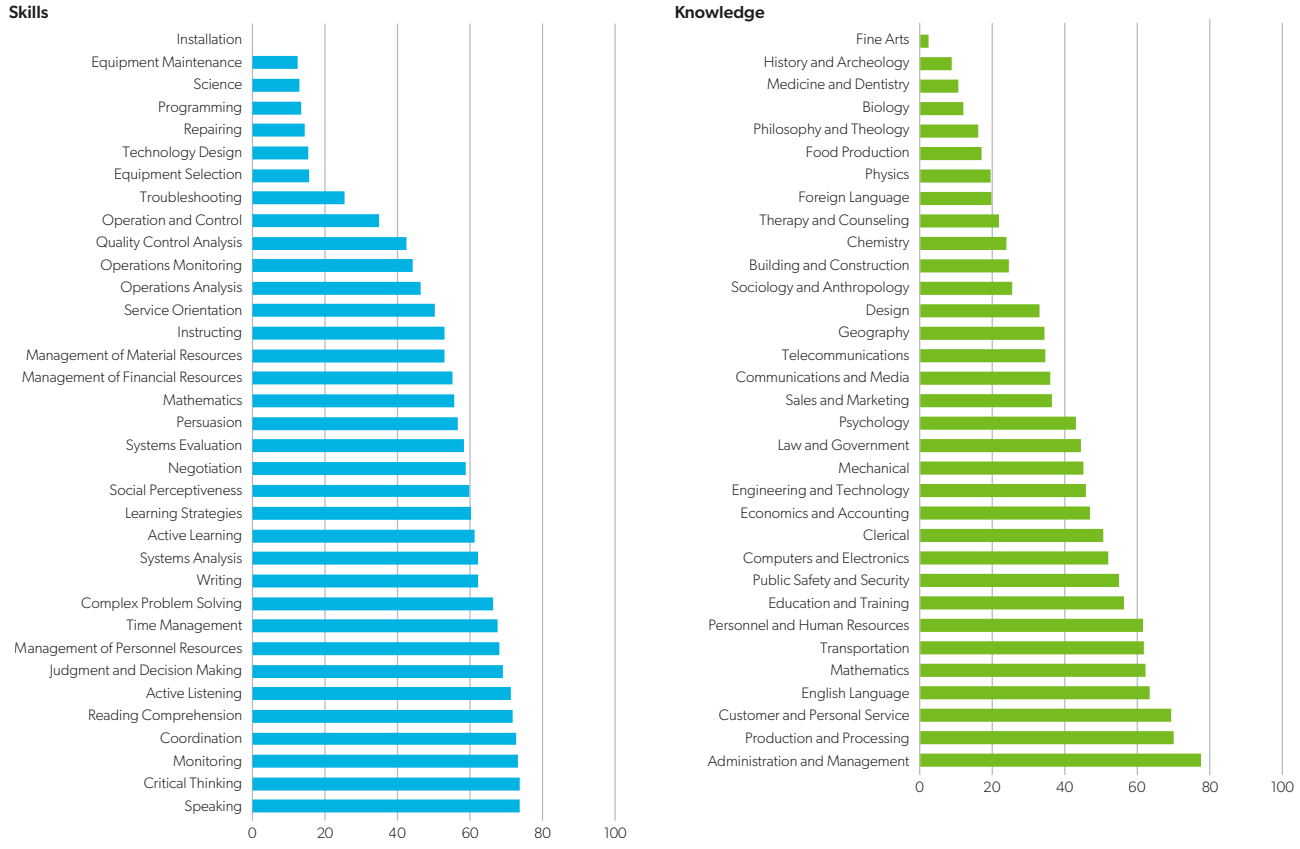
Heavy equipment operators

Figure 6-7

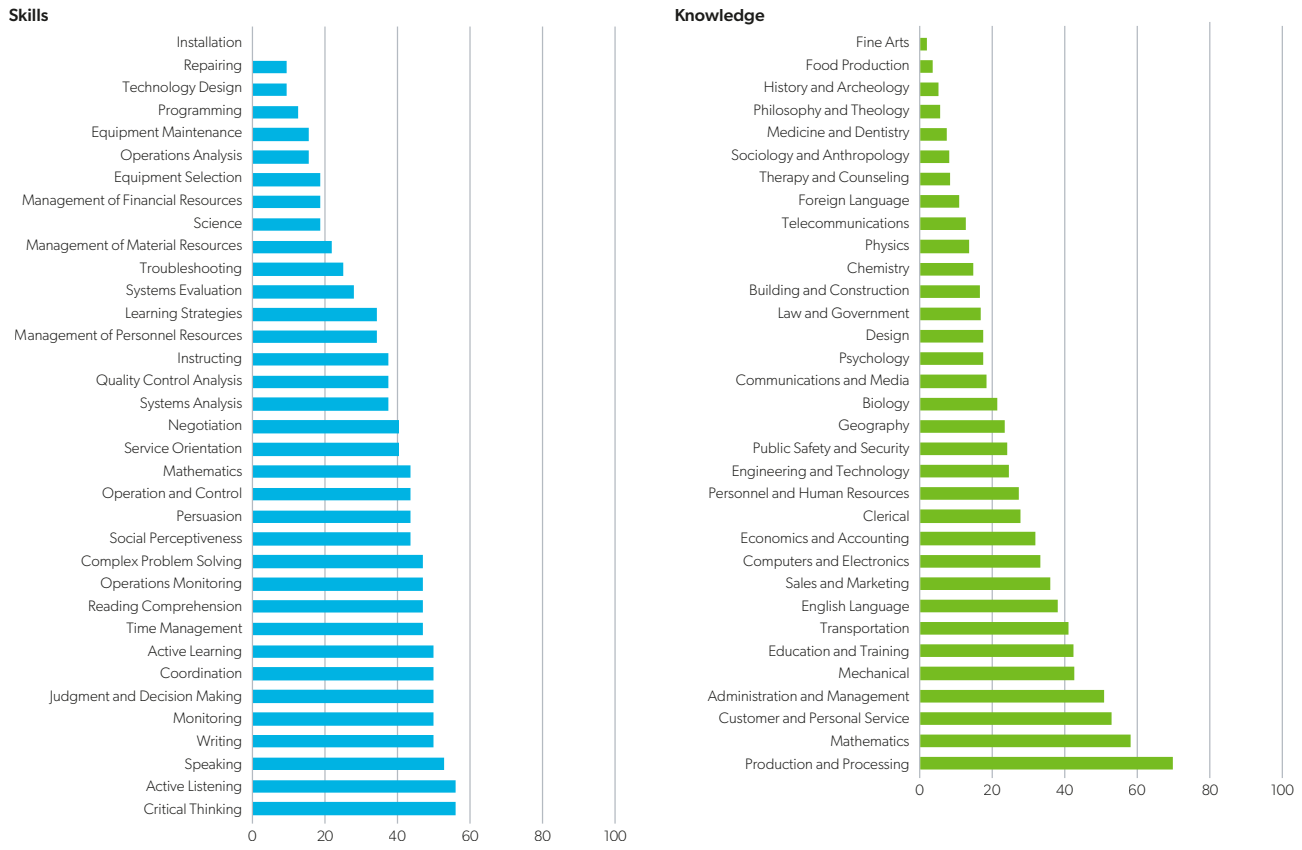


Manufacturing managers

Figure 6-8



Lumber graders and other wood processing inspectors and graders Figure 6-9



Future skills needs for resource extraction and preparation (forest management, logging, and lumber milling)

The growth of mass timber will have different impacts on each part of the supply chain. In resource extraction, mass timber solutions do not immediately impact logging and forest management activities. Rather, these sectors are impacted by ongoing trends in these industries. Forest fires, the pine beetle epidemic, environmental considerations of protecting old-growth trees, and climate change, all of which have taken a large toll on forest health in BC, have created a need to shift the approach towards managing forests. Instead of managing forests just by considering the volume of trees harvested through the AAC, there is now a need to focus on managing forest health, an approach that has had an increased focus in BC in recent years.[97] In the logging sector specifically, the emergence of automated technologies has been, and will continue to be, a major disrupter. The use of automated tools to harvest trees and transport wood logs will lead to increased demand for digital skills among workers employed in logging. This includes using sensors and positioning technologies that will allow workers to carry out harvesting more effectively. Moreover, using drones and analytical tools to determine tree health will require logging workers to acquire analytical skills.

In terms of resource preparation, mass timber production requires the input of a wood product that contains lower moisture content than traditional lumber produced by sawmills. This requirement means additional drying cycles and more time spent in the drying stages to produce the wood necessary for mass timber production.[98] The workers performing this task might be employed by either mass timber manufacturers or sawmills. Regardless, as mass timber grows, workers involved in lumber preparation will need to expand their skill set to include using the necessary tools and equipment to reduce the wood's moisture content. This will require increased knowledge of the different methods used in drying lumber. Workers will also need to better understand the lumber specifications required by mass timber manufacturers. These specifications include the lumber's moisture content, thickness, and grade. Similarly, lumber graders responsible for the necessary quality control and for grading wood products according to the industry specification will need to acquire knowledge specific to mass timber products in order to grade products accordingly.

Manufacturing

Mass timber manufacturing

In mass timber manufacturing, the primary wood product produced by sawmills is processed into finished products that can then be assembled at the construction site. For this report, activities represented by the Veneer, plywood and engineered wood product manufacturing sector (NAICS 3219) were deemed closest to mass timber manufacturing. The tasks performed within mass timber manufacturing can be divided into four categories: material handling, production of mass timber products, plant operations, and management.

Similar to material handlers in resource preparation at sawmills, material handlers in manufacturing are responsible for loading and offloading products. They load timber products received from sawmills and storing them. They also operate machinery and equipment to store and load finished products in warehouses and vehicles, respectively.[99]

In production, the key occupations are labourers in wood, pulp and paper processing, other wood processing machine operators, and woodworking machine operators. Labourers in wood, pulp and processing within manufacturing complete tasks similar to those expected of this occupation in resource preparation at sawmills.[100] They are mainly involved in loading timber in machines and conveyor belts during various processes of mass timber manufacturing. They also move timber across various stages of the production process.[101]

Other wood processing machine operators and woodworking machine operators (NOC categories used to refer to operators conducting a range of tasks within a manufacturing facility) are mainly focused on tasks specifically related to mass timber production. Other wood processing machine operators perform the additional processing of timber received at mass timber plants.[102] They use drying kilns to reduce the wood's moisture content as the production of mass timber products requires timber with low moisture content.[103] They are also involved in glueing layers of timber, which is a component of mass timber manufacturing. Entry into the occupation might require some college education and previous work experience, with on-the-job training provided.[104]

Woodworking machine operators are responsible for cutting layers of timber and glueing them together to create mass timber panels.[105] They are also responsible for operating CNC machines to fabricate mass timber panels. The 3D design for a mass timber building is first inputted into a CNC machine, which is then used to fabricate and produce the components of the building structure. Entry into this occupation requires secondary school education, with most training provided on the job. However, some jobs might require college education.[106] Woodworking machine operators is a relatively low-skilled occupation, with work in these roles requiring skills in the operation of machinery, alongside knowledge of mechanical equipment and production processes.

Table 8: Occupations in mass timber manufacturing, tasks performed in each occupation, which regions have the highest concentration of each occupation within British Columbia, and source of future labour demand

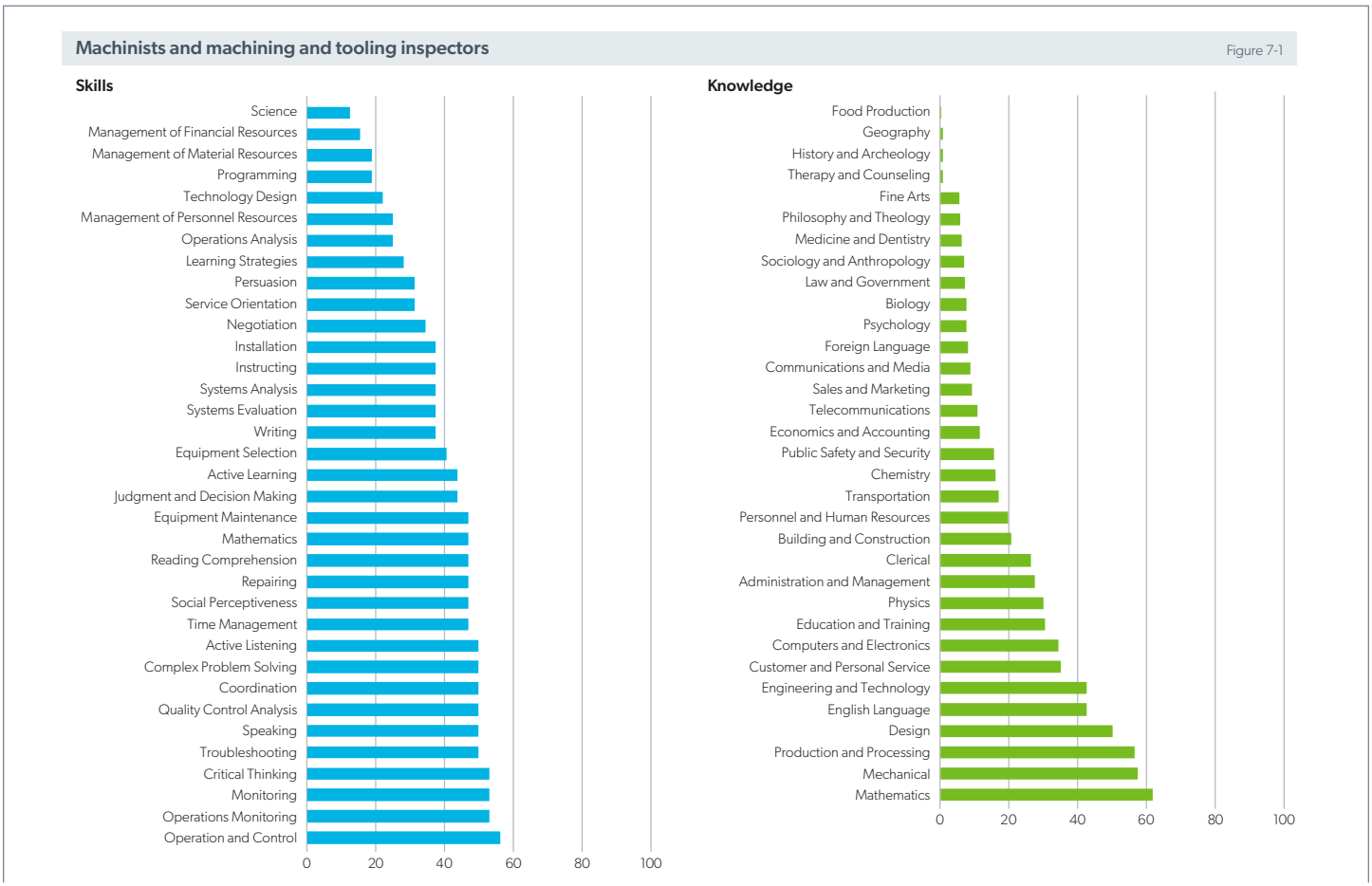
Occupation	Tasks performed	Top 3 geographical regions of employment	Source of future labour demand	Number of people employed in BC
Other wood processing machine operators	Dry timber, trim and press layers of wood	Mainland/Southwest (33.9%), Thompson-Okanagan (27.1%), Cariboo (16.8%)	Replacement of retiring workers	590
Woodworking machine operators	Operate CNC machines to fabricate structures	Mainland/Southwest (48.8%), Thompson-Okanagan (16.5%), Vancouver Island/Coast (11.0%)	Replacement of retiring workers	705
Industrial engineering and manufacturing technologists and technicians	Program CNC machines	Mainland/Southwest (71.7%), Thompson-Okanagan (11.2%), Vancouver Island/Coast (9.5%)	Replacement of retiring workers (70.2%) and economic growth (29.8%)	1,515
Construction millwrights and industrial mechanics	Install and repair machinery	Mainland/Southwest (36.2), Thompson-Okanagan (17.3%), Cariboo (13.3%)	Replacement of retiring workers (84.1%) and economic growth (15.9%)	6,625

Machinists and machine tool operators in mass timber use CNC machines to operate on wood, producing products with very specific dimensions. Mass timber manufacturers might also employ workers experienced in using CNC machines from other sectors (i.e., workers producing metal or plastic products through CNC machines). However, employing CNC operators familiar with materials other than wood will require them to adjust to working with a new raw material that has different physical properties from the ones these workers are used to. It will also require knowledge of construction processes and design requirements. Additionally, manufacturing facilities might employ industrial engineering and manufacturing technologists and technicians to program the CNC machines to fabricate mass timber products.[107] They develop applications using tools such as computer-aided design (CAD) and computer-aided manufacturing (CAM) design software to tune the CNC machines for mass timber production.[108] This regulated occupation requires college-level education and work experience to obtain the necessary certification.[109] Industrial technologist is a rather high-skilled occupation requiring strong verbal and written communications skills, alongside knowledge in areas related to engineering and design.

