Addressing Skilled Labour Shortages in Biomanufacturing Sector in British Columbia

by

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B.Comm., University of British Columbia, 2015

Project Submitted in Partial Fulfillment of the
Requirements for the Degree of
Master of Public Policy

in the
School of Public Policy
Faculty of Arts and Social Sciences

SIMON FRASER UNIVERSITY
Spring 2022

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Abstract

The study explores policy options to address skilled labour shortages in the biomanufacturing sector in British Columbia ("BC"). Interviews with local biomanufacturing companies and analysis of BC labour market reports reveal several issues that affect labour supply and demand, that could cause severe labour shortages in the near future, resulting in the industry's limited ability to increase sales and production and foregone economic profit for the province. An examination of three jurisdictions is used to identify specific factors that contribute to the development of a strong talent ecosystem. Interviews with local biomanufacturing companies also inform policy options that could improve talent attraction and retainment in the sector. Results indicate that BC's biomanufacturing labour market could benefit from three consecutive policy options: 1) Creating a sector coalition focused on integrating employer perspectives into existing educational initiatives; 2) Building a Biomanufacturing Training Center in Metro Vancouver to address a gap in hands-on training provided to students in biomanufacturing -related fields; 3) Establishing a Life Sciences and Biomanufacturing Cluster in BC, focused on sector's competitive in attracting talent, investment, and collective effort in removing barriers that indirectly affect labour in biomanufacturing.

Keywords: biomanufacturing; labour demand; labour supply; skilled labour shortages; public policy

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List of Term and Acronyms

BC	British Columbia
BETC	Biomanufacturing Education and Training Center
BTEC	Biomanufacturing Training and Education Center
CASTL	Canadian Alliance for Skills and Training in Life Sciences
CCPC	Canadian-controlled private corporation
Cluster	"A geographical proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and externalities" (Porter, 1990). In context of this research, a cluster includes biomanufacturing companies, other companies that provide support (legal, architectural, financial, materials, regulatory), economic development agencies, workforce investment boards, a regional trade organization, higher education, private research organizations, etc (Dahms, 2003).
CM&E	Canadian Manufacturers and Exporters.
CMO	Contract Manufacturing Organizations
EMA	European Medicines Agency
FDA	U.S. Food and Drug Administration
GDP	Gross Domestic Product.
cGMP	Current Good Manufacturing Practice. GMP is a "system for ensuring that products are consistently produced and controlled according to quality standards. It is designed to minimize the risks involved in any pharmaceutical production that cannot be eliminated through testing the final product." (ISPE, 2022). GMP is concerned with both production and quality control (Government of Canada, 2022).
Ibec	Irish Business and Employers Confederation.
IEP	Internationally educated professionals.
ISEDC	Innovation, Science and Economic Development Canada
LSBC	Life Sciences BC
LSO	Life Sciences sector in Ontario
NAICS	North American Industry Classification System
NIBRT	National Institute for Bioprocessing Research and Training

NOC	National Occupational Classification
PE	Prince Edward Island
PSE	Post-Secondary Education
PREO	Public Research and Education Organizations
R&D	Research and Development
the Sector	BC Biomanufacturing Sector
Skilled labour	Labour force that has specialized training, education or a learned skill-set to perform the work. It is characterized by higher or specialized education.
SME	Small and medium-sized enterprises. Statistics Canada divides employment size category as follows: Micro (1-4), Small (5-99), Medium (100-499), and Large (500+).
SRED	Scientific Research and Experimental Development tax
STEM	Science, Technology, Engineering, and Math
US	United States of America
VOC	Vocational education that provides the student with skills and competencies directly related to an occupation.
WDA	Workforce Development Agreement
WIL	Work-integrated learning.
Youth	The definition of "youth" varies depending on the source, ranging from under 30 to under 25.

1. Introduction and Policy Problem

Biomanufacturing has become an important tool in biotechnological advancements and pharmaceutical drug research and development (Gaisser, 2010), enabling innovations in biopharmaceutical treatment of cancer, HIV, metabolic disorders, chronic conditions, and infectious diseases (Dogramatzis, 2010). The development of recombinant DNA technology, the creation of monoclonal antibodies in hybridomas, as well as later developments in cell and gene therapy and RNA technologies (Spence, 2021) has revolutionized the biopharmaceutical manufacturing, demonstrating higher prevention and treatment potential for some diseases than the traditional small-molecule drugs (Kamarck, 2006; Dogramatzis, 2010). The last 50 years have been marked by significant breakthrough in biomanufacturing technics and infrastructure that enabled more effective and efficient production of large quantities of high molecular weight biologics (Jacoby, 2015; Raynolds, 2010; Dogramatzis, 2010). That breakthrough and innovation has changed the global economic landscape for biomanufacturing and biotechnology in general, leading to the formation of a global bio-sector network and national hubs, that are largely supported by the national industry policies, commercialization of the explorative research programs of Public Research and Education Organizations ("PREOs") and strategic alliances with a venture capital firms and transnational corporations (Raynolds, 2010). The scientific breakthrough of biopharmaceutical manufacturing has resulted in production of life-vital treatments that caused a major medical revolution, attracting large amount of capital to the global biomanufacturing sector, making it one of the largest valued and rapidly developing industries in the world (Ernst & Young, 2021; IFPMA, 2021; Haaf, 2020), projected to reach USD $85,201.2 billion in terms of revenue by 2031 (Cision, 2022).

Canada has a strong history of achievements in the area of biomanufacturing and life sciences; however, the sector has been experiencing a decline, effectively taking Canada out of the top global players' network (Government of Canda, 2022; Ernst & Young, 2021; Hilberdink, 2018). The limitations and gaps in Canada's biomanufacturing capacity to produce life-saving vaccines for its people have been exposed by the recent COVID-19 pandemic (Government of Canda, 2022; LSBC, 2021). The pandemic has highlighted an over-reliance on foreign production of vital medications, especially during a health emergency situation, revealing a gap in national health security and medical sovereignty (Ibid.). During the COVID-19 pandemic, Canada depended 100 percent on importing all of its vaccines (Government of Canda, 2022), even though "virtually every COVID-19 vaccine and candidate in late-stage clinical development was consulted, initiated, developed, or manufactured by Vancouver community members" (LSBC, 2021). It has also showcased that the biomanufacturing sector is closely integrated with Research and Development ("R&D") and that having a strong network of researchers is not enough to compete globally, as all bio-tech companies need assistance in bringing their products to clinical trials and scaling product development (Ibid.). With the objectives of growing a strong, competitive domestic life sciences sector with cutting edge bio manufacturing capabilities and ensuring preparedness for pandemics or other health emergencies, Canada established a Canada's Biomanufacturing and Life Sciences Strategy in July 2021 (Government of Canda, 2021) and Canada's Health and Biosciences Economic Strategy Table identified a series of targets for Canada's life sciences sector, such as doubling Canada's bioscience firms, biopharmaceuticals exports, and the number of high-growth bio-tech firms by 2025 (Government of Canda, 2018; Ernst & Young, 2021).

By 2021, the Government of Canada had identified major national hubs for biomanufacturing, vaccine and therapeutics ecosystem to allocate its investment ($1.6 billion) in 30 pandemic response and life science innovation projects (Government of Canada, 2021). British Columbia (BC) attracted 14 percent of total Canada's investment in 2020 and 2021, resulting in over $222 million for five projects, including antibody therapy research and the construction of an antibody production facility (AbCellera Biologics), preparation of preclinical efficacy data in live SARS-CoV-2 (COVID-19) and preparation for clinical trials and manufacturing of BOLD-100 investigational therapy (Bold Therapeutics), production of ribonucleic acid vaccines and future genetic medicines (Precision NanoSystems Inc.), advancement of bacTRL-Spike oral DNA vaccine candidate in preclinical and phase 1 clinical trials (Symvivo), and provision of proof-of-concept evidence for preventative treatment of COVID-19 (Qu Biologics) (Government of Canada, 2021). This investment placed BC as the third largest in Canada, behind Ontario ($729 million, 10 projects) and Quebec ($425 million, 10 projects) (Ibid.).

Biomanufacturing in BC (the "Sector") has seen record growth and contributed greatly to the global pandemic response (LSBC, 2021), being home to Canada's largest biotech company, STEMCELL Technologies; Canada's largest medical device company, Starfish Medical; and Canada's three largest biotech companies, AbCellera Biologics, Aurinia Pharmaceuticals, and Zymeworks Inc (Ibid.; Government of BC, 2022). With a developed a competitive advantage in oncology, antibody therapy, and R&D services over the other Canadian provinces (LSBC, 2021), the Sector has become one of the fastest growing sectors in Canada, with Vancouver recently named the top life sciences start up ecosystem in the world, listing it as the only Canadian city in the top 25 (Startup Genome, 2021). BC's biomanufacturing has developed the following important products such as rapid diagnostic tests for diseases such as HIV/AIDS, hepatitis C and Ebola; protein therapeutics for treating cancer, autoimmune and inflammatory diseases; and the first Food and Drug Administration ("FDA")-approved oral medication for treating adult patients with active lupus nephritis (Government of BC, 2022). The province has recognized the Sector's contribution to health and economic well-being of BC and committed to position the BC as a major Canadian a hub for life sciences and biomanufacturing under the Stronger BC Economic Plan (Ibid.).

1.1. Policy Problem

Despite recent growth, the Biomanufacturing sector's development and international competitiveness continues to be challenged by several factors, one of them being skilled labour shortages with demand for skilled labour significantly outpacing the supply (LSBC, 2021; BioTalent, 2021; Government of Canada, 2021). It was estimated that more than 61 per cent of BC biomanufacturers struggle to fill vacancies, with 15 percent experiencing extreme labour shortages (BioTalent, 2021). If the issue is not addressed promptly, the problem of skilled labour shortages will further constrain BC market development, affect the overall economic performance of the province, thereby losing a chance to become a large global player in biomanufacturing (Ibid.; LSBC, 2022). Moreover, lack of qualified talent for the Sector has been recognized as one of the top priorities by Government of Canada and industry experts (Government of Canada, 2021; LSBC, 2022). BC and Canada in general are not viewed as a preferred training site for international highly skilled personnel in the biomanufacturing field, which limits the ability to recruit talent (Ernst & Young, 2022). Some BC biomanufacturing companies already rely significantly on hiring recent graduates from the Ontario, Quebec and international institutions (Interviews, 2022), which represents challenges such as talent mobility and increased competition for talent from other national and international companies.

Having a strong labour pool with qualified skills for the biomanufacturing sector is integral to future industry success (Murray, 2022). Without skilled labour, BC biomanufacturing sector will not be able to sustain its R&D and manufacturing leadership and attract vital investment to the province. Transnational corporations prioritize new locations for their biomanufacturing facilities based on the availability of skilled labour and supportive educational institutions as one of the most differentiating factors (Ernst & Young, 2022; Heavey, 2016). BC is economically strong and has a highly educated population with strong research institutions. It is critical to leverage this position and provide timely policy solutions to address skilled labour shortages and provide support to the Sector's further growth (Ernst & Young, 2022; BioTalent, 2021). These policies would not only improve economic performance of biomanufacturing in the province, but also contribute to Canada's medical sovereignty and global excellence in life sciences and biomanufacturing.

1.2. Structure of the Study

This study is divided into 11 sections. Table 1 provides a detailed structure of the study and presents an overview of each section.

Table 1. Structure of the study

Section 1	Provides an introduction and background to the policy problem.
Section 2	Presents an overview of life sciences and biomanufacturing sectors in BC, including definitions of these sectors, current economic characteristics, trends that affect the sectors' development, as well as financial and educational resources available for BC life sciences and biomanufacturing business.
Section 3	Focuses deeper on labour market in biomanufacturing sector in BC, drawing on the analysis of labour supply and labour demand factors. The section concludes with the issue of skilled labour shortages in the BC sector.
Section 4	Reviews the methodology used in the study, including a statistical approach, interviews, and limitations.
Section 5	Provides a jurisdictional scan of Ireland, Germany and US, as global leaders in biomanufacturing, and analyzes best practices and success factors of these three jurisdictions.

Section 6	Provides an analysis of interviews with biomanufacturing companies located in BC. The section highlights findings on major issues associated with skilled labour shortages, as indicated by these companies.
Section 7	Introduces policy options to address skilled labour shortages in biomanufacturing in BC and implement changes.
Section 8	Lists evaluation criteria used to assess policy options identified in section 6.
Section 9	Evaluates policy options, using criteria introduced in section 7.
Section 10	Provides final recommendations on how to address skilled labour shortages in the biomanufacturing sector in BC, using short-term and long-term approach.
Section 11	Provides a conclusion to the study with a summary of findings and policy recommendations.

2. Research Context: Sector Overview and Profile

In order to understand the labour market situation in the biomanufacturing sector and its implications on the sector's economic indicators, this section provides an overview of the biomanufacturing and life sciences sectors.

2.1. Definitions of Life Sciences and Biomanufacturing Sectors

The life sciences and biomanufacturing sectors' definitions and statistical profiles presented are based on the North American Industry Classification System ("NAICS") to analyze statistical data such as business counts, employment, wages, revenue, gross domestic product ("GDP"), and the trade of goods and services. The definition is consistent with the language used by Government Canada in the Canada's Biomanufacturing and Life Sciences Strategy as well as the language used by the Life Sciences BC. Therefore, "biomanufacturing and life sciences refer to the study and manufacturing of living systems (like plants or animal cells) as its base, to make vaccines and therapeutics in biomanufacturing facilities" (Government of Canada, 2022).

The definition of the life sciences sector presented in this report is based on three main industry NAICS groups: 1. Research, Testing and Medical Laboratories; 2. Medical Devices and Equipment; and 3. Drugs and Pharmaceuticals (Appendix A). The definition of the biomanufacturing sector and some data presented in this report is based on two main groups of NAICS sector codes: 1. Medical equipment and supplies manufacturing and 2. Pharmaceutical and medicine manufacturing (LSBC, 2021), (Statistics Canada, 2021) (Appendix A), representing a sub-sector of life sciences. Appendix A refers to NAICS classification provided by LSBC and BioTalent Canada. The findings of these associations have been used in this report; hence, it is important to be familiar with their sector classifications, as they differ slightly on some assumptions and level of detail.

Some literature identifies biomanufacturing as "a type of manufacturing that utilizes biological systems to produce commercially important biomolecules for use in the agricultural, food, material, energy, and pharmaceutical industries" (Zhang, 2017). My study uses the term "biomanufacturing" in the context of pharmaceutical and medical equipment manufacturing only, sometimes referred to in different studies as “bio-health” (BioTalent, 2021) (Appendix A).

Notably, biomanufacturing is an important sub-sector of bio-economy and biotechnology. Bio-economy cuts across bio-health (which is a focus of this study), bio-agriculture, bio-energy, and bio-industrial (BioTalent, 2021). Biotechnology is a subset of bio-economy where biological resources could be processed or treated by biological means, in addition to chemical, or physical (Haaf, 2020). It is important to understand these definitions as biomanufacturing is often analyzed within the context of these industries.

2.2. Overview of the Life Sciences Sector in BC

Life sciences sector in BC encompasses fields that involve the scientific study of living organisms and uses innovations in biotechnology to deliver commercially viable products and services in health, medicine and pharmaceuticals, as well as agriculture and food science (LSBC, 2021; Deloitte, 2019). In addition to that, the sector includes companies that directly support these activities along the entire commercial value chain (Ibid.).

The function of delivery of commercially viable products in life sciences is performed by the biomanufacturing sector. In addition to that, the process of biomanufacturing is inextricably linked to the research processes in the life sciences sector (Reynolds, 2010), as will be later examined in section 2.3 of this study. Thus, it is important to understand the economic development of the life sciences sector along with the biomanufacturing sector and its labour market’s characteristics and trends.

