Cleantech Policy in British Columbia:
A Stakeholder Perspective on What Role the Provincial Government Should Play in Encouraging Innovation

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Executive Summary

Introduction and Background

As the negative impacts of human activities on earth continue to change our environment, technological innovation offers the potential to reduce these impacts while growing our economy and creating jobs. Some estimates put the global trade in Cleantech at more than USD 2 trillion, with BC receiving more than $1.4 billion in revenue from domestic Cleantech companies (Analytica Advisors, 2016; Trade and Invest BC, n.d.). Billions of dollars are being spent by private and public organizations to advance innovation in the Cleantech field, but not all these efforts are being done in a cost-effective manner. The misallocation of political and financial resources can result in wasted time and money for stakeholders. This misallocation can also hold back the development of promising new technologies due to a lack investment and support.

This research project has been conducted on behalf of Clean Energy Canada, an environmental non-governmental organization based out of the Simon Fraser University's Centre for Dialogue, whose mandate is to accelerate Canada's transition to clean and renewable energy sources. The research question for this report was:

What types of provincial policies are best suited to encourage growth in the BC Cleantech sector?

Cleantech is a broad term with many interpretations, but for the purpose of this report Cleantech will include low-carbon energy sources (wind, solar, water, biomass, biofuels, hydrogen, geothermal, fuel cells, nuclear), energy infrastructure, wastewater treatment, agriculture, recycling and remediation, transportation, chemistry, information technology, efficient extractive and industrial processes, and energy efficient appliances. To answer the research question, open-ended interviews were conducted with a cohort of Chief Executive Officers (CEO) and other senior employees of BC Cleantech companies to ascertain the biggest challenges facing the sector and what the provincial government can do to help overcome them. Thirteen companies were interviewed for this report, with participants chosen through the use of Analytica Advisors Cleantech industry reports, personal contacts of the client and researcher, and individuals who were referred by other participants.

BC had more than 200 companies involved in the Cleantech field and directly employed more than 6,400 people in 2014 (Trade and Invest BC, n.d.). Provincial programs to support this sector include the Innovative Clean Energy (ICE) fund, several government backed venture capital (VC) funds, grant funding and other programs offered through the BC Innovation Council, Cleantech focused research centres based out of post-secondary institutions, energy efficiency regulations through BC Hydro, the BC Hydro Standing Offer Program, the Scientific Research and Experimental Development tax credit, the Carbon Neutral Government program, and the BC carbon tax. BC has

recently announced a $100 million investment in the BCTech fund, which will provide funding to the sectors of Information and Communications Technologies (ICT), Digital Media, Life Sciences/Healthcare, and Cleantech.

Literature Review

The literature review for this report covered the Porter Hypothesis, market failures that result in under-investment of Cleantech research, innovation theory in relation to Cleantech, and the various policy instruments available to influence Cleantech innovation. Research into Cleantech policies has repeatedly shown that environmental policies can have a positive impact on Cleantech innovation. Contrary to early theories on Cleantech innovation such as the Porter Hypothesis, market-based instruments such as carbon taxes and tradable permits do not seem to be superior to other forms of policy support such as Research and Development (R&D) grant funding and enforced technology standards.

While still having a positive influence on Cleantech innovation, market-based instruments seem to lag behind other forms of innovation support. This is due to greenhouse gas (GHG) emitting firms choosing to use less risky and cheaper methods of reducing emissions, such as fuel switching or using already available technology. Market-based instruments are, however, superior policy instruments for reducing GHG emissions.

There is general agreement in this field that a well-balanced policy approach, using a variety of instruments, is needed to address climate change and encourage innovation. Financial barriers to Cleantech innovation have been recognized as a limiting factor for firms looking to innovate, and one that government can play a supportive role in addressing, but at present there is little research to judge the effectiveness of different policy tools intended to help reduce these financial barriers. The presence of official and unofficial knowledge networks in close proximity to Cleantech firms has also been identified as an important factor in the growth of Cleantech firms.

Smart Practices Scan

Many countries in the world have ambitions of creating world-leading Cleantech sectors and there are a variety of tools that governments use to achieve this end. Successful countries all have advanced research infrastructure established through universities and other post-secondary institutions. Many of these institutes offer their services to Cleantech companies at reduced usage fees and also have legal arrangements that allow companies to use the intellectual property (IP) that is developed at these institutes. A common occurrence in successful Cleantech jurisdictions is a single point of contact for innovative companies looking to access to government funding, network with other professionals in the sector, or to connect with private investors for their technology.

Financial tools are also widely used by different governments to encourage private sector investment in Cleantech ventures. These tools are typically designed to decrease the risk to private investors in the hopes of encouraging investment, as opposed to crowding them out. Examples of these financial tools include:

- Financial guarantees offered by Export Development Canada (EDC),
- The US Department of Energy's (DEO) Loan Programs Office (LPO) that provides financial loan guarantees to lending institutions that finance Cleantech companies,
- Washington State's Clean Energy Fund (CEF) that provides loan subsidies to Cleantech companies and tax subsidies to financial institutions that loan to them,
- Swedish Energy Agency loans to Cleantech companies,
- And Danish loans made by agencies such as the Danish Growth Fund and the Danish Green Investment Fund.

Findings and Discussion

Almost the entire cohort of interview participants stated that their business model depended on export growth, with only a single company saying that BC was the prime market for their business. The two most commonly cited export destinations were the rest of Canada and the US, with China being the third most cited future export destination. China is ultimately a very difficult market to enter and most companies interviewed felt that they were not yet ready to enter the Chinese market, although the country featured prominently in their future goals. The primary challenges in going to China are IP protection and a lack of experience in doing business in this market. Most companies are planning on entering China through strategic partnerships with either large multinational corporations or Chinese companies that will guide them in the market and have a vested interest in protecting the IP. BC Cleantech companies need a proven business model with a history of profitable deployments in order to attract these partnerships.

Financial challenges were identified as the most pressing issue for BC Cleantech companies. Grant funding was important to many participants and the dormancy of the ICE program has had a negative impact on the industry. The ICE fund has suffered from a reduction in funding in recent years and has not held an open Call-for-Applications since 2010.

VC is difficult to access for Cleantech companies in BC due to a risk-averse nature amongst VC funds in the province. Cleantech is high risk and projects usually involve timelines that are longer than the standard 3-5 years that VC investors are seeking. Many companies expressed a need for debt financing, as opposed to equity financing such as VC, in order to expand their business and grow into new markets. Companies are unable to take out loans that are needed to expand their operations, again due to their high risk profile. Cleantech companies are often expected to post large financial guarantees or bonds at the outset of a Cleantech project, which can be recouped by the customer should the project fail due to various reasons, but the limited balance sheets of these

small companies make posting these financial guarantees impossible without taking loans from lending institutions. These institutions are hesitant to loan large sums of money to companies with limited assets that can be held as collateral and that are developing technology that does not have an already established market. Should the technology fail to live up to expectations, should the project be more expensive than anticipated, or should the market demand fail to deliver the expected revenue once complete, the financial institutions may have to write-off the loans if the company declares bankruptcy.

Companies interviewed for this report mostly stated that they did not enter into formal collaborations with universities and other research institutes here in BC. Expensive usage fees and concerns about IP ownership and licensing have resulted in many companies preferring to conduct research on their own. Companies also reported that much of the research being done was not a "good fit" for the company, as it was academic in nature and often focused on different scientific areas. Cleantech companies in BC benefit from the universities by recruiting graduates and coop students, through training and continuing education of staff, and through direct consultations with professors and researchers. Although the universities are an essential part of the Cleantech eco-system through the many informal connections between the industry and academia, the lack of formal collaborations that are seen in other jurisdictions may indicate a missed opportunity and an under-utilization of research infrastructure.

Participants reported that the provincial programs in place to support Cleantech in BC are difficult to navigate and poorly communicated. There needs to be a single point of contact that will employ industry consultants who will maintain working relationships with companies operating in BC. These industry advisors should be modelled after similar positions already employed by Government of Canada programs such as Sustainable Development Technologies Canada (SDTC), the Industrial Research Assistance Program (IRAP), and the Concierge services.

The literature review for this report suggested that a carbon tax, while being instrumental at reducing GHG emissions, would have a negligible effect on innovation without the price for carbon being unfeasibly high. The results of the research interviews support this position. While the carbon tax will remain an integral part of BC's efforts to reduce GHG emissions, and will be essential for signalling the province's commitment to supporting Cleantech policy in general, it will likely be insufficient to induce innovation amongst BC Cleantech companies without additional polices, even with the expected increase to $50/tCO2*e* by 2022. As per the findings of the literature review, in order to accelerate innovation in the BC Cleantech sector, provincial government support in the near future should focus on direct support of R&D activities and Cleantech companies, while the carbon price steadily increases to encourage the use of new technologies as they become cost-effective over the long term.

Conclusions

Policy Recommendations

Recommendation #1: *Restructure the ICE program into a broad Cleantech supporting agency.*

The BC ICE program should be expanded to include all Cleantech sectors and not just clean energy, be provided a consistent source of funding, hold regular Calls-for-Applications, and serve as a central point of contact for Cleantech innovation in BC. ICE should also explore partnership opportunities with federal departments that offer programs to support Cleantech innovation such as SDTC and IRAP.

Recommendation #2: *Create additional financial instruments to support the provision of debt financing for Cleantech companies.*

The province needs to create financial instruments such as loan guarantees, concessional loans, lines of credit and bonds to address the lack of debt financing available to the sector and explore options for partnering with other levels of government to help provide this financing. The goal of these financial instruments should be to help reduce the risk of private financial institutions in order to leverage additional funding into the sector.