Mass timber factory operations also involve construction millwrights who install the machinery used in plants.[110] They are also responsible for maintaining and repairing the machinery used during mass timber manufacturing. Since mass timber is a relatively nascent industry, there will likely be demand for millwrights to support the development of new production facilities.[111] However, mass timber production uses newer types of machinery that are traditionally not used in wood product manufacturing, meaning that millwrights may need to upgrade their skills to work in new production facilities. Moreover, the occupation has been affected by ongoing trends in the industry. Both the decline in wood products manufacturing and the continued rapid technological developments have caused a decrease in demand for this occupation.[112] Millwrights are required to successfully complete of an apprenticeship program.[113]

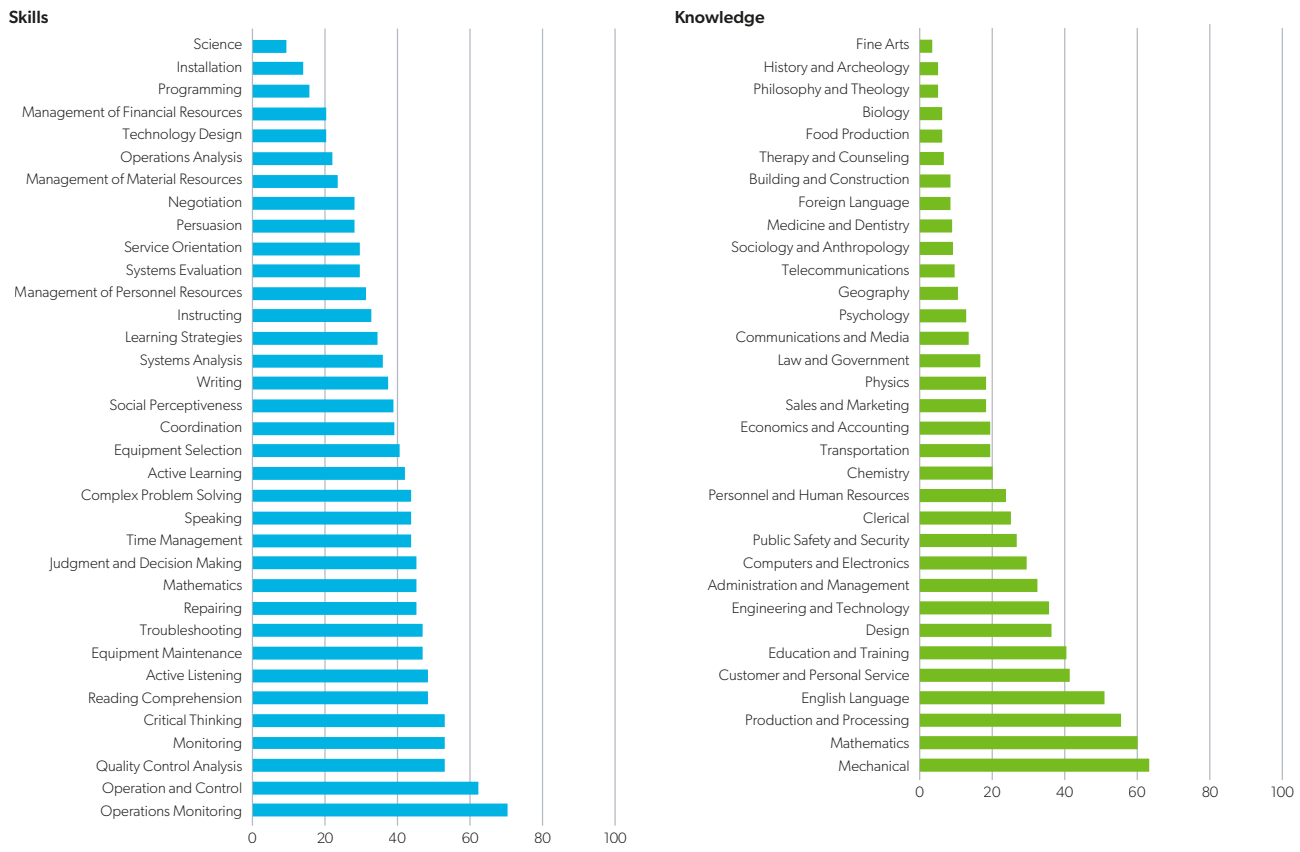
Supervisors and managers in mass timber manufacturing will likely require the same skill set as these occupations at sawmills in resource preparation in terms of managing production targets and work schedules. However, the nature of their work also requires extensive coordination with stakeholders from the construction and design sectors, meaning coordination and communications skills are important. In terms of knowledge, manufacturing mass timber products requires increased knowledge of the construction sector's needs and processes, as well as knowledge of building design and specifications.

Figure 7: Future skills and knowledge needs for workers in mass timber manufacturing (absolute scores on the importance of a skill or knowledge area, 0-100)



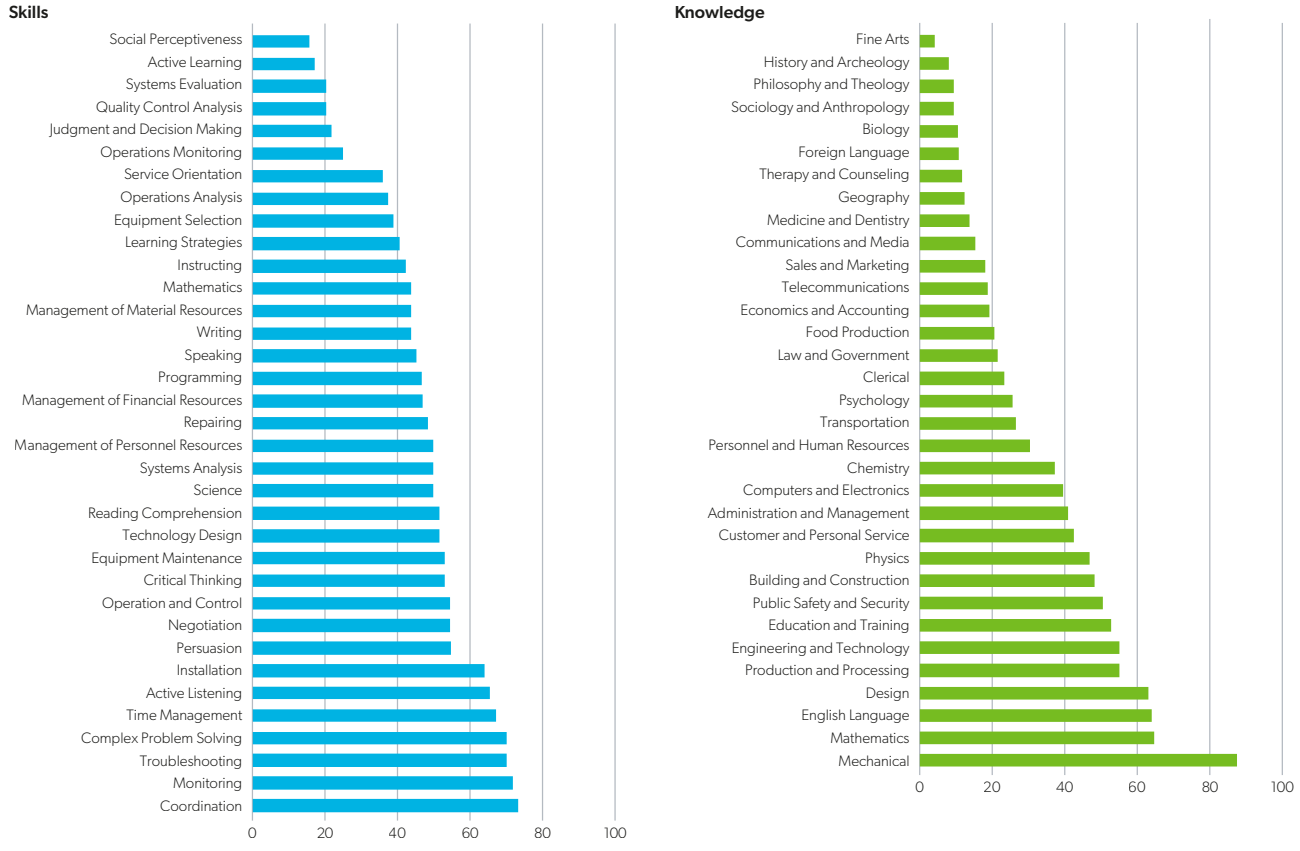
Machining tool operators

Figure 7-2



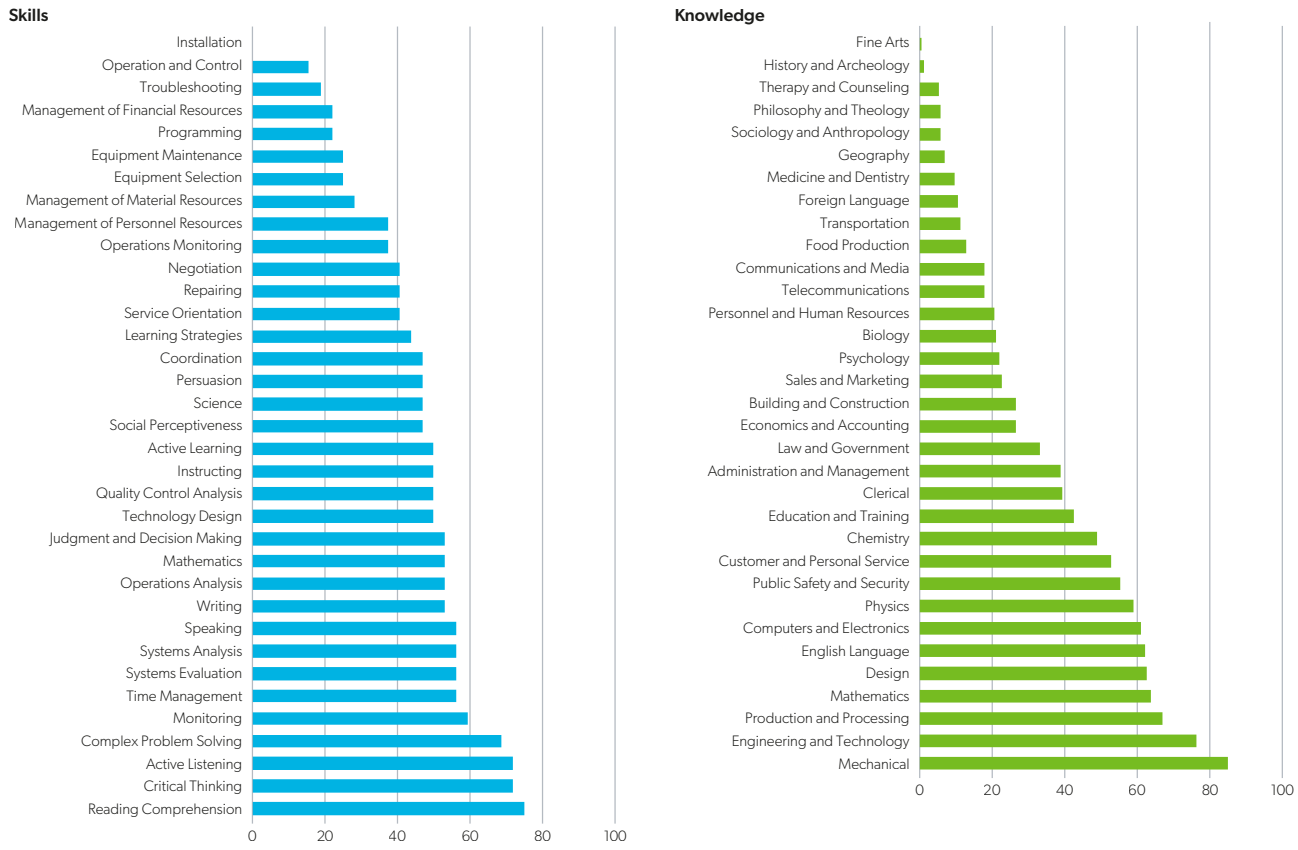
Construction millwrights and industrial mechanics

Figure 7-3



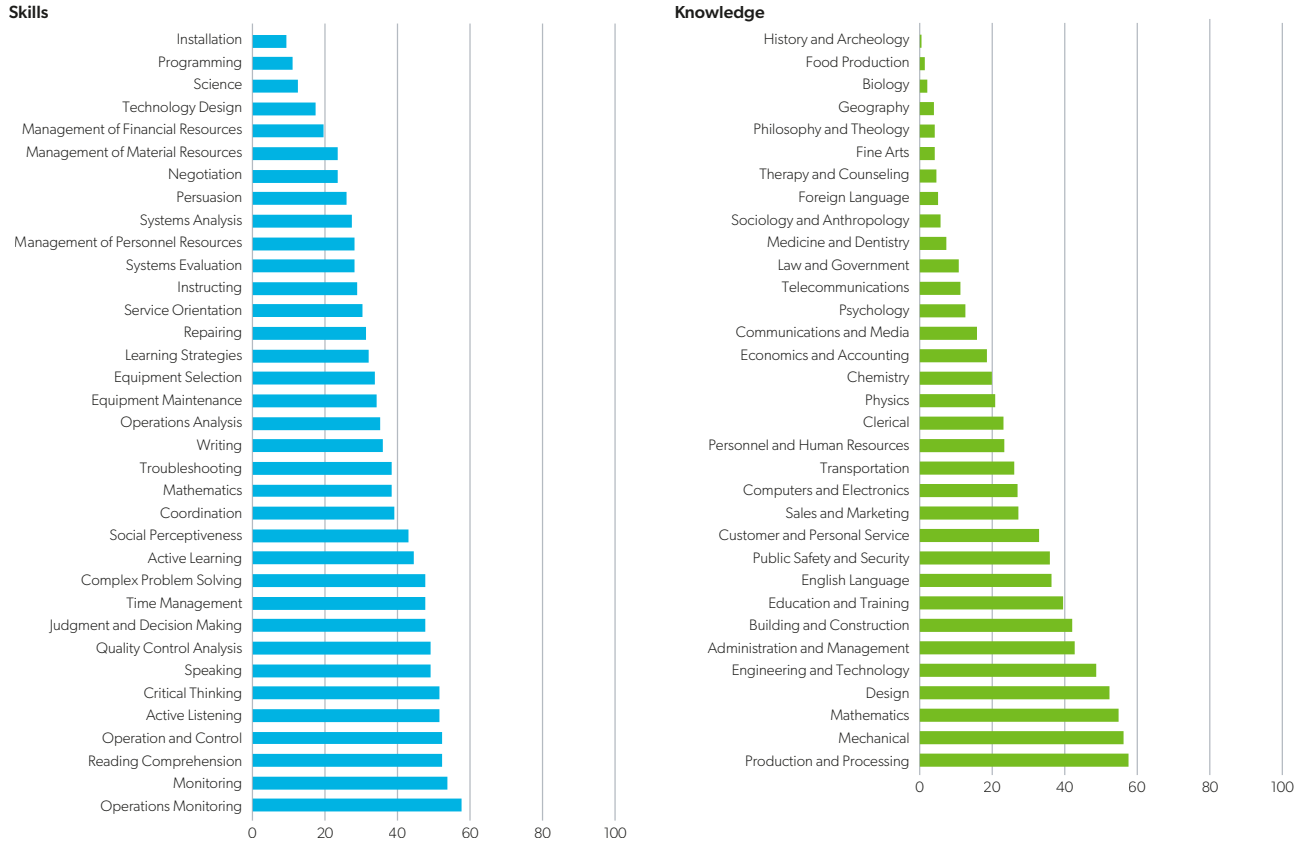
Industrial engineering and manufacturing technologists and technicians

Figure 7-4



Woodworking machine operators

Figure 7-5



Other wood processing machine operators Figure 7-6

Future skills needs for mass timber manufacturing

As a result of differences between mass timber manufacturing and wood product manufacturing more broadly, occupations throughout the supply chain will require an upgrading of soft skills. Workers in the sector will need to enhance their communications and coordination skills as manufacturing mass timber building components requires input from stakeholders in the design and construction sector. Workers need knowledge of the requirements that the manufactured structure needs to meet in terms of construction and design specifications. They also need knowledge of the processes involved in building design and construction. Furthermore, since each project requires customization, workers also would require a deeper understanding and knowledge of client needs.

Workers will also need to upgrade their skills related to producing mass timber products. Traditionally, wood products manufacturing produces large volumes of wood products, and production processes are less complex than those required to build mass timber products.[114] The scale of mass timber manufacturing — which involves working with larger wood products to create a whole structure in a manufacturing plant — and the requirements to produce goods directly for the construction sector will require different areas in which workers have to be knowledgeable.

For example, mass timber products require stronger adhesion to perform load-bearing functions in a building and align with safety requirements.[115] Workers making the shift from wood manufacturing into mass timber manufacturing will therefore require stronger knowledge of different adhesives used in mass timber manufacturing and their application. Additionally, mass timber production requires working with newer production technologies, which the workers in these occupations might not be used to. For example, mass timber manufacturing involves the use of CNC machines. While some professionals in wood manufacturing do already use CNC machines to produce cabinets, furniture, windows, and doors, workers from other industries, such as metal or plastic processing, lack experience working with wood as a production material. This knowledge gap illustrates a clear need to upskill workers coming from both within and outside sectors in the supply chain.

Expansion of mass timber production will also require a focus on developing wood manufacturing workers' skills in using digital tools and producing precise building structures using sophisticated machinery. Precision is required in the manufacturing of the components of a mass timber building (as the building structure has to be assembled on-site, meaning all pieces need to be able to connect and openings in panels need to be created during the manufacturing process for installing the mechanical, electrical and plumbing systems). Therefore, there is a strong

need to use digital 3D modelling tools and CNC machines to aid in the manufacturing process by fabricating digital models of building structures.[116] It is thus necessary to upgrade workers' skills to use digital tools, such as CNC machines, to fabricate building structures based on 3D models. Additionally, an understanding of Design for Manufacturing and Assembly (DfMA) principles is highly desirable. DfMA is an engineering principle that seeks to maximize the ease of manufacturing and assembly while minimizing the waste, cost, and complexity (amongst other factors) of manufacturing and assembly.[117] Workers involved in mass timber production will also need to be able to understand CAD drawings and convert them into a format that CNC machines can run. This is an area where the wood manufacturing sector lacks skilled workers, even for traditional wood product manufacturing.[118]

As it pertains to specific occupations, managers and supervisors in mass timber manufacturing also require upskilling. Managers and supervisors are typically involved in managing the production line and ensuring that production targets are met. When working with mass timber, they have to shift their focus to consulting with the designers, engineers, and construction managers to finalize the design of the building and align the manufacturing schedule with the construction schedule. Since mass timber aims to reduce inventory and follows the 'just-in-time' method, managers must optimize the production process, especially regarding time management.[119] Managers in mass timber manufacturing also need to communicate effectively with design and construction professionals, alongside use critical thinking skills when challenges in the design process arise. Finally, managers and supervisors have to understand the requirements of design and construction professionals and acquire technical knowledge of construction to effectively design and manufacture a structure that meets the needs of the construction industry.

Table 9: Difference between traditional wood product manufacturing and mass timber manufacturing

Traditional wood product manufacturing	Mass timber manufacturing
Producing large volumes of wood products according to client specification	Producing a customized product according to client specification
Using CAD and CNC machines to manufacture wood products	Use CAD and CNC machines to translate 3D models into building components
Work in singular teams	Work in multi-disciplinary teams
Do not require extensive knowledge and coordination of end-user processes	Requires knowledge and extensive coordination with end-user processes

Adoption

Design

The design process involves preparing the blueprints and sketches of the building to be constructed by construction professionals. Activities in design are represented in this report by the Architectural, engineering and related services (NAICS 5413) and Specialized design services (NAICS 5414) sectors. The tasks in design can be split into three categories: building design, building system design, and project management.