The emergence of the life sciences sector in BC has been led largely by innovation in health and biosciences in particular in the Metro Vancouver region, with companies that provide cutting-edge research and the development of therapeutics, tools, and essential equipment for healthcare purposes (ISEDC, 2017). **Error! Reference source not found.** provides a snapshot of the BC’s life sciences sector’ main competitive characteristics, all of which are a product of the biomanufacturing processes.

Figure 1. Life Sciences in BC – Competitive Characteristics Snapshot

- Home to Canada's largest biotech company (by market cap) and Canada's largest medical device design company.
- Second largest exporter of medical devices after Ontario and is the primary exporter of ultraviolet and infrared ray equipment in Canada.
- Established leadership in antibodies.
- Number one exporter of prostheses with 81 percent of Canada's export value share to European Union markets.

Source: Life Sciences BC, 2021

The sector's geographic and business model characteristics are consistent with the life sciences characteristics in other countries with strong R&D and biomanufacturing (TEConomy Partners LLC, 2020; Dogramatzis; 2010; Haaf, 2020; O'Byrne, 2013; Reynolds, 2010). These characteristics include:

- **Domination of small and medium-sized companies.** The BC's Life Sciences sector is dominated by small operations (93 percent) with fewer than 50 employees (BC Stats, 2018). Half of these operations tend to be micro-sized organizations with less than 5 employees on board (Ibid.). In addition to that, more than half (57 percent) have been in business less than 15 years (Government of British Columbia "(GoB"), 2020). This characteristic of the life sciences BC sector indicates that future policies need to have a tailored approach to issues unique to small and medium-sized enterprises ("SMEs") and a developing biomanufacturing market.

- **Concentration of businesses in major city centers, near research centres, hospitals, and universities.** Most of British Columbia's life sciences businesses are located in major city centers, close to major research centers, hospitals, and universities (GoB, 2020). In addition, most life sciences companies in BC are located in the Lower Mainland/Southwest region (66 percent), followed by the Vancouver Island/Coast (14 percent), the Thompson-Okanagan regions (11 percent) and other outlying regions in the province (eight percent) (LSBC, 2020). This shows that PREO-generated knowledge and research is spatially 'sticky' and is closely tied to the location in which it is generated (Reynolds, 2010). This characteristic provides an insight for future policy making to ensure the geographic features are considered.

2.2.1. Life Science BC Economic Profile

With more than 2,400 companies and 18,000 people employed, the BC's life sciences sector is the third largest provincial life sciences sector in size, behind Ontario and Quebec in terms of sector employment, wages, revenue, and gross domestic product (Statistics Canada, 2019) (LSBC, 2021). Despite being third, BC's market is the fastest growing market and has a reputation as an incubator for up-and-coming businesses (Ibid.). It also plays an important role in supporting the provincial health care system and international trade with European and trans-Pacific markets, supported by the BC's strategic location on Canada's Pacific coast. (Ibid.).

Table 2 provides a snapshot of the sector's economic profile in British Columbia and Ontario. Life Sciences sector in Ontario ("LSO") was selected as a benchmark, because Ontario is currently the leading province in life sciences in Canada in terms of revenue and number of companies. Medical equipment and supplies manufacturing (NAICS 3391) and Pharmaceutical and medicine manufacturing (NAICS 32541) are also provided in

Table 2 to show the size of the biomanufacturing sector relative to life sciences.

Table 2. Economic profile of LSBC as compared to LSO

Sector Size	LSBC	LSO	Source
Number of Companies	2,486	6,140	(Statistics Canada, Business Register, 2019)
Medical equipment and supplies manufacturing (NAICS 3391)	441[1] (18 % of LSBC)	1,006 (16% of LSO)	(Statistic Canada, 2020)
Pharmaceutical and medicine manufacturing (NAICS 32541)	103[2] (4.1 % of LSBC)	275 (4.5% of LSO)	(Statistic Canada, 2020)
Employment	17,379	47,151	(BioTalent, 2021)
Financial Performance			

[1] The breakdown includes employer and non-employer or indeterminate establishments.

[2] Ibid.

Revenue	$5.4 bil (2018)	$56.8 bil (2016)	(LSBC, 2021; LSO, 2019)
Federal investment in the sector	$222 mil	$729 mil	(Government of Canada, 2022)

The BC life sciences sector has been experiencing strong growth over the last five years, becoming one of the fastest-growing sectors in the province (GoB, 2020). The pre-pandemic growth in the BC's life sciences sector constituted 5.7 percent increase in revenue and a 5.6 percent increase in employment from 2017 to 2018 (Ibid.). In 2018, the provincial sector's GDP growth surpassed Canada's bio-health GDP growth of 1.0 percent and the province's aggregate GDP growth of 2.7 percent (Ibid.), even though the Sector's performance as share of GDP still rates below the performance, 2.5 percent of national GDP, of life sciences in United States (Ibid). The sector also showcased capacity for sustained growth during the changing economic landscape during the COVID-19 pandemic (Ibid.; ISEDC, 2021), indicating an opportunity for BC to leverage an emerging market and increase BC's presence on the interprovincial and international arena.

The growth was supported by capital raised by the biomanufacturing companies. The capital raised has more than doubled since the onset of COVID-19 pandemic through the Federal investment and venture capital (LSBC, 2021). The investor interest in BC's life sciences companies has been on the rise since 2019, reaching $2.3 billion (BCSC, 2020). Rising global attention to Vancouver and British Columbia's biomanufacturing sector indicates outstanding opportunities to ensure the continued growth of the sector.

The main contributor to the life sciences sector's growth has been Drugs and Pharmaceuticals industry group (GoB, 2020). Even though this industry group represents only 12 percent of life sciences companies in British Columbia and 22 percent of employment, the group earned the majority of revenue reaching 72 percent in 2018, surpassing all other provinces (Ibid.). Notably, the Drugs and Pharmaceuticals industry group was also the top revenue earner in the U.S. life sciences sector nationally and across most states (Ibid.). This trend is important as it shows an area of strength in BC's life sciences and its relation to biomanufacturing.

There are a number of trends that have contributed to the life sciences and biomanufacturing sectors' economic growth. These trends include:

- **Dynamic post-secondary system.** With the majority life sciences employees representing skilled, professional labour force (BioTalent, 2021), a dynamic post-secondary system is important for the sector's growth. BC's 25 post-secondary institutions enrolled 22,500 students in life sciences-related academic programs in 2017/18, representing a 13 percent increase over four years (GoB, 2020). As PREOs support most SMEs in the life sciences and biomanufacturing sectors it is important to consider the structure of post-secondary systems and its localized research capabilities (O'Byrne, 2013).

- **Strong venture capital investment.** Life sciences and biomanufacturing in BC benefit from the large Canadian venture capital market. BC is home to more than half of the Canadian-listed life sciences venture companies (LSBC, 2021). Between 2007 and 2017, venture capital investment in Canada, measured as a share of GDP, ranked constantly second-highest out of the G7 countries, trailing only the U.S. Venture capital investments have tripled in the country between 2014 and 2019, from $2.1 billion to $6.2 billion, with investments in life sciences companies coming second after those in IT companies (Ibid.). Additional investment was raised to address COVID-19 emergency, specifically cell systems delivery, messenger ribonucleic acid vaccine technology generation, assembly of home-grown respirators, manufacturing of COVID-19 therapeutics and personal protective equipment for frontline workers (LSBC, 2021).

These trends indicate that BC has important ingredients to continue developing its biomanufacturing and life sciences goods and services: strong education base and developed venture capital market (Cooke, 2001). In addition, market data indicates an opportunity to grow the biomanufacturing sector's production due to a $6.9 billion deficit in trade in life sciences goods (GoB, 2020; BC Stats, 2018).

There are also trends that could significantly reduce BC's life sciences and biomanufacturing sectors' growth. These trends include:

- **Rising demand for skilled labour in the BC's life sciences sector.** The life sciences sector employed 17,379 people in 2018 (BC Stats, 2018), with many employers doubling the number of staff (Interviews, 2022). As the sector continues to expand rapidly, the demand for biomanufacturing positions within the next five to ten years is expected to be filled by only 25 percent, given the current supply of biomanufacturing labour.[3] (Bio-Talent, 2021). Nearly two-thirds (61 percent) of life sciences employers indicate that they have faced some form of recruitment challenges, with 15 percent already experiencing significant challenges (Ibid.). It was estimated that the life sciences and biomanufacturing sectors in Metro Vancouver alone would need an additional 3,400 workers by the end of the decade, with the majority of new staff filling the positions in R&D (22 percent) and manufacturing (17 percent) (BioTalent, 2021). Provided that the sector is developing rapidly, current and future labour shortages need to be addressed fast in order to have a sustainable growth in life sciences and biomanufacturing and establish a global leadership in these sectors.

- **Low number of relevant programs in post-secondary system.** Even though BC institutions provide a range of health, applied and natural sciences programs (Ibid.), most undergraduate and post-graduate programs relevant to the life sciences and biomanufacturing are offered by institutions in Ontario and Quebec, as sown in Table 3 (BioTalent, 2021). This trend indicates an opportunity for improving provincial educational system to better suit the demand for skills in the life sciences and biomanufacturing sectors and establish a stronger labour pool in closer proximity to local companies.

Table 3. Programs relevant to the life sciences sector by province/region.

Program area/ Level of study	Number of programs offered	West (BC and AB)	Ontario	Quebec
Physical and life sciences and technologies *Undergraduate*	550	19%	42%	18%
Physical and life sciences and technologies *Post-graduate*	360	14%	39%	28%
Health and related fields *Undergraduate*	30	7%	46%	21%
Health and related fields	55	16%	47%	24%

3 BioTalent Canada conducted quantitative and qualitative data collection, and included both primary and secondary sources. Primary sources included a survey with 573 bio-economy employers, career perception survey with 1,531 Canadians from specific sub-groups, stakeholder roundtables with a cross-section of 119 bio-economy stakeholders, interviews with 138 bio-economy stakeholders, 10,826 job postings analysis, environmental scan etc(BioTalent, 2021).

Post-graduate				

Source: BioTalent, 2021

- **Delays in drug approvals and other regulatory hurdles.** Canada's approval of innovative drugs usually lags from several months to years, behind the FDA and the European Medicines Agency ("EMA") (Rawson, 2021). Between 2012 and 2019, almost 95 per cent of 224 new drugs approved by Health Canada were authorized a median of nine and a half months earlier by the FDA and more than five months earlier by the EMA (Ibid.). The delayed market availability of therapeutics in Canada is due to several factors, including authorization process, where Canada is considered a secondary market to FDA and EMA, with tough government-controlled health technology assessment and price negotiation organizations, weaker intellectual property protections, as well as public drug plans reluctant to cover more drugs (Ibid.).

- **High costs of doing business compared to other locations in North America.** The costs of doing business in British Columbia are higher than in other locations in North America (GoB, 2020). Life sciences in BC could benefit from a competitive edge on corporate income tax, labour costs, and cost for power and facilities (Ibid.).

The trends discussed above indicate that the life sciences sector in BC is well poised to continue its maturation and grow its capacity for both R&D and product manufacturing; however, several challenges related to labour shortages, lack of industry-specific programs and regulatory burdens need to be addressed in order to have a sustainable and significant growth.

The pandemic has further reinforced the need to be ready for future global health crises and support local leadership and innovation for life sciences goods and services. The global demand for life sciences products is expected to continue rising, with countries re-evaluating the importance of their domestic capabilities, so they can be more resilient in the face of future health emergencies (OECD, 2009). With Canada's interest in developing the life-sciences sector and a launch of the Biomanufacturing and Life Sciences Strategy (Government of Canada, 2021) and more than $2.2 billion over seven years from Budget 2021, BC needs to ensure its competitiveness and leadership in the Life Sciences and Biomanufacturing sector.

2.3. Role of Biomanufacturing in Life Sciences

This section provides background information on the role of biomanufacturing in life sciences and drug development process (Figure 2). It is important to understand the nature of biomanufacturing and drug development processes, as it indicates the sector's inextricable connection to the research procedures in the life sciences sector, inform the requirements for labour in biomanufacturing and provide insight for policy making.

Biomanufacturing processes differ from other manufacturing processes in a way that biomanufacturing requires significant R&D involvement and involves high regulations, significant risk of uncertainty, intensive requirement of skilled-labour, and high capital costs associated with building a facility (Jacoby, 2015; Reynolds, 2010). Notably, the sector is always feeling pressure to innovate, to create new discoveries and reduce costs, which leads to a complex and rapidly evolving nature of biomanufacturing processes and a dynamic product life cycle (Dogramatzis, 2010; Reynolds, 2010). This section will highlight the following features of biomanufacturing that can significantly affect labour policy (Reynolds, 2010): structure of biomanufacturing processes, operating and capital costs, locations, and regulations.

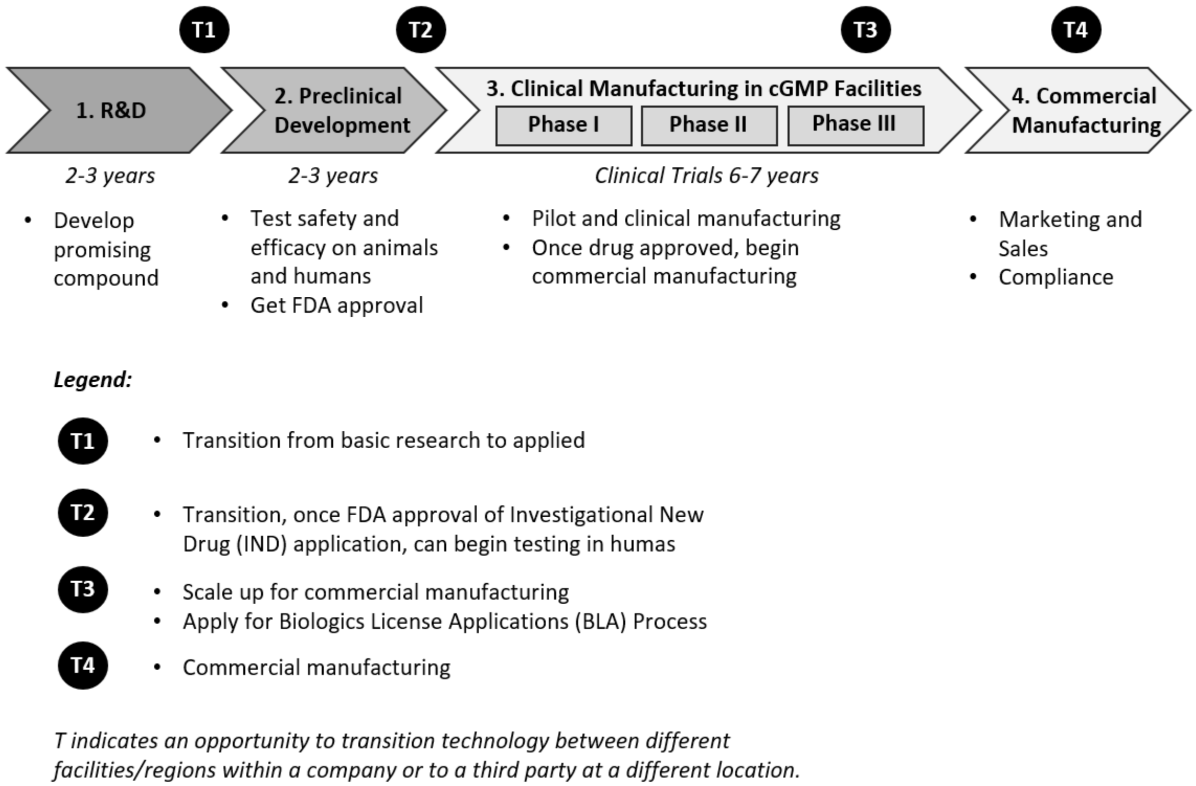
2.3.1. Structure of Biomanufacturing Processes

As in pharmaceutical manufacturing, biomanufacturing involves two types of drug manufacturing (Reynolds, 2010):

1. **Primary manufacturing.** This stage includes making of the drug substance, known as Active Pharmaceutical Ingredient in pharmaceuticals, and is considered the most complicated part of the biomanufacturing process. Figure 2 outlines the basic biomanufacturing process for primary manufacturing of monoclonal antibodies.