Recommendation #3: *Increase the VC funding available for Cleantech companies and give this funding a mandate to accept investments that have higher risk profiles and longer timelines.*

Cleantech development is inherently more risky than other types of technology development due to technological, market, and political risks. Creating a VC environment that is open to these risks is necessary to support the industry. It is especially important for Cleantech companies that they be given timelines in the 5-10 year range instead of the 3-5 year range as is typical for VC investments. The $100 million investment in the BCTech fund is an important contribution to the VC landscape in BC, but it will be important to make sure that the funding is equally distributed to its four target sectors and that Cleantech is not left out.

Recommendation #4: *Develop and employ industry advisors to provide consultation and support to Cleantech stakeholders in BC attempting to access programs across all levels and branches of government.*

Creating a single point of contact for stakeholders will help to ensure that they are up-to-date on application timelines and requirements, that they are aware of new programs they may be eligible for, and will create a dependable avenue for consultation between the industry and the government. These advisors could be managed through the reformed ICE program or through another government department.

Recommendations for Further Research

Recommendation for Further Research #1: *Strategies for increasing industry participation with academic research institutions that could result in better optimization of research infrastructure in BC should be explored.*

While it is difficult to say if the BC Cleantech industry is negatively affected by the current system of post-secondary research, examples from other parts of the world indicate that alternative arrangements could be beneficial for the industry in BC. While supporting the informal connections between industry and the academic Cleantech sectors, BC should explore new ways of encouraging research collaboration between these two groups of stakeholders.

Recommendation for Further Research #2: *The needs of Cleantech start-ups should be further explored.*

The needs of companies in the start-up phase of development, which is earlier than the companies included in this research, could provide information about Cleantech needs at the concept stage, patent development, the usefulness of start-up incubators, and company formation. Start-ups are often created to commercialize the findings of university research, and as such they may also provide additional insight about how best to utilize post-secondary research infrastructure.

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Hydrogen in Motion
Ivey International Inc.
Dependable Turbines Ltd.
Nexterra Systems
Prism Engineering
S2G Bio-chemicals Inc.
SES Consulting Inc.
Sono Ash
Turbulent Diffusion
Quadrogen Power Systems

List of Abbreviations

Alberta Innovates Energy and Environment Solutions	AI-EES
Advanced Research Projects Agency-Energy	ARPA-E
BC Innovation Council	BCIC
BC Immigrant Investor Fund	BCIIF
BC Renaissance Capital Fund	BCRCF
1990 Clean Air Act	CAA
Cleantech Accelerator Centre	CAC
Climate Change and Emission Management Corporation	CCEMC
Canadian Controlled Private Corporation	CCPC
Clean Energy Fund	CEF
Chief Executive Officer	CEO
Chief Operations Officer	COO
Carbon Dioxide equivalent	CO2*e*
Concentrated Solar Power	CSP
Chief Technology Officer	CTO
Department of Energy	DOE
Export Development Canada	EDC
European Emission Trading Scheme	EU-ETS
Fiscal Year Plan	FYP
Greenhouse Gas Emissions	GHG
Innovative Clean Energy fund	ICE
Information and Communications Technologies	ICT
International Energy Agency	IEA
Intellectual Property	IP
Independent Power Purchasers	IPP
Material Handling Equipment	MHE
National Research Council of Canada Industrial Research Assistance Program	IRAP
International Renewable Energy Association	IRENA
Investment Tax Credit	ITC
Loan Programs Office	LPO

Production Tax Credit	PTC
Photo-Voltaic solar	PV
Research, Development, and Demonstration	RD&D
Renewable Portfolio Standard	RPS
Sustainable Development Technologies Canada	SDTC
Small and Mediums sized Enterprise	SME
Sulphur Dioxide	SO2
Standing Offer Program	SOP
Scientific Research & Experimental Development tax credit program	SR&ED
Unmanned Aerial Vehicle	UAV
Venture Capital	VC
Washington Economic Development Financing Authority	WEDFA

List of Tables and Figures

1. Introduction

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What types of provincial policies are best suited to encourage growth in the BC Cleantech sector?

Cleantech is a broad term with many definitions, but for the purpose of this report Cleantech will include low-carbon energy sources (wind, solar, water, biomass, biofuels, hydrogen, geothermal, fuel cells, nuclear), energy infrastructure, wastewater treatment, agriculture, recycling and remediation, transportation, chemistry, information technology, efficient extractive and industrial processes, and energy efficient appliances. To answer the research question, this report conducted open-ended interviews with a cohort of CEOs and other senior employees of BC Cleantech companies to ascertain what are the biggest challenges facing the sector and what the provincial government can do to help overcome these challenges.

This report will utilize a literature review, a smart practices scan, and participant interviews to determine what the BC government should be doing to help the Cleantech sector in BC. Global international trade in Cleantech (imports and exports) was estimated to be worth more than USD 2 trillion in 2014 and grew at a rate of 3.5% during the years of 2008-2014 (Analytica Advisors, 2016, p. xiii). BC is well situated to take advantage of this growing market and expanding the provincial market share of this sector has been a focus of the BC government for years.

2. Background

The term Cleantech came into use in the late 1990's and early 2000's in regard to technologies that have potential to reduce environmentally negative outputs from human activity. These technologies can include low-carbon energy sources (wind, solar, water, biomass, biofuels, hydrogen, geothermal, fuel cells), energy infrastructure, transportation, chemistry, information technology and energy efficient appliances (Erzurumlu & Erzurumlu, 2013). There is no uniform definition of Cleantech and other jurisdictions use terms such as environmental technology, greentech, low carbon technology, eco-innovation, and sustainable technology, all of which refer to the same family of technological or process innovations.

The term "Cleantech" is typically used in North America, whereas "eco-innovation" is typically used by European governments. Cleantech is the chosen term used in this research project, however in the literature review and smart practices sections other terms are used in order to avoid confusion when referencing their respective source materials. The terms listed above should all be considered synonymous with Cleantech.

There are two categories of Cleantech that are typically discussed. The first category is energy producing technologies and these go by the terms "renewable energy", "clean energy", and "low-carbon energy." These can include wind turbines, solar panels, tidal/marine/small-scale hydro energy, ethanol production, bio-mass electrical generation, and fuel cells amongst other types. Non-energy producing technologies in Cleantech are often referred to as "environmental goods and services" and include areas such as soil remediation, water and wastewater treatment, and green chemistry amongst others.

2.1. The Current State of Cleantech in Canada and BC

Cleantech in Canada has seen significant growth over the past decade. In 2014 there were more than 750 Canadian Cleantech companies directly employing more than 55,600 people across Canada (Analytica Advisors, 2016, p. 7). This makes the Canadian Cleantech sector larger than the Canadian industries of aerospace manufacturing (45,000 jobs), pharmaceuticals (26,000 jobs), and forestry and logging (38,500 jobs). The industry had an 8% compound annual growth rate (CAGR) from 2011-2013, but slowed significantly in 2014. The CAGR for 2012-2014 was only 1%. The sector had industry revenue of $11.63 billion in 2014, 57% of which came from exports to other countries (p. xxiv). Some analysts predict this industry will have revenue of at least $18 billion by 2022 (p. xxi).

British Columbia has a Cleantech sector that numbered more than 200 companies in 2014. In that year this sector produced $1.4 billion in revenue and had a direct workforce of 6,400 people (Trade and Invest BC, n.d.). The largest sub sector of Cleantech in BC is energy production, followed by energy efficiency/green buildings and biomass products (Analytica Advisors, 2015, p. 73).

2.2. BC Cleantech Support

There is a broad array of government programs in place to support Cleantech in BC, originating from Federal, Provincial, and Municipal governments. This section will focus on provincial programs but will also discuss programs from other levels of government when they are directly related to provincial programs being discussed. This section covers the major programs offered in BC and is not meant to be exhaustive.

2.2.1. Research Centres

Post-secondary institutions in BC have several research centres that are focused on Cleantech and sustainability. BC has a network of eight Green Centres of Excellence that are partnered with academic institutions in order to bring together experts from the private, public and academic worlds in order to collaborate on the applied research and development of new technologies (Trade and Invest BC, n.d.). In addition to the Centres of Excellence, there are other research centres in BC such as the Clean Energy Research Centre at UBC (University of British Columbia, n.d.).

Table #1 –BC Centres of Excellence

Centre of Excellence Name	Academic Institution	Area of Research
Centre for Energy Systems Applications	BCIT	Renewable energy technologies in an integrated systems approach.
Energy House	Northern Lights College	Wind turbines, photovoltaic, solar thermal and biomass.
Jim Pattison Centre of Excellence in Sustainable Building Technologies and Renewable Energy Conservation	Okanagan College	Sustainable construction management technology, geothermal, electrical, carpentry, green building design and construction.
Institute for Integrated Energy Systems	UVic	Renewable energy systems and hydrogen fuel cell technology.
Institute for Resources, Environment and Sustainability	UBC	Sustainable resource management and ecology
Centre for Interactive Research on Sustainability	UBC	Sustainable transportation, clean energy/technology
National Research Council Institute for Fuel Cell Innovation	UBC	Hydrogen and fuel cell systems
Pacific Institute for Climate Solution	UVic, UBC, SFU and University of Northern British Columbia	Low-carbon economy, climate change, sustainable communities, resilient ecosystems

(Source: Trade and Invest BC, n.d.)

2.2.2. Scientific Research &Experimental Development

The BC provincial government has a Scientific Research and Experimental Development tax credit (SR&ED) for qualified companies in BC that are engaged in technology innovation. Canadian Controlled Private Corporations (CCPC) may claim a 10% refundable tax credit for qualifying expenditures in a tax year, to a limit of $3 million annually. This refundable tax credit allows developing companies that are not generating revenue to receive assistance from the program. Companies may also receive a 10% non-refundable tax credit for BC expenditures above the $3 million limit. This non-refundable tax credit will be applied to the company's taxable revenue from the income it has generated in that year. This program is very similar to the SR&ED tax credit offered by the Government of Canada, with the most notable difference being that the federal SR&ED offers a larger credit for qualifying CCPCs. The federal SR&ED program offers a 15% refundable tax credit up to $3 million and a 35% non-refundable tax credit on amounts above $3 million. Combined, these two SR&ED programs can provide a 45% tax credit for BC companies engaged in R&D activities, with 25% of that amount offered as a refundable tax credit (Government of BC, n.d.*a*; Canada Revenue Agency, n.d.).