In building design, architects and drafting technologists and technicians are involved in preparing the building design. Architects are responsible for conceiving building designs according to client needs. They prepare the necessary drawings and models encapsulating the blueprint of the building, which is later used by on-site construction staff for constructing the building.[120] Architects are also involved in the bidding process. Moreover, they develop plans containing not only the building design, but the materials required, the financial cost for implementing the plan, and the relevant timelines for the construction process.[121] Entry into this occupation requires completing at least a bachelor's degree in architecture and passing the architect registration examination in BC.[122]

Meanwhile, drafting technologists and technicians are responsible for supporting architects and engineers.[123] They use CAD software to prepare the relevant drawings and sketches for building construction. They are also involved in preparing construction cost estimates and tender documents.[124] Entry into the occupation usually involves obtaining a college diploma and the necessary work experience to obtain a certification from a relevant provincial association.[125] Both architect and drafting technologists and technicians are highly skilled occupations. Both require strong communications and critical thinking skills, as the nature of work involves communication and coordination with multiple stakeholders and solving complex problems. Moreover, both occupations require a strong knowledge of the processes and tools used in design and construction.

In building system design, mechanical engineers are mainly involved in designing a building's mechanical systems.[126] These include the heating, ventilation, and air conditioning systems. They are also involved in preparing the cost estimates, material requirements, and installation timelines for these systems.[127] Entry into the occupation requires obtaining a mechanical engineering degree and accreditation as a professional engineer by a provincial or territorial association of professional engineers.[128] Meanwhile, electrical and electronics engineers are involved in the design of the building's electrical and power systems.[129] They plan and design the electrical systems and circuits installed in a building. Furthermore, they are involved in preparing contracts and tenders, as well as developing cost estimates and time schedules.[130] Entry into this occupation is also regulated, requiring the completion of an undergraduate degree in electrical

Table 10: Occupations in design, tasks performed in each occupation, which regions have the highest concentration of each occupation within British Columbia, and source of future labour demand

Occupation	Tasks performed	Top 3 geographical regions of employment	Source of future labour demand	Number of people employed in BC
Architects	Prepare building design, prepare building plans	Mainland/Southwest (84.04%), Vancouver Island/Coast (10.7%), Thompson-Okanagan (4.2%)	Replacement of retiring workers (42.2%) and economic growth (57.8%)	3,505
Drafting technologists and technicians	Prepare drawings and sketches, operate CAD software	Mainland/Southwest (73.5%), Vancouver Island/Coast (12.4%), Thompson-Okanagan (7.3%)	Replacement of retiring workers (57%) and economic growth (43%)	3,935
Mechanical engineers	Design building heating and cooling systems	Mainland/Southwest (75.6%), Vancouver Island/Coast (11.4%), Thompson-Okanagan (6.0%)	Replacement of retiring workers (53.7%) and economic growth (46.3%)	5,845
Electrical and electronic engineers	Design building electrical and power systems	Mainland/Southwest (82.6%), Vancouver Island/Coast (8.7%), Thompson-Okanagan (5.4%)	Replacement of retiring workers (54.3%) and economic growth (45.7%)	4,705
Civil engineers	Plan construction projects, ensure adherence to building codes	Mainland/Southwest (75.6%), Vancouver Island/Coast (11.2%), Thompson-Okanagan (8.2%)	Replacement of retiring workers (61.2%) and economic growth (38.8%)	9,320
Engineering managers	Plan and oversee activities, develop policies and procedures	Mainland/Southwest (76.7%), Vancouver Island/Coast (10.7%), Thompson-Okanagan (6.0%)	Replacement of retiring workers (69%) and economic growth (31%)	4,065

or electronics engineering and accreditation as a professional engineer by the relevant association.[131] Both mechanical and electrical engineers require strong problem solving skills, as well as knowledge of theoretical and practical aspects of engineering and technology.

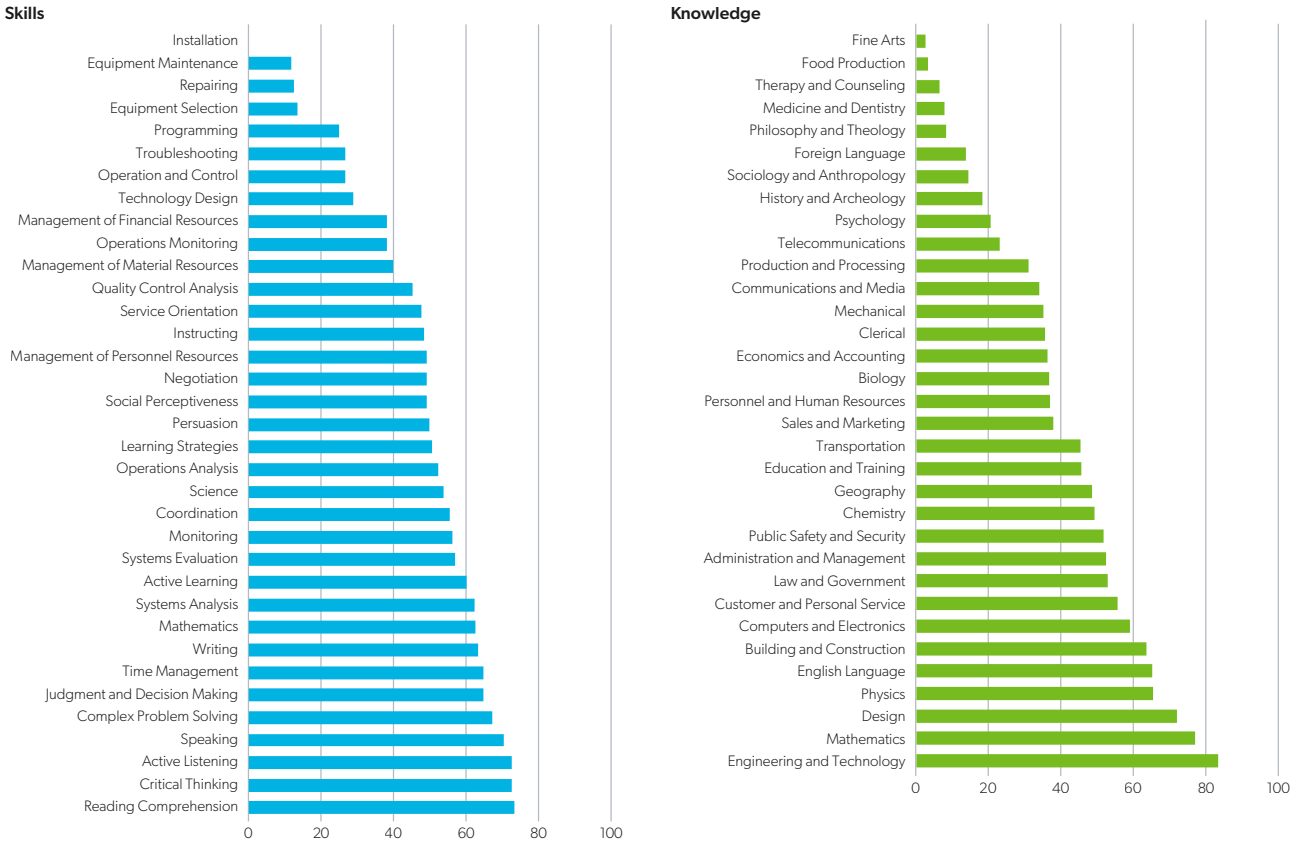
In project management, civil engineers play a crucial role in transforming concepts of building design plans into tangible projects.[132] They carry out feasibility and technical analyses of the land before the construction process. They also ensure adherence to building codes and are involved in selecting project materials.[133] Civil engineers also plan, and supervise the adherence to, construction work plans. Similar to other engineering professions, entry into the occupation requires obtaining a civil engineering undergraduate degree and accreditation as a professional engineer.[134]

Engineering managers, by contrast, are responsible for planning and monitoring the overall activities of an engineering firm.[135] They are responsible for overseeing and reviewing the technical work conducted by various teams. They set the standards and procedures to be followed by engineering staff.[136] They also consult with clients and prepare proposals. Entry into the profession requires accreditation as an engineer and extensive experience working as an engineer. Similar to other engineering-related occupations, both civil engineers and engineering managers require a combination of communications and problem solving skills, as well as knowledge of design and engineering.

Figure 8: Current skills and knowledge needs for workers in design and engineering (absolute scores on the importance of a skill or knowledge area, 0-100)