2. **Secondary manufacturing.** This stage involves the development of the drug product formulated for human consumption. This stage is the more routine and mobile of the two manufacturing types.

Figure 2. Drug development process and life cycle of biomanufacturing



Source: Graphic adapted from Reynolds, 2010

2.3.2. Costs of Labour

While the cost of biomanufacturing differs greatly, labour expenses, despite high wages, account approximately for 15 to 30 percent of total manufacturing costs (Ibid.; Deloitte, 2019). With overall manufacturing representing approximately 20 percent of the total cost of sales, biomanufacturing labor accounts only for 6 percent of total sales (Reynolds, 2010). The rest of the costs are charges incurred in the end-to-end supply chain from port of entry to the dispensing of medicines to patients (IFPMA, 2021). In some cases, the cost of labor can drop to as little as 2.5 percent of the total cost of goods sold, even though the sector hires graduates with degrees in biotechnology, microbiology, chemistry and biochemistry (Reynolds, 2010). Representing only a small fraction of total sales, labour costs play an important factor in economies of scale, because the cost of labour as share of total costs drops as the scale of a facility increases (Ibid.).

A general estimate of operating expenses for manufacturing breaks down as depicted in Table 4:[4]

Table 4. Operating Expenses for Biomanufacturing

Capital and Operating Expenses	Percent of total costs
Capital	30-40%
Materials	20-30%
Labour	30%
Utilities and Waste	5%

Source: Reynolds, 2010

2.3.3. Cost of Building Biomanufacturing Facilities and Bioreactors

The cost of building a new biomanufacturing facility with a bioreactor remains one of the highest across all industries, surpassing the cost of capital required for pharmaceutical facilities by three times (Ibid.; Jacoby, 2015), indicating that companies would have to justify building their own plant (Reynolds, 2010). The cost of building a commercial plant can run up to several billion dollars, depending on the size (Government of Canada, 2021; Denault, 2008), with approximately USD $4,000 per liter of installed bioreactor capacity (Raynolds, 2010). Different biomanufacturing facilities could require from 2,000 to more than 10,000 liters capacity (Ecker, 2020). Prior to making significant investments in a new plant, companies evaluate the size of the skilled labour force available locally along with an established biomanufacturing ecosystem or a cluster in the region (Ernst and Young, 2021).

2.3.4. Location of Biomanufacturing facilities

The location of biomanufacturing facilities and their proximity to R&D hubs matter significantly in the biomanufacturing process. This is due to high uncertainty and little predictability during the clinical trials, innovative nature of the R&D activities, non-standardized technology and considerable knowledge transfer between the R&D team and process development and manufacturing teams (Reynolds, 2010; Dogramatzis, 2010; Darmody, 2021). As a result, most biomanufacturing facilities in the world, both clinical and commercial, are located within 100 miles of company R&D operations

[4] This applies to a facility producing monoclonal antibodies at 1000kg/yr. For smaller quantities, capital outlays would be greater. See Ransohoff, 2004.

(Reynolds, 2010). This also leads to process innovation in biomanufacturing, which is important not only for bringing down the overall cost of manufacturing, but also for continuous improvement of the product and economies of scale (Ibid.). The factor of location directly impacts the number and quality of labour hired for biomanufacturing processes, as companies tend to engage more local labour with high skills in different areas of Biology, Chemistry, Engineering and Technology (Reynolds, 2010; Darmody, 2021).

Due to the demand for high-skilled labour by the R&D companies and their biomanufacturing facilities, the industry tends to be concentrated within a close geographic proximity to PREO structures and localized knowledge fields formed by the sector's complex relationships and networks (Ibid.). This often results in the formation of industrial clusters (Reynolds, 2010; Darmody, 2021) with non-reproducible, region-specific organizational forms, innovative capabilities and sector's development trajectory (Reynolds, 2010).

There are, however, four different points in the manufacturing process where a company could transition a technology transfer between different facilities/regions within a company or to a third party at a different location (Figure 2) (Reynolds, 2010). However, the movement of the drug substance between multiple locations and complexity of the task still keeps most companies of scale (i.e., not start-ups) producing in-house and not outsourcing to a third party (Ibid.). Some companies with established and standardized commercial production tend to relocate to tax-advantaged locations, high-wage, high-cost countries that are able to provide essential skilled labour to biomanufacturers along with cheaper production due to tax advantages (Reynolds, 2010).

Understanding the life cycle of biomanufacturing is important for developing labour policies, as it provides insight on possible business models with different opportunities for in-house or outsourcing manufacturing. The preferred business model would impact the companies' demand for skilled labour in BC.

2.3.5. Regulation

The Life Sciences sector is strictly regulated by FDA and EMA to provide better consumer safety. These regulations concern biomanufacturing processes and dictate the structure of the facility to ensure it is certified according to current Good Manufacturing Practice ("cGMP") (Government of Canada, 2022). Currently to fabricate, package, label, distribute, import, wholesale or test drugs, all biomanufacturing facilities have to be cGMP certified (Ibid.). This indicates that the expansion of the biomanufacturing sector in BC is contingent upon the availability of cGMP-certified facilities and cGMP-trained people to operate these facilities.

2.4. Biomanufacturing in BC

Biomanufacturing sector in BC takes 28 percent of the bio-economy in Metro Vancouver and remains a key economic driver in the life sciences sector. The sector has exemplified significant growth following the onset of COVID-19 pandemic (LSBC, 2021). It was estimated that future growth might be delayed by existing and future labour shortages (BioTalent, 2020).

In 2019, BC biomanufacturing companies together with biotech companies raised record financing, signaling the growth potential of the sector (Ibid.). The top four deals raised almost $700 million and an additional $200 million was raised in the first quarter of 2020 (Ibid.).

The sector plays an important role in supporting the provincial health care system, international trade, and global research in messenger ribonucleic acid vaccines (LSBC, 2021). Overall, the sector follows the same trends as any other regional biomanufacturing sub-sector: most BC companies (99 percent) are SMEs (Statistics Canada, 2020), located in Metro Vancouver area close to PREOs such as University of British Columbia, Simon Fraser University, BC Institute of Technology, Vancouver Coastal Health Research Institute (BioTalent, 2021; GoB, 2020), and the majority of labour employed is skilled labour (BioTalent, 2021).

2.4.1. Existing Policies that Support BC Biomanufacturers

In addition to a number of world-class research institutions and research centers such as Vancouver Coastal Health Research Institute with its nine research centers, biomanufacturing in BC is supported by a cohesive ecosystem of industry associations, funding and equity funds, labour and training programs, and research funding organizations (GoB, 2020), as depicted in Table 5.

Table 5. List of organizations that support biomanufacturing companies in BC

Category	Organizations that support biomanufacturing companies in BC
Industry associations	LSBC and BC Tech Association
Innovation support and funding and equity funds	Innovate BC, Pacific Economic Development Canada, ISEDC, Trade and Invest BC, National Research Council, Global Affairs Canada, BC Renaissance Capital Fund, BC Tech Fund, Business Development Bank of Canada
Labour and training program	Innovate BC, BC Provincial Nominee Program, BioTalent and Mitacs
Research funding organizations	Genome BC, Genome Canada, the Michael Smith Foundation for Health Research, Canadian Institutes of Health Research, Natural Sciences and Engineering Research Council

Source: GoB, 2020

Biomanufacturing companies in BC, that are Canadian-controlled private corporations ("CCPC"), may also apply for the Scientific Research and Experimental Development ("SRED") Provincial and Federal tax (Government of BC, 2022). The federal amount of SRED is 35 percent (up to a threshold of $3 million) and 15 percent beyond this amount or for other corporations other than CCPCs (GoB, 2020). And 10 percent on eligible expenses or investments from the province (Government of BC, 2022). Notably, provincial SRED in BC is significantly lower than the one provided in Quebec, which can constitute up to 30 percent (Revenue Quebec, 2022). BC also provides a Small Business Venture Capital Tax Credit, equaling 30 percent of investment, that is designed to encourage investors to make equity capital investments in new proprietary technology developed in BC (Government of BC, 2022).

Overall, the existing supporting infrastructure creates a favorable market for further development of the biomanufacturing sector. Additional research may be required to understand how BC can improve its programs and whether more labour and training subsidies and tax credits could help address skilled labour shortages issue.

2.4.2. Advocacy to increase number of labs and manufacturing facilities in BC.

One of the biggest concerns for biomanufacturing is a shortage of suitable real estate for labs and manufacturing facilities (LSBC, 2021), especially within a tight Metro Vancouver market. There has been vocal advocacy by the industry to increase its accessibility (LSBC, 2021). In 2020, two well-capitalized B.C. companies, AbCellera Biologics Inc. and Precision NanoSystems Inc., have invested in new facilities, with $175.6 million support from the Government of Canada's Strategic Innovation Fund to AbCellera towards the company's existing drug discovery technology, as well as the development of a 130,000-square-foot Good Manufacturing Practices ("GMP") manufacturing facility (LSBC, 2021). The facility will be the first of its kind in Canada (Ibid.) and will accelerate programs from a drug target to the submission of an Investigational New Drug application (AbCellera, 2021). The facility is scheduled to be ready for cGMP manufacturing in early 2024 (Ibid.). The construction of new biomanufacturing facilities means rising demand for labour in biomanufacturing, which can further exacerbate the issue of skilled labour shortages in BC unless proper policies are established.

2.4.3. Employment and Labour Shortages

In Metro Vancouver alone, pharmaceutical and medicine manufacturing companies employ 3,010 people, which represents 19 percent of total bio-economy employment (BioTalent, 2021). Medical equipment and supplies manufacturing companies employ 1,410 employees, representing nine percent of total bio-economy employment (Ibid.). R&D and manufacturing account for more than forty percent of life sciences jobs in Metro Vancouver, as indicated in Table 6 (BioTalent, 2021), they also account for nearly half of all bio-economy jobs in British Columbia and Alberta (Ibid.).

Table 6. Employment by job category in life sciences sector in Vancouver

Job Category	Life Sciences
Research and development	27%
Manufacturing and production	14%
Management, finance, and administration	12%
Distribution and logistics	6%
Quality control and quality assurance	5%
Marketing, business development and sales	5%
Information technology	4%
Legal and regulatory affairs	2%
Other	25%

Source: BioTalent, 2021

Companies' needs vary by discipline and also level of specialization (BioTalent, 2021) (Interviews, 2022). However, most of the jobs require professional skills, i.e. some form of post-secondary education (Ibid.). The interviews' analysis has identified three tiers of positions required for biomanufacturing, indicating a wide range of skills and degrees required for filling these positions. The distribution of these skills and degree qualifications varies from company to company (BioTalent, 2021; Interviews, 2022). However, the majority of biopharmaceutical manufacturing employees are expected to have a basic knowledge of biology and chemistry with at least two years of post-secondary education (Jacoby, 2015; Interviews, 2022). The three tiers of positions are as follows:

1. **Research and Development.** These positions require people with specialized technical/research skills as well as those who understand business context of the sector to commercialize innovation. Many of these positions are filled with people with Doctoral or Master's degrees (BioTalent, 2021) (Interviews, 2022).

2. **Technical Operations / Production.** The positions require people with some form of postsecondary education or training, including certificates, Bachelor's and Master's degrees, as well as cGMP certification and training. The positions include work in labs, knowledge of aseptic technics, logistics and operations, finished goods production, sterilization, product line maintenance, chemistry, biotech, and analytics (Interviews, 2022).

3. **Warehouse staff / Assembly.** Warehouse staff constitute the smallest share of positions and are filled with non-professional staff for positions in assembly line. The positions would still require some soft skills and adaptability skills from an employee (Ibid, 2022). Three out of four interviewed companies confirmed that they do not employ staff with no postsecondary education.

There is little opportunity for people with only high school education to find a position in the biomanufacturing sector. The three tiers highlight the importance of a robust and flexible education system in place to support current and future labour demand in the field.

To conclude, biomanufacturing in BC has been rapidly developing over the last few years, incentivized by the Canadian government to enhance domestic and international vaccine and therapeutics manufacturing. The sector remains diverse in types of products being produced and requires a diverse nature of skills to maintain its excellence. Most of the skills required by the sector require post-secondary education ("PSE") accreditation or certification. One of the main challenges that slows down the BC biomanufacturing sector includes growing skilled labour shortages and lack of scalable real estate for labs and manufacturing facilities.

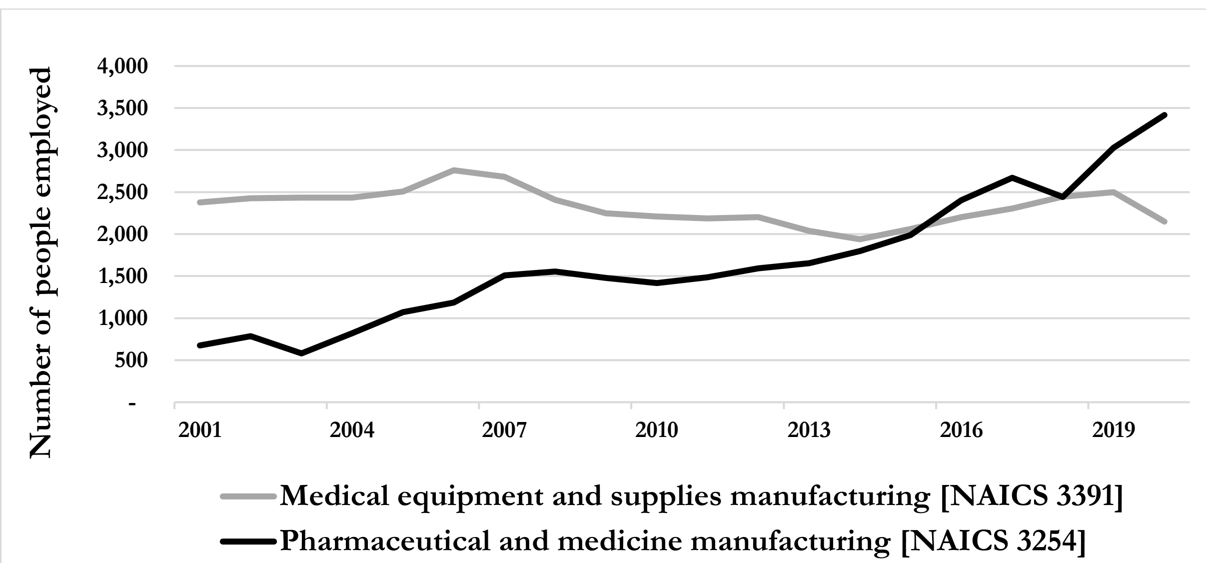
3. Labour Market Review

The overview of the life sciences and biomanufacturing sectors in BC has indicated the need for BC's biomanufacturing sector to level up its talent recruitment. By examining factors that affect the demand and supply of labour in biomanufacturing, this section identifies specific issues that need to be addressed by policy makers. The section concludes with a rational for addressing the policy problem of skilled labour shortages in biomanufacturing.