The Government of Canada commissioned a study on innovation in Canada and the effect of federal support programs for companies engaged in R&D activities (Public Works and Government Services Canada, 2011). Amongst its findings, the report found that Canada had one of the highest tax subsidy rates for innovation in the OECD. Only France and Spain provided higher tax subsidy rates as a percentage of their investment in R&D (p. 6-8). The report suggested that this reliance on indirect support was not optimal and that the government should reduce its SR&ED expenditures and redirect that funding to direct support programs such as research grants and financing tools. One of the main criticisms of the SR&ED is that it is a general tax credit and does not discriminate between projects. Therefore, funding is inevitably spent on programs that never had a strong chance of being commercially successful or on projects that do not provide any significant benefit to society (p. 6-10). The SR&ED program has not been altered significantly since these suggestions were made.

2.2.3. Government Sponsored Venture Capital

The BC Renaissance Capital Fund (BCRCF) is a VC fund of the BC Immigrant Investor Fund (BCIIF), which is a BC crown corporation that invests and manages BC's portion of the federal Immigrant Investor Program. The BCRCF made $90 million in investments to eight VC fund managers that were responsible for investing in four target areas: Cleantech, Information Tech, Life Sciences, and Digital Media. The federal Immigrant Investment Program was terminated in 2014, and as such the BCRCF is currently not pursuing additional investment opportunities (BC Immigrant Investor Fund, n.d.). The BC government announced in December 2015 that it would be using $100 million to create a VC fund known as the BCTech Fund. This fund-of-funds will provide early stage financing to the technology sector in BC. This fund will also be responsible for managing the $90 million in assets previously managed by the BCRCF (Government of BC, n.d.*b*). Kensington Capital

Partners was chosen to manage this capital fund. They were given the mandate to invest in the sectors of ICT, Digital Media, Life Sciences/Healthcare, and Cleantech (Kensington Capital Partners, n.d.). A report by the VC fund Yaletown Partners, a recipient of BCRCF funding, observed that early stage capital financing for the BC technology sectors tend to be well established but suffers from a lack of growth and expansion capital (Johns, 2016, p. 5).

2.2.4. BC Innovative Clean Energy Fund

The ICE fund was created in 2008 to support the Province's energy, economic, environmental and greenhouse gas reduction priorities, and to advance B.C.'s clean energy sector. The fund has contributed over $48 million since its inception to more than 60 projects throughout BC. The focus of the fund is on projects that are in the pre-commercial phase of product development. ICE was originally funded by a .04% levy on the final sale of electricity, natural gas and fuel-oil, but this levy was eliminated with the creation of the HST. The levy has been re-instated along with the PST but electricity sales are no longer included. The levy is now estimated to raise $6.5-7 million a year (BC Ministry of Energy and Mines, 2014, p.7). ICE has not held an open Call-for-Applications since 2010. Table #2 gives a breakdown of the project expenditures found in the 2014 ICE performance report.

Table #2 - ICE fund distribution by technology

Technology	# of Projects	ICE Fund Investments	Project Value
Bioenergy	17	$ 28,957,000	$ 125,932,834
Energy Conservation	4	$ 5,589,163	$ 20,628,957
Energy Management	4	$ 7,300,858	$ 22,460,929
Energy Storage	1	$ 203,775	$ 617,500
Geoexchange	2	$ 1,075,115	$ 3,993,969
Hydro	1	$ 44,000	$ 200,000
Ocean - Wave/Tidal	2	$ 2,469,622	$ 7,806,900
Solar	6	$ 2,052,321	$ 8,142,273
Waste to Energy	1	$ 666,666	$ 2,000,000
TOTAL	**38**	**$ 48,358,519**	**$ 191,781,362**

(Source: BC Ministry of Energy and Mines, 2014, p. 13)

The ICE fund has also provided more than $31 million in funding for the Clean Energy Vehicle program since its inception. This program has provided point-of-sale incentives for electric and hydrogen fuel cell vehicles, investments in fuelling/charging infrastructure, funding for academic research programs, and funding for electrician training (Government of BC, n.d.*c*).

2.2.5. BC Innovation Council

The BC Innovation Council (BCIC) is a public organization that encourages the development, application and commercialization of innovative technology in BC. The BCIC offers programs that provide funding, consultation, mentoring and training opportunities for companies looking to

commercialize innovative products. The BCIC offers several programs of interest to Cleantech in BC. The Venture Acceleration Program is designed to help early stage entrepreneurs grow their companies through mentoring and networking opportunities, provided by a team of Executives-in-Residence. The BCIC Ignite program provides funding to consortia (of two or more private companies, organizations or academic researchers) that intend to commercialize new technologies or innovations in natural resources or applied sciences within a three year timeframe. Grants of up to $300,000 can be awarded to participants and projects must receive matching funding of at least a 2:1 ratio from other sources. The BCIC also offers numerous other smaller programs designed to help entrepreneurs with networking opportunities and co-op grants for hiring students (BC Innovation Council, n.d.).

The BCIC runs a network of start-up accelerators that help start-up companies in several fields get their products developed and commercialized. The Foresight Cleantech Accelerator Centre (CAC) is a program intended to help early-stage Cleantech entrepreneurs grow their business in BC. Foresight provides entrepreneurs with office and lab space, clinics and seminars on professional topics such as fund raising, IP rights, and customer development, and by providing funding to help businesses develop prototypes for their innovations. The ARCTIC program holds a competition every six months, wherein small companies design innovations needed to address a specific problem identified by industry consultations. Five companies are then chosen to develop prototypes. The industry sponsor will eventually choose at least one product for field testing, after which time successful products may be commercialized with further help from Foresight (Foresight Cleantech Accelerator Centre, n.d.).

2.2.6. BC Hydro Standing Offer Program

BC Hydro provides a fixed price to the producers of Clean Energy in BC through the Standing Offer Program (SOP). Eligible projects must apply to the program, which has a specific amount of energy it can take in a given year from SOP projects. Independent Power Producers (IPP) that are developing projects that utilize wind, solar, geothermal, hydro, ocean, biogas/mass, or biogenic waste heat can apply to the SOP program and receive between $102 and $112 per MWh, depending on the region they are producing in. For comparison, small-scale hydro operations from IPPs are available to BC Hydro for various prices starting at $93/MWh, and the Site C dam is expected to produce energy at $83/MWh. There is no distinction between renewable energy technology types in determining what price the IPP will receive under the SOP. There is also a "micro-SOP" program that is intended to encourage First Nations communities to collaborate with industry partners to produce community-scale renewable electricity projects (BC Hydro, 2016; BC Hydro, 2013 p. 3-48).

2.2.7. Carbon Tax

BC introduced a carbon tax in 2008 that started at $10/ ton of carbon dioxide equivalent ($tCO2e$) emissions and increased it each year until it reached $30/$tCO2e$ in 2012, where the price remains

today. The carbon tax is revenue neutral, with all revenue received being returned to the BC economy via reductions in business taxes, personal income taxes, or tax rebates for low-income British Columbians. The tax covers approximately 70% of all CO2 emissions in BC, including almost all fossil fuels burned in the province. Process emission are explicitly not included under the tax, therefore emissions resulting from methane released during natural gas processing, CO2 emissions from cement production and agricultural sources are not taxed under the current system (Pembina Institute, 2014). Estimates on the impact of the carbon tax on GHG reductions within BC range from 5-15% and estimates for the reduction of gasoline consumption range from 7-17%. Estimates of the economic impact of this carbon tax indicate it had either a slightly positive impact or no significant impact at all (Murray & Rivers, 2015).

2.2.8. Energy Efficiency Regulations

The Energy Efficiency Standards Regulations (Government of BC, 2015) described the energy efficiency standards that must be met by new appliances, consumer electronics, heating and cooling devices, building materials, electric motors, water heaters, and lighting fixtures. There are also specific performance requirements for various technology types found in other regulations. For example the BC government passed a law requiring all natural gas liquefaction plants to have a CO2 intensity of .16 tonnes of CO2*e* per ton of LNG created (McCarthy Tétrault, 2016, p. 28).

2.2.9. BC's Carbon Neutral Government Program

In July 2010, BC implemented its Carbon Neutral Government program that required all provincial government agencies and crown corporations become carbon neutral. In order for these agencies to become carbon neutral, they have been required to purchase carbon offsets for whatever carbon emissions they cannot eliminate through efficiency upgrades and other means. The Pacific Carbon Trust was a crown corporation established to purchase carbon offsets to be used in the Carbon Neutral Government program. In 2013, the BC Auditor General released a report that found that the Pacific Carbon Trust was not purchasing credible offsets and not taking sufficient steps to ensure the quality of the offsets it purchased. Many of the offsets were considered not additional, which means that they would have occurred even if the trust had not purchased them (BC Auditor General, 2013). Later that year the crown corporation was dissolved and the carbon offset program was taken over by the Climate Action Secretariat within the BC Ministry of Environment. In 2015, government agencies purchased $15.6 million worth of carbon offsets from the BC Carbon Offset Registry, displacing more than 624 thousand tCO2*e* emissions (BC Ministry of Environment, 2015, p.6). Companies are able to obtain credits for carbon offsets by following directions laid out on the BC government climate change website and include verification from two independent auditors to ensure that the offsets are additional to a business-as-usual scenario. The website also publicly lists offset projects that are currently available and those that have been retired. The carbon offset registry is currently purchasing offsets from eligible projects for a price of $8.50/tCO2*e* and is selling these offsets to government agencies at a price of $25/tCO2*e* (Government of British

Columbia, n.d.*d*). At this time, there are no performance reviews or audits available on the Carbon Offset Registry after control was assumed by the Climate Action Secretariat.