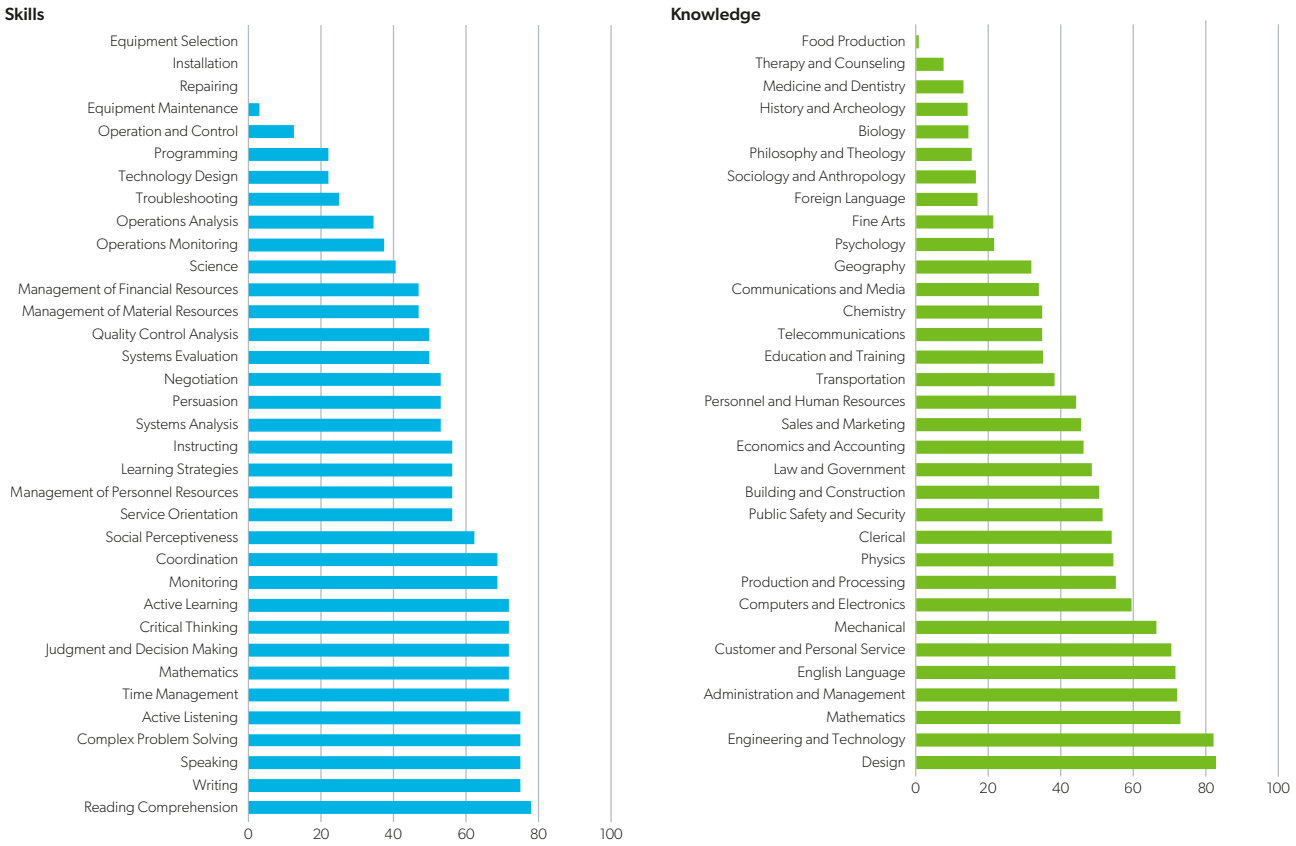
Civil engineers

Figure 8-1



Engineering managers

Figure 8-2

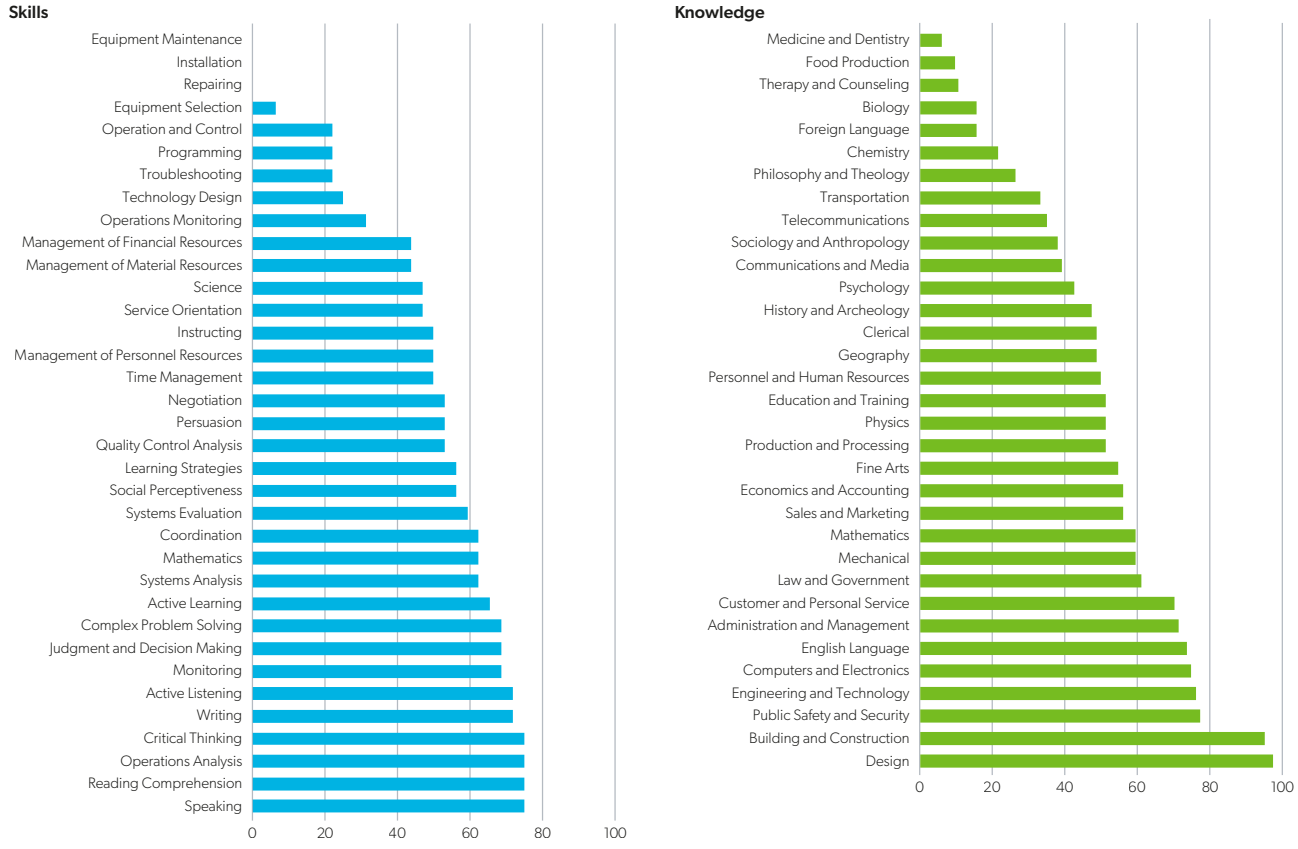


Drafting technologists and technicians

Figure 8-3

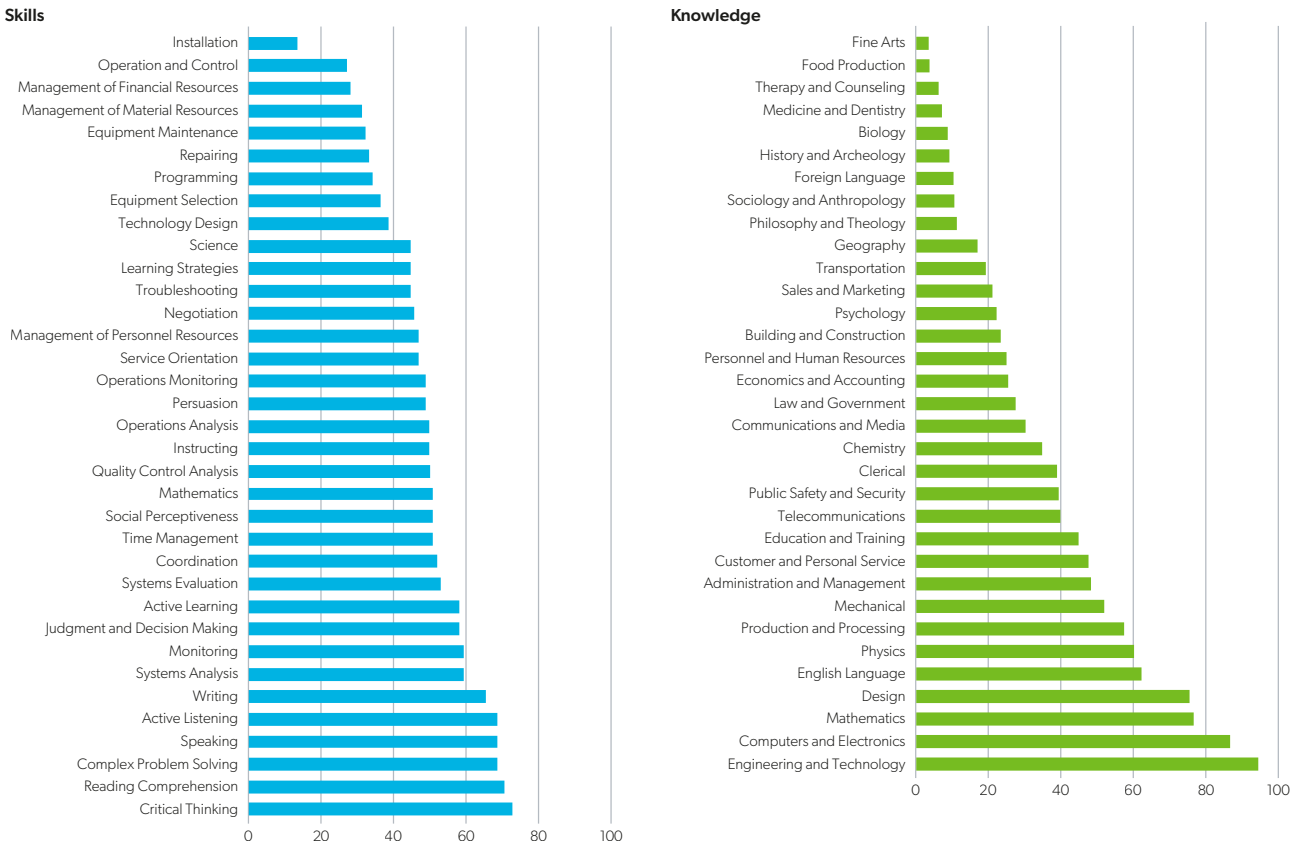
Architects

Figure 8-4



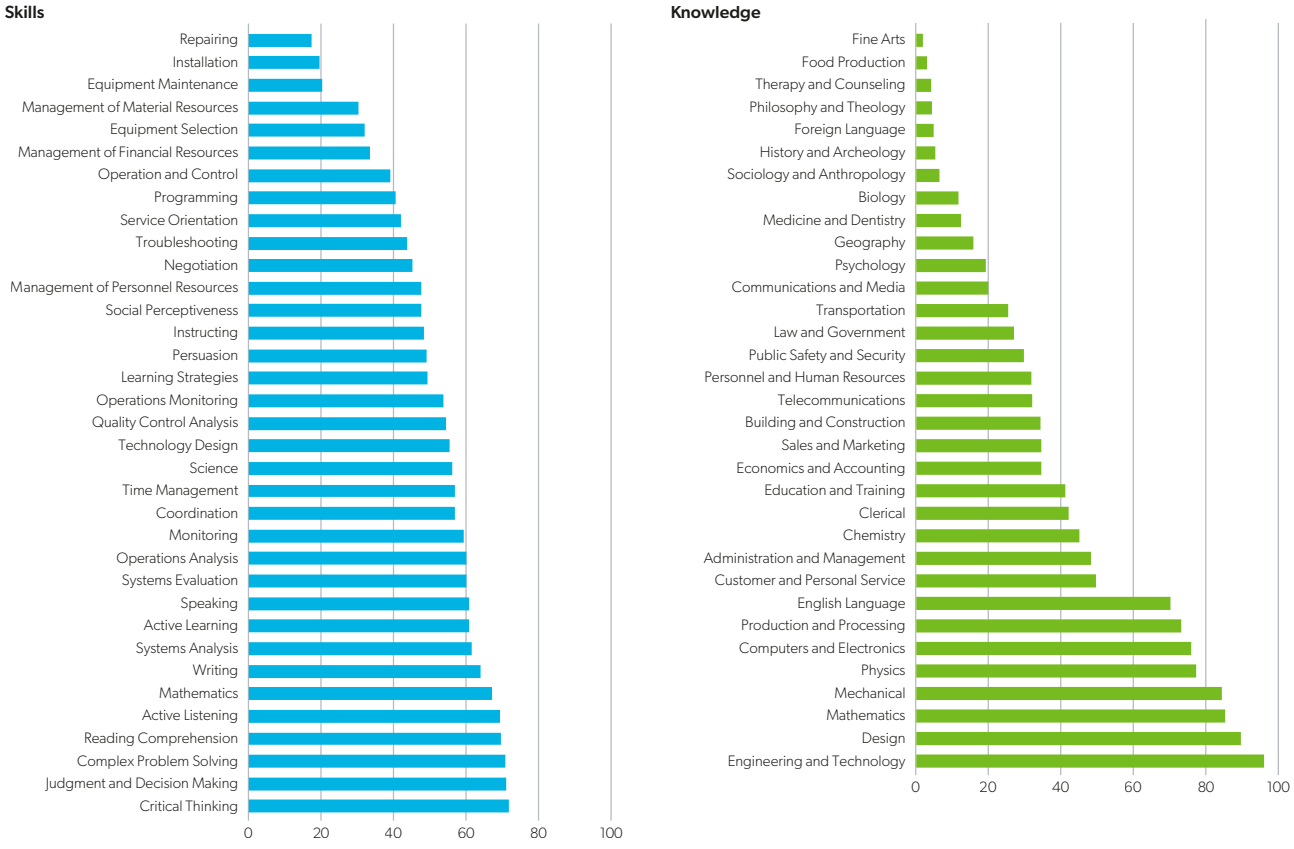
Electrical and electronics engineers

Figure 8-5



Mechanical engineers

Figure 8-6



Future skills needs in adoption (design and engineering)

Unlike traditional construction, the design and assembly of mass timber buildings require a multidisciplinary approach. Traditionally, a building's design is prepared by architects, while construction contractors implement the design by creating a structure based on that design. The producers of building materials (such as steel and concrete) are not involved in the design and planning process. The building material for traditional buildings is usually built in large volumes, with construction stakeholders procuring it in bulk.[137] For mass timber structures however, the construction process requires manufacturers, designers, and constructors to coordinate extensively, particularly in the design and pre-construction stages.[138] Designers, manufacturers, skilled trades workers, and constructors need to provide their inputs in the formation of a 3D model that encapsulates the design and structure of the building, and will be used in building construction and system installation.[139] After the design and formation of a 3D model, the cost estimates and schedule for the construction are prepared. Mass timber typically involves a 'just-in-time' manufacturing approach in Canada, with little room for inventory storage at the manufacturing and construction stages. This leads to the synchronization of manufacturing and construction timelines.

Workers involved in this process require a better understanding of manufacturing processes, as well as the digital tools and software used to design buildings, such as building information modelling (BIM) systems.[140] In particular, construction managers, designers, engineers, and contractors need to upgrade their digital skills to effectively use these tools. These occupations will also need to build upon their soft skills as coordination and teamwork will become an even more important part of their work.

Another difference is that traditionally, architects and engineers design buildings using concrete or steel as the primary construction material. Working on mass timber projects requires learning about modular construction and using wood as the construction material. As discussed above, the shift to modular construction requires coordination with stakeholders from manufacturing and construction, alongside proficiency in DfMA principles and digital tools such as BIM and CAD. Meanwhile, working with wood requires acquiring knowledge about the structural properties of wood and planning the design accordingly. Architects and engineers need to focus on moisture management, which is vital to maintain the structural integrity of the wood, alongside designing a building enclosure in line with wood's properties.[141] Moreover, the design has to include fire safety and acoustics provisions, as wood has different properties than concrete in terms of flammability and sound transmission. Architects and engineers also have to keep in mind the load-bearing capacity of wood, and have to calculate the size and number of panels and beams required for a given structure as part of this process.[142] They also have to select the appropriate connectors for connecting mass timber panels.

Mechanical and electrical engineers involved in designing the MEP systems also have to adjust their planning process and learn about the structural properties of wood.[143] During the design and planning process, mechanical and electrical engineers must engage with manufacturers, ironworkers and carpenters to plan the fabrication and installation of the MEP systems. As the openings for MEP systems are constructed during manufacturing, there is little room for customization in the assembly process. Therefore, input from all relevant stakeholders must be obtained in the planning stages. Also, mechanical and electrical engineers need to understand the thermal properties of wood while designing heating and cooling systems. Wood has low thermal conductivity, meaning its heat absorption and release rate are low relative to alternatives.[144] Thus, mechanical and electrical engineers need to design heating and cooling systems that maximize the building's thermal efficiency within the context of wood's properties.

Table 11: Difference between traditional design and mass timber design process

Traditional design process	Mass timber design process
Structure and building systems designed according to concrete properties	Structure and building systems designed according to wood properties
Design prepared in isolation from construction	Design prepared in consultation with construction and manufacturing professionals

Construction

Construction is the final stage in the supply chain, where the timber that has been extracted from forests and prepared and processed in mass timber manufacturing companies, is finally assembled at the building site. Activities in construction are represented in this report by sectors Residential building construction (NAICS 2361), Non-residential building construction (NAICS 2362), Foundation, structure, and building exterior contractors (NAICS 2381), Building equipment contractors (NAICS 2382), and Building finishing contractors (NAICS 2383). In construction, the tasks can be divided into three categories: building formation, building system installation, and management.

In terms of building formation, the key occupations are heavy equipment operators, carpenters, and construction helpers. The heavy equipment operators are usually involved in preparing the building site for construction.[145] They operate machinery, such as bulldozers, to excavate earth and rock from the construction site.[146] They also carry out the piling process to erect the necessary support structures for the building's construction. Entry into the occupation usually requires completion of an apprenticeship program.[147]

Table 12: Occupations in construction, tasks performed in each occupation, which regions have the highest concentration of each occupation within British Columbia, and source of future labour demand

Occupation	Tasks performed	Top 3 geographical regions of employment	Source of future labour demand	Number of people employed in BC
Carpenters and ironworkers	Form building foundation, install floor beams, walls, and roofs	Mainland/Southwest (52.6%), Vancouver Island/Coast (21.2%), Thompson-Okanagan (13.5%)	Replacement of retiring workers (72.4%) and economic growth (27.6%)	27,210
Construction trade helpers and labourers	Load and unload construction material, support tradespersons and heavy equipment operators, mix various materials	Mainland/Southwest (62.0%), Vancouver Island/Coast (14.5%), Thompson-Okanagan (12.8%)	Replacement of retiring workers (66.6%) and economic growth (33.4%)	28,995
Heavy equipment operators	Excavate and prepare the building site for construction, lay support structures for building construction	Mainland/Southwest (33.0%), Thompson-Okanagan (20.7%), Vancouver Island/Coast (15.8%)	Replacement of retiring workers (74.6%) and economic growth (25.4%)	12,090
Plumbers	Install, maintain, and repair plumbing systems	Mainland/Southwest (66.1%), Vancouver Island/Coast (14.8%), Thompson-Okanagan (10.6%),	Replacement of retiring workers (80.8%) and economic growth (19.2%)	9,520
Electricians	Installation, maintain, and repair electrical and power systems	Mainland/Southwest (60.1%), Vancouver Island/Coast (17.3%), Thompson-Okanagan (13.2%)	Replacement of retiring workers (72,8%) and economic growth (27.2%)	15,325
Heating, refrigeration and air conditioning mechanics	Install, maintain, and repair heating and cooling systems	Mainland/Southwest (61.5%), Thompson-Okanagan (17.3%), Vancouver Island/Coast (13.8%)	Replacement of retiring workers (74.1%) and economic growth (25.9%)	3,330
Residential and commercial installers and servicers	Install prefabricated components	Mainland/Southwest (62.1%), Vancouver Island/Coast (16.3%), Thompson-Okanagan (15.9%)	Replacement of retiring workers (69.5%) and economic growth (30.5%)	7,690
Construction managers	Plan and oversee construction projects, manage human resources and procurement	Mainland/Southwest (66.6%), Vancouver Island/Coast (13.6%), Thompson-Okanagan (11.9%)	Replacement of retiring workers (80.1%) and economic growth (19.9%)	17,030

Carpenters are involved in the interpretation and implementation of building blueprints and designs.[148] They estimate the required amount of building materials. They are also responsible for laying the foundation of the building and installing beams. Moreover, they install components of the building, such as floors, walls, and roofs.

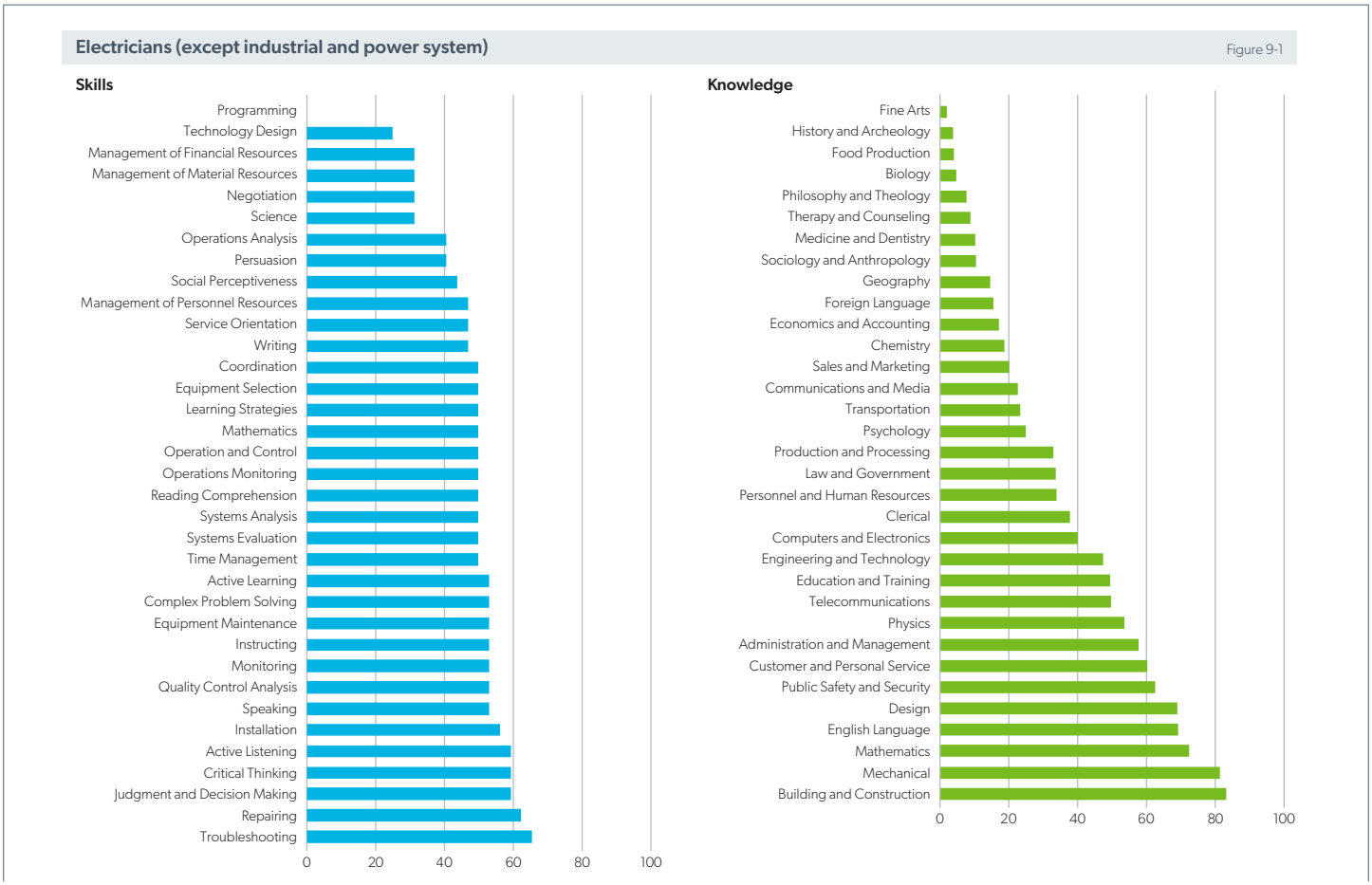
Construction trade helpers and labourers are responsible for supporting tradespeople and construction managers on job sites.[149] This occupation does not have any specific educational or training requirements, and the required health and safety training is provided on the job.[150] Construction trade helpers and labourers require communications and problem solving skills, and an understanding in the usage of mechanical equipment.

In building systems installation, the key occupations are plumbers, electricians, residential and commercial installers and servicers, and heating, refrigeration and air conditioning mechanics. Plumbers are involved in the interpretation and implementation of blueprints that specify the plumbing systems in a building.[151] They install and join pipes in the building using specialized equipment.[152] They also install and repair the water supply systems and the waste and drainage systems in a building. Plumbing requires the successful completion of an apprenticeship program.[153]

Electricians are responsible for installing, maintaining, and repairing the electrical systems in a building.[154] They interpret and implement the electric system designs contained in the building design and blueprints.[155] They are responsible for installing the building's electrical wiring, as well as installing electrical components such as switches and circuit breakers. Electricians are required to complete an apprenticeship program.[156]

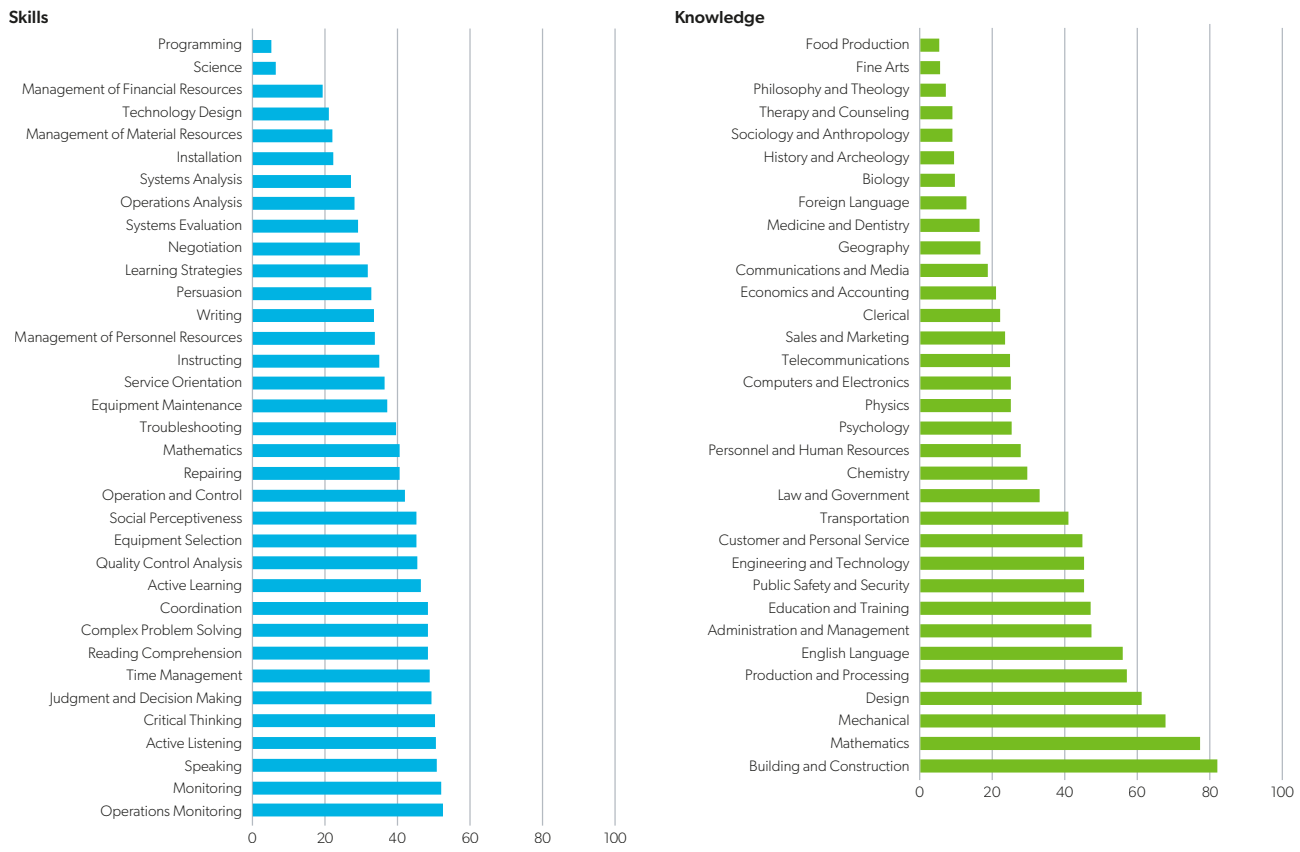
Heating, refrigeration and air conditioning mechanics are responsible for installing the cooling, ventilation, and heating systems in a building.[157] They assemble refrigeration and air conditioning equipment. They carry out the necessary maintenance work and repair to heating, ventilation, and cooling systems.[158] They are also responsible for recharging and recalibrating building systems. Like electricians, mechanics are also required to complete an apprenticeship program.