3.1. Demand for Biomanufacturing Labour

British Columbia's biomanufacturing sector employed 5,566 people in 2020, representing approximately 0.2 percent of the province's total employment (Open Canada, 2022). The number of people employed in the sector has been steadily increasing over the last 20 years, with most growth occurring in the Pharmaceutical and Medicine Manufacturing, as shown in Figure 3 (Ibid.). Overall, the sector has grown by 82 percent from 2001 to 2020. Pharmaceutical and Medicine Manufacturing has also experienced a 37 percent growth from 2019 to 2020, largely driven by demand for locally manufactured vaccines and therapeutics (Ibid.).

Figure 3. Employment in Biomanufacturing sector in BC, 2001-2020



Source: Open Canada, 2022

The 13 percent growth of British Columbia's Biomanufacturing sector from 2019 to 2020 topped the growth of the Canadian sector and surpassed Ontario and Quebec (Ibid.). Notably, the employment growth occurred in tandem with growth from the health care sector, highlighting close relationship between the two sectors (BioTalent, 2021.).

With the hiring on the rise, nearly two-thirds of employers indicated that they have difficulty recruiting or retaining qualified staff due to a lack of skilled and experienced talent (BioTalent, 2021). The outlook suggests the issue will continue and likely worsen through to 2029 (Ibid.). It has been estimated that approximately 36,000 new workers will be needed in the Canadian biomanufacturing sector by 2029, with 1,010 manufacturing and production and 990 research and development workers being in demand in Metro Vancouver region (Ibid.). Notably, the majority of the forecasted demand would occur in R&D (22 percent) and Manufacturing (17 percent), with nearly 80 percent of those to replace exiting workers (Ibid.).

COVID-19 highlighted a significant gap in the Canadian and BC's biomanufacturing and processing capacity, provided that Canada was unable to produce sufficient personal protective equipment and manufactured vaccines to meet its needs (BioTalent, 2021). With new facilities being built by STEMCELL Technologies and AbCellera to remedy this, BC's biomanufacturing sector would require skilled people to operate them (STEMCELL, 2018) (AbCellera, 2021). A supply of talent does not currently exist to satisfy the demand (BioTalent, 2021).

In order to better understand current and future demand for labour in the biomanufacturing sector, several demand factors have been analyzed. The factors affecting the demand for labour in biomanufacturing have been drawn from research produced by BioTalent (BioTalent, 2021) and Life Sciences BC (LSBC 2021):

1. Rising local and global demand for health products;
2. Competitive life sciences sector wages;
3. Growing investment in the biomanufacturing and life sciences sector;
4. Demand for technical and soft skills;
5. Competition for talent; and
6. Labour force diversity in biomanufacturing.

3.1.1. Rising local and global demand for health products

Rising local and global demand for vaccines and therapeutics creates an anticipation factor in the biomanufacturing sector and shifts the demand for labour up. Domestic consumption of vaccines and therapeutics, has astronomically increased from $473 million in 1997 to $4.8 billion in 2019 (Mitacs, 2021) and is expected to rise further (Ibid.). As chronic illnesses are becoming more common and the risk of another global pandemic remains high, the demand locally produced vaccines and therapeutics will continue to grow (Ernst and Young, 2021; Government of Canada, 2022).

3.1.2. Competitive life sciences sector wages

Competitive and high sector wages for life sciences and biomanufacturing affect both the demand and supply of skilled labour in BC. With the low labour supply, companies are trying to attract talent by setting high wages, indicating a relatively inelastic demand for essential skills and talent in the rapidly developing sector. In 2020, the life sciences sector in BC paid just under $12.8 billion in total compensation, up 7 percent from 2018 (Statistics Canada, 2022). Wages in the life sciences sector in BC are on average lower than in Ontario or Quebec (Ibid.) (Appendix B. Table B1). This could potentially drive some talent away from the BC market to other Canadian provinces or other countries, such as US, reducing the supply of labour even further.

Overall wages recorded in the Drugs and Pharmaceuticals industry group in BC are lower than wage in the R&D industry group (Statistics Canada, 2022). With a looming skilled labour shortage in the manufacturing sector, BC employers could consider rising biomanufacturing labour wages to attract more talent and skilled employees. However, competitive wages remain one of the top HR challenges for the bio-economy in Metro Vancouver, with 36 percent of surveyed employers reporting insufficient resources to pay competitive wages (BioTalent, 2021). This indicates that the demand is becoming more sensitive to the market price for labour.

3.1.3. Growing investment in the biomanufacturing and life-sciences sectors

The increased federal support through the Biomanufacturing and Life Sciences Strategy, newly built BC biomanufacturing facilities (STEMCELL, 2018) (AbCellera, 2021), as well as a growing international investment in Canada's and BC's biomanufacturing (LSBC, 2021) are expected to grow the industry and as a result increase the demand for skilled labour. In addition to that, the provincial investment of $16.25 million in the manufacturing sector through the "B.C. Supply Chain Resiliency and Value-Added Manufacturing Project", is expected to contribute to the accelerated manufacturing scale up and increased production (BC Manufacturing Grant, 2022), leading to a rising demand for skilled labour in the biomanufacturing field.

3.1.4. Demand for soft and technical skills

Finding people with the right sets of skills seems to be a top challenge for the sector (BioTalent, 2021), shifting the demand curve for skilled labour further up. The employers are mostly hiring from the following disciplines such as molecular biology, bioinformatics and proteomics combine with chemistry (Green, 2021) for positions ranging from Lab Technicians to Quality Assurance and Quality Control Technicians, Biochemists, Analytical chemists, Microbiologists, Process Engineers (Ibid.) (Interviews, 2021). In addition to technical and research skills, employers are looking for "soft" professional and interpersonal skills (Ibid.). The demand for technical and soft skills is also observed globally, with the following positions being the most difficult to hire: engineers, followed by automation engineers, manufacturing science and technology staff, CQ&V engineers, and QA staff (NIBRT, 2020).

Using the example of Regenerative Manufacturing workforce, manufacturing operations management and cell science are the highest-demanded skill sets among skilled technician workforce (Green, 2021). The manufacturing operations management most critically demanded skills include documentation (needed by 93.9 percent), validation (91.8 percent), standards (88.4 percent), and regulation (85.7 percent) (Ibid.).

3.1.5. Competition for talent

High competition for talent among local, Canadian and international Science, Technology, Engineering, and Math ("STEM") companies shifts the demand curve up for skilled labour. Biomanufacturing employers do not only compete for talent among themselves, they also compete with other sectors, such as hospitals and computer and electronic product manufacturing, for candidates with technical and research skills, and with companies across the economy for non-technical skills (BioTalent, 2021). Low awareness of the manufacturing positions and career options among new graduates (Interviews, 2022) create fewer labour substitutes in the local talent pool. In addition, many start-up companies lack HR departments, which slows down the recruiting process (BioTalent, 2021), keeping the demand for labour high.

3.1.6. Labour force diversity in biomanufacturing

Lack of labour force diversity exacerbates the demand for skilled labour by narrowing the pool for recruiters. Even though, Metro Vancouver employs a higher proportion of visible minorities (an average of 29 percent) and women (BioTalent, 2021) (Interviews, 2022), experts note that it's of the utmost importance that employers actively expand recruitment and retention strategies to include a more diverse talent pool in order for the industry to meet forecasted talent needs of the next decade. Currently there is a need for better representation of indigenous people, people with disabilities, internationally educated professionals, and recent immigrants (BioTalent, 2021).

3.1.7. Other factors affecting demand

There are other factors that affect the demand, including shortage of wet-lab and manufacturing space, scarcity of executive-level talent, lack of commercialization expertise, inconsistent collaboration across levels of government, academia, research and industry to scale companies and adopt innovation, and the lack of a coordinated data strategy (BioTalent, 2021). These factors can negatively affect development and revenue of biomanufacturing companies the income and therefore, shifting the demand curve for labour downwards.

3.2. Supply of biomanufacturing Labour

Current labour supply in biomanufacturing provides recruitment challenges to 61 percent of employers and severe labour shortages to 15 percent of employers (BioTalent, 2021). It has been predicted that the supply of biomanufacturing talent will represent less than 25percent of the demand by 2029 (Ibid.), with severe shortages experienced for the lab technicians and production (Ibid.). The shortage in R&D is expected to be moderately severe due to high historic rates of workforce entrants for R&D related roles, with labour supply between 25 percent and 75 percent of labour demand (Ibid.).

In order to better understand current and future supply of labour in the biomanufacturing sector, several supply factors have been analyzed. The factors affecting the supply for labour in biomanufacturing have been drawn from research produced by BioTalent (BioTalent, 2021) and Life Sciences BC (GoB, 2020; LSBC 2021):

1. Changing demographics: aging workforce;
2. International talent and Canadian immigrants;
3. Geo-mobility of talent and skills;
4. Availability of educational programs required by the industry;
5. High cost of living in Metro Vancouver; and
6. Low use of co-op system.

3.2.1. Changing demographics: aging workforce

The supply of labour in biomanufacturing sector as well as many other industries in Canada is falling, greatly affected by the changing demographics as baby boomers, those with significant amounts of experience, are at the age of retirement (BioTalent, 2021). The supply curve is also shifted down due to a decline in youth share of population and working age population.

The youth share of Canada's population has been declining steadily over the past two decades and will likely continue to do so, falling from 33 percent in 2000 to an expected 26 percent in 2029, in line with decreasing fertility rates (Ibid.). This is concerning because a strong supply of youth is needed to age into the workforce and replace older workers, whose numbers are growing as quickly as the youth share of the population is shrinking (Ibid.). The working-age population (25 to 54 years old) has also declined since 2000 but, unlike with youth, is projected to remain stable at around 40 percent over the next decade. The population share of individuals aged 55 and older climbed from 22 percent in 2000 to 32 percent in 2019 and is expected to reach 34 percent by 2029 (Ibid.)

To ensure the supply of labour meets the demand, Metro Vancouver biomanufacturing companies will have to recruit more heavily from under-tapped talent pools, including recent immigrants and internationally educated professional (Ibid.)

3.2.2. International talent and Canadian immigrants

Domestic enrolment in post-secondary biomanufacturing-related programs is expected to decrease over the next ten years, driven largely by the declining proportion of youth in the Canadian population and overall decreases in undergraduate enrolment (BioTalent, 2021). The shortage in talent pool could be alleviated through growing enrolments of international students or through the existing immigration programs (GoB, 2020).

Between 2012–2013 and 2016–2017, international enrolments in Canadian undergraduate biomanufacturing and bio-economy-related degree programs[5] increased by 73 percent (BioTalent, 2021). However, less than 30 percent of international students stay in Canada and become permanent residents (Ibid.). Notably, international student enrolment is sensitive to macroeconomic factors such as global pandemics, international affairs, and countries' state of the economy. Between the 2019–2020 and 2020–2021 academic years Canada's international enrollment decreased by as much as 30 percent (Ibid.).

Internationally educated professionals ("IEPs") constituted 17 percent of the bio-economy workforce and recent immigrants (five years in Canada or less) constituted 9 percent in 2019 (BioTalent, 2021). The representation of IEPs and recent immigrants in

[5] Assuming a similar share in the Biomanufacturing-related degree programs.

the biomanufacturing sector could be higher, provided that IEPs and recent immigrants constitute 28 percent of the total population (New to BC Report, 2018). The recent changes in the National Occupational Classification (“NOC”), which is a major part of Canada’s immigration system, will greatly impact the Express Entry system, which will take effect in Fall 2022 (Statistics Canada, 2022). The old NOC system presented some hiring challenges for companies, for example not providing specific definitions of skills qualified under NOC for biologists (Interviews, 2022). The current NOC’s four-category “skill level” structure was replaced by a new six-category system that outlines the level of Training, Education, Experience and Responsibilities (TEER 0 to 5) to enter each occupation (Statistics Canada, 2022). The new system will provide more clarity on the level of education and work experience required in different occupations, including biomanufacturing, and facilitate easier immigration for people in low-skilled jobs (Ibid.). Notably, the federal government conducts a major revision of NOC system every ten years (Ibid.). For a rapidly developing sector like biomanufacturing and life sciences 10 years represents a long period, as innovation might outpace the system. A more frequent review of the immigration skills classification may be required, based on international best practices (Ibec, 2021).

3.2.3. Geo-mobility of talent and skills

The low mobility of Canadian university graduates and generally low awareness of biomanufacturing careers also reduces the bio-economy labour supply, making it more elastic (BioTalent, 2021; Interviews, 2022). Many employers in BC rely greatly on graduates from Ontario, Quebec, or from other countries to fill job vacancies (Ibid.), while most students (90 percent) prefer to stay in the region where they graduate (BioTalent, 2021). This finding indicates that many BC companies located in Metro Vancouver benefit from a proximate location to several established post-secondary institutions. It also highlights the vitality of local educational institutions to the industry and the supply of labour.

3.2.4. Availability of educational programs required by the industry

Even though the overall STEM enrolment in Canadian colleges increased by 15 percent between 2014–2015 and 2018–2019 (BioTalent, 2021), most undergraduate and post-graduate programs relevant to bio-economy and biomanufacturing are offered by institutions in Ontario and Quebec (Ibid.), resulting in higher labour supply in those two regions (Ibid.). BC manufacturers have to work harder to recruit interprovincial graduates and bring them to BC (Ibid.) (Interviews, 2022). Paired with low mobility of talent, this lower availability of educational programs puts a downward pressure on the supply of skilled labour for biomanufacturing.

In addition to a lower number of graduates and graduate programs in BC, employers report an experience gap for existing new graduates seeking employment (LSBC, 2021; Interviews, 2022). Many employees have to provide additional up-skilling training to new graduates (Ibid.) The lack of graduates with proper training also decreases the supply of skilled labour.

3.2.5. High cost of living in Metro Vancouver

High cost of living in Metro Vancouver puts pressure on employers to pay higher more competitive wages to their employees in order to keep the supply of labour, without losing talent to other markets (BioTalent, 2021). However, one-third of employers cite insufficient resources to pay competitive wages as a top HR challenge, and their challenges are expected to worsen throughout the decade (Ibid.). Subsidies and other instruments are actively used by these firms get the talent they require (Interviews, 2022).

3.2.6. Low use of Work-Integrated Learning

Despite the fact that Work-Integrated Learning ("WIL"), such as co-op, work placements, internships and placements that combine practical work experience with formal in-class training (CEWIL, 2022), have proved to be an effective mechanism in bridging biomanufacturing employers and new graduates, the uptake of WIL among Canadian students remains low, putting a downward shift on the supply curve of skilled labour (BioTalent, 2021). While student satisfaction is usually high and most students who participate in WIL say it helped them find a job, only 27 percent of university undergraduate students in physical and life sciences and technology fields have participated in a work placement (Ibid.). The participation is also low among Master's (18 percent) and PhD students (11 percent) across Canada (Ibid.). There is opportunity for employers in leveraging existing co-op systems, as a recent study at the University of

Waterloo revealed that employers gain $2 in economic gains for every dollar spent on co-op students (University of Waterloo, 2019).

3.3. Rationale for the Policy Problem

The analysis of demand and supply of skilled labour in biomanufacturing and life sciences indicates that if conditions do not change, supply will not be sufficient to meet biomanufacturing labour demand, resulting in significant challenges for biomanufacturing companies in maintaining and scaling their business operations. As a result, biomanufacturing companies would potentially consider other geographic locations in Canada or internationally for their manufacturing facilities, which would not only affect the employment in BC, but also result in lost economic impact from these employees.