2.3. Global Market Growth

Global growth in Cleantech deployment has been increasing rapidly over the past decade, and the two largest markets in the world are China and the US. Estimates vary on the size of the global economy for Cleantech, but the US Department of Commerce estimates that the global market for "environmental goods and services" was USD 1.05 trillion in 2015 (2016, p. 3). This section will focus on the markets of China and the United States and the potential for growth of BC Cleantech companies in these markets in the coming years. The section on China will discuss the sectors of water and wastewater treatment, biomass, and renewable energy generation. The US section will discuss biomass, renewable energy generation, and hydrogen systems. These subsectors were chosen because of their prevalence in the BC Cleantech industry and their potential for growth in these export markets.

2.3.1. China

China was one of the largest global consumers of Cleantech in 2015, spending an estimated USD 60.7 billion on environmental goods and services. China has seen a 13% compound annual growth rate in its environmental technologies market over the past decade (US Department of Commerce, 2016, p. 21). Despite this tremendous amount of spending activity, exporting to China remains very difficult due to several factors. IP rights are not well protected at the moment and IP infringement is common place with few legal avenues for recourse available to international companies. There is also a preference in China to make use of domestic companies, especially those that are State-owned, in renewable energy and environmental technologies. This tendency may increase in the future, as environmental technologies are one of seven "strategic industries" that China intends to support by encouraging domestic consumption. Despite the significant barriers to entry into the Chinese market, the sheer size of the market means that if a company is able to capture even a small fraction of it, the financial benefits could be substantial (p. 21-22).

2.3.1.1. Water and Wastewater Treatment

China has set ambitious goals for water quality by 2030 and has committed to spending more than USD 920 billion on water infrastructure over the next five to seven years. In the period of 2016-2017, China anticipates spending USD 543 million on drinking water treatment, wastewater treatment, and desalinization plants across 18 projects. Key technologies that are expected to be in demand include advanced filtration, membrane filtration, waste-to-energy technology, anaerobic digestion, biological de-nitrification, in addition to conventional engineering and mechanical services and supplies. China intends to eventually provide universal wastewater collection and

treatment and has an interim goal of 95% in urban areas by 2020. China also has ambitious plans for sludge treatment, ground water remediation and pollution prevention (US Department of Commerce, 2016, p. 25-26).

2.3.1.2. Bio-mass

There is substantial opportunity in China for an increase in biomass usage in their energy mix. Bioethanol production in China was 2.1 billion litres in 2010 and there is an official target of 12.5 billion litres by 2020 (International Renewable Energy Association [IRENA], 2014, p. 28). The government is supporting this effort by offering production subsidies as well as mandating ethanol blending in gasoline and other fuel sources. There has been some push back from this expansion, as ethanol production has begun competing with food crops for arable land. Future ethanol growth could potentially come from lingo-cellulosic ethanol that does not compete with food production for its feed stock, making use of forestry waste, switch grass, and other organic sources. China also has ambitious plans for the deployment of small-scale biogas digesters that would supply biogas for home cooking and heating. More than 440 million people in 2011 still relied on traditional biomass (wood) stoves for cooking. Many of these wood stoves could be replaced using biomass systems that would utilize food scraps, household sewage and manure from livestock to produce biogas. In 2010 China had 41 million biogas digesters and has a target of 80 million by 2020. Utility-scale biomass power in China is also growing rapidly, with an official goal of increasing biomass power from 5.5 GW in 2010 to 30 GW of capacity in 2020. China currently has one of the world's largest biomass power plants, which has a capacity of 1.2 GW of electricity. Chinese policy has been consistent in its support of biomass energy, with preferential loans, tax reductions, R&D funding, and funding for demonstration plants. In 2011, China spent USD 760 million in support of biomass development (IRENA, 2014, p. 29).

2.3.1.3. Renewable Power Generation

The potential for renewable energy generation in China is enormous. Bloomberg New Energy Finance reported that China spent USD 110.5 billion on clean energy in 2015 (BNEF, 2016*a*) and the IEA predicts that by 2021, more than one-third of all installed global onshore wind and photo-voltaic (PV) solar capacity will be located in China (IEA, 2016*a*, p. 15). In 2015, more than 50% of additional power generating capacity installed in China was from renewable energy sources (p. 48). China's 13th Fiscal Year Plan (FYP) 2016-2020 has ambitious goals for renewable energy production. In the period of 2015-2020, onshore wind is expected to expand from 128 GW to 250 GW, PV Solar to expand from 100 GW to 150 GW, and Concentrated Solar Power (CSP) to expand from 3 GW to 10 GW (p. 51). Growth in conventional hydro capacity is expected to slow in these years due to increased social costs from these projects, however there will likely be some expansion of pumped hydro storage projects (p. 53).

2.3.1.4. China Conclusion

Despite China becoming the largest market in the world for environmental and renewable energy technologies, opportunities for export into this market will be difficult for international companies. Poor IP protection makes China a risky market to enter for many companies, as there is the potential for Chinese companies to steal the technology and reproduce it domestically. Market forces are also making China difficult to operate in for solar and wind companies. An oversupply of solar panel and wind turbine production facilities have driven down prices for these two technologies in China, leading to bankruptcies and corporate takeovers of domestic Chinese suppliers. China has tried to address this oversupply by encouraging domestic consumption of Chinese supply to the detriment of international competitors (US Department of Commerce, 2016, p. 26). The Chinese market for renewable energy and environmental technologies is simultaneously the largest and the most challenging in the world.

2.3.2. United States

2.3.2.1. Biomass

Between 2014 and 2015, the US installed more than 400 MW of new electrical generating capacity using biomass, biogas, and waste-to-energy technologies. Investment in this area has been spurred by the Production Tax Credit (PTC) and the Investment Tax Credit (ITC) by the federal government. These tax credits have been extended to the end of 2020, with a phase-out period starting in 2018, and apply to eligible renewable energy projects that begin construction prior to the cut-off date. Asset financing for new biomass in 2015 was USD 349 million, while biogas facilities received asset financing of USD 285 million. There have been no significant investments in waste-to-energy facilities since 2012. Investments in the biomass energy sector are heavily dependent on federal tax incentives, and as such have seen a lot of volatility over the past decade as the tax credits have become highly politicized. For example, investments reached a peak of USD 1.7 billion in 2012, but saw only USD 117 million in 2013 and USD 39 million in 2014. The extension of the credits until 2020 should provide some policy certainty in the near future, giving projects the predictability they need to make investment decisions. Despite the variability in this market, the bio-energy sector in the US has the potential to be a billion dollar industry in the coming years (BNEF, 2016*b*, p. 71-73).

2.3.2.2. Renewable Energy Generation

The United States added 16.5 GW of new renewable energy capacity in 2015. Utility-scale PV solar capacity saw an increase of 4.4 GW and investments of USD 1.5 billion worth of VC and private equity expansion capital, as well as USD 8.1 billion in asset capital for project development and operations. Distributed PV systems, those found on residential houses and commercial buildings, expanded by 2.9 GW. Residential PV systems were the fastest growing segment in the US solar market. The growth of the PV solar market has been driven by decreasing prices for all components

of solar systems. Growth in this market has been steadily increasing and has not been impacted by political uncertainty to the degree that wind and biomass technologies have been. (BNEF, 2016*b*, p. 53-57, 85-87; IEA, 2016*a*, p. 54-55).

Large-scale wind deployment was 8.5 GW of new capacity installed in 2015, and saw asset financing of USD 10.6 billion. Much like biomass, the wind energy sector is heavily influenced by government tax credits. Deployment over the past 5 years has been very unsteady, with record deployments in 2012 of 14 GW followed up in 2013 by only .7 GW of new capacity. The renewal of the ITC and PTC tax credits until 2020 should allow for a smoother development of wind turbine projects (BNEF, 2016*b*, p. 60-66), however with the recent change in leadership of the US government, Cleantech related policies and departments could be facing significant changes in the coming years.

2.3.2.3. Hydrogen Fuel Cells

Hydrogen fuel cells are being used in a wide variety of functions and all segments are seeing steady and increasing growth. Stationary and mobile fuel cells are currently deployed in 41 US states and are being used in forklifts, busses, cell towers, as back-up generators for IT data centres, in military unmanned aerial vehicles (UAV), in combination with wind and solar installations to provide energy storage, and light and heavy duty automotive vehicles (US DOE, 2016). The market for fuel cell material handling equipment (MHE) has seen significant growth over the past few years as large multinational companies are adopting fuel cell powered forklifts in their warehouses. Companies deploying these vehicles include Coca-Cola, FedEx, Proctor & Gamble, Wal-Mart, BMW and others, and have grown these deployments from 7,700 in 2015 to more than 11,000 in 2016. This growth is expected to continue, as fuel cell MHEs have shown to have lower operating costs than traditional battery powered forklifts (p. 25). Several states have made significant funds available to companies looking to establish hydrogen fuelling infrastructure, as well as purchase rebates for fuel cell vehicles. California, Connecticut, and New York are the leaders amongst US states for their support of hydrogen fuel cells. California has nearly 50 hydrogen fuelling stations operating or under development, with an ultimate goal of 100 stations supported by an annual commitment of USD 20 million to help develop this infrastructure. One recipient of this government support is HTEC Hydrogen Technology & Energy Corporation, a BC based company that received a USD 300,000 grant from the California Energy Commission to build a hydrogen fuelling station in Woodside California (US DOE, 2015, p. 45). California has more than 210 MW of power generation from fuel cells at locations such as Universities, municipal buildings and hospitals. Connecticut has at least 35MW of fuel cells deployed with another 20MW currently planned. It is expected that Toyota will open a public hydrogen fuelling station in Connecticut in 2017, one of 12 such stations expected to be constructed on the North Eastern US. The hydrogen industry in Connecticut generated more than USD 700 million in revenue and investment in 2015. Both California and Connecticut offer USD 5,000 rebates for the purchase of new fuel cell vehicles. New York state currently has 14 MW of fuel cells in operation and is also expecting a public hydrogen fuelling station to be opened by Toyota in 2017 (US DOE, 2016, p. 1-3).