Figure 9: Current skills and knowledge needs for workers in construction (absolute scores on the importance of a skill or knowledge area, 0-100)



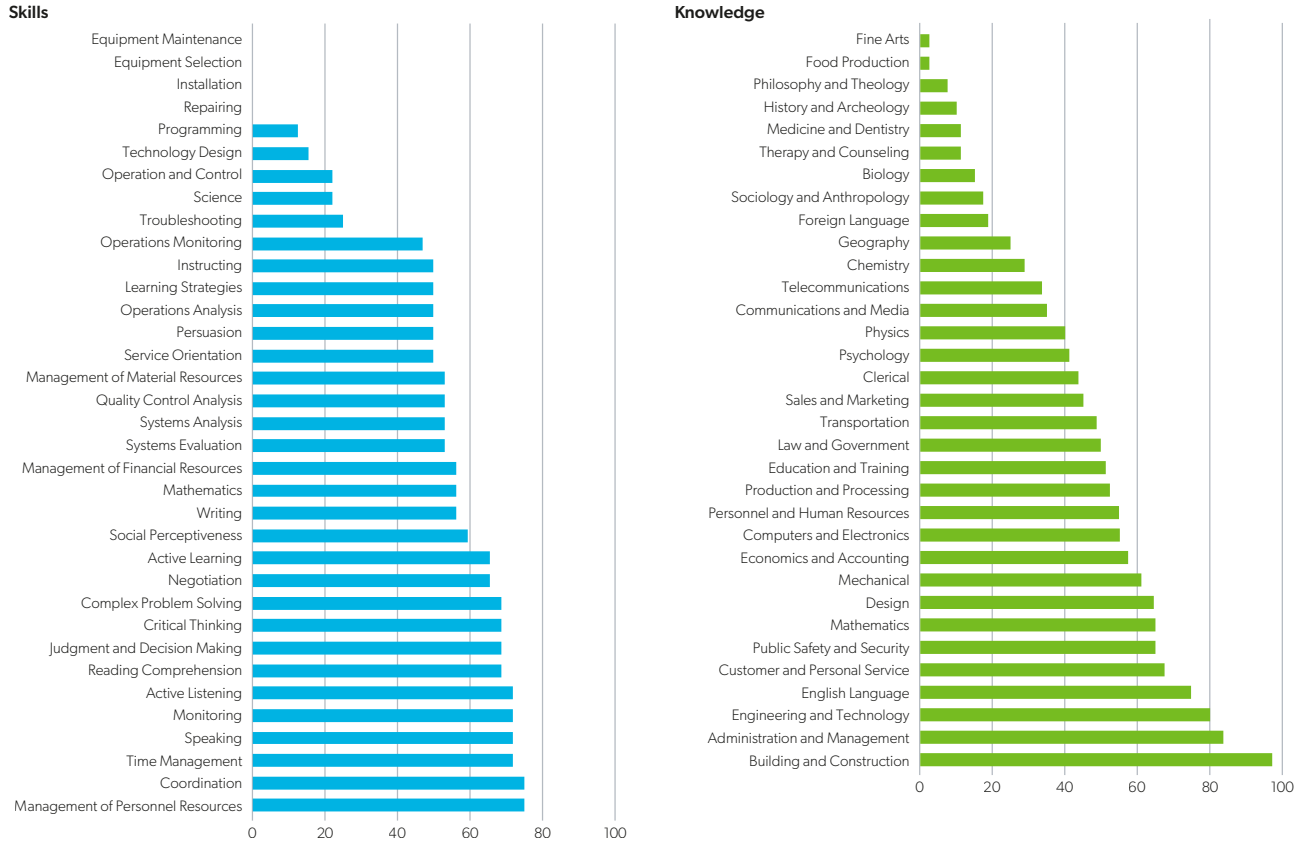
Carpenters

Figure 9-2



Construction managers

Figure 9-3

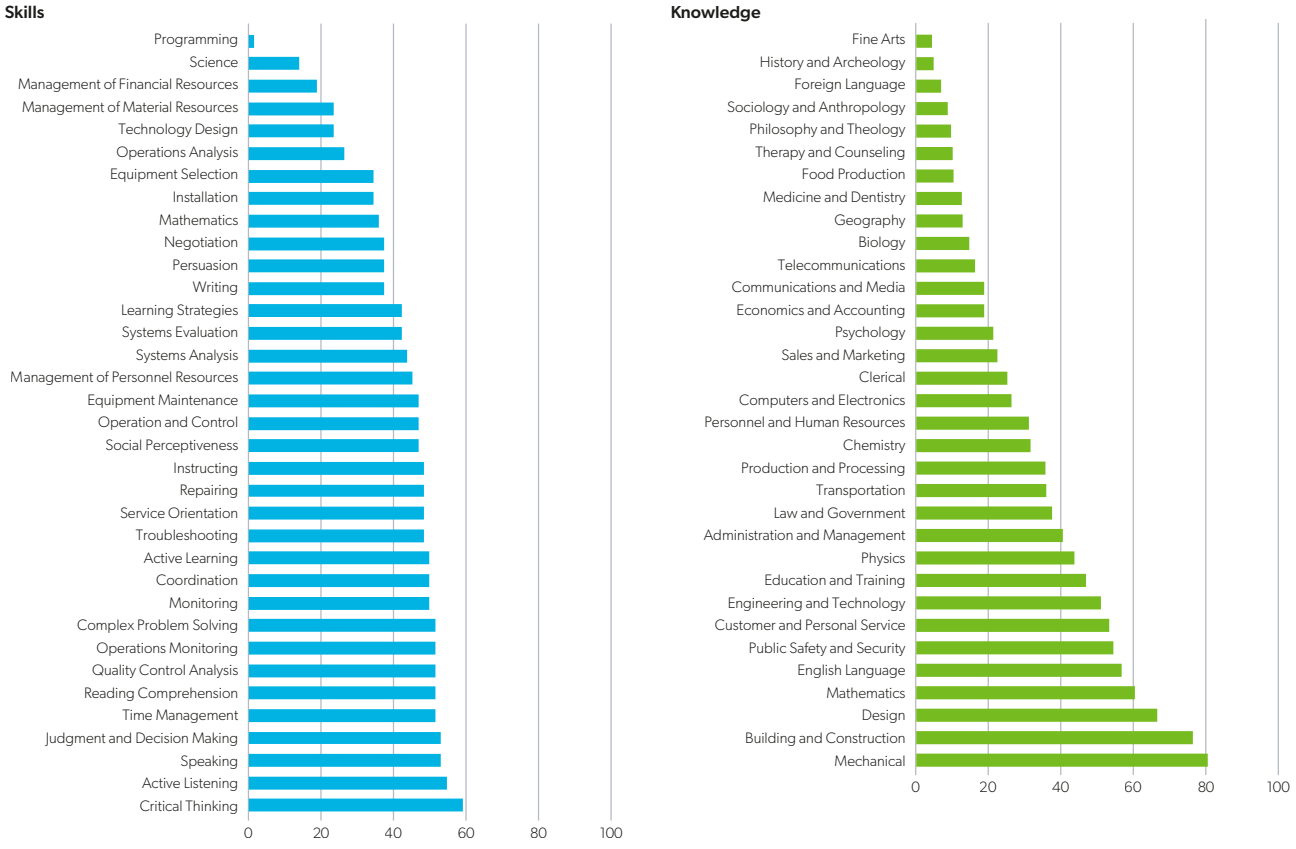


Construction trades helpers and labourers

Figure 9-4

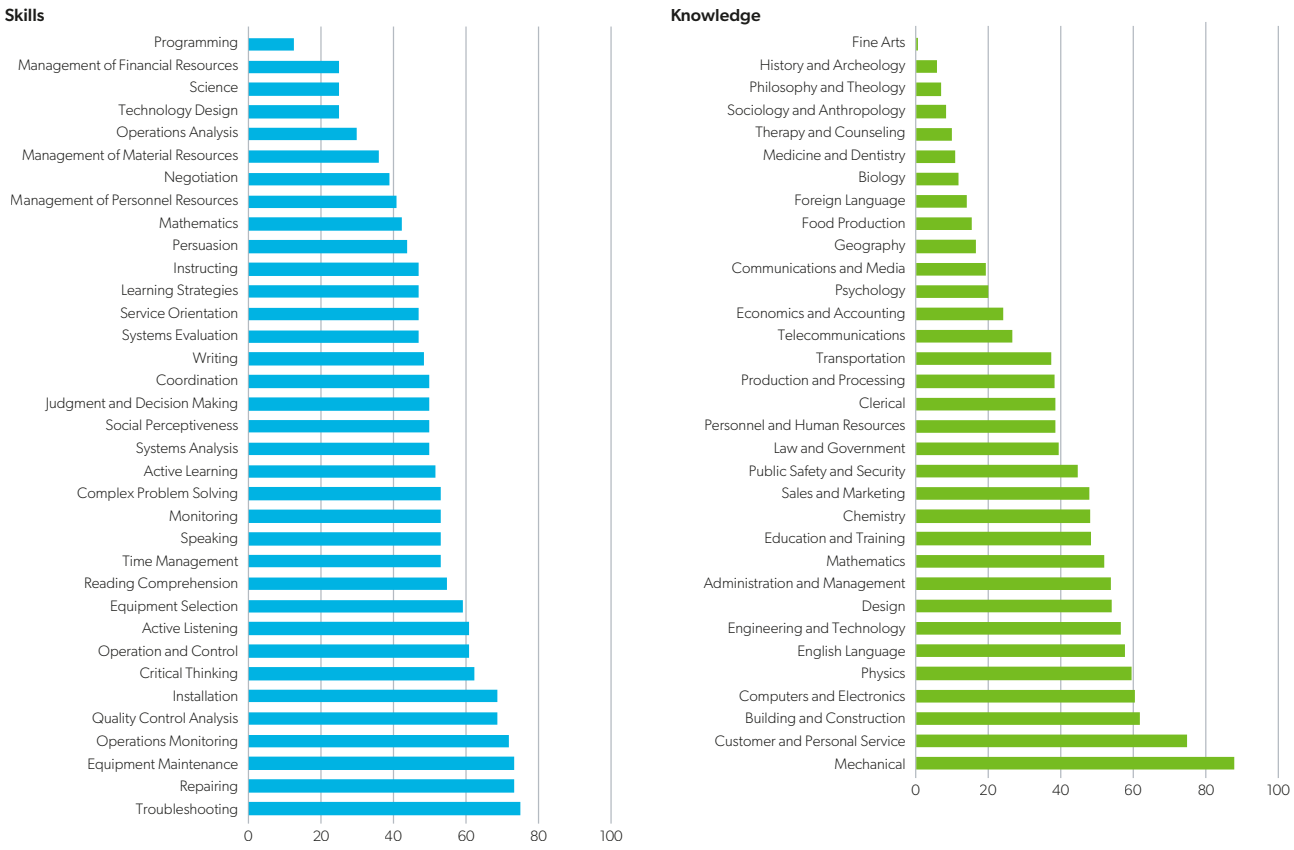
Plumbers

Figure 9-5



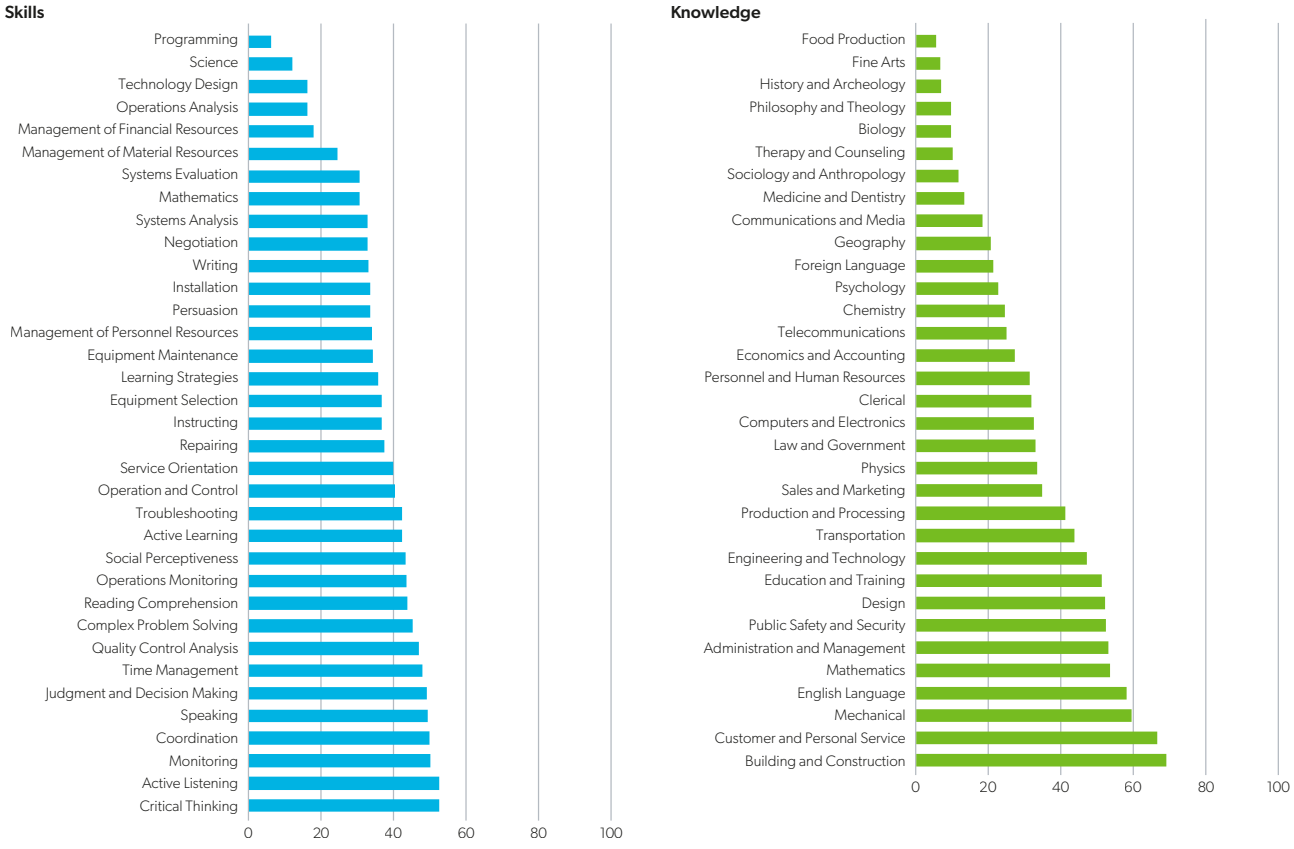
Heating, refrigeration and air conditioning mechanics

Figure 9-6

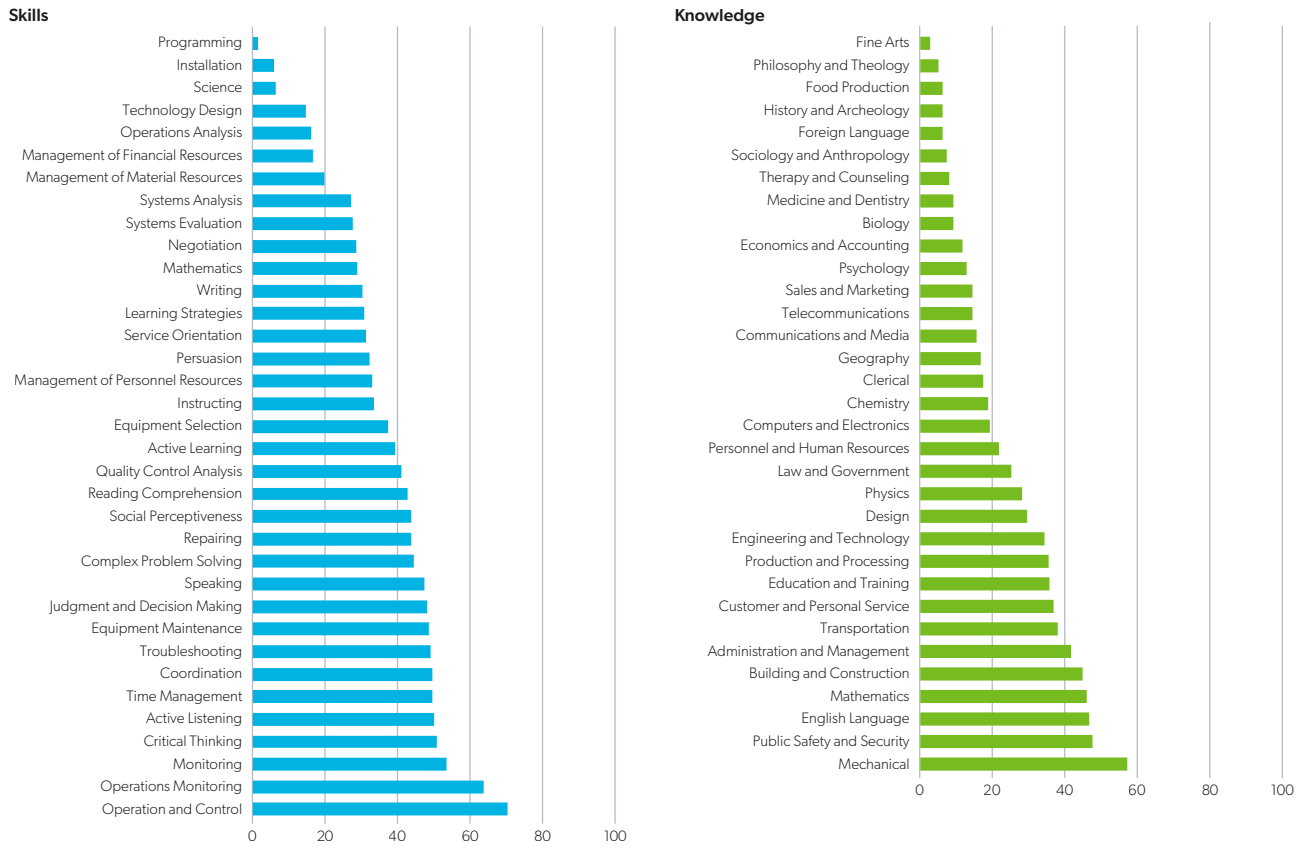


Residential and commercial installers and servicers

Figure 9-7



Heavy equipment operators Figure 9-8



Residential and commercial installers and servicers are primarily responsible for installing the prefabricated components of a building, such as windows, doors, electric appliances, water heaters, and septic systems.[159] They are also responsible for the repairing and maintenance of such components. Most of the skills necessary to perform the job functions in this occupation are imparted through on-the-job training.[160]

Occupations in building system installations are high-skill occupations requiring problem solving and communications skills. Notably, heating, refrigeration and air conditioning mechanics require troubleshooting and repairing skills. Moreover, these occupations require a strong knowledge of mechanical equipment and construction processes.