Policymakers should also keep in mind that the labour involved in biomanufacturing processes is highly skilled and highly paid, which could translate in significant direct, indirect and induced impacts for the province (IFPMA, 2021) (Deloitte, 2019). Using the example of Ontario in 2016, an estimated expenditure of $52.4 billion by the life sciences sector resulted in an estimated total economic contribution of $58.1 billion to Ontario's GDP and supported total employment of 191,294 jobs for Ontarians, accounting for direct, indirect and induced contributions (Deloitte, 2019).

The analysis suggests there are several ways to increase the supply of labour in the Biomanufacturing field in order to meet the rising demand, including:

- Establishing a collaboration among universities and industry to improve existing programs and create additional certifications, programs or training suitable for the Biomanufacturing field.
- Creating incentives for higher WIL uptake among students, by reducing cost barriers and accommodating international students in the process.
- Marketing Biomanufacturing as a career choice for STEM graduates.
- Providing subsidies to companies to support hiring, training, and retaining new labour.
- Diversifying workforce to increase the number of immigrant workers, women, Indigenous workers, and other minority groups.
- Attracting more international students to STEM fields and providing favorable conditions to stay and work in Canada after graduation.

The issue of skilled labour shortages is complex and requires participation of many stakeholders, closing the gap between demand and supply will take a concerted and coordinated effort, leveraging a wide range of potential tools, actions and strategies. Coordinated effect will be required from all levels of governments, life sciences and biomanufacturing sectors, and PREOs.

4. Methodology

This study considers a simple research question: **how can BC address skilled-labour shortages in the Biomanufacturing sector?**

A mixed-methods approach was used in this study to gather and analyze data on skilled labour shortages, currently available resources for Biomanufacturing companies in British Columbia, and practices in other jurisdictions, i.e. Ireland, Germany and United States ("US"). Study findings and recommendations were informed by interviews with Manufacturing Industry experts and BC Biomanufacturers, as well as publicly available data from the Government of BC, Statistics Canada, Government of Canada Open Data, Canadian Manufacturers and Exporters ("CM&E"), Life Sciences BC ("LSBC"), BioTalent's Labour Market Intelligence reports, and the Organization of Economic Co-operation and Development.

4.1. Interviews

The study was informed by four interviews with the BC biomanufacturers located in Metro Vancouver area and one industry association. The input of interviews is incorporated throughout this study, in particular four interviews with the BC biomanufacturers helped to inform the sector's labour market and most effective policy options to address existing labour issues. The interviews provide an informative look at the problems facing the economy from the view of the biomanufacturing employers. These contributions were invaluable to the analysis of skilled labour shortages in BC's biomanufacturing.

4.2. Jurisdictional Scan and International Best Practices

This study provides best practices of two established leaders, Germany and US, and one emerging leader, Ireland in the field of Biomanufacturing. Germany and United States were selected for this study as both countries have been scoring as the top-ranking nations for 'knowledge of professionals' and 'ability to meet future capacity' (Rais, 2018). Provided that knowledge of professionals as well as availability of professionals remains the constraining factor in Canada's and BC's biomanufacturing labour supply and Sector development (BioTalent, 2021; Government of Canada; 2022), both Germany and United States provide examples of policies and practices that have helped them overcome labour shortages and remain biomanufacturing leaders on the global arena. United States continues to be the world's number one biomanufacturer (Rais, 2018; Phillips, 2020). It is also a geographic neighbor of BC and Canada, sharing not only the border but also a similar geopolitical and economic landscape, which would help in the analysis of education systems and state's support for biomanufacturing businesses (Darmody, 2021). This will give context to the role of provincial cluster development, given that BC is also competing with Ontario and Quebec for talent and market share (IBS, 2018).

Germany is known for its flexible and robust dual education system and research excellence (Lorenz, 2018; Oeben, 2021), both of which have greatly contributed to biomanufacturing development by training future technicians to meet the needs of area employers (Albrecht, 2020; Agia, 2010). In addition to that, Germany has a robust start-up system and cluster network made up of technology parks, incubators, and local agencies, which create a landscape that is conducive to skill and R&D development in labour force (Albrecht, 2020). The role of a cluster will be examined here again in the context of the Sector's success.

Ireland scored highly on 'knowledge of bio professionals', and second only to Germany in terms of 'growth potential' amongst European Union countries (Rais, 2018). Ireland also managed to emerge as a strong biomanufacturing market due to robust government policies, so it is important to include it this jurisdictional scan as an example for BC (Innophrama education, 2022; Ibec, 2020).

Canadian jurisdictions were excluded from analysis as Canada's biomanufacturing sector as a whole has not reached the level of development of the forementioned countries (Government of Canada; 2022). Ontario and Quebec have both announced their ambitious strategies in becoming key global players in life sciences and biotechnology sectors (Ontario, 2022; BioQuebec, 2022; Quebec, 2017). These strategies have not been fully implemented yet; hence, Ontario and Quebec will not be covered in best practices. However, some of their labour-related strategies will be highlighted in the "What does it mean for British Columbia?" section.

4.3. Limitations

Interviews conducted in this study represent only a small portion of the total biomanufacturing companies in BC and, therefore, they do not provide an encompassing view of the sector.

All interviews were held with Senior or General HR staff, who might not have sufficient data on the financial performance of the organization and a need for a specific financial policy program.

Some data and research analysis were presented by industry associations and their definitions of the life sciences and biomanufacturing sectors could differ to some extent in this study. The definitions used by the associations as well as links to their methodologies are provided in Appendix A. Notably, NAICS codes that define biomanufacturing also include the manufacturing of small molecule drugs (Statistics Canada, 2021), affecting the accuracy of data.

It is understood that the issue of skilled labour shortages is not an only reason to the problem of restrained growth in the biomanufacturing. Other issues such as low investment into technology and infrastructure need to be addressed possibly simultaneously in order to reach higher economic outcomes. This study will focus on skilled labour shortages in biomanufacturing in BC, and propose, evaluate, and recommend policies that would address the issue.

5. International Best Practices

The biopharmaceutical and medical devices industry makes major contributions to the prosperity of the world economy, with a total annual contribution to the world's GDP is USD 1,838 billion in combined direct, indirect and induced effects (IFPMA, 2021). In addition to that, the sector contributes greatly to the Global Health Progress and attaining better outcomes for the Sustainable Development Goal 3 on good health and wellbeing (Ibid., UN, 2022). Given the economic and health pillars of the biomanufacturing sector, many industrialized economies are increasingly recognizing it as an important sector in the developing world. The established leaders in global biomanufacturing competition are US, Germany, Japan, and United Kingdom. The rapidly emerging bio hubs include Ireland, China, Singapore and Sweden (Rais, 2018).

The sections provide best practices of two established leaders, Germany and US, and one emerging leader, Ireland in the field of biomanufacturing.

5.1. Best practices: Ireland

Ireland started actively attracting more biopharmaceutical manufacturers in 2010 amid concerns of a "patent cliff" or struggle against low-cost competition (Forfas, 2020). Now Ireland is home to 19 out of 20 world's top pharmaceutical companies, with more than 30,000 people employed in pharma at the Industrial Development Agency Ireland ("IDA")[6] client companies (Ibec, 2020). Ireland is now the third largest exporter of pharmaceuticals globally (UN International Trade Statistics Database; 2020), with biomanufacturing being a hallmark of Ireland's success in the sector (IDA Ireland, 2022).

Throughout 80's, 90's and early 2000s Ireland managed to boost its labour participation rates in biomanufacturing, which supported the country's intention in creating biomanufacturing clusters and attracting transnational corporations (O'Byrne, 2013; Heavey, 2016). First and foremost, Ireland developed a strong and transparent regulatory framework with compelling policies to attract transnational corporations. Then, Ireland set one of the world's lowest corporate tax rates at just 12.5 percent with a large

[6] The mandate of IDA Ireland is to attract and retain foreign direct investment into Ireland (IDA Ireland, 2022).

tax credit of 25 percent attributed to in house research, development, innovation and training (IDA Ireland, 2022). Favorable tax climate and close geographic proximity to European and US markets made Ireland a desirable location for many biomanufacturers (Innophrama education, 2022).

In addition to low tax policy, Ireland also carried out a number of policies addressing the availability of skilled labour in the country (O'Byrne, 2013; Heavey, 2016). First of all, the Government of Ireland funded the National Institute for Bioprocessing Research and Training ("NIBRT") (€60 million investment by the IDA), a world-class institute that provides training to over 4,000 people annually and develops research solutions for the bioprocessing industry (Heavey, 2016).

Secondly, Ireland formed collaborative clusters to foster operational and research excellence and practitioner-to-practitioner knowledge sharing (O'Byrne, 2013). Organizations, such as the Irish Centre for Business Excellence and Irish Business and Employers Confederation ("Ibec"), work with the IDA to facilitate best practice-sharing between companies (IDA Ireland, 2022). Ireland's educational institutions have also established strong cooperative links with the sector, where feedback from the industry on skills and training needs feeds directly into educational programs (Ibec, 2020). Also, new dedicated Government Department for Higher Education, Innovation and Science established in July 2020 (IDA Ireland, 2022). Ireland is currently working on developing a "national end-to-end skills strategy for the manufacturing industry that supports enterprise-led skills development and lifelong learning" and "incentivizing the co-location of R&D capacity with high end manufacturing in Ireland" (Forfas, 2020).

5.2. Best practices: Germany

Germany has a long tradition as the "World's pharmacy" and keeps on leading the innovation in that industry (GTAI, 2021). Located in the heart of Europe, Germany benefits from its geographic location, proximity to exporting markets, excellent infrastructure, and highly skilled workforce (Ibid.). Germany boasts to be a location of over 400 universities with numerous specialized research institutes, including Fraunhofefr Society, the Max-Planck-Society, the Helmholtz Centers, and the Leibiz Association, with over 1,000 publicly financed institutions (Ibid.).

Part of the country's success in biomanufacturing is in over 30 biotechnology clusters and two life science incubators that contribute to innovation in biopharmaceuticals by connecting academic and industrial players in the field of drug development (Ibid.). Germany also hosts over 15 start-up centers dedicated specifically to biotech and life sciences companies, supporting entrepreneurs bringing their ideas to the market (Ibid.). The cluster network creates a landscape that is conducive to skill and R&D development in labour force, as it supports the competitiveness of businesses and brings in collective effort to address barriers in the sector (Albrecht, 2020).

Germany's biomanufacturing sector benefits from a dual education system in vocational training, which allows to secure highly-qualified personnel and meet the industry's needs (Lorenz, 2018; Casper, 2000). The system provides benefits of both classroom-based and on-the-job training over a period of three years (Ibid.). The flexibility of the education system and availability of on-the-job training contributes to labour force developsmetn and provides training that is demanded by the industry (Lorenz, 2018; Casper, 2000; Albrecht, 2020). More than 80 percent of the German workforce received vocational training or an academic degree, with 10 percent receiving vocational education ("VOC"), 50 percent receiving skilled craftsmen or dual education apprentices, and 22 percent being university graduates (GTAI, 2021). The German Chambers of Industry and Commerce and the German Confederation of Skilled Crafts work closely with the industry and the government to ensure quality training is provided and standards are followed (Ibid). German VOC is focused on shorter and more practice-oriented apprenticeships that reduce the overall labor-related regulatory framework that especially affects SMEs (Casper; 2000; Reiss, 2004).

Germany also provides labour-related incentives that significantly reduce operating expenses of biomanufacturing businesses. These incentives are divided into three categories: programs focusing on recruitment support, training support, and wage subsidies (GTAI, 2021). These policies combined with a complex cluster network and dual system in education allow Germany to maintain its leadership position in biomanufacturing.

5.3. Best practices: United States

United States has been a long-standing leader in biomanufacturing. In a global rating, United States scored as the top-ranking nation for all major categories – ‘knowledge of professionals’, ‘ability to meet future capacity’, ‘bio innovation’, ‘quality of processing’ and, even ‘growth potential’, ahead of all emerging and established markets (Rais, 2018). BC could learn from its neighbour the historical factors and policies that have been supporting the growth of the biomanufacturing sector and maintain the leadership position.

United States recognized that university-led R&D in the biosciences plays a central role in scientific discovery and the industry’s innovation ecosystem (Taeconomy Partners LLC, 2020). Along with the government investment in university-led R&D, biopharmaceutical companies recognize the need to nurture the development of the biomanufacturing talent pool through education and vocational programs (Ibid.; Jacoby, 2015). One example is a partnership established in 2013 between local biomanufacturing companies, the Worcester Polytechnic Institute and the Massachusetts Life Science Center (quasi-government agency) to open the Biomanufacturing Education and Training Center (“BETC”) (Ibid). Operated by the Worcester Polytechnic Institute, the BETC was established as a fully functional biopharmaceutical manufacturing pilot plant that provides hands-on training and educational opportunities for students and employees. All curricula are prepared by industry and mentor students (Ibid.).

North Carolina established a similar center, the Golden LEAF Biomanufacturing Training and Education Center (“BTEC”), in 2007 in collaboration with North Carolina State University and other North Carolina Biomanufacturing organizations (Ibid). The BTEC is run by an advisory board comprised of leaders from several biopharma companies. From 2007 to 2014, the annual academic enrollment at BTEC grew over 350 percent (Ibid.).

Universities in US are not the only educational places that have adjusted their education systems to support the biomanufacturing sector. Systemic developments are also made at the community college and high school levels (Ibid; NC State University, 2016). A number of schools with biomanufacturing associate’s degree programs have organized together to operate the North Caroline BioNetwork Capstone Center, focusing on enhancing the real-life aspect of programs in recent years (Ibid.).

All of these developments are supported by cluster developments in these specific regions (Darmody, 2021). Clusters spur economic development and allow for an agile and responsive system, that provides an agglomeration of skilled talent and investment that is needed in the industry (Ibid.; Jacoby, 2015).

5.4. What does it mean for British Columbia?

The review of best practices in Unites States, Ireland, and Germany reveal that strong government policies are essential to support the biomanufacturing sector in order to for it to be successful and competitive on the global arena. With regards to policies that address skilled labour shortages, the following approaches stand out:

- Strong collaboration between industry and education systems should be established in order to continuously update and improve programs related to biomanufacturing.
- Biomanufacturing training centers are essential to educate and train students with hands-on knowledge and training.
- Biomanufacturing and life sciences clusters contribute to economic development of the sector by involving all stakeholders to increase competitiveness in attracting talent and investment, providing a centralized approach in talent monitoring, and addressing collective efforts on existing barriers.

From that we can conclude, that BC could benefit from similar policy interventions that address the shared needs of groups of firms. Labour policy interventions need to address three important dimensions: training, attraction, and retainment of talent.

5.4.1. Collaboration between industry and education systems on program development

All three jurisdictions, Ireland, Germany and United Sates, emphasize the importance of developing strong collaboration between industry and education systems. Skilled and well-educated talent is seen as competitive advantage in biomanufacturing and deemed essential for biomanufacturing business development and growth. Best practices also emphasize that the educational systems should include not only universities but also high school, colleges and vocational training institutions, for earlier biomanufacturing involvement and development.

British Columbia already has organizations that aim to foster collaboration between the sector and educational institutions. These organizations include: LSBC, BioTalent, BC Tech Association, Mitacs, etc. (GoB, 2020). However, these efforts are not unified and the goal of establishing a strong collaboration has not been prioritized yet. A similar situation was faced by Ireland and United States, when at different points in time countries faced limited innovative capacities as a result of the limited ability to form substantial alliances with PREO actors (O'Byrne, 2013; Heavey, 2016). As a result, there was limited PREO activity due to extremely limited infrastructural and skills investments by public actors, as well as limited commercialization skills and competences of PREO actors (Ibid.). The history of Ireland and United States proved that wholesome sectoral activity and dynamic involvement of key actors in these activities is a key to successful development of collaborative alliances and later on a biomanufacturing and life sciences industrial cluster.