2.3.2.4 US Conclusion

Despite the politicization of several federal renewable energy policies, the US market for Cleantech products remains one of the largest in the world alongside China. Government support programs on both the federal and state level are scheduled to continue supporting Cleantech development and deployment, although changes in the federal government could bring with it a change in environmental policies and new directors for departments such as the EPA. Consumer behaviour in the US is also pushing Cleantech deployment, as prices continue to drop below that of conventional energy sources and individuals make the choice to adopt Cleantech solutions even in the absence of government support. Sales from Canadian Cleantech companies to the US comprised 34% of all sales in 2014, compared to 23% for sales to all other non-US markets combined. Given the growth of the Cleantech market in the US, and the relative ease for Canadian businesses selling their products south of the border compared to non-US markets, the US will likely remain the primary source of Canadian Cleantech exports for the foreseeable future (Analytica Advisors, 2016, p. 90).

3. Methodology, Methods and Analysis

3.1. Methodology

This project utilizes a literature review, a smart practices scan, and primary information obtained in interviews with individuals involved in the private sector of the BC Cleantech industry. A SWOT analysis will be used to organize the findings from the research interviews.

A smart practice scan, also known as a "best" practice scan, is an attempt to examine the successful practices of other jurisdictions and to assess whether they are transferrable to other locations (Bardach, 2009, p. 95). The jurisdictions to be included were decided partly by suggestions from the client and partly decided based on jurisdictions that are seen as leaders in Cleantech development. The choice of these jurisdictions was determined by several criteria. Firstly, the chosen locations are those that are recognized as international leaders in using Cleantech policy to further innovation in the sector. Recognition here can be found through international organizations that release regular reports on Cleantech innovation, such as the Cleantech Group, the EU based Eco-Innovation Observatory, CleanEdge, and the OECD. Secondly, jurisdictions were selected based on the comparability of their economies to BC. Oregon and Washington State will be of particular interest due to their proximity to BC, their similarity in economic conditions, and in their success relative to other US jurisdictions in the field of Cleantech innovation (CleanEdge, 2016).

A SWOT analysis will be used to understand BC's relative strengths and weaknesses in the sector and to determine what opportunities exist for growth in BC. A SWOT analysis is a technique that allows strategic planners to identify forces and factors that will impact an organization's short and long term success. It involves analysing internal strengths (such as established Cleantech companies in BC), internal weaknesses (such as a shortage of skilled workers), external threats (such as competition for skilled workers, changes in government policies by trade partners), and external opportunities (such as growing demand for Cleantech products internationally) (Simerson, 2011, p. 115). This SWOT analysis will be constructed using data acquired in semi-structured interviews with key figures in the BC Cleantech sector.

The findings section of this project will present the findings of the participant interviews and the SWOT analysis. The Discussion section will look at what has been learned in all the preceding sections and present possible options for improving the BC Cleantech sector.

3.2. Participant Selection

This project used qualitative primary data collection in the form of semi-structured interviews. These interviews were conducted with key individuals in the BC Cleantech sector to identify what government policies have been helpful and what policies would be useful to address the future

needs of the sector. This project sought to interview individuals who were senior employees at Cleantech companies in BC, with a minimum participation target of 12 interviews. Most of the participants were President/CEOs, but our selection also included Chief Technology Officers (CTO), Vice Presidents/Directors of Business Development, and other senior managers. To be considered, companies had to be actively engaging in applied R&D activities with the goal of commercializing the product of that R&D. Companies that were entirely focused on Cleantech deployment, such as renewable energy companies building wind farms but not developing wind turbine technology themselves, were not considered for this research. Potential participants were selected by several means. The primary source of recruitment information was the Analytica Advisors 2015 and 2016 Canadian Cleantech Industry Reports, which provided a list of Cleantech companies in Canada along with contact information such as email address and phone numbers. Companies that listed email addresses for senior employees and were located in BC were emailed the Invitation to Participate. Companies that only listed general email addresses, and no personal addresses of senior employees, were also included. The Invitation to Participate also contained a request for the recipient to pass along our invitation to other companies or persons that may wish to participate in the hopes that they would reach out to us. The client for this project also provided contact information for several companies that had expressed interest in participating. Lastly, internet search engines were used to find BC Cleantech companies that may not have been covered under the other recruitment methods.

In total, invitations were sent out to individuals at 39 companies, 7 general information email addresses for their respective companies, and we received 5 requests to participate from persons who were referred to us from our initial email contacts. We received 18 positive responses in total and were able to interview 16 of these individuals, the final two being unable to participate due to scheduling conflicts and project time constraints. The positive response rate for our email campaign, not including referrals, was 33%. Three of these completed interviews were ultimately removed from the analysis because it was discovered after the interview began that they did not meet the criteria for this project as they were not conducting R&D and were instead entirely focused on deployment. The findings and analysis of this project were taken from the 13 viable interviews that were conducted.

3.3. Interviews

Semi-structured interviews, as described by Cohen and Crabtree (2006, p. 1), are one-on-one interviews that begin with a formal interview guide containing a list of predetermined questions common for each interviewee. As the interview progresses, the interviewer may ask follow-up questions that are not included on the guide. In this way, the conversation and the data obtained is not restricted to the question format and allows the participants to express their views on their own terms, while the predetermined questions provide a basis for comparison between participants. The interviews were recorded, transcribed, and the answers were entered into an excel spreadsheet where they were categorized into similar themes for each answer. This process of grouping answers by theme is known as “open coding” under Strauss and Corbin’s version of

Grounded Theory (Kendall, 1999, p.746).This method allowed the researcher to conveniently observe which themes were most common for a given question, while the ability to enter text into individual cells made it easy to record specific answers and their context for analysis.

3.4. Methodological Weaknesses

Sampling bias is a concern for any research project in which participation is voluntary and not random. This concern was mitigated by the use of an external source of contact information, in this case the Analytica Advisors 2015 and 2016 Cleantech Industry reports. All participants with a BC address were included in our recruitment drive and these provided the majority of participants. Personal contacts of the client and the researcher provided only one viable interview, however the client did assist in obtaining interviews by contributing a follow up email to several respondents. Referrals from participants added an additional degree of objectivity to the selection process. Participating companies represent many different technology fields and are at various stages of product development.

Another possible weakness of the research is that the quality of interviews may have improved towards the end of the interview phase, as the researcher became more capable at interviewing and more knowledgeable about the subject matter thereby pursuing additional avenues of discussion. The initial research design for this project planned on conducting several preliminary interviews that would not be included in the final analysis to help correct this possibility, but this option was not pursued due to project time constraints.

4. Literature Review

The literature review involved researching Cleantech innovation and related concepts. There are several definitions for Cleantech as well as several commonly used synonyms for the term. Academic databases were searched using terms such as "cleantech," "innovation," "eco-innovations," "determinants/drivers of eco-innovation," "environmental technologies" and "low carbon technology." More recent studies were given priority over older research however certain older studies are included due to their importance in this field. The first concept covered is the Porter Hypothesis, which stipulates that strict environmental regulation can induce efficiency and innovation in new technologies in order to improve competitiveness. The literature review then discusses innovation theory and its relation to Cleantech. Finally the literature review covers the various policy tools available to support Cleantech innovation and discusses which tools, if any, have been found to be more successful than others.

4.1. Porter Hypothesis

There is no consensus amongst researchers on what innovation policies are best suited to induce success in the Cleantech sector. The Porter Hypothesis posits that strict environmental regulations can induce innovation in new environmental technologies (Porter and van der Linde, 1995; Wagner, 2003; Lanoie, Laurent-Luchetti, Johnstone and Ambec, 2011). Jaffe and Palmer (1997, p. 610) expanded the Porter Hypothesis to include three versions. The "narrow" version of the Porter Hypothesis claims that market-based instruments, such as emissions taxes or tradable permits, are better at creating incentives for innovation than are more prescriptive regulations like technology standards. The "strong" version of the Porter Hypothesis states that well-designed environmental regulations may, in some cases, induce cost-saving innovations that more than offset the cost of compliance with the regulations leading to increased profitability. In this instance, firms undertaking these innovations would enjoy a first mover advantage over other firms that resisted making environmental upgrades and would also see cost reductions from a more efficient use of inputs such as energy and raw materials. This would lead to a "double dividend" of environmental benefits and increased corporate profitability. Research done on the "strong" version of the Porter Hypothesis has failed to find evidence that well-designed environmental regulations will lead to both an improvement of a firm's environmental impact and its competitiveness. Firms have been seen to offset their costs of compliance with more efficient technologies, but these offsets are not sufficient to cover the total cost of regulatory compliance (Lanoie et al., 2011, p. 835).

The "weak" version of the Porter Hypothesis simply claims that strict and well-designed environmental regulation enhances innovative activity for environmental products, but makes no claim about this specifically benefiting the regulated firms. There is significant evidence to support the "weak" version of the Porter Hypothesis and its theory that well-designed environmental regulations lead to environmental innovations. As for the "narrow" version of the Porter Hypothesis, there is disagreement amongst researchers about what instruments are the most cost-

effective at inducing Cleantech innovation (Popp, 2006; Lanoie et al., 2011; Ambec, Cohen, Elgie, & Lanoie, 2013, p. 9).