In management, the key occupation is a construction manager.[161] Construction managers are responsible for planning the construction completion cycle, achieving the relevant deliverables and deadlines, and adhering to the budget.[162] They ensure adherence to quality standards. They are also responsible for managing the human resources and procurement aspects of the construction process.[163] Entry into the occupation requires extensive professional and supervisory experience in a professional engineering or Red Seal occupation with educational credentials in construction management or project management.[164] Construction managers need strong communications and resource management skills, alongside a strong knowledge of construction, engineering, and administration.

Future skills needs for adoption (construction)

Traditionally, construction managers and contractors participate in the construction process through the 'design-bid-build' model. In this model, the design and construction process are carried out separately. Construction professionals are involved in the process after the design is complete, where construction managers interpret and implement the building design. In mass timber however, construction professionals need to be involved in the design process and provide their input in modelling the structure of the building.[165] Moreover, mass timber products are proprietary products of each manufacturer, which further necessitates stronger coordination between manufacturers and construction managers.[166] This need will lead to increased time in the planning and pre-construction stages to effectively plan the construction of the building. Construction managers also have to schedule their work activities accordingly and align the construction process with the manufacturing process. Finally, greater familiarity with DfMA skills, as well as knowledge of BID, CAD, and CAM design software, will be required from construction teams as they collaborate with manufacturers, and more on-site panel assembly takes place on job sites.

For carpenters, ironworkers and other tradespersons, working on mass timber projects requires adapting their overall approach to working with prefabricated structures. Traditionally, most of the construction work is done on-site, with the building's construction and design crews working in silos. When working with

mass timber panels, construction managers have to understand the manufacturing process and be involved in the pre-construction phase to provide their inputs on building design. They will also have to understand the manufacturing timeline. In terms of construction, carpenters have to learn how to assemble mass timber panels into a structure, particularly using fasteners and connectors to join panels together, which stakeholders have likened to working with steel or iron. This task requires knowledge of using connectors and the properties of wood as a load-bearing material. Moreover, carpenters also need to understand how to raise panels using cranes and how to install these panels on the relevant floors. Raising and installing panels has to be carefully managed to avoid any damage.[167]

Carpenters also have to pay attention to moisture management during construction and avoid moisture exposure to mass timber panels.[168] Other skilled workers, most notably ironworkers, have highly relevant transferable skills, such as hoisting and fastening large elements. Carpenters will need to pair some of the skills ironworkers possess with a knowledge of wood's properties as a construction material. The role of construction helpers will be reduced as mass timber requires less labour compared to traditional construction. Construction labourers and helpers will be involved in protecting the wood from moisture and ensuring that panels received at the site are not impacted by sudden weather changes. They can also support construction site management, as the panels are received in a particular order and need to be assembled in a specific way.

Finally, all journeypersons involved in building system installation, such as MEP systems, need to be involved in the design process. These workers have to provide their input on the creation of openings for the installation of MEP systems. They need to coordinate with MEP engineers and manufacturers to design the MEP systems of the building. Moreover, like carpenters, since they will be working with finished products, there is a much less margin for error in the MEP installation process and has to be done in a precise manner.

Table 13: Difference between traditional and mass timber construction process

Traditional building construction	Mass timber construction
Construction process isolated from design	Construction process intertwined with design and manufacturing
Cement/steel used as primary raw material	Wood used as primary raw material with steel and cement components
Building structure built on-site	Building structure assembled on-site
Concrete and wood frames built on-site	Mass timber panels and panels installed on-site

What training programs exist for the mass timber supply chain?

In BC, educational institutions and industry associations have led efforts to train the workforce on working with mass timber. For this report, a list of available training programs has been compiled by researchers, detailed by occupation and function, as seen in Table 14.

In addition, various industry organizations, such as BC Wood, conduct stakeholder engagement in the construction and design space, organize seminars for professionals on the uses of mass timber, and provide online learning materials.

From Table 14, it is clear that additional programs are needed to support workers in the production space, such as in the forest management and manufacturing sectors. Current trainings offered in the province emphasize the adoption challenges, focusing on training for construction and engineering workers or general professionals looking to better understand the challenges that accompany using mass timber solutions in buildings.

It is also critical to note that stakeholders have identified the majority of occupations discussed in this report would not need to be fully retrained to work with mass timber. Rather, they would need to upskill, and these gaps can be plugged in a relatively small amount of time.

For example, stakeholders estimated engineers would require around 60 hours of additional training to learn the necessary knowledge to work with mass timber products. As such, stakeholders have noted that they are keen to explore the creation of shorter, more targeted programs that promote entry into the supply chain for professionals in different occupations.

Table 14: Mass timber training programs currently offered

Institution	Type of provider	Course name	Targeted occupations	Length and mode of training	Cost	Region
British Columbia Institute of Technology (BCIT), School of Construction and the Environment**	Academia	Introductory Studies in Mass Timber Construction[169]	Carpenters, ironworkers, construction managers, building inspectors, designers, 3D modellers, mass timber and steel fabricators, cost estimators, etc.	Micro-credential, online/self-paced, part-time	$671	Online
		Construction of Mass Timber Structures[170]	Carpenters, ironworkers, foremen, construction managers, and other building installers with construction experience	Associate Certificate, blended (online and one 2-week in-person practicum course), 6 months, part-time (8-10h/week)	$8,160	Online, with in-person component in Burnaby
University of Northern British Columbia (UNBC)	Academia	Mass Timber Development[171]	People with current or aspiring careers in mass timber manufacturing techniques	Micro-credential, blended (online/self-paced and in-person)	$1,350 (*option to take single courses for $50 — 250)	Online, with in-person component in Prince George
		Master of Engineering in Integrated Wood Design[172]	N/A	Master's degree, in-person, 12 months, full-time	Basic Tuition Unit: $5,521.60 The minimum fee for the Master's degree is three full-time tuition fee units	Prince George
University of British Columbia (UBC)	Academia and Industry	DfMA Workshop[173]	General professionals in the field	One three-day in-person workshop	$695	Vancouver
		Advancements in Engineering Mass Timber Buildings[174]	General professionals in the field	One-time online seminar series	Free	Online
	Academia	Tall Wood Structures[175]	Engineers, architects, and other interested professionals	Micro-certificate, online, 8 weeks, part-time (7-8h/week) *new course	Eligible for StrongerBC future skills grant. $2,400 (Full Certificate) $650 (Individual Courses)	Online
		Fire Safety for Timber Buildings[176]	General professionals in the field	Micro-certificate, online, 8 weeks, part-time (7-8h/week) *new course	Eligible for StrongerBC future skills grant. $2,400 (Full Certificate) $650 (Individual Courses)	Online
		Hybrid Timber Construction[177]	General professionals in the field	Micro-certificate, online, 8 weeks, part-time (7-8h/week) *new course	Eligible for StrongerBC future skills grant. $2,400 (Full Certificate) $650 (Individual Courses)	Online

*** In addition to the above courses, BCIT is currently piloting two advanced stand-alone courses in mass timber construction:*
1) Cost estimation for Mass Timber Construction (online, 3 credits)
2) Digital Project Delivery for Mass Timber Construction (online, 3 credits)

Conclusion

The growth of the mass timber technology is currently one of the key priorities of the Government of British Columbia, as it encapsulates several policy areas, including reducing greenhouse gas emissions, attaining affordable housing, and revitalizing the forestry sector. However, a lot of questions remain as to how the growth of this technology will influence the skills needs across the different sectors related to production and adoption. While this report does not take a position on any of these questions, it does recognize that the growth of mass timber offers insights into the challenges different sectors will face in the years to come around automation, retraining, and supporting new economic opportunities. Our analysis finds that sections of the mass timber supply chain are at different points in their evolution and that each sector within the supply chain will have distinct training needs. Skills training will be especially important for mass timber production, specifically in the manufacturing sector where some of the biggest changes are expected. Individuals working in manufacturing will need to upskill and become proficient at using CNC machines and learn the vocabulary of the construction sector. In other sectors, such as design and construction, greater coordination, communication, and critical thinking skills will be needed to manage the changes that mass timber growth will bring about. Moreover, short courses on timber construction and design that include practical training are useful for professionals like architects, designers and engineers, who have experience working with steel and concrete, but not wood.

The changes brought upon by mass timber can be divided into two types: changes in processes and changes in tasks. In some cases, the tasks completed within an occupation are impacted by greater use of mass timber, but not through changes in any specific activities. Rather, they are influenced by how an activity is approached. For example, in installation of plumbing and refrigeration systems, greater precision will be required to install the same components, as all wiring and plumbing networks need to line up exactly with pre-cut openings in panels that were originally created by manufacturers. Table 15 summarizes these changes in processes and tasks for occupations involved in the mass timber supply chain.

When considering how best to support the growth of the workforce throughout this supply chain, two realities must be acknowledged. First, mass timber's economic potential is unlikely to prove fully transformative for any of the sectors discussed in this report. Second, this lack of aggregate potential does not mean it does not offer a chance for rural or resource-dependent communities to attract investment and create jobs. An opportunity need not change everything to be impactful for some. For policymakers in BC, supporting the growth of this opportunity in northern, interior, and coastal resource communities who have identified mass timber as an area of interest will require skills training supports. These programs will need to be developed in skills ecosystems within or around these communities, not simply in urban hubs.

The challenge of supporting mass timber solutions in BC should be best recognized as two challenges: production and adoption, each with separate stakeholders, sectors, and regions involved. It is possible to succeed on one front and not the other — mass timber could become an export opportunity for the province but have limited uptake through its adoption. The inverse is also true; mass timber structures could become popular within the province, with the majority of panels used being manufactured elsewhere. Given that success can take many forms, and each path would benefit many communities, the emphasis should be on ensuring communities who are interested in advancing this opportunity are well-positioned to seize it. By refocusing on the most interested communities and helping them overcome the challenges they face, policymakers can ensure mass timber proves transformative for those looking to capture its benefits.

Table 15: Changes in tasks and processes across different occupations associated with mass timber

Occupation	Change in tasks	Changes in processes
Lumber graders and other wood processing inspectors and graders	Classify mass timber products based on new industry classification	No changes in processes
Other wood processing machine operators	Increase the amount or intensity of the drying cycles to reduce wood moisture	No changes in processes
Woodworking machine operators	Use sophisticated software and machinery to produce precise components	Incorporating input from design and construction into each product
Other wood processing machine operators	Produce stronger adhesion in layers of wood	Incorporating input from design and construction into each product
Supervisors, wood product processing	Customize each product according to client needs	Coordinating with design and construction professionals
Manufacturing managers	Plan production according to construction schedule	Increased communication with design and construction professionals
Architects	Prepare building design according to wood's structural properties	Engaging with manufacturers and construction professionals
Mechanical engineers	Design mechanical systems according to the thermal properties of wood	Engaging with manufacturers and construction professionals
Electrical and electronic engineers	Design electrical systems according to the properties of wood	Engaging with manufacturers and construction professionals
Construction managers	Use of BIM	Involvement in the pre-construction stage, coordinating with designers and manufacturers
Carpenters and ironworkers	Assemble building components on site, greater use of wood connectors	Provide inputs in the design process
Construction trade helpers and labourers	Support moisture management, manage construction site for on-site assembly	No change in processes
Plumbers	Precision in working with manufactured components	Involvement in design, coordinating with engineers and manufacturers
Electricians	Precision in working with manufactured components	Involvement in design, coordinating with engineers and manufacturers
Heating, refrigeration and air conditioning mechanics	Precision in working with manufactured components	Involvement in design, coordinating with engineers and manufacturers

Recommendations

Recommendation #1: Ensure training programs are available for all industries and occupations within the supply chain, distinguishing between production and adoption.

Throughout the supply chain, there is a need to ensure training programs are available for workers seeking to work on mass timber projects. Policymakers need to ensure training is available for all sectors involved in the production and adoption of mass timber. This means designing training programs that tackle the major challenges experienced by each set of workers.

- Focus on upskilling workers in production in regions where investments in mass timber facilities are anticipated, recognizing that investments in skills training need to follow investments in production facilities or buildings.
- Ensure all occupations involved in the adoption side receive greater training in communication, collaboration, and coordination between sectors. These include occupations such as architects, electricians, and plumbers.
- Create opportunities for reskilling occupations where the primary change is not about the need to collaborate across sectors but related to changes in the technology/technologies used. These include occupations such as manufacturing engineers, mechanical/electrical engineers, and carpenters.

Recommendation #2: Ensure training programs focus on upskilling for gaps (i.e., they should be short, targeted, and low-cost) rather than full retraining.

This report has identified that the majority of skills gaps within the supply chain can be filled by upskilling workers rather than designing full retraining programs.

- These programs should be designed to minimize the time and cost associated with retraining.
- Stakeholders have suggested that their preferred mode of learning mass timber related skills would be short, targeted training programs or industry roundtables. These training programs could be focussed on software skills (e.g., Revit), manufacturing and design (e.g., DfMA, BIM, and CAD), as well as artificial intelligence and robotics skills, as stakeholders indicated that these programs would be ideally suited to teaching digital skillsets required on the job.

These reskilling programs will need to be designed in a flexible manner, recognizing how fast-paced technological advancements tend to be. Additional programmes within educational institutions that can incorporate these issues can help prepare the future workforce as mass timber grows.

Appendix 1: Methodologies used in this report

Supply chain mapping

The mass timber supply chain outlined in this report was mapped using a combined approach of literature reviews and stakeholder conversations. The key sectors linked to the mass timber supply chain include forestry, manufacturing, architecture, design, engineering, and construction. Across these sectors, the most important activities relevant to the mass timber sector were identified based on conversations with expert stakeholders.

Foresight exercise

A foresight exercise was undertaken to understand different potential future scenarios for mass timber. This was to identify the possibilities, challenges, and opportunities that may emerge in the sector. Based on the literature search and stakeholder conversations, three key metrics were identified for the growth of mass timber: supply of fibre, housing demand and policies, and skill availability. Following this, all three metrics were combined into scenarios that describe a possible future for mass timber. These scenarios are not predictions but identify a potential set of trajectories that may emerge.

Table 16: Scenarios used in foresight exercise

	Scenario 1: Best-case scenario	Scenario 2: Consistent, slower growth	Scenario 3: Challenges to growth
Fibre supply	High	Low	Low
Housing demand and policies	High	High	Low
Skills availability	High	Low	Low

Scenerio 1: Best-case Scenario

The mass timber sector is able to quickly overcome the challenges limiting its growth. Manufacturers are able to procure the necessary amount of high-quality and sustainably sourced lumber to meet all their production needs rising from growing demand. Building codes allow mass timber products to be used more frequently in high-rise buildings. There are several incentives in place for the rapid adoption of mass timber products in Canada and internationally. An adequate number of skilled professionals are available across the supply chain (forestry, manufacturing, design, construction, etc.). There are ample training and upskilling opportunities available for workers across the supply chain to fill roles in this sector.

Scenerio 2: Consistent, slower growth

The mass timber opportunity grows slowly and faces numerous challenges. Timber supply remains unpredictable and low, potentially because of poorer quality at a high price point. Existing manufacturers are less able to scale up to meet opportunities, and wait times for mass timber products remain long. However, policy change supports greater demand. Building codes allow mass timber to be used more freely in high-rise buildings. There are several incentives in place for the rapid adoption of mass timber, and demand remains high. For companies, hiring and training challenges remain. There are chronic labour shortages in the construction sector, with fewer people entering the skilled trades. There are not many training or re-skilling opportunities available for workers.

Scenerio 3: Challenges to growth

In this future, the challenges faced in the production and adoption of mass timber products prove difficult to overcome. Timber supply remains unpredictable and low, potentially because of poorer quality at a high price point. Existing manufacturers are less able to scale to meet opportunities, and wait times for products remain long. Jurisdictions delay changes in building codes, preferring traditional forms of construction. Developers do not invest in mass timber buildings as costs remain higher, and demand does not grow at expected rates. The use of mass timber panels in buildings and homes grows slower than expected or hovers around the current levels, representing a lower share of the construction industry than desired. Labour shortages persist within the construction sector, and growth in the skilled trades is slow. There are not many training or re-skilling opportunities available for workers.

O*NET analysis

A skills profile was developed for each occupation. This was done using the Occupational Information Network (O*NET) database. The O*NET database describes all occupations across the United States in terms of the importance and level of skills, knowledge areas required to perform the job, tasks performed at the job, technological tools used at the job, and work experience and education requirements for the role. Though the O*NET has been developed for the United States, many researchers have developed concordance matrices so that they are applicable to the Canadian context. For carrying out a concordance of Canadian National Occupational Classification (NOC) with each O*NET occupation, a crosswalk developed by the Brookfield Institute was used to match each NOC with the corresponding O*NET title.