There are some Canadian examples that have recently emerged as a result of collaboration among government, industry and PREOs. The Canadian Alliance for Skills and Training in Life Sciences ("CASTL") is dedicated to providing world-class training for bioscience talent creation specializing in biopharmaceutical processing (NIBRT, 2021). By partnering with the National Institute for Bioprocessing Research and Training NIBRT in Ireland, CASTL will be an exclusive provider of NIBRT licensed training programs in Canada. It has already gained attention and support from Biomanufacturing companies across Canada (Ibid.). CASTL has also partnered with Prince Edward Island ("PE"), to develop and deliver bioscience programming for youth, adolescents, and young adults within the public school system and in communities across in PE (CASTL, 2022). This commitment is designed to engage more youth in life science and expose them to careers in that field. CASTL programs are a good example of local Canadian success in uniting academia, government and industry to provide essential biomanufacturing training. However, much of that training is provided in a classroom or digital setting. A lack of a dedicated training center in Canada, as well as in BC, continues to be a barrier.

5.4.2. Biomanufacturing Training Center

Another important step for successful labour policy in biomanufacturing is the opportunity to provide on-site training. Employees need to be cGMP trained to be competent in manufacturing market-ready biopharmaceuticals. Establishing a Biomanufacturing Training Center that provides access to innovative processes used in the industry, as well as application of all cGMP standards, would establish provincial competence and capacity in biomanufacturing workforce development.

The policies of establishing a Biomanufacturing Training Center have been implemented not only in US, Ireland and Germany but have also proved successful in other countries such as Korea, China, India, and Brazil (Jacoby, 2015). The facilities help attract more students and produce skilled certified talent that is ready to hiring by the industry. The availability of an educated workforce remains the main deciding factor in Canada for building new manufacturing facilities, as can be seen from the example of recently announced Biologics Manufacturing Centre in Montréal, Québec (Ernst and Young, 2021) and Centre for Commercialization of Regenerative Medicine and McMaster Innovation Park Biomanufacturing Campus in Hamilton, Ontario (Canadian Manufacturing, 2020).

5.4.3. Biomanufacturing and Life Sciences Cluster

There is opportunity for cluster development in BC, as the sector has been evolving rapidly and could benefit by working collectively to fill gaps in the cluster ecosystem and staff with industry expertise. BC's biomanufacturing sector's development has proved to be self-reinforcing, but it could benefit from a series of strategic investments designed to spur further development. Advanced biomanufacturing countries such as Germany and United States, show how innovation attracts complex biomanufacturing activity to their countries due to strong support and involvement of stakeholders in the sector that is able to keep high-skilled talent and innovative technology in its region.

The benefits of agglomeration for companies in a cluster could occur through three foundations (Donahue, 2018):

1. Increase competitiveness of companies by attracting investment and talent.

2. Provide a centralized approach to skills monitoring, program development, and recruitment.

3. Address collective efforts on existing barriers that directly or indirectly affect labour in biomanufacturing, such as regulations, IP, immigration, collaboration with local and international PREOs etc.

The examples of Germany, United States, and Ireland indicate that biotech clusters help support domestic capacity, knowledge generation, and investment, not just attracting foreign investment in this space. BC's biomanufacturing and life sciences sector and Canadian Life Sciences Hub in general could also potentially benefit from proximity to major biomanufacturing centers in the US, much in the same way the UK benefits from proximity to Ireland (Forfas, 2020).

Lastly, the examples of Germany, United States and Ireland show that even a geographically small country could have a network of clusters established to support its sector. Canada currently has three strong Biotech hubs in biomanufacturing: BC, Ontario and Quebec (IBS, 2018). It has been proposed to create one integrated cluster across Canada unified by biomanufacturing (Ibid.) Previous research and jurisdictional analysis, however, suggests that it is better to establish a cluster that is situated in one geographical location and could offer certain specialization in the industry (Darmody, 2021; Reynolds, 2010). This should not preclude national exchange of experience, knowledge and innovation (Ibid.). Ultimately, the cluster should aim to foster the right environment for the region, including biomanufacturing infrastructure, talent attraction and retention, and supply chain operations support (Ibid.).

6. Interviews

In order to get a better understanding of the local market and challenges faced by biomanufacturing companies with regards to skilled labour shortages, four interviews were held with biomanufacturing companies located in Metro Vancouver and one interview with an Industry association. Each company designated one person for an interview.

The companies differ by the type of manufacturing, company size, company development, and product development, providing an insight on a diverse sector outlook. Table 7 below summarizes the main diverse characteristics of these companies and highlights challenges faced by companies with respect to labour and staffing.

Table 7. Comparison of companies that participated in interviews

	Company A	Company B	Company C	Company D
Type of Manufacturing	Biologics	Prospective Biologics	Biologics / Medical device	Medical device
Size	Medium/Large	Small	Small	Small
Stage	Developed	Start-up / Developing	Start-up	Developed
Manufacturing skill levels	Professional	Professional	Professional	Professional / Non-professional
International talent	Yes	Yes North American talent only for R&D positions	No Would consider potentially	Yes Talent recruiting companies for all position types
In-house training	Yes	Yes	No	Yes
HR Capacity	Yes	Yes	No	Yes
Main challenges	1.Education programs 2.Promotion of careers in manufacturing 3. Cost of living 4.Lab space	1.Education programs 2.Cost of living 3.Lab space	1.Education programs 2.Cost of living 3.Lab space	1.Soft and adaptability skills 2.In-house training 3.Cost of living

Despite differences in the type and size of manufacturing and types of product lines, the companies have provided similar input on the challenges in the biomanufacturing labour market, with only a few unique characteristics. The main issues associated with labour shortages addressed in interviews included issues connected to education programs and certifications, high cost of living, and shortage of lab space. Sections below will discuss each issue in more detail. Notably, one company also used unskilled labour in its production line. This company commented on facing different challenges associated with hiring unskilled labour. However, these challenges are not discussed in this paper as this research concerns skilled labour shortages only. Further research may be required on understand the market for unskilled labour and policies that could help address it.

6.1. Post-Secondary Education System and Programs

Three companies reported employing only skilled labour with either professional certifications or diplomas in biomanufacturing. This is consistent with the literature review, which indicates that most companies in biomanufacturing hire skilled labour only (Jacoby, 2015). As indicated above, only one company employed unskilled labour that did not require any post-secondary education. All companies confirmed that the greatest competitive advantage of their organization was people. All companies reported hiring challenges associated with finding employees with the right skill set, training, and experience. Respondents indicated that not having the right people could cause potential production delays or impact their ability to get production quality up to the right level. The following themes have specifically come up as a result of a discussion on education, certification, and training needs of employers:

- **Existing education programs do not match the needs of manufacturers.** All manufactures had to provide extensive in-house training to bring employees up to speed. Respondents highlighted the need for flexible initiatives to help facilitate connections between graduates and industry. Current collaboration efforts between select employers and programs are not scaled to the full potential yet. Some respondents mentioned that it should be the responsibility of the schools to provide better specialized training to students and the costs should not be borne by students or companies. A partnership between schools and industry should be established to identify gaps in current and future training.

- **Lack of cGMP training in BC and Canada.** BC biomanufacturing labour can only access the cGMP certification online, through sources such as Cat CTT and other training organizations. The practical training is provided by the companies in-house, to ensure that the cGMP-certified employee can work to the quality required at the manufacturing facility and regulatory institutions. Companies can also get funding from organizations like AMP AP to provide cGMP training to its employees. One company was looking forward to the upcoming training opportunities though CASTL (Source).

- **Careers in biomanufacturing are not well-known and are not promoted among students.** Three respondents mentioned that students in Biology and Chemistry programs are not well aware of career opportunities in biomanufacturing. The efforts undertaken by some companies in the industry to promote it at career fairs is not enough to increase the supply of newly graduated talent. In addition to that, several respondents indicated that they prefer to collaborate with Ontario and Quebec post-secondary institutions, as they supply BC biomanufacturing organizations with the talent they need. This indicates a gap in partnership between BC PSEs and the sector.

- **Successful but insufficient use of WIL programs.** Work Integrated Learning programs and other co-op placements like BioTalent Canada's Student Work Placement Program provide biotech employers with a way to tie students to the industry prior to graduation. These programs offset some of the costs and mitigates the financial risks for companies. Respondents indicated that their companies were more likely to hire a co-op student as a future permanent employee. Respondents also noted that not many applicants go through the WIL program. Some suggested that the program could be expensive for students and also not available for international students.

- **High demand for soft and business skills.** Three companies reported a need for soft and business skills in their organizations in addition to technical requirements. They suggested that PSEs could improve their programs by including these training in their curriculum.

6.2. High Cost of Living

All respondents indicated that high cost of living in Vancouver and Metro Vancouver created a barrier in hiring and in two cases deterred several out-of-province and international applicants. On top of paying competitive wages, biomanufacturers reported the need to pay even higher wages to attract talent, as cost of living, especially housing remains high.

- **Rising housing prices.** It is hard for manufacturers to pay wages that can compete with the rising prices on housing in BC, and particularly, Metro Vancouver, and with the cost of living in Ontario and neighboring US. One respondent mentioned that creating more bio-tech campuses could help build the infrastructure, expand business operations and attract more talent, which reflects the findings of jurisdictional scan in this research.

- **Wage subsidies.** Three respondents mentioned that wage subsidies provided by BioTalent, BC Tech and Innovate BC are very useful especially at an early stage of a company development. These subsidies support organizations to train new grads and co-op students to undergo their WIL. Respondents mentioned that some barriers still exist in receiving these grants, as many requirements have to be satisfied by students, include PR or citizenship status. Employees that come to work in BC from international schools or have work permits are usually not eligible for those subsidies/programs. Three respondents indicated that their organization used the tax break available for up-skilling their employees, however, they found application process challenging because training and retraining would not always fit the definition of up-skilling.

- **Subsidies for diversified hiring.** Respondents mentioned that many grants, subsidies or programs target specific population that is currently underrepresented in biomanufacturing-related programs, including minorities, people with disabilities, women etc. Respondents mentioned that BC could benefit more from more organizations like the Society for Canadian Women in Science and Technology that could promote work in biomanufacturing people who are currently underrepresented in biomanufacturing-related programs.

6.3. International talent

All respondents either had international employees on-board or tried to hire one. Three respondents experienced difficulties in hiring international employees, such as lengthy bureaucratic process and justifying hiring an international person instead of a Canadian employee. Two respondents reported losing candidates to foreign competitors, because the visa obtaining process was too long. All respondents mentioned that it would not be worth the time for their organization to approach international candidates for technician positions with Bachelor degree only. They would usually pursue international candidates with specialized knowledge (usually PhD level). Two respondents mentioned how classification under Biologist could be more defined.

Two companies mentioned that that they are actively hiring or looking to hire people from Ireland, because Ireland has great training and education on cGMP. However, it was mentioned that only few candidates stay on board long-term because they either want to be close to their families or cost of living in Vancouver is too expensive. Two respondents indicated that their organizations are hesitant to hire from countries other than US, Ireland, and a few European countries because manufacturing standards might be different. Respondents also noticed a significant drop in international applicants during the pandemic and travel restrictions. Organizations need to be prepared for that in case any future outbreaks or significant external global events happen.

6.4. Shortage of Lab Space

Lack of real-estate for companies' lab and manufacturing facilities expansion was mentioned as another problem that indirectly affects the labour market. It creates difficulties for companies to plan their expansion and attract new employees. One respondent mentioned that companies are also considering establishing their manufacturing facilities in the United States, due to better availability and affordability of space, and larger labour pool of skilled candidates. This could result in lost economic opportunities for British Columbia.

Provided that the issue of lab space shortage is indirectly affecting the biomanufacturing labour pool, this factor is not addressed in the policy options.

7. Policy Options

This study has identified three major issues directly affecting skilled labour shortages in the Biomanufacturing sector in BC: 1) A set of challenges related to skill training and labour force upscaling within the existing post-secondary education system and programs, 2) Low wages and high cost of living in Vancouver, and 3) Challenges in hiring international talent. The policy options proposed in this study would focus on the first two issues, as the upcoming NOC classification system changes in the Fall 2022 (Government of Canada, 2022) would possibly help address the third issue of hiring international talent. A different study could help assess the success of these changes on hiring international skilled labour in biomanufacturing sector.

The proposed policy options are intended to address existing labour shortages in biomanufacturing sector. Although, policies here are analyzed independently, they are not mutually exclusive and in real life would build upon each other.

7.1. Policy Option 1: Biomanufacturing Coalition

This policy is based on suggestions provided in the interviews and best practices established by Ireland, Germany, and United States. The policy seeks to address a variety of issues identified in the interviews and literature, including existing education programs not matching the needs of manufacturers; lack of cGMP training in BC and Canada; careers in biomanufacturing not well-known and not promoted among students; insufficient use of WIL programs; and high demand for soft and business skills.

It was clear from the interviews that firms are already at capacity and do not have time and resources to simultaneously expand their operations and talent base and actively engage with educational institutions to foster change in the education and training systems and promote biomanufacturing careers for new students. This policy would provide a good pre-condition (Reynolds, 2010) to encourage a Bio-cluster emergence (Policy Option 3).

The policy option proposes a creation of a sector-specific working group, similar to the Government Department for Higher Education, Innovation and Science in Ireland (Ibec, 2021), which would coordinate the work of a Biomanufacturing Coalition, that would include employers, PREOs, and associated biomanufacturing, life sciences, and tech organizations with the following objectives in mind:

- Create an inventory of skills and stakeholders' ecosystem;
- Develop more employer-led training initiatives and integrate employer perspectives into educational programs;
- Provide continuous monitoring of skills and training data;
- Hold awareness and promotion campaigns among High School and PSE students;
- Co-ordinate with Statistics Canada a more frequent update of NOC system for immigration and
- Advocate for a diversified biomanufacturing labour force.

The integration of industry and institutions will be key for this policy. Institutions are critical to promoting economic growth (Reynolds, 2010; Darmody, 2021) and contributing to working economic cluster, but their programs, certifications and trainings need to fit the demand of high-paced innovative industries like biomanufacturing better (Ibid).

7.1.1. Governance

This policy would be initiated by the BC Ministry of Advanced Education and Skills Training. The implementation could be carried out by one of the existing Industry Advocacy groups, such as LSBC or BioTalent with a support from the BC Ministry of Advanced Education and Skills Training. All stakeholders would work toward building the collaboration internally, informing the demand for skills and training as well as education policy needs that need to be addressed in the region.

7.1.2. Main Stakeholders

The main stakeholders under Policy Option 1 are biomanufacturing companies, provincial government, and PSEs.

7.1.3. Funding

The funding for this policy implementation would come largely from the Provincial Government, which administers education funding and transfers allocated for innovation.

7.2. Policy Option 2: Building a Biomanufacturing Training Center in Metro Vancouver

This policy option is informed by existing successful Biomanufacturing Training Centers in Ireland, such as NIBRT, and United States, such as BTEC and BETC, as well as success of German's dual education system that offers hand-on experience to students.

The Center will present a multi-functional building, which will replicate the most up-to-date industrial bioprocessing facilities with a simulated cGMP facility and a pilot plant, consisting of extensive upstream, downstream, fill-finish and the associated analytical facilities (NIBRT, 2022). The Programs could provide programs similar for those provided at BTEC: Minors (Undergraduate and Graduate), Certificates (Undergraduate and Graduate), Post-Baccalaureate Studies, Certificate Masters, workshops and tours to high school students (BTEC, 2016). As the Center would be first of its kind in Canada, it would possibly attract students and workers from all over Canada.