4.2. Innovation

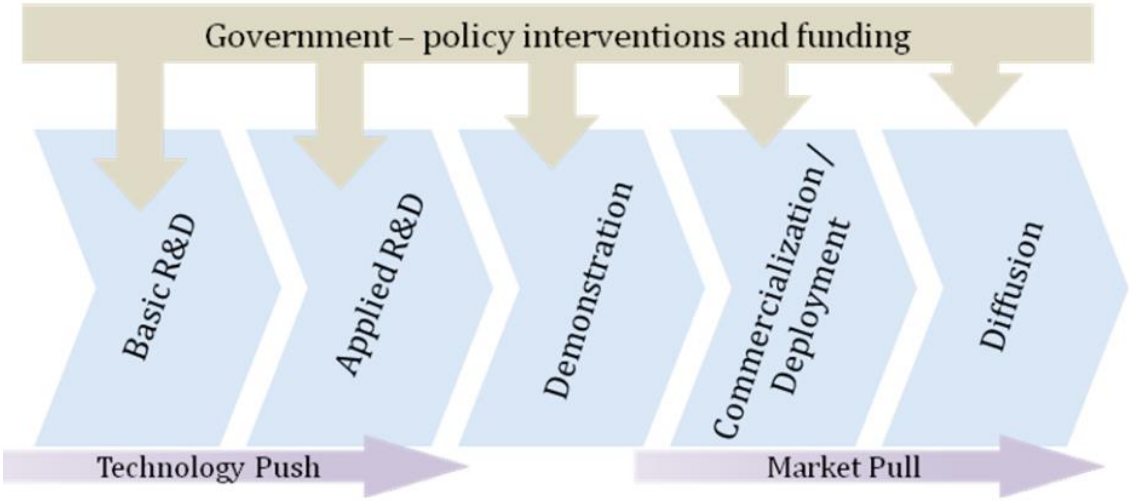
4.2.1. Models of Innovation

There are various definitions of innovation in general and in reference to Cleantech specifically. Cleantech innovation, or eco-innovation, can involve new technologies, new production processes, or simply more efficient administrative protocols. The definition used here will be the definition proposed by Kemp and Pearson:

> "Eco-innovation is the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organisation (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives (2007, p. 7)."

Traditional innovation policy is seen as a linear model in which inventions proceed along a fixed course, impelled by technology development forces in the early stages and with market demand pulling the invention through to full commercial deployment and diffusion into the market. In this traditional model, shown in Figure 1, policy makers play a large role in the opening phases of development, where they provide research infrastructure and grant funding for tech start-ups, but a decreasing role as the company nears commercial deployment (Tawney, Almendra, Torres, and Weischer, 2011, p. 23).

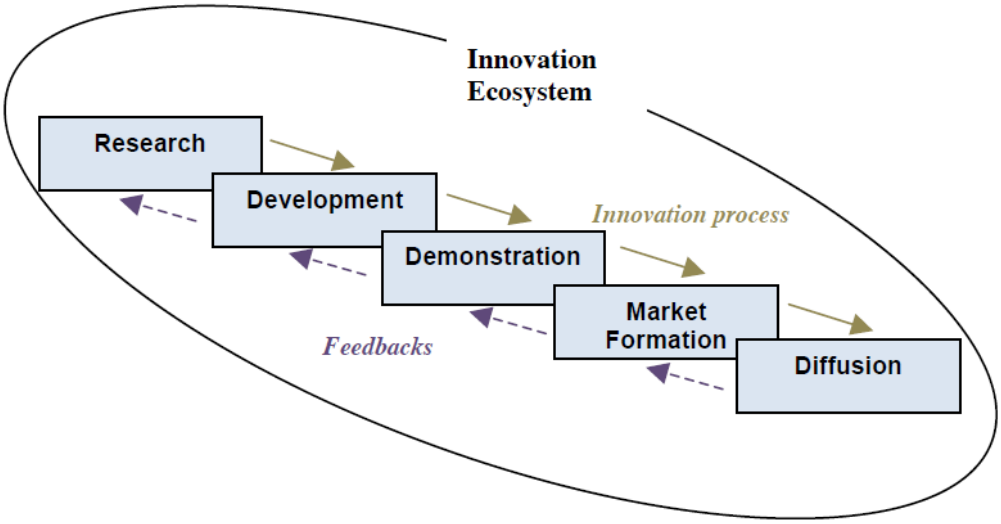
Figure 1 - The Linear Innovation Model



(Source: Tawney, et al., 2011)

An alternative to the linear model is an iterative model, in which innovation is not seen as a straight forward progression to a final goal, but as a circular process that is constantly adapting its progress based on feedback and re-evaluation. This iterative model more closely resembles the innovation process for Cleantech in the real world because it captures some of the uncertainty and complexity that is experienced by stakeholders. Policy makers in this iterative model remain as participants throughout the process, not only serving to provide research infrastructure in the opening phases, but also in financing, regulatory development, and market creation in later phases (Tawney et al., 2011, p. 23). The iterative model is becoming more widely adopted, as is seen by its use by the IEA in its annual Energy Technology Perspectives report (2016*b*).

Figure 2 - The Iterative Innovation Model



(Source: Tawney et al., 2011)

4.2.2. Behaviour of Innovative Firms

Horbach, Rammer, and Rennings (2012) identify several factors that influence a Cleantech firm's decision to innovate. Some of these factors are separate from regulatory choices discussed in the Porter Hypothesis. A firm's proximity to knowledge infrastructure is considered a main driver to R&D investment (p. 114). Firms also identified expected future regulations as being equally important as current regulations (p. 115). Regulations, such as energy efficiency or emission standards, are observed to have a high degree of importance for Cleantech innovations, more so than for innovation in other sectors (p. 117).

New innovations in Cleantech face different driving influences stemming from different stakeholders in the process. Erzurumlu and Erzurumlu (2013) categorize innovation drivers for

Cleantech firms into three categories: operations (supply) side on the part of the firm; marketing (demand) side drivers from the consumer; and regulatory drivers on the part of the government (p. 101). According to Erzurumlu, the regulatory drivers that have the most beneficial impact on the development of Cleantech are defined as price-setting activities, low entry barriers to the sector, and regulatory certainty. Cleantech development progresses best in regulatory environments characterized by price-settings regulations, such as carbon pricing, low economic barriers to entry, such as through state-sponsored financial support and subsidies, and through regulatory certainty, such as through setting long-term policy goals and establishing clear regulations sooner rather than later (p. 104).

4.2.3. Market Failures

When dealing with environmental technologies, there are two market failures that cause companies to hold back potential funding from R&D activities. The first market failure is the problem of "environmental externalities." Since the cost of pollution is passed on to third parties, both in time and geography, firms have no incentive to reduce these costs as they are not impacted by them. The second market failure is the "knowledge as a public good" nature of R&D spending. Discoveries that are made by companies may benefit society as a whole, and as such the innovating firms are not able to capture all the benefits of their innovation investment. Firms are essentially giving away their resources for the benefit of others in society. While some firms may act philanthropically and choose to donate their resources for the good of society, many others will follow their own self-interest and under-invest in technologies that they cannot profit from (Popp, 2006, p. 1).

4.3. Policy Tools

4.3.1. Emission Trading Systems

There are many policy tools available to governments to help induce Cleantech innovation, but there is a lack of agreement on the part of researchers as to which policy tools are most effective. The "narrow" version of the Porter Hypothesis suggests that market-based instruments, such as carbon taxes and emission trading schemes, are superior to regulatory instruments due to their flexibility, which allows firms to choose the path that is most cost-effective for them (Jaffe and Palmer, 1997, p.610). Calel and Dechezlepretre, in a study using survey data from more than 3,000 regulated firms in Europe, found that the European Emission Trading Scheme (EU-ETS) had a significant positive impact on Cleantech innovation for regulated firms (2016). This study compared EU-ETS firms against similar firms that were not covered under the same system. This made no comparisons between the tradable permit scheme and other potential policy options. The study found that firms preferred to make their emission reduction targets by using the lowest-cost compliance methods available, such as fuel switching (using less emission intensive fuel such as natural gas instead of coal) or by using technology that was already in commercial use but had previously been too expensive to invest in (p. 176).

The United States introduced a permit trading system for sulphur dioxide (SO2) emissions in 1995 for coal fired power plants. Taylor, Rubin and Hounshell (2005) examined this system to compare the impact of the trading scheme on innovation when compared against performance-based technological standards. The researchers found that the permit trading system created by the 1990 Clean Air Act (CAA), although widely considered to have been successful at reducing SO2 emissions, was significantly less effective at inducing innovation than the environmental regulations in the decades preceding the act. They found that the regulatory "demand-pull" of stringent environmental performance standards, when combined with the "technology-push" of government support for R&D efforts, was more effective than the market-based approach that incentivised emission reductions (p. 370). As discussed by other researchers (Acemoglu, Akcigit, Hanley and Kerr, 2016; Calel and Dechezlepretre, 2016; Belis-Bergouignan, Oltra, and Saint Jean, 2004), market based approaches encourage a least-cost method for emission compliance that discourages more expensive and risky technologies that require significant capital investments and long lead times.

4.3.2. Carbon Taxes

An econometric study by Acemoglu et al. (2016) compared carbon taxes against a policy using R&D subsidies to induce Cleantech innovation (p. 53). Their econometric model found that the optimal system started with high subsidies/low carbon taxes and progressed to a low subsidy/high tax policy. The authors found that a low carbon price in the initial years was not sufficient to overcome a cost-effectiveness gap for new technologies and that R&D subsidies were needed to induce innovation, which would thereby make innovations more cost-effective in later years and allow a carbon tax to induce innovation and adaptation (p. 87). The model showed that utilizing only carbon taxes to keep a global temperature increase to less than 2°C had significantly higher social welfare costs. The high carbon tax required to motivate innovation would be too expensive for society and result in a net welfare loss compared to an optimal policy. The optimal policy of initially high subsidies and low carbon taxes, progressing to a system of low subsidies and high carbon taxes, was found to be preferred across a wide range of variables and discount rates. Such a policy mix would spur innovation in the early years of the system due to its high R&D subsidies, and then spur deployment through the use of increasing carbon taxes (p. 101).