For the purpose of this report, the knowledge areas from O*NET were used as a proxy for the technical skill set and know-how required to perform tasks in an occupation. This was because

knowledge more adeptly describes the technical knowledge required to perform the tasks in a certain occupation. Finally, the top knowledge areas were identified using the concordance of the top five NOC codes identified for each industry with their O*NET equivalents. In the final stage, the top ten knowledge areas in terms of their ranking were selected for the skills analysis. This exercise informs us about the most important skills for a given occupation within a specific industry. Through this exercise, we were able to understand the most important skills that are currently required for each portion of the mass timber supply chain.

Interviews and workshops

Interviews were conducted with stakeholders across the supply chain. Insights from these interactions were transcribed, and relevant themes were identified. A workshop was conducted with stakeholders across academia, manufacturing, industry associations and policy makers for the Northern BC region. Insights from this workshop were transcribed and common themes were identified.

Survey

To understand the skills that will play an important role in future for mass timber, a perception survey was created. The online survey had nearly 40 questions that captured perceptions of the most important future skills for the mass timber sector. The survey was disseminated using the SurveyMonkey platform. Publicly available information was used to send the survey to respondents across the forestry, manufacturing, architecture, design, engineering, and construction sectors. A total of 20 responses were received, of which 16 were complete. This was one method of data collection to inform the research and was supplemented by the foresight exercise, interviews, and a workshop.

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

The analysis adopted the approach by Atiq et al. (2022)[178] to understand the impact of a net-zero transition in Canada on skills and jobs across different sectors of the economy. Different sectors were identified as part of the supply chain, and occupations were listed for each sector using the North American Industry Classification System (NAICS). The NAICS is the standard classification system used by statistical agencies of the Canadian federal government to describe economic activity across different industries in Canada. For the purpose of this report, 4-digit NAICS codes were used to provide the most detailed breakdown for industries in the mass timber supply chain. Following are the relevant industries identified along with their NAICS codes.

Table 17: Four-digit North American Industry Classification System (NAICS) codes identified for the mass timber supply chain

Industry in supply chain	NAICS code	Description
Logging	1133	Logging
Forest management	1153	Support activities for forestry
Lumber production	3211	Sawmills and wood preservation
Mass timber manufacturing	3212	Veneer, plywood, and engineered wood product manufacturing
Design	5413	Architectural, engineering and related services
Design	5414	Specialized design services
Construction	2361	Residential building construction
Construction	2362	Non-residential building construction
Construction	2381	Foundation, structure, and building exterior contractors
Construction	2382	Building equipment contractors
Construction	2383	Building finishing contractors

For each of the relevant NAICS sectors, employment data was retrieved for each NOC. The dataset used for this was the Labour Force Survey 2022, retrieved from Statistics Canada's Real-Time Remote Access tool. The dataset provides a breakdown of employment numbers by occupation code (i.e., NOC) in each sector (i.e., NAICS) for all provinces across Canada. For the mass timber sector, we studied trends for the province of BC as well as Canada. For each sector, the key occupations were identified in terms of number of people employed and relevance to the mass timber supply chain. The following are the top five occupations in each industry.

Table 18: National Occupational Classification (NOC) codes identified for the mass timber supply chain

Industry in supply chain	NOC code	Description
Logging	83110	Logging machinery operators
Logging	84110	Chain saw and skidder operators
Logging	72410	Heavy duty equipment mechanics
Logging	82010	Supervisors, logging and forestry
Logging	80010	Managers in natural resources production and fishing
Forest management	84111	Silviculture and forestry workers
Forest management	22113	Conservation and fishery officers
Forest management	22112	Forestry technologists and technicians
Forest management	21111	Forestry professionals
Lumber production	75101	Material handlers
Lumber production	73400	Heavy equipment operators
Lumber production	94123	Lumber graders and other wood processing inspectors and graders
Lumber production	95103	Labourers in wood, pulp and paper processing

Industry in supply chain	NOC code	Description
Lumber production	94120	Sawmill machine operators
Lumber production	62100	Technical sales specialists — wholesale trade
Lumber production	64101	Sales and account representatives — wholesale trade (non-technical)
Lumber production	92014	Supervisors, forest products processing
Lumber production	90010	Manufacturing managers
Mass timber manufacturing	94129	Other wood processing machine operators
Mass timber manufacturing	94124	Woodworking machine operators
Mass timber manufacturing	22302	Industrial engineering and manufacturing technologists and technicians
Mass timber manufacturing	72400	Construction millwrights and industrial mechanics
Mass timber manufacturing	92014	Supervisors, forest products processing
Mass timber manufacturing	90010	Manufacturing managers
Design	21200	Architects
Design	22212	Drafting technologists and technicians
Design	21301	Mechanical engineers
Design	21310	Electrical and electronics engineers
Design	21300	Civil engineers
Design	20010	Engineering managers
Construction	72310	Carpenters
Construction	73400	Heavy equipment operators
Construction	75110	Construction trades helpers and labourers
Construction	72300	Plumbers
Construction	72200	Electricians (except industrial and power system)
Construction	72402	Heating, refrigeration and air conditioning mechanics
Construction	73200	Residential and commercial installers and servicers
Construction	70010	Construction managers

Appendix 3: Assumptions and limitations

A major limitation was that our survey had a limited number of responses despite several attempts to increase the response rate. Therefore, due to the small sample size, a detailed statistical analysis was not possible. Nonetheless, several common themes that respondents shared were identified, and these are presented in the report.

According to the survey responses, crucial occupations, such as crane operators, mass timber detailers, and code consultants, may not have been included in the survey. We acknowledge that every sector has several occupations. We focused on the top five occupations (in terms of number) across every sector. Future studies should look at other related occupations where skills changes may be impacted due to mass timber.

As mass timber is a new technology, it is not entirely clear which new occupation codes may emerge in future. Therefore, comprehensively capturing new occupations and their corresponding skills requirements was difficult. This remains an area for future research.

Endnotes

1 Office of Mass Timber Implementation. (2023). *Mass Timber.* Government of British Columbia. Retrieved March 4, 2023, from https://www2.gov.bc.ca/gov/content/industry/construction-industry/mass-timber

2 Niquidet, K., & Kan, J. (2021). *The Economic Impact of British Columbia's Forest Sector. BC Council of Forest Industries*. https://cofi.org/wp-content/uploads/TECHNICAL-REPORT_COFI-2019-FOREST-INDUSTRY-ECONOMIC-IMPACT-STUDY-FINAL.pdf

3 Natural Resources Canada. (2021). *The State of Mass Timber in Canada* [ArcGIS Dashboard]. Government of Canada. Retrieved May 23, 2023, from https://nrcan-rncan.maps.arcgis.com/apps/dashboards/041e338d2a4d4b3a82ff2c238a9f0f93

4 Government of British Columbia. (n.d.). *Forest Tenures*. Retrieved January 9, 2023, from https://www2.gov.bc.ca/gov/content/industry/forestry/forest-tenures

5 Canada Mortgage and Housing Corporation. (2022, June 23). *Canada's Housing Supply Shortage: Restoring affordability by 2030.* https://www.cmhc-schl.gc.ca/en/blog/2022/canadas-housing-supply-shortage-restoring-affordability-2030

6 Devisscher, T., Spies, J., & Griess, V. C. (2021). Time for change: Learning from community forests to enhance the resilience of multi-value forestry in British Columbia, Canada. *Land Use Policy, 103,* 105317. https://doi.org/10.1016/j.landusepol.2021.105317

7 McIlhenney, K., & Hayter, R. (2014). Sustaining jobs and environment? The value-added wood industry in Metro Vancouver, British Columbia. *Local Environment, 19*(6), 605–625. https://doi.org/10.1080/13549839.2013.854755

8 Grace, P., Kozak, R., & Nelson, H. (2018). Understanding SME Success in the Value-added Forest Products Sector: Insights from British Columbia. *BioProducts Business*, *3*(9). https://biobus.swst.org/bpbj/index.php/bpbj/issue/view/28

9 Office of Mass Timber Implementation. (2023). *Mass Timber.* Government of British Columbia. Retrieved March 4, 2023, from https://www2.gov.bc.ca/gov/content/industry/construction-industry/mass-timber

10 Niquidet, K., & Kan, J. (2021). *The Economic Impact of British Columbia's Forest Sector.* BC Council of Forest Industries. https://cofi.org/wp-content/uploads/TECHNICAL-REPORT_COFI-2019-FOREST-INDUSTRY-ECONOMIC-IMPACT-STUDY-FINAL.pdf

11 Natural Resources Canada. (2022, December 9). *Canadian Forest Service Statistical data* [Dataset]. Government of Canada. Retrieved December 9, 2022, from https://cfs.nrcan.gc.ca/statsprofile/employment/bc

12 Ministry of Forests. (2023, January 24). *New forestry program will expand manufacturing, create jobs* [News Release]. Government of British Columbia. https://news.gov.bc.ca/releases/2023FOR0006-000079

13 Natural Resources Canada. (n.d.). *The State of Mass Timber in Canada* [ArcGIS Dashboard]. Government of Canada. Retrieved May 23, 2023, from https://nrcan-rncan.maps.arcgis.com/apps/dashboards/041e338d2a4d4b3a82ff2c238a9f0f93

14 naturally:wood. (n.d.). *Mass timber and taller wood construction*. Retrieved May 23, 2023, from https://www.naturallywood.com/topics/mass-timber/

15 Government of British Columbia. (2022, April 7). *Mass Timber Action Plan*. Retrieved March 5, 2023, from https://www2.gov.bc.ca/gov/content/industry/construction-industry/mass-timber/mass-timber-action-plan

16 Karacabeyli, E., Douglas, B. (Eds.). (2013). *CLT handbook: Cross-laminated timber (U.S. edition)*. FPInnovations. https://cdn2.hubspot.net/hubfs/5577290/PDFs/CLT%20Handbook/CLT_USA-Complete-document-Think_Wood.pdf

17 WoodWorks. (n.d.). *Mass Timber: Shifting Labor from Jobsite to Shop* [Info Sheet]. Retrieved May 25, 2023, from https://www.woodworks.org/wp-content/uploads/info_sheet-Shifting-Mass-Timber-from-Jobsite-to-Shop.pdf

18 Natural Resources Canada. (n.d.). *The State of Mass Timber in Canada* [ArcGIS Dashboard]. Government of Canada. Retrieved May 23, 2023, from https://nrcan-rncan.maps.arcgis.com/apps/dashboards/041e338d2a4d4b3a82ff2c238a9f0f93

19 naturally:wood. (2022). *Mass Timber in British Columbia* [Factsheet]. https://www.naturallywood.com/wp-content/uploads/mass_timber_factsheet_naturally-wood.pdf

20 Natural Resources Canada. (2021). *The State of Mass Timber in Canada* [ArcGIS Dashboard]. Government of Canada. Retrieved May 23, 2023, from https://nrcan-rncan.maps.arcgis.com/apps/dashboards/041e338d2a4d4b3a82ff2c238a9f0f93

21 Wikstrom, L. (2023). *Designing the Forest and Other Mass Timber Futures*. Routledge. https://doi.org/10.4324/9781003183198

22 Nepal, P., Johnston, C. M. T., & Ganguly, I. (2021). Effects on Global Forests and Wood Product Markets of Increased Demand for Mass Timber. *Sustainability*, *13*(24), 13943. https://doi.org/10.3390/su132413943

23 Comnick, J., Rogers, L., & Wheiler, K. (2022). Increasing Mass Timber Consumption in the U.S. and Sustainable Timber Supply. *Sustainability*, *14*(1), 381. https://doi.org/10.3390/su14010381

24 Zelaya, A. (2020). Business Oregon. (2020). *Identifying Drivers and Barriers for Investment in Oregon's Mass Timber Manufacturing Supply Chain*. Tallwood Design Institute & Business Oregon. https://digital.osl.state.or.us/islandora/object/osl%3A978527

25 Ministry of Forests. (n.d.). *2021 Economic State of British Columbia's Forest Sector.* Government of British Columbia. https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/forest-industry-economics/economic-state/2021_economic_state_of_the_bc_forest_sector.pdf

26 Zelaya, A. (2020). Business Oregon. (2020). *Identifying Drivers and Barriers for Investment in Oregon's Mass Timber Manufacturing Supply Chain.* Tallwood Design Institute & Business Oregon. https://digital.osl.state.or.us/islandora/object/osl%3A978527

27 Zelaya, A. (2020). Business Oregon. (2020). *Identifying Drivers and Barriers for Investment in Oregon's Mass Timber Manufacturing Supply Chain.* Tallwood Design Institute & Business Oregon. https://digital.osl.state.or.us/islandora/object/osl%3A978527

28 Zelaya, A. (2020). Business Oregon. (2020). *Identifying Drivers and Barriers for Investment in Oregon's Mass Timber Manufacturing Supply Chain.* Tallwood Design Institute & Business Oregon. https://digital.osl.state.or.us/islandora/object/osl%3A978527

29 Ministry of Forests. (n.d.). *2020 Major Timber Processing Facilities in British Columbia*. Government of British Columbia. https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/fibre-mills/mill_list_report_2020.pdf

30 Zelaya, A. (2020). Business Oregon. (2020). *Identifying Drivers and Barriers for Investment in Oregon's Mass Timber Manufacturing Supply Chain.* Tallwood Design Institute & Business Oregon. https://digital.osl.state.or.us/islandora/object/osl%3A978527

31 Structurlam. (n.d.). *Cross Laminated Timber Design Guide Version 9*. https://wood-works.ca/wp-content/uploads/Cross-Laminated-Timber-Design-Guide-Structurlam.pdf

32 naturally:wood. (n.d.). *Mass timber and taller wood construction*. Retrieved May 23, 2023, from https://www.naturallywood.com/topics/mass-timber/

33 WoodWorks. (2023, Jan 23). *Open-Source Mass Timber Installer Training Curriculum.* Retrieved January 23, 2023, from https://www.woodworks.org/mass-timber-installer-training-curriculum/

34 WoodWorks. (2023, Jan 23). *Open-Source Mass Timber Installer Training Curriculum.* Retrieved January 23, 2023, from https://www.woodworks.org/mass-timber-installer-training-curriculum/

35 de Lint, M. (2019, November 19). Mass timber building construction is an emerging trend around the world – is it time for more timber in Canada? *Evergreen.* https://www.evergreen.ca/blog/entry/mass-timber-building-construction-is-an-emerging-trend-around-the-world-is-it-time-for-more-timber-in-canada/

36 Fast, P., Gafner, B., Jackson, R., & Li, J. (2016). *Case Study: An 18 Storey Tall Mass Timber Hybrid Student Residence at the University of British Columbia, Vancouver*. World Conference on Timber Engineering. https://www.fastepp.com/wp-content/uploads/WCTE-Tallwood-House-at-Brock-Commons-Case-Study-Credit-Fast-Epp.pdf

37 Edenhoffer, K., & Hayter, R. (2013). Reprint of "Organizational restructuring in British Columbia's Forest industries 1980 - 2010: The survival of a dinosaur." *Applied Geography, 45*, 375-384. https://doi.org/10.1016/j.apgeog.2013.06.001

38 Schultz, R., Kozak, R., Merkel, G., Sunderman, R., & Thrower, J. (2013). *Growing the BC Interior Value Added Wood Sector: Summary Report*. The Southern Interior Beetle Action Coalition. https://bcruralcentre.org/wp-content/uploads/2021/01/SIBAC-Growing-the-BC-Interior-Value-Added-Wood-Sector-Summary-Report-June-27-2013.pdf

39 Ministry of Forests. (n.d.). *British Columbia Forest Product Prices: Selected Statistics for the week ending May 19, 2023.* Government of British Columbia. https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/forest-industry-economics/weekly-prices/forest_product_prices_-_2023-05-19.pdf

40 Polaris Market Research. (2022). *Cross Laminated Timber Market Share, Size, Trends, Industry Analysis Report, By Type (Adhesive Bonded, Mechanically Fastened); By Industry; By End-Use; By Region; Segment Forecast, 2022 - 2030*. https://www.polarismarketresearch.com/industry-analysis/cross-laminated-timber-market

41 BC Housing. (2023, April 3). *BC Government Announcement: New action plan delivers more homes for people, faster* [News Release]. https://news.bchousing.org/bc-government-announcement-new-action-plan-delivers-more-homes-for-people-faster/; Augustine, T., Kendrick, M., Khan, A., McNally, J., Newcombe, G., Okeke, C., & Renzetti, N. (2023). *Ready for Green Jobs*. PLACE Centre. Smart Prosperity Institute. https://placecentre.smartprosperity.ca/ready-for-green-jobs/

42 Insights from stakeholder interviews.

43 Insights from stakeholder interviews.

44 WSP. (2022, June 17). *Wood You Believe: Mass Timber Leading a Renaissance in Modern Construction.* https://www.wsp.com/en-us/insights/2022-mass-timber-in-modern-construction

45 de Lint, M. (2019, November 19). Mass timber building construction is an emerging trend around the world – is it time for more timber in Canada? *Evergreen.* https://www.evergreen.ca/blog/entry/mass-timber-building-construction-is-an-emerging-trend-around-the-world-is-it-time-for-more-timber-in-canada/

46 Comnick, J., Rogers, L., & Wheiler, K. (2022). Increasing Mass Timber Consumption in the U.S. and Sustainable Timber Supply. *Sustainability*, *14*(1), 381. https://doi.org/10.3390/su14010381

47 Daneshvar, H., Goni, T., Zhang, S., Kelterborn, R., & Chui, Y. H. (2021). Structural Timber Design in Curricula of Canadian Universities: Current Status and Future Needs. *Education Sciences*, *11*(12), 765. https://doi.org/10.3390/educsci11120765

48 Roos, A., Woxblom, L., & McCluskey, D. (2010). The influence of architects and structural engineers on timber in construction – perceptions and roles. *Silva Fennica*, *44*(5). https://doi.org/10.14214/sf.126

49 WorkBC. (n.d.). *Logging machinery operators*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/logging-machinery-operators

50 WorkBC. (n.d.). *Logging machinery operators*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/logging-machinery-operators