The Center will be managed by a hired Management Team with expertise in life sciences and biomanufacturing. The establishment of curriculum and continuous update of training requirements would be carried out by an Advisory Board, consisting of local companies' representatives, academia, and other applicable stakeholders.

The outcomes of this policy would be to grow the skilled labour force in BC by providing cutting edge training and research solutions. The Center would also serve as major research center in developing innovative technologies to advance biopharmaceutical and medical device manufacturing.

7.2.1. Governance

This policy would be initiated by the BC Ministry of Jobs, Economic Recovery and Innovation. The implementation could be carried out by the existing Industry Advocacy groups, such as Life Sciences BC, Ministry of Jobs, Economic Recovery and Innovation, and Innovation, Ministry of Advanced Education and Skills Training.

7.2.2. Main Stakeholders

The main stakeholders under Policy Option 2 are biomanufacturing companies, provincial government, federal government, other Canadian provinces, and PSEs.

7.2.3. Funding

The funding for this policy implementation would come from the Provincial and the Federal Governments. The cost of the facility would depend on the size and the number of students, ranging from CAD $92 million[7] to $107 million[8], including equipment (BTEC, 2016) (Science Business, 2011). The cost of operating a facility on an annual basis could be approximately $5.5 million (BTEC, 2016).

7.3. Policy Option 3: BC's Life Sciences and Biomanufacturing Cluster

This policy option is based largely on best practices established by Ireland, Germany and United States for creating economic clusters for biomanufacturing and biotechnology to establish support to their sector and maintain global leadership.

BC's Life Sciences and Biomanufacturing Cluster would focus on establishing a robust and regenerating ecosystem in Metro Vancouver that produces the innovation, talent, and economic opportunities that firms need to thrive. This initiative would build on the existing investment and developments in the sector, as well as the stronger

[7] USD 54 million to build BTEC in 2006. Adjusted for an annual 2% pre—pandemic inflation rate.

[8] EUR 57 million in 2011 converted to CAD, using exchange rate of 1.40164, as indicated by FX Exchange for 30/09/2011. Adjusted for an annual 2% pre—pandemic inflation rate.

institutional capacity established in Policy Option 1 and Policy Option 2. The cluster would focus on the following pillars (Donahue, 2018):

- Increase competitiveness of companies by attracting investment and talent;
- Provide a centralized approach to skills monitoring, program development, and recruitment; and
- Address collective efforts on existing barriers that directly or indirectly affect labour in biomanufacturing, such as regulations, IP, immigration, collaboration with local and international PREOs etc.

The ability of BC to support the creation of young, high-growth firms seems to be particularly important, as these are the vehicles for innovation and the quality job creation that results in high direct, indirect and induced outputs (LSBC, 2021). The cluster would focus on expanding the capabilities of the life sciences and biomanufacturing sectors, attracting more foreign investment and talent to come to Vancouver. Companies located outside of the geographic cluster would still benefit from a generally larger labour pool.

Apart from addressing issues on labour, training and education, the cluster would address issues on regulations, such as delayed FDA approvals, improving IP, adapting tax system, and resolving any other information gaps. The cluster would benefit other existing innovation hubs and clusters such as Biotech, Hospitals, Bio-Economy, Food processing.

If the cluster manages to attract transnational corporations and grow Canadian businesses to large global companies, there would be a possibility for the industry to invest in real estate development with residential campuses/neighborhoods developed for many bio-industry employees, in a similar fashion to existing and rapidly growing Texas Medical Center (Martens, 2021) and proposed Middlefield Park Master Plan by Google (Kelly, 2020).

7.3.1. Governance

The cluster will be industry-driven and university-fueled; however, the initiation of the industry and management would be undertaken collaboratively by an existing Industry Association, such as LSBC, the BC Ministry of Jobs, Economic Recovery and Innovation, and an active Board represented by the sector and other stakeholders. The

Cluster would be in a form of a leadership structure (Porter 1998; vom Hofe and Chen, 2006), with more responsibilities assigned to LSBC but ultimately involving all related parties.

7.3.2. Main Stakeholders

The main stakeholders under Policy Option 3 are biomanufacturing companies, municipalities, provincial government, federal government, PSEs, industries that support the BC's biomanufacturing sector (construction, real estate, finance, hospitals) and those sharing common labour pool or research activity (other manufacturing sectors, biotech, bio-agro and other subsets of bio-economy).

7.3.3. Funding

Continuous streams of funding would be attributed by the Provincial and Federal Government (As part of the larger Life Sciences and Biomanufacturing Development Strategy in Canada). The funding would support the growth of new and innovative companies, increase funding and grants for research proof of concept, grow specialized business support services, attract new venture capital, and establish a strong ecosystem, including access to knowledge and hand-on training (Global Connect, 2010; Irisgroup, 2017). The Capital attributed by the BC and Canadian Government would work on attracting venture capital from all over the world.

8. Evaluation Criteria

This section describes the criteria and measures used to evaluate each policy option. Criteria compare and assess alternative policies, while measures operationalize and assess each criterion. Table 8 provides a summary of criteria and measures used in this study.

Policy options considered here will be analyzed by their impact on BC's current skilled labour shortages in the biomanufacturing sector according to four different criteria. **The option's ability to decrease skilled labour shortages in biomanufacturing in BC is the most important criterion.** Options are also judged on their timely feasibility, level of administrative ease, and cost associated with implementing that policy option. Options are rated by their impact on the status quo along a continuum of Good, Moderate, and Poor. Options are correspondently rated from 3 (Good) to 1 (Poor).

Table 8. Policy Analysis Criteria and Measures

Criteria	Definition	Measures	Value
Development	Decreased skilled labour shortage in biomanufacturing sector	Self-reported labour shortage ("LS')	Good = 6 (LS significantly reduced) Moderate = 4 (LS moderately reduced) Poor = 2 (LS reduced to some extend but some issues pertain)
Administrative Ease	Provincial government support required to implement policy	Number of changes in existing structure and programming	Good = 3 (Few changes) Moderate = 2 (Some changes) Poor = 1 (Significant changes)
		Level of coordination between provincial government and other stakeholders	Good = 3 (Low level of coordination) Moderate = 2 (Moderate level of coordination) Poor = 1 (High level of coordination)
Cost	Cost associated with implementing the policy	Amount of funding required to implement policy	Good = 3 (Low cost) Moderate = 2 (Moderate cost) Poor = 1 (High cost)
Stakeholder Acceptance	Stakeholders' willingness to contribute to policy implementation	Level of compliance by stakeholders	Good = 3 (High level of compliance) Moderate = 2 (Moderate level of compliance) Poor = 1 (Low level of compliance)

8.1. Development

This criterion is concerned with assessing the number of skilled labour employed in biomanufacturing sector. Provided that current labour demand is significantly greater and outpaces labour supply in the market for skilled biomanufacturing skills, this criterion would aim to estimate the reduction of that labour market inefficiency. There are several ways to measure that policy option, given that skilled labour in biomanufacturing comes from different hiring streams, such as local talent, co-op placements, international students, and immigration; as well as requires different retaining strategies, such as attractive and affordable city, availability of training and interorganizational mobility. Also, the numerical weight for this criterion is double (G=6, M=4, P=2) given the importance of skilled labour availability on the market.

A policy that is ranked “Good” indicates that the policy is able to significantly reduce the gap between demand and supply of biomanufacturing labour, by addressing both companies’ hiring and retaining needs. A policy that is ranked “Moderate” indicates that the policy is able to moderately reduce the gap between demand and supply of biomanufacturing labour, but does not satisfy all conditions for efficient and successful talent hiring and retainment. A policy that is ranked “Poor” somewhat reduces reduce the gap between demand and supply of biomanufacturing labour but some issues on the labour market will pertain, affecting both the recruitment and retainment of labour.

8.2. Administrative Ease

This criterion is concerned with the level of provincial government support required to implement policy. The criterion is measured two ways: 1. By the number of changes to the existing structure and programming, and 2) By level of coordination between provincial government and other stakeholders. The more people, teams and departments a policy requires and the more stakeholders it needs to involve, the more complex is the administrative implementation of it. Stakeholder include: federal and local government, international governments, development agencies, biomanufacturing industry, local PREOs, enterprise boards, venture capital firms, companies participating in the biomanufacturing supply chain, NGOs and industry associations.

A policy that is ranked “Good” indicates that the provincial government needs to undergo few changes and involve few stakeholders. A policy that is ranked “Moderate” indicates that the provincial government will be required to make some changes within its department and involve several stakeholders to coordinate policy implementation. A policy that is ranked “Poor” would require significant changes in structure and programming of the provincial government and will require collaboration across multiple stakeholders in different organization and industries.

8.3. Cost

This criterion assesses the budgetary impact on governments of implementing a policy option. Notably, all policy options require an ongoing investment. However, Policy Option 2 in addition to that also requires high upfront capital cost investment. Operational feasibility on assessing financial capacity is also included in the cost calculation. These two elements are described throughout the analysis, but they are aggregated to a single ranking. Cost assessments are based on the findings from literature review and are measured on the three-point scale as well, where “Good” is assigned to policy with lower costs and “Poor” to policy with higher costs.

8.4. Stakeholder Acceptance

The implementation of policies requires the active involvement of some stakeholders. Therefore, it is important to understand their perceived willingness to comply with the policy implementation. The criterion is measured by the level of stakeholders’ compliance to implement a given policy. The level of compliance could be affected by the change that a stakeholder has to undergo, perceived risks or changes that could affect the stakeholders. A score of “Good” indicates that policy implementation meets high level of compliance of all stakeholders included in the policy. A score of “Moderate” indicates a moderate level of compliance due to minor challenges associated with policy implementation for these stakeholders. A score of “Poor” indicates low level of compliance due to significant barriers for some or all stakeholders included in the policy implementation.

9. Analysis

This section provides an analysis of policy options identified in Section 7 of this study, using the evaluation criteria provided in Section 8.

9.1. Development

Table 9. Development Criterion Evaluation Matrix

Criterion	Policy Option 1: Coalition	Policy Option 2: Training Center	Policy Option 3: Cluster
Development	Moderate (4)	Good (6)	Good (6)

When focusing on the criteria of "Development", all policy options manage to address the objective of reducing skilled labour shortages in the BC's biomanufacturing sector. However, Policy Option 1 rated slightly lower than the other policies (Table 9) due to the lower degree of impact on labour force. Under this policy option, PSE programs would not be able to provide hands-on training to students. In addition to that, other issues that indirectly affect biomanufacturing labour force in BC, such as shortage of lab space or delays in Canadian drug approvals, will still pertain. Thus, a larger labour gap between supply and demand will continue to persist. Nevertheless, this option manages to increase skilled labour supply by creating a collaboration between companies and PSEs to ensure a better match of education programs, enhanced marketing outreach to students, higher uptake of WIL, and faster integration of a diverse workforce. These outcomes have been achieved by other jurisdictions such as Ireland, Germany and US that have established some level of collaboration between PSE's and biomanufacturing companies (Ibec, 2021; GTAI, 2021; Taeconomy partners LLC, 2020).

Policy Option 2 scored "Good" (Table 9) because this option would provide hands-on training that is highly desired by the sector (Interviews, 2022). The advantages of building a Biomanufacturing Training Centre were outlined in the jurisdictional scan, where Ireland's NIBRT and North Carolina's BETC and BTEC have managed to support the growing demand for biomanufacturing skills and training in the regions, fostering faster integration of talent into the labour force and promoting clear and flexible career paths in biomanufacturing (Darmody, 2021; Jacoby, 2015).

Policy Option 3 scored “Good” because this option would provide a unified strong voice for the developing sector, establishing grounds for the sector’s further financial growth and competitiveness and directly affecting companies’ ability to attract and retain labour (TRBT, 2022; Darmody, 2021). A cluster would also be able to enhance the collaboration efforts discussed in Policy Option 1, by bringing new partnerships with international PREOs and facilitating better international student involvement in WIL programs and exchange of innovations and opportunities among countries (BTEC, 2016; Darmody, 2021; NIBRT, 2021). Policy Option 3 would also attract more investment to the biomanufacturing sector, which would fuel the revenues of local companies, especially SMEs, allowing more progressive and ambitious business models with increased opportunities for labour development (Taeconomy partners LLC, 2020). More investment in biomanufacturing companies could also translate into higher wages, which would help address the issues of high-cost of living in Vancouver and interprovincial and international competition for talent recruitment and retainment. In addition, Policy Option 3 would address existing barriers that indirectly affect labour. Such barriers include a shortage of lab space, an inefficient process for drugs marketing authorization, and any inefficiencies and gaps in immigration regulations. For example, the cluster would be able to use the collective effort to advocate for a more often review of the NOC immigration system, as it currently takes 10 years which is longer than countries with faster immigration track for skilled labour, such as Ireland (IDA Ireland, 2022).

9.2. Administrative Ease

Table 10. Administrative Ease Criterion Evaluation Matrix

Criterion	Policy Option 1: Coalition	Policy Option 2: Training Center	Policy Option 3: Cluster
Administrative Ease *Number of changes in existing structure and programming*	Moderate (2)	Good (3)	Moderate (2)
Administrative Ease *Level of coordination between provincial government and other stakeholders*	Good (3)	Poor (1)	Poor (1)

9.2.1. Number of changes in existing provincial structure and programming

For the first measure of Administrative Ease, Policy Option 1 and Policy Option 3 scored “Moderate” (Table 10), because both options require an allocation of new staff members to implement and continue moderating two policies. The example of Ireland shows that the country established a new department, the Government Department for Higher Education, Innovation and Science, to oversee the work of existing coalitions, the state agencies and public institutions operating in education and research (Government of Ireland, 2022). For BC, this policy suggests an allocation of a new unit within the BC Ministry of Advanced Education and Skills Training and its program on Workforce Development Agreement (“WDA”) (Government of Canada, 2020), that will support LSBC or any other agency leading the BC’s Biomanufacturing Coalition. Notably, the objective of WDA concurs with the objective of these policy options to reduce skilled labour shortages (Ibid.). The creation of a cluster would require a similar approach, with no major restructuring at the provincial level, with a formation of one unit within an existing department, such as the Ministry of Jobs, Economic Recovery and Innovation, provided the province would follow a shared leadership structure (Donahue, 2018).

Policy Option 2 scored “Good” (Table 10) for this measure because the province would not need to allocate a special unit or department to oversee this policy. The Training Center would be governed by a Board and managed by the sector and PREO advisors, following a similar governance structure of the NIBRT (NIBRT, 2022).

9.2.2. Level of coordination between provincial government and other stakeholders

For the second measure of Administrative Ease, Policy Option 2 and Policy Option 3 scored “Poor” (Table 10), because both options require high level of coordination between the provincial government and other stakeholders. Policy Option 2 poses potential conflicts with other provinces, especially Ontario and Quebec, indicating that BC will need to reconcile this policy with the provinces and the federal government. Other provinces are interested in building a Training Center within their regions because it would increase the supply of skilled labour to local companies. This conflict of interest could result in long negotiation and coordination process for the BC provincial government. Notably, Canada could consider two Training Centers, one in Eastern Canada (Ontario or Quebec) and one in Western Canada (BC), to ensure a balanced growth of skilled labour across Canada and satisfy the rising demand for skilled labour in these main life sciences and biomanufacturing provinces. Additional analysis may be required to include the projected number of graduates and their economic impacts on the province and country.