In a different econometric study, Popp (2006) created a model that compared the outputs of carbon taxes and R&D subsidies, both individually and combined, against the business-as-usual scenario to determine the impacts on carbon emissions and innovation. Government funded R&D subsidies help correct for the knowledge as a public good market failure, as the public will partly pay for and receive the benefits of Cleantech research. Placing a price on carbon addresses the externality market failure, as it creates a financial cost associated with emissions and thereby gives an incentive to adopt more efficient technologies (p. 313). The study concluded that R&D spending, whether combined with carbon taxes or on their own, had significant positive results for technology innovation. Scenarios that employed only carbon taxes also saw innovation improvements, but less than a policy scenario that combined both options. When comparing the

innovation results of each policy in isolation, either a carbon tax or R&D subsidies, the subsidies provided much better results for innovation in the long-run. What was clear in all scenarios was that R&D subsidies had relatively little impact on emission reductions compared to carbon taxes. Emission reductions occurred from the impetus of a carbon price that forced firms to adopt new technology. Simply creating new or more efficient technologies was not sufficient to motivate firms to adopt these new technologies (p. 335). Popp also concludes that, in the absence of a carbon tax, the limitations of R&D will make it unlikely that innovation alone will create significant emission reductions (p. 336).

4.3.3. Technology Regulations and Standards

Montero (2001) found that technology standards enforced through direct regulations were more effective at inducing innovation than a system of tradable or auctioned emission permits. Montero's paper presented a possible explanation for this advantage of regulations over permits. Under an emission permit scheme, firms that invest in innovation sell their excess permits onto the market, thereby reducing the price of permits for their competitors and their compliance costs. In this case, the benefits to the innovative firm are reduced due to the lowering of their competitor's costs, thereby allowing the rival firm to increase output and maintain market share. Alternatively, a firm that innovates due to technological regulations does not share its benefits with its rivals. The compliant firm is then able to increase its market share without reducing its competitor's costs (p. 40).

The preference of regulations over market-based approaches is also found in Kemp and Pontoglio (2011). These authors concluded that market-based instruments do not live up to the theoretical expectations that they are preferable to other policy options for inducing innovation, and that there is no meaningful way to rank the various policy options that can be used to induce Cleantech innovation. The paper finds that at best, market-based policies are useful for non-innovative or marginally innovative changes. Their conclusions go on to state that regulations show more evidence of stimulating radical innovation than market-based instruments (p. 34).

4.3.4. Financial Instruments

One aspect of Cleantech innovation that is brought up by policy makers, innovators, and academics is the role that financial constraints play in limiting the growth and success of innovation; however the present state of research on this topic is very limited. A literature review done by Johnson and Lybecker (2012) found that academic literature on financing in relation to Cleantech innovation was "virtually non-existent" (p. 1). What studies have been done seem to indicate that different stages of the innovation life-cycle are best served with separate policies for support. Products early in the development cycle seem to benefit from technology-push policies, as well as direct government funding for fundamental R&D that may not have immediate commercial application.

Later in the development cycle, funding to support market opportunities become more important for attracting financing for Cleantech R&D projects (p. 2).

One area that government has typically tried to financially support Cleantech ventures is through backstopping VC funds that invest in Cleantech start-up companies. A recent working paper from the MIT Energy Initiative suggests that VC may not be the appropriate source of finance capital for Cleantech ventures due to the long timelines required for product development in this area (Gaddy, Sivaram, & O'Sullivan, 2016). The paper compares VC Cleantech investments to those of medical and software technology companies to examine which sector had the best returns for VC investors. Cleantech has had a dismal rate of return between the years of 2006-2011, significantly underperforming the other sectors. Over the course of these years, VC investors lost more than half of the USD 25 billion that they had invested. The end result has been that appetite for new investments in this sector has dried up significantly, leading to fewer Cleantech companies being created. The paper cites four reasons why Cleantech is ill-suited for VC investment firms:

1. Investments were illiquid and tied up capital longer than the 3-5 years that VC firms anticipated, because "working out the kinks in science is time consuming";
2. Cleantech enterprises are very expensive to scale-up;
3. They are competing in commodity markets with razor thin margins, facing well-established incumbents;
4. And finally because expected acquirers such as utilities and industrial giants are unwilling to invest in risky start-ups with uncertain growth prospects (p. 9).

The paper concludes that Cleantech needs "patient capital" that will invest early and accept long timelines before realizing a return on their investment. Sources of such patient capital could come from pension funds, sovereign wealth funds, and family investment offices that are often willing to wait long periods of time before obtaining a return on investment, but are inexperienced in technological innovation. Using such patient capital, and utilizing government support such as shared research facilities and grant funding, can postpone the need for companies to take on VC financing and thereby bring the product development timeline to within the 3-5 year timeframe expected by these investors (p. 12).

Ghisetti, Mazzanti, Mancinelli, & Zoli (2015) found in their study that small and medium sized enterprises (SMEs) faced higher financial barriers than large firms who often have better access to long-term capital and more developed human capital. Small firms in particular perceive financial barriers as a deterrent to investing in Cleantech innovation. Financial institutions are often hesitant to loan to SMEs involved in Cleantech due to the long time frames involved in Cleantech investments (p. 13). The authors concluded that properly designed policy could stimulate financial institutions to increase their exposure to green investments by altering the risk/return ratio so that the benefits either become worth the long-term wait, or are realized in a shorter time frame (p. 15).

Pinget, Boquet, and Mothe (2015) conducted a study of SMEs in France engaged in Cleantech innovation to analyse the barriers these firms faced in their activities. The study concluded that, when compared to firms engaged in conventional technology innovation or no innovation at all, Cleantech SMEs faced higher barriers accessing financing, finding market opportunities for their products, and in sourcing the required knowledge capital and skilled labour for their activities (p. 138, 147-148). The literature on financial barriers to Cleantech innovation, and on the policy tools used to reduce those barriers, is still nascent and under-developed. As such, there is little or no ex-post analysis of public policy tools that have been introduced to address financial barriers facing Cleantech innovation.

4.3.4. Knowledge Networks and Public Research Infrastructure

The role of knowledge networks in the development of Cleantech innovations has been widely discussed and is considered by many authors to be a powerful determinant of Cleantech innovation (Pinget et. al, 2015; Díaz-García, González-Moreno, & Sáez-Martínez, 2015). Horbach (2014, p.34) observed that Cleantech innovations have a higher dependence on external knowledge sources, such as universities and research centres, compared to other types of innovation. Ghisetti, et. al (2015) support this position, stating that "the complexity and the multiplicity of capabilities required by EI [Eco Innovation] (e.g. technological, organization and institutional) make the eco-innovator even more reliant on numerous, external knowledge sources and on repeated interaction over time (p. 8)".

A common form of organization for publicly financed research is the "Triple Helix" structure (Etzkowitz, 2003). In this type of structure, government, industry, and academia form a three-way partnership in order to advance research and innovation. The Triple Helix differs from two previous paradigms that were structured either around statist, top-down approaches where government directed the actions of Academia and Industry, or laissez-faire approaches that saw each sector operating independently and without interaction. Under a Triple-Helix paradigm, each stakeholder takes on attributes of the other partners, while still maintaining their fundamental functions. Universities maintain their roles of knowledge dissemination and discovery, while also taking on business and governance functions. Industry remains the source of productive activity, while also playing a bigger role in research and in higher-level training. Governments continue their function of providing rules of the game, but also begin providing start-up capital and other financing services to help company start-ups and other commercialization activities (Etzkowitz, 2003, p. 309). The Triple Helix approach has become common in many countries of the world and examples can be found in the United States and in Scandinavian countries such as Denmark.

4.4. Conclusions

Research into Cleantech policies has repeatedly shown that environmental policies can have a positive impact on Cleantech innovation. Contrary to early theories on Cleantech innovation,

market-based instruments such as carbon taxes and tradable permits do not seem to be superior to other forms of policy support, such as R&D grant funding and enforced technology standards. While still having a positive influence on Cleantech innovation, market-based instruments seem to lag behind other forms of innovation support. This is due to emitting firms choosing to use less risky and cheaper methods of reducing emissions, such as fuel switching or using already available technology. Market-based instruments are, however, superior policy instruments for reducing GHG emissions. There is general agreement in this field that a well-balanced policy approach, using a variety of instruments, is needed to address climate change. The research done in this literature review supports these findings. Financial barriers to Cleantech innovation have been recognized as a limiting factor for firms looking to innovate, and one that government can play a supportive role in addressing, but at present there is little research to judge the effectiveness of different policy tools intended to help reduce these financial barriers. The presence of official and unofficial knowledge networks in close proximity to Cleantech firms has also been identified as an important factor in the growth of these firms.

5. Smart Practices Scan

This project will utilize a smart practices scan, examining the Cleantech policies of nearby jurisdictions such as Washington State and Oregon, as well as national governments that have been identified internationally as leaders in Cleantech innovation. A smart practice scan, also known as a "best" practice scan, is an attempt to examine the successful practices of other jurisdictions and to assess whether they are applicable in a different context (Bardach, 2009, p. 95). The jurisdictions to be included were decided partly on from suggestions from the client (Washington State), partly on jurisdictions that are seen as leaders in Cleantech development, such as Sweden, Denmark, and the United States federal government, and partly on findings from the participant interviews such as selected Government of Canada programs. The choice of these jurisdictions was determined by several criteria. Firstly, the chosen governments were those that are recognized as international leaders in using Cleantech policy to further innovation in the sector. Recognition here was assessed through international organizations that release regular reports on Cleantech innovation, such as the Cleantech Group, the EU based Eco Innovation Observatory, CleanEdge, and the OECD. Secondly, jurisdictions were selected based on the comparability of their economies to BC. Oregon and Washington State were chosen due to their proximity to BC, their similarity in economic factors, and in their success relative to other US jurisdictions in the field of Cleantech innovation (CleanEdge, 2016). Three programs offered the Government of Canada will also be discussed, as these programs were repeatedly brought up by different interview participants.

5.1. Sweden

Sweden has been recognized by several international institutions as being a leader in Cleantech development and deployment. The Global Cleantech Innovation Index 2014 ranked Sweden 4th overall for Cleantech innovation activities, 1st in General Innovation Drivers, and 4th in the Evidence of Emerging Cleantech category (Cleantech group, 2014). Sweden has adopted what it calls a "generational goal," in which "the objective is to pass on to the next generation a society in which the major environmental problems have been solved, without causing environmental and health problems beyond Sweden's borders" (Jansson, 2015, p. 2). For the past several years, the Eco-Innovation Observatory has ranked Sweden amongst the top Europe countries in the categories of: total R&D personnel and researchers; government environmental and energy R&D appropriations and outlays; eco-innovation patents; and eco-innovation-related publications (p. 5-7). Sweden struggles in other categories such as resource efficiency outcomes, possibly due to higher energy usage stemming from its colder northern winters, and socioeconomic outcomes such as exports of products from eco-innovation industries (p. 7-8). Sweden enjoys the lowest GHG emission intensity in Europe, thanks to 97% of its electricity being produced from low CO2 emission sources such as its nine nuclear reactors (p. 7). Compared to other countries, Sweden has struggled with its ability to turn its high outputs of Cleantech R&D into commercially successful products and companies (p. 8). Sweden has begun several initiatives to improve its commercialization of Cleantech research,

such as its single web portal for Cleantech information and its creation of an export promotion and consultation department, known as Team Sweden (p. 20).

Sweden has several government agencies that conduct research in Cleantech sectors. These agencies all combine government, industry, and academic funding to pursue research carried out in collaborations between post-secondary institutions and industry professionals. There are a total of 25 government agencies involved in meeting the government's aggressive environmental goals. Some of the major research agencies include the Swedish Energy Agency, the Swedish Environmental Research Institute, the Swedish Environmental Protection Agency, and the Swedish innovation agency known as Vinnova (Jansson, 2015, p. 18). In order to help stakeholders navigate the various agencies and programs involved in the Swedish Cleantech sector, the Swedish government in 2013 launched a web portal at www.SwedishCleantech.se. The goal of this website is to help Cleantech companies find funding opportunities through public sources, private loans, and VC investors, as well as provide consultation services. The website also serves as an index of Cleantech companies for potential investors and companies. In addition to this website, a national eco-coordinator was appointed in 2015 to help strengthen coordination between the various stakeholders in order better improve Swedish environmental outcomes (p. 20).

The Swedish Energy Agency offers loans to Cleantech companies that are in the commercial and pre-commercial phase. Conditional Loans to companies in the pre-commercial phase are interest free until they begin generating revenue and carry an interest rate of prime + 6%. Growth Loans are given to companies looking to scale-up their operations and achieve market growth. They have an interest rate of prime + 6%, are awarded in amounts up to EUR 1 million, and begin accruing interest three months after the loan date (Swedish Energy Agency, 2014, p. 5).

Team Sweden is an initiative by the Swedish government that intends to serve as a forum for dialogue between government and the industry, with the aim of improving Swedish exports. There will be a sub-group for both environmental technology and for energy (Jansson, 2015, p.20). Team Sweden will provide guidance, financing, marketing and consultation to Swedish firms that are looking to export their goods around the world (Government Offices of Sweden, 2016).

Swedish universities provide research infrastructure and facilities to companies that want to form research partnerships in many areas of sciences. The KTH Royal Institute of Technology (Kungliga Tekniska Högskolan) has several research institutes that offer services for companies wishing to collaborate on Cleantech research. The Hammarby Sjöstadsverk research facility offers services to companies and researchers focused on water and wastewater treatment, providing facilities for research, product development and demonstration. KTH also offers a Solar Facilities lab and the recently founded KTH Centre for Sustainable Built Environment activities (Hammarby Sjöstadsverk, n.d., Jan 17, 2017).

Sweden instituted a carbon tax in 1991 in order to help reduce GHG emissions. While the price of the tax seems high at USD 150/tCO2*e*, the tax has a very narrow scope. The electricity sector is not covered by this tax, and the industrial sector is only taxed at 50% of the overall rate. The sectors

most impacted by the carbon tax are the transportation sector and the heating sector. Swedish cities make widespread use of district heating and these have historically been run on fuel-oil and other fossil fuels. Since the creation of the carbon tax, district heating suppliers have significantly increased their use of biomass fuel such as forestry waste products and peat-fuel. These fuels are considered renewable energy sources and are exempt from the carbon tax (Johansson, 2000, p. 4, 6). Sweden also participates in the EU-ETS (World Bank, n.d.).

Sweden has a type of Renewable Portfolio Standard (RPS) that it calls an Electricity Certificate Program and is a joint program with Norway. Under this program, electricity producers in Norway and Sweden will be responsible for meeting a set amount of renewable energy production quotas in a given year. Excess renewable energy may be sold to other firms as certificates, who may in turn use these certificates to meet their quota obligations (IEA, 2016*c*).

5.2. Denmark

The Eco-Innovation Observatory ranked Denmark first among 28 EU countries in 2015 for eco-innovation (Varga, 2015). Denmark has not finished less than 4th since 2010 and in 2015 received very high marks in the category of eco-innovation inputs, which is measured by government spending on R&D, number of personnel employed in energy R&D, and the total value of early stage green investments (p. 4). Denmark also performed very well in terms of eco-innovation outputs, measured by environmental patents, research publications per capita (p. 6), and in exports of products from eco-industries (p. 8).

The Danish government has numerous agencies that are intended to help fund, research, and promote Danish Cleantech activities. The major agencies include the Danish Eco-Innovation Program, the Innovation Network for Environmental Technologies, the Green Development and Demonstration Programme, the Energy Technology Development and Demonstration Program, the PSO-programs, the Innovation Fund Denmark, the Danish Green Investment Fund, the Danish Growth Fund (Vaekstfonden), the Market Development Fund, and the Green Labs initiative. These agencies serve a variety of functions and most of them cover more than one phase of the product innovation cycle. Agencies such as the Danish Eco-Innovation Program focus on the applied or fundamental stage of innovation. The Energy Technology Development and Demonstration program supports innovations that are at or near the demonstration phase. The various public investment funds are intended to support innovations that are close to being commercially viable. Programs such as the Market Development Fund are intended to increase export growth for Danish companies. These programs span the innovation cycle from fundamental R&D, to product demonstration and testing, to full commercialization and export development support (Varga, 2015, p. 19-24).

The Danish Green Investment Fund (Danmarks Grønne Investeringsfond) is an independent state loan fund established in 2014 to co-finance projects in the areas of environmental savings,

renewable energy production, and resource efficiency. The fund offers Green Loans in conjunction with private financial institutions for companies looking to deploy and scale up their Cleantech operations. Loans are intended for projects that are commercially viable, helping to bridge the gap between the demonstration phase and full commercialization (Danish Green Investment Fund, n.d.).

The Danish Growth Fund (Vaekstfonden) is an independent investment fund owned by the Danish state. Its objective is to promote growth of small and medium sized companies to facility greater socio-economic returns. While it is not focused on Cleantech specifically, Cleantech companies are able to access these programs and benefit from them. Two programs of particular interest are the Business Loans program and the Guarantee program. The Growth fund offers loans to companies looking to expand their operations and move into new markets, as well as to invest in more efficient operations. Loans must be part of a complete financial solution that includes financial support from other institutions, and an emphasis is placed on providing financing to companies that do not have enough collateral to receive full funding from a bank. The Guarantee program offers to insure loans and credits of up to DKK 2 million from other financial institutions, to a maximum of 75% of the total amount. The program works in conjunction with other collateral that the company has offered for the financial loan. The program is intended for small and medium businesses and charges a rate of 1.5% of the total financing amount for a period of up to 10 years (The Danish Growth Fund, n.d.).

Denmark has an established network of publicly available test and demonstration facilities for Cleantech R&D. Denmark is particularly renowned for work in developing wind turbines and in this area it has eight facilities that companies can use to test and demonstrate their technologies. The Danish website megavind.windpower.org offers a current list of test facilities for wind power across the globe, along with contact information for these facilities. The Megavind organization also serves as a portal for funding opportunities from different government agencies and publishes research and analysis reports free of charge (Megavind, n.d., Dec 12, 2017).

GHG emissions in Denmark are given a price via two methods, the EU-ETS and a domestic carbon tax. Denmark instituted a carbon tax in 1992 and has made changes to it several times since then. In 2014 the tax equalled USD 31/tCO2*e* and covered all fossil fuels types. Some sectors are given partial exemptions or refunds if they are simultaneously covered under the EU-ETS. Fossil fuels used for electricity generation are not taxed on their carbon, however there is a tax on electricity production in general (World Bank, n.d.).

5.3. Washington State

Washington State has been recognized as one of the leading US states for Cleantech development (Clean Edge, 2016). It has many environmental and economic conditions in common with BC and as such there are lessons to be learned from their experience. Like BC, Washington State has a historical legacy of cheap and abundant hydroelectricity that makes it difficult for newer, more expensive forms of renewable electricity to be competitive. The two regions share other features

such as strong post-secondary institutions clustered in a single region, a mature forestry