51 WorkBC. (n.d.). *Chain saw and skidder operators*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/chain-saw-and-skidder-operators

52 WorkBC. (n.d.). *Chain saw and skidder operators*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/chain-saw-and-skidder-operators

53 WorkBC. (n.d.). *Chain saw and skidder operators*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/chain-saw-and-skidder-operators

54 WorkBC. (n.d.). *Chain saw and skidder operators*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/chain-saw-and-skidder-operators

55 WorkBC. (n.d.). *Heavy-duty equipment mechanics.* Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/heavy-duty-equipment-mechanics

56 WorkBC. (n.d.). *Heavy-duty equipment mechanics.* Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/heavy-duty-equipment-mechanics

57 WorkBC. (n.d.). *Heavy-duty equipment mechanics.* Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/heavy-duty-equipment-mechanics

58 WorkBC. (n.d.). *Heavy-duty equipment mechanics.* Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/heavy-duty-equipment-mechanics

59 WorkBC. (n.d.). *Supervisors, logging and forestry.* Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/supervisors-logging-and-forestry

60 WorkBC. (n.d.). *Managers in natural resources production and fishing*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/managers-natural-resources-production-and-fishing

61 WorkBC. (n.d.). *Managers in natural resources production and fishing*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/managers-natural-resources-production-and-fishing

62 WorkBC. (n.d.). *Managers in natural resources production and fishing*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/managers-natural-resources-production-and-fishing

63 WorkBC. (n.d.). *Silviculture and forestry workers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/silviculture-and-forestry-workers

64 WorkBC. (n.d.). *Silviculture and forestry workers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/silviculture-and-forestry-workers

65 WorkBC. (n.d.). *Silviculture and forestry workers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/silviculture-and-forestry-workers

66 WorkBC. (n.d.). *Silviculture and forestry workers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/silviculture-and-forestry-workers

67 WorkBC. (n.d.). *Silviculture and forestry workers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/silviculture-and-forestry-workers

68 WorkBC. (n.d.). *Silviculture and forestry workers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/silviculture-and-forestry-workers

69 WorkBC. (n.d.). *Conservation and fishery officers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/conservation-and-fishery-officers

70 WorkBC. (n.d.). *Conservation and fishery officers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/conservation-and-fishery-officers

71 WorkBC. (n.d.). *Conservation and fishery officers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/conservation-and-fishery-officers

72 WorkBC. (n.d.). *Conservation and fishery officers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/conservation-and-fishery-officers

73 WorkBC. (n.d.). *Forestry technologists and technicians*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/forestry-technologists-and-technicians

74 WorkBC. (n.d.). *Forestry technologists and technicians*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/forestry-technologists-and-technicians

75 WorkBC. (n.d.). *Forestry technologists and technicians*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/forestry-technologists-and-technicians

76 WorkBC. (n.d.). *Forestry professionals*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/forestry-professionals

77 WorkBC. (n.d.). *Forestry professionals*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/forestry-professionals

78 WorkBC. (n.d.). *Forestry professionals*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/forestry-professionals

79 WorkBC. (n.d.). *Forestry professionals*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/forestry-professionals

80 WorkBC. (n.d.). *Material handlers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/material-handlers

81 WorkBC. (n.d.). *Material handlers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/material-handlers

82 WorkBC. (n.d.). *Heavy equipment operators (except crane)*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/heavy-equipment-operators-except-crane

83 WorkBC. (n.d.). *Lumber graders and other wood processing inspectors and graders*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/lumber-graders-and-other-wood-processing-inspectors-and-graders

84 WorkBC. (n.d.). *Lumber graders and other wood processing inspectors and graders*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/lumber-graders-and-other-wood-processing-inspectors-and-graders

85 WorkBC. (n.d.). *Lumber graders and other wood processing inspectors and graders*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/lumber-graders-and-other-wood-processing-inspectors-and-graders

86 WorkBC. (n.d.). *Sawmill machine operators*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/sawmill-machine-operators

87 WorkBC. (n.d.). *Sawmill machine operators*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/sawmill-machine-operators

88 WorkBC. (n.d.). *Labourers in wood, pulp and paper processing*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/labourers-wood-pulp-and-paper-processing

89 WorkBC. (n.d.). *Labourers in wood, pulp and paper processing*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/labourers-wood-pulp-and-paper-processing

90 WorkBC. (n.d.). *Sales and account representatives, wholesale trade (non-technical)*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/sales-and-account-representatives-wholesale-trade-non-technical

91 WorkBC. (n.d.). *Sales and account representatives, wholesale trade (non-technical)*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/sales-and-account-representatives-wholesale-trade-non-technical

92 WorkBC. (n.d.). *Supervisors, forest products processing*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/supervisors-forest-products-processing

93 WorkBC. (n.d.). *Supervisors, forest products processing*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/supervisors-forest-products-processing

94 WorkBC. (n.d.). *Supervisors, forest products processing*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/supervisors-forest-products-processing

95 WorkBC. (n.d.). *Manufacturing managers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/manufacturing-managers

96 WorkBC. (n.d.). *Manufacturing managers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/manufacturing-managers

97 Kurjata, A. (2023, Jan 13). *Why are B.C. mills closing and forestry jobs disappearing? Many blame a beetle*. CBC News. https://www.cbc.ca/news/canada/british-columbia/british-columbia-forestry-future-pine-beetle-1.6712576

98 Karacabeyli, E., & Lum, C. (Eds.). (2022). *Technical Guide for the Design and Construction of Tall Wood Buildings in Canada*. FPInnovations. https://web.fpinnovations.ca/tallwood/

99 WorkBC. (n.d.). *Material handlers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/material-handlers

100 WorkBC. (n.d.). *Labourers in wood, pulp and paper processing*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/labourers-wood-pulp-and-paper-processing

101 WorkBC. (n.d.). *Labourers in wood, pulp and paper processing*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/labourers-wood-pulp-and-paper-processing

102 WorkBC. (n.d.). *Other wood processing machine operators*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/other-wood-processing-machine-operators

103 WorkBC. (n.d.). *Other wood processing machine operators*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/other-wood-processing-machine-operators

104 WorkBC. (n.d.). *Other wood processing machine operators*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/other-wood-processing-machine-operators

105 WorkBC. (n.d.). *Woodworking machine operators*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/woodworking-machine-operators

106 WorkBC. (n.d.). *Woodworking machine operators*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/woodworking-machine-operators

107 WorkBC. (n.d.). *Industrial engineering and manufacturing technologists and technicians*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/industrial-engineering-and-manufacturing-technologists-and-technicians

108 WorkBC. (n.d.). *Industrial engineering and manufacturing technologists and technicians*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/industrial-engineering-and-manufacturing-technologists-and-technicians

109 WorkBC. (n.d.). *Industrial engineering and manufacturing technologists and technicians*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/industrial-engineering-and-manufacturing-technologists-and-technicians

110 WorkBC. (n.d.). *Construction millwrights and industrial mechanics*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/construction-millwrights-and-industrial-mechanics

111 WorkBC. (n.d.). *Construction millwrights and industrial mechanics*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/construction-millwrights-and-industrial-mechanics

112 WorkBC. (n.d.). *Construction millwrights and industrial mechanics*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/construction-millwrights-and-industrial-mechanics

113 WorkBC. (n.d.). *Construction millwrights and industrial mechanics*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/construction-millwrights-and-industrial-mechanics

114 Woodbridge Associates. (2009). *Opportunity BC 2020 - BC's Forest Industry: Moving from a Volume Focus to a Value Perspective*. BC Business Council. https://bcbc.com/dist/assets/publications/opportunity-bc-2020-bcs-forest-industry-moving-from-a-volume-focus-to-a-value-perspective/2020_200910_Woodbridge.pdf

115 Structurlam. (n.d.). *Cross Laminated Timber Design Guide Version 9*. https://wood-works.ca/wp-content/uploads/Cross-Laminated-Timber-Design-Guide-Structurlam.pdf

116 Structurlam. (n.d.). *Cross Laminated Timber Design Guide Version 9*. https://wood-works.ca/wp-content/uploads/Cross-Laminated-Timber-Design-Guide-Structurlam.pdf

117 Sild, S. (2022, November 4). Design for Manufacturing and Assembly. *Fractory*. https://fractory.com/design-for-manufacturing-and-assembly-dfma/

118 Enzer, M. (2015, September 3). *DfMA - One of the keys to unlocking a more efficient industry*. Mott Macdonald. https://www.mottmac.com/views/dfma---the-key-to-a-more-efficient-industry

119 WoodWorks. (n.d.). *Modular Construction*. Retrieved May 25, 2023, from https://www.woodworks.org/learn/off-site-panelized-construction/modular-construction/

120 WorkBC. (n.d.). *Architects*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/architects

121 WorkBC. (n.d.). *Architects*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/architects

122 WorkBC. (n.d.). *Architects*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/architects

123 WorkBC. (n.d.). *Drafting technologists and technicians*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/drafting-technologists-and-technicians

124 WorkBC. (n.d.). *Drafting technologists and technicians*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/drafting-technologists-and-technicians

125 WorkBC. (n.d.). *Drafting technologists and technicians*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/drafting-technologists-and-technicians

126 WorkBC. (n.d.). *Mechanical engineers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/mechanical-engineers

127 WorkBC. (n.d.). *Mechanical engineers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/mechanical-engineers

128 WorkBC. (n.d.). *Mechanical engineers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/mechanical-engineers

129 WorkBC. (n.d.). *Electrical and electronics engineers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/electrical-and-electronics-engineers

130 WorkBC. (n.d.). *Electrical and electronics engineers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/electrical-and-electronics-engineers

131 WorkBC. (n.d.). *Electrical and electronics engineers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/electrical-and-electronics-engineers

132 WorkBC. (n.d.). *Civil engineers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/civil-engineers

133 WorkBC. (n.d.). *Civil engineers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/civil-engineers

134 WorkBC. (n.d.). *Civil engineers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/civil-engineers

135 WorkBC. (n.d.). *Engineering managers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/engineering-managers

136 WorkBC. (n.d.). *Engineering managers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/engineering-managers

137 Ahmed, S., & Arocho, I. (2020). Mass timber building material in the U.S. construction industry: Determining the existing awareness level, construction-related challenges, and recommendations to increase its current acceptance level. *Cleaner Engineering and Technology*, *1*, 100007. https://doi.org/10.1016/j.clet.2020.100007

138 Ahmed, S., & Arocho, I. (2020). Mass timber building material in the U.S. construction industry: Determining the existing awareness level, construction-related challenges, and recommendations to increase its current acceptance level. *Cleaner Engineering and Technology*, *1*, 100007. https://doi.org/10.1016/j.clet.2020.100007

139 Kesik, T., & Martin, R. (2021). *Mass Timber Building Science Primer*. Mass Timber Institute. https://academic.daniels.utoronto.ca/masstimberinstitute/wp-content/uploads/sites/5/2021/04/MTBSP-Version1.0-04-13-21.pdf

140 Kesik, T., & Martin, R. (2021). *Mass Timber Building Science Primer*. Mass Timber Institute. https://academic.daniels.utoronto.ca/masstimberinstitute/wp-content/uploads/sites/5/2021/04/MTBSP-Version1.0-04-13-21.pdf

141 Ramage, M. H., Burridge, H., Busse-Wicher, M., Fereday, G., Reynolds, T., Shah, D. U., Wu, G., Yu, L., Fleming, P., Densley-Tingley, D., Allwood, J., Dupree, P., Linden, P. F., & Scherman, O. (2017). The wood from the trees: The use of timber in construction. *Renewable and Sustainable Energy Reviews*, *68*, 333–359. https://doi.org/10.1016/j.rser.2016.09.107

142 Ramage, M. H., Burridge, H., Busse-Wicher, M., Fereday, G., Reynolds, T., Shah, D. U., Wu, G., Yu, L., Fleming, P., Densley-Tingley, D., Allwood, J., Dupree, P., Linden, P. F., & Scherman, O. (2017). The wood from the trees: The use of timber in construction. *Renewable and Sustainable Energy Reviews*, *68*, 333–359. https://doi.org/10.1016/j.rser.2016.09.107

143 Ramage, M. H., Burridge, H., Busse-Wicher, M., Fereday, G., Reynolds, T., Shah, D. U., Wu, G., Yu, L., Fleming, P., Densley-Tingley, D., Allwood, J., Dupree, P., Linden, P. F., & Scherman, O. (2017). The wood from the trees: The use of timber in construction. *Renewable and Sustainable Energy Reviews*, *68*, 333–359. https://doi.org/10.1016/j.rser.2016.09.107

144 Ramage, M. H., Burridge, H., Busse-Wicher, M., Fereday, G., Reynolds, T., Shah, D. U., Wu, G., Yu, L., Fleming, P., Densley-Tingley, D., Allwood, J., Dupree, P., Linden, P. F., & Scherman, O. (2017). The wood from the trees: The use of timber in construction. *Renewable and Sustainable Energy Reviews*, *68*, 333–359. https://doi.org/10.1016/j.rser.2016.09.107

145 WorkBC. (n.d.). *Heavy equipment operators (except crane)*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/heavy-equipment-operators-except-crane

146 WorkBC. (n.d.). *Heavy equipment operators (except crane)*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/heavy-equipment-operators-except-crane

147 WorkBC. (n.d.). *Heavy equipment operators (except crane)*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/heavy-equipment-operators-except-crane

148 WorkBC. (n.d.). *Carpenters*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/carpenters

149 WorkBC. (n.d.). *Construction trades helpers and labourers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/construction-trades-helpers-and-labourers

150 WorkBC. (n.d.). *Construction trades helpers and labourers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/construction-trades-helpers-and-labourers

151 WorkBC. (n.d.). *Plumbers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/plumbers

152 WorkBC. (n.d.). *Plumbers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/plumbers

153 WorkBC. (n.d.). *Plumbers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/plumbers

154 WorkBC. (n.d.). *Electricians (except industrial and power system)*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/electricians-except-industrial-and-power-system

155 WorkBC. (n.d.). *Electricians (except industrial and power system)*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/electricians-except-industrial-and-power-system

156 WorkBC. (n.d.). *Electricians (except industrial and power system)*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/electricians-except-industrial-and-power-system

157 WorkBC. (n.d.). *Heating, refrigeration and air conditioning mechanics*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/heating-refrigeration-and-air-conditioning-mechanics

158 WorkBC. (n.d.). *Heating, refrigeration and air conditioning mechanics*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/heating-refrigeration-and-air-conditioning-mechanics

159 WorkBC. (n.d.). *Residential and commercial installers and servicers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/residential-and-commercial-installers-and-servicers

160 WorkBC. (n.d.). *Residential and commercial installers and servicers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/residential-and-commercial-installers-and-servicers

161 WorkBC. (n.d.). *Construction managers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/construction-managers

162 WorkBC. (n.d.). *Construction managers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/construction-managers

163 WorkBC. (n.d.). *Construction managers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/construction-managers

164 WorkBC. (n.d.). *Construction managers*. Retrieved March 3, 2023, from https://www.workbc.ca/career-profiles/construction-managers

165 Structurlam. (n.d.). *Cross Laminated Timber Design Guide Version 9*. https://wood-works.ca/wp-content/uploads/Cross-Laminated-Timber-Design-Guide-Structurlam.pdf

166 Lindsay, B. (2019). *Mass Timber Construction Management: Economics, Logistics & Risk Analysis* [Presentation Slides]. WoodWorks. https://www.woodworks.org/wp-content/uploads/presentation_slides-Mass-Timber-Construction-Management-Lindsey-200722.pdf

167 Lindsay, B. (2019). *Mass Timber Construction Management: Economics, Logistics & Risk Analysis* [Presentation Slides]. WoodWorks. https://www.woodworks.org/wp-content/uploads/presentation_slides-Mass-Timber-Construction-Management-Lindsey-200722.pdf

168 Karacabeyli, E., & Lum, C. (Eds.). (2022). *Technical Guide for the Design and Construction of Tall Wood Buildings in Canada*. FPInnovations. https://web.fpinnovations.ca/tallwood/

169 British Columbia Institute of Technology. (n.d.). *Introductory Studies in Mass Timber Construction*. School of Construction and the Environment. Retrieved June 20, 2023, from https://www.bcit.ca/programs/introductory-studies-in-mass-timber-construction-microcredential-part-time-0800cm/

170 British Columbia Institute of Technology. (n.d.). *Construction of Mass Timber Structures*. Retrieved June 20, 2023, from https://www.bcit.ca/programs/construction-of-mass-timber-structures-associate-certificate-part-time-5225acert/

171 Continuing Studies. (n.d.). *Mass Timber Development Micro-credential*. University of Northern British Columbia. Retrieved June 20, 2023, from https://www2.unbc.ca/continuing-studies/courses/mass-timber-development-micro-credential

172 School of Engineering. (n.d.). *Master of Engineering in Integrated Wood Design*. University of Northern British Columbia. Retrieved June 20, 2023, from https://www2.unbc.ca/engineering/meng-integrated-wood-design

173 Centre for Advanced Wood Processing. (n.d.). *Mass Timber—Design for Manufacturing and Assembly (DfMA) Workshop 2.0*. University of British Columbia. Retrieved June 20, 2023, from https://cawp.ubc.ca/event/mass-timber-design-for-manufacturing-and-assembly-workshop/

174 Architectural Institute of British Columbia. (n.d.). *UBC - Advancements in Research for Engineering Applications in Mass Timber Buildings*. Retrieved June 20, 2023, from https://aibc.ca/event/ubc-advancements-in-research-for-engineering-applications-in-mass-timber-buildings/2022-06-01/

175 UBC Faculty of Forestry. (n.d.). *Online Certificates*. University of British Columbia. Retrieved June 20, 2023, from https://forestry.ubc.ca/future-students/certificates/

176 UBC Faculty of Forestry. (n.d.). *Online Certificates*. University of British Columbia. Retrieved June 20, 2023, from https://forestry.ubc.ca/future-students/certificates/

177 UBC Faculty of Forestry. (n.d.). *Online Certificates*. University of British Columbia. Retrieved June 20, 2023, from https://forestry.ubc.ca/future-students/certificates/

178 Atiq, M., Coutinho, A., Islam, A., & McNally, J. (2022). *Jobs and Skills in the Transition to a Net-Zero Economy*. Smart Prosperity Institute. https://institute.smartprosperity.ca/sites/default/files/Jobs_and_Skills_in_the_Transition_to_a_Net-Zero_Economy.pdf

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