While Policy Option 2 is focused on interprovincial coordination of policy effort, Policy Option 3 requires coordination with local municipalities, businesses, PREOs, and other industries supporting Biomanufacturing in BC. The implementation of this policy would require significant coordination and support of SMEs, in order for the cluster to be successful (Donahue, 2018).

Policy Option 1 scored “Good” because this option will require a low level of coordination, as there is existing WDA infrastructure that will allow for an efficient cooperation between the BC Ministry of Advanced Education and Skills Training and PSEs.

9.3. Cost

Table 11. Cost Criterion Evaluation Matrix

Criterion	Policy Option 1: Coalition	Policy Option 2: Training Center	Policy Option 3: Cluster
Cost	Good (3)	Moderate (2)	Poor (1)

Policy Option 1 scored “Good” (Table 11) because establishing a coalition does not require high amount of funding to implement the policy. The policy will depend upon continuous funding to LSBC and a provincial government unit to provide continuous policy management and stakeholder engagement of the sector and education institutions. The policy will build on an existing funding stream available through the Workforce Development Agreement. Notably, for the year 2022-2023, BC Ministry of Advanced Education and Skills Training allocated $715 million to the WDA on an annual basis, a small portion of which could be designated for the implementation of Policy Option 1 (Government of Canada, 2020). The reallocation of funding to the biomanufacturing skills stream could be $4 million based on an estimate for BC Reskilling program for technology careers (BC Tech Association, 2021).

Policy Option 2 scored “Moderate” because the construction of a new Biomanufacturing Training Center requires a high allocation of additional funding. The cost of the facility will depend on the size and the enrollment size and can range from CAD $92 million[9] to $107 million[10], including equipment (BTEC, 2016) (Science Business, 2011). The cost of operating a facility on an annual basis could be approximately $5.5 million (BTEC, 2016). Provided that there is currently no Biomanufacturing Training Center in Canada, the Federal government could contribute to share some costs, as the Center would support the biomanufacturing skills development across Canada, which aligns with the pillars of the Canada's Biomanufacturing and Life Sciences Strategy. The Training Center could also be created with a combination of industry resources in addition to provincial and federal (Dahms, 2003).

Policy Option 3 requires investment in a world-leading talent pool, start-ups support, infrastructure and innovation, as a result this option scored “Poor”. The cost of implementing this policy could take up to $700 million based on funding allocation to BC Technology and Innovation clusters in Vancouver and Metal Tech Alley in Kootenays (Government of BC, 2022).

9.4. Stakeholder Acceptance

Table 12. Stakeholder Acceptance Criterion Evaluation Matrix

Criterion	Policy Option 1: Coalition	Policy Option 2: Training Center	Policy Option 3: Cluster
Stakeholder Acceptance	Moderate (2)	Good (3)	Moderate (2)

Policy Option 1 scored “Moderate” on Stakeholder Acceptance because most stakeholders under this policy are likely to comply with the policy implementation as it

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[9] USD 54 million to build BTEC in 2006. Adjusted for an annual 2% pre—pandemic inflation rate.

[10] EUR 57 million in 2011 converted to CAD, using exchange rate of 1.40164, as indicated by FX Exchange for 30/09/2011. Adjusted for an annual 2% pre—pandemic inflation rate.

benefits all parties. Under this policy, companies have access to more skilled talent (Interviews, 2022), schools get credit for better students' work placement following graduation (Interviews, 2022), and government benefits from reduced skilled labour shortages in biomanufacturing and higher economic participation from labour force and businesses. However, some PSEs may be reluctant to undergo change, as their programs could require significant adaptation to satisfy the requirements of the biomanufacturing sector.

On the contrary, Policy Option 2 scored "Good", because the existing PSE programs will not be required to undergo significant adaptation. The Center will have the capacity to develop it own programming and certification (BTEC, 2016). Some PSEs may be interested in sharing the space with the Center or incorporate some of its training in the mandatory curriculum; however, these steps will be voluntary for PSEs and not restraining their willingness to comply with the policy.

Policy Option 3 scored "Moderate" as coordination of a cluster requires a buy-in not only from the biomanufacturing sector (Donahue, 2018) but also from other sectors and industries that support the BC's biomanufacturing sector (construction, real estate, finance, hospitals, municipalities, departments of provincial government and federal government) and those sharing common labour pool or research activity (other manufacturing sectors, biotech, bio-agro and other subsets of bio-economy) (BioTalent, 2021). There could be delays, opposition, or insufficient willingness to participate in implementing this policy among some of the forementioned stakeholders. For example, prioritization of the biomanufacturing cluster may result in some push back from other manufacturing industry's sectors (Interviews, 2022). However, many organizations from the private sector would benefit from the cluster due to higher economic activity in BC (Donahue, 2018) and more skilled labor force for other subsets of the bio-economy (BioTalent, 2021).

10. Recommendations

Based on the policy options analysis, the three policies (Table 13) scored relatively close to each other, with Policy Option 2 on building a Biomanufacturing Training Center leading the evaluation.

Table 13. Policy Evaluation Matrix Summary

	Short Term (1-2 Years)	Short Term (2-4 Years)	Long Term (5-10 Years)
Criteria	**Policy Option 1: Coalition**	**Policy Option 2: Training Center**	**Policy Option 3: Cluster**
Development X2	Moderate (4)	Good (6)	Good (6)
Administrative Ease	Moderate (2)	Good (3)	Moderate (2)
	Good (3)	Poor (1)	Poor (1)
Cost	Good (3)	Moderate (2)	Poor (1)
Stakeholder Acceptance	Moderate (2)	Good (3)	Moderate (2)
Total	**14**	**15**	**12**

I recommend that all three policy options be implemented over the next ten years, as all three help address different elements of the skilled labour shortages issue in BC's Biomanufacturing. Policy Option 1 aims to address some issues related to post-secondary education systems and programs, such as matching the needs of manufacturers and existing education and training programs; promoting careers in biomanufacturing; and intensifying greater use of the WIL programs. Policy Option 2 largely addresses the need for hands-on training and cGMP training in biomanufacturing. Policy Option 3 offers to increase competitiveness of firms and provide a collective effort approach on addressing other issues in biomanufacturing, including timely changes in immigration to attract more foreign talent, attracting more investment that would allow companies to secure higher wages for talent, addressing high cost of living in Vancouver.

I suggest that the policies should be executed on a sequential basis with Policy Option 1 and Policy Option 2 implemented within the next 1 to 4 years and Policy Option 3 implemented as a long-term strategy, conditional to successful implementation of the first two policies and continued favorable market conditions for a biomanufacturing cluster development.

Policy Option 1 scored well on Development and the highest on Administrative Ease and Cost. I suggest that this policy is implemented within the next two years, also building on the fact that it takes approximately two years to create and implement a new education program at a university setting (Interviews, 2022). This policy option would also provide a solid foundation for future policies on reducing skilled labour shortages. It deals with inefficiencies within existing education programs, as opposed to Policy Option 2, which will bring new certifications to BC.

The implementation of Policy Option 2 should start immediately as well, but it will require longer time to bring the policy to fruition, as it is more costly and requires a significant level of coordination between the provincial governments and the federal government, as well as a thorough understanding on the specific programs to be offered at the Training Center to better satisfy the needs of BC biomanufacturing. Prior to Policy Option 2 implementation, BC should develop the criteria to justify public funding, which could include direct, indirect and induced benefits from newly trained employment, reduced skilled labour shortages in biomanufacturing and biotech sectors, and increased participation from youth in biomanufacturing-related education programs. Policy Option 2 is also associated with a challenge of long coordination time between provinces, especially Ontario and Quebec, because these provinces might be interested in building a Biomanufacturing Training Center in their regions too, which could cause delays in negotiations as well as debates over building one or two Centers in Canada.

Finally, I propose to implement Policy Option 3 over the long term, once Policy Option 1 and Policy Option 2 are established. The first two options would resolve a significant part of the skilled labour shortages issue and build a powerful foundation for the future biomanufacturing cluster. Provided that Policy Option 1 and 2 are successful, they would result in not only in reduced skilled labour shortages but also in rising number of new companies and an expansion of existing ones, indicating the possibility for cluster development in BC. Given a rapid global development of the biomanufacturing sector and the speed of innovation, it will be important to assess the BC biomanufacturing sector again prior to establishing a cluster, focusing on specialization and composition of firms, their size and development stage, need for commercialization, and inter-firm dependence (Donahue, 2018; Cooke, 2000). The following basic criteria should be satisfied (Donahue, 2018):

- Critical mass of firms and institutions that address shared needs;
- Geographic proximity of firms;
- Solid industrial base, with the organizational structures linking science to industry, venture capital and intellectual property rights; and
- Economic independence of companies that gain competitive advantage from each other with vertical and horizontal relationships.

If these preconditions are not satisfied, the cluster might fail or develop slowly, as in the example of Lombardy in Italy (Orsenigo, 2000).

Together, the three policy options would significantly reduce skilled labor shortages in BC and provide economic support to a rapidly developing biomanufacturing sector in BC.

11. Conclusion

This study indicates that the biomanufacturing sector in BC is well positioned to continue its growth and maturation; however, it has to address the rising skilled labour shortages in order to continue its growth (GoB, 2020; BioTalent, 2021). Skilled labour is at the core of the biomanufacturing sector's development (Government of Canada, 2022). This has been recognized by all countries with biomanufacturing presence (IFPMA, 2021) and proved to be a building stone for any country's global competitive position and national medical sovereignty in overcoming future pandemics. It is important for the provincial government to act now on addressing skilled labour shortages in biomanufacturing to leverage Canada's interest to support the sector financially through the Biomanufacturing and Life Sciences Strategy, to increase competitiveness of the local biomanufacturing sector (LSBC, 2021), and to gain leadership at one of the highest-valued industries in the world (IFPMA, 2021).

This report addressed the issue of skilled labour shortages in the biomanufacturing sector in BC and proposed the implementation of three policy options based on the feedback received from the industry and jurisdictional research on best practices in addressing skilled labour shortages in leading countries. The proposed policies are suggested to be implemented on a sequential basis with two policies implemented in the short-term and one policy in the long-term, condition to the successful outcomes of the first two policies. The proposed policies include:

1. **Establishing a biomanufacturing coalition between the provincial government, PSEs, and biomanufacturing companies in BC.** This policy option would seek to address a variety of issues in the existing education structure, including education programs not matching the needs of manufacturers; lack of cGMP training in BC and Canada; lack of promotion of careers in biomanufacturing; and insufficient use of WIL programs.

2. **Building a Biomanufacturing Training Center in Metro Vancouver.** The implementation of this policy option would reduce skilled labour shortages by establishing certifications and education programs with hands-on training that is in significant demand by biomanufacturing companies.

3. **Instituting a BC's Life Sciences and Biomanufacturing Cluster.** The cluster policy option would increase the biomanufacturing sector's competitiveness and help attract more investment and talent to the region.

Future research could focus on identifying exact skills sets required by the BC biomanufacturing sector; analyzing the effect of the Canadian NOC changes in 2021 on the biomanufacturing sector in BC; and calculating the need and marginal utility of increased government subsidies for in-house training and talent development.

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Appendix A.

Definitions of Life Sciences and Bio-Economy

Life Sciences BC definition of the life sciences sector

Table A1. Life Sciences BC definition of the life sciences sector

Industry Group	NAICS	Industry Description
Research, Testing and Medical Laboratories	541380	Testing laboratories
	541710	Research and development in the physical, engineering and life sciences
	6215	Medical and diagnostic laboratories
Medical Devices and Equipment	339110	Medical equipment and supplies manufacturing
	417930	Professional machinery, equipment and supplies merchant wholesalers
Drugs and Pharmaceuticals	3254	Pharmaceutical and medicine manufacturing
	414510	Pharmaceuticals and pharmacy supplies merchant wholesalers
	6215	Medical and diagnostic laboratories

Source: Table adapted from GoB, 2020

BioTalent Canada definition of Bio-Economy

Table A2. BioTalent Canada definition of Bio-Economy

Bio-Economy	"The bio-economy is defined as the economic activity associated with the invention, development, production and use of primarily bio-based products, bio-based production processes and/or biotechnology-based intellectual property. It includes the use of resources from agriculture, forestry, fisheries/aquaculture, organic waste and aquatic biomass." (BioTalent, 2021)
Bio-Health	"The bio-health sub-sector encompasses the invention, development, manufacturing, commercialization and use of products that improve therapeutics, diagnostics, prevention and health administration, as well as the development and production of nutraceuticals and applications of medical cannabis. Research and development activities contribute to the development of new products, bio-based technologies and intellectual property related to the production of bio-health products and technologies." (BioTalent, 2021)
Bio-Energy	"The bio-energy sub-sector encompasses the invention, development, production, commercialization and use of renewable fuels through the conversion of organic material into heat or power. Research and development activities contribute to the development of new products, bio-based technologies and intellectual property related to the production of bio-energy." (BioTalent, 2021)

Bio-Industrial	"The bio-industrial sub-sector encompasses the invention, development, manufacturing, commercialization and use of goods for industrial use, such as bio-chemicals and bio-materials, through the conversion of organic material. Research and development activities contribute to the development of new products, bio-based technologies and intellectual property related to the production of bio-industrial products. Among others, the development and production of biocatalysts are an integral part of this sub-sector." (BioTalent, 2021)
Agri-bio	"The agri-bio sub-sector encompasses the invention, development, production, commercialization and use of new or modified products resulting from the manipulation, modification or alteration of the natural features of plants and crops, animals and/or other food sources. Research and development activities contribute to the development of new products, bio-based technologies and intellectual property that support improved quality, yield and efficiency in the agricultural sector and food production." (BioTalent, 2021)

Source: BioTalent, 2021

Appendix B.

Life sciences compensation

Table B1. Total compensation per hour worked in Life Sciences sector across provinces in 2020

	Canada	BC	ON	QC	AB	YT	MB	NL	NS	PE	SK	NB
Pharmaceutical and medicine manufacturing [NAICS 3254]	$53.94	$40.64	$56.56	$55.50	$51.25	$ -	$50.35	$ -	$44.80	$41.64	$25.38	$ -
Medical equipment and supplies manufacturing [NAICS 3391]	$38.08	$37.14	$39.41	$37.45	$34.42	$47.10	$46.31	$28.50	$31.60	$23.62	$30.59	$26.97
Personal and household goods wholesaler-distributors [NAICS 414]	$48.59	$37.84	$53.89	$47.65	$39.49	$63.65	$29.36	$42.27	$34.35	$33.52	$36.66	$32.90
Machinery, equipment and supplies wholesaler-distributors [NAICS 417]	$51.73	$47.44	$54.44	$49.70	$56.80	$69.34	$42.95	$49.13	$49.38	$41.86	$37.26	$34.76
Other professional, scientific and technical services including scientific research and development [NAICS 541B]	$44.26	$42.88	$48.18	$39.25	$44.61	$46.68	$34.09	$45.66	$34.87	$30.13	$33.85	$30.91
Scientific research and development services [NAICS 5417]	$53.34	$51.94	$60.85	$44.66	$50.00	$48.80	$42.38	$53.99	$45.26	$40.52	$38.98	$34.20
Miscellaneous ambulatory health care services [NAICS 621A]	$40.83	$42.80	$39.91	$42.36	$42.70	$56.17	$38.74	$30.85	$37.84	$33.93	$38.42	$40.03
Average across life sciences	**$47.25**	**$42.95**	**$50.46**	**$45.22**	**$45.61**	**$47.39**	**$40.60**	**$35.77**	**$39.73**	**$35.03**	**$34.45**	**$28.54**

Source: Statistics Canada, 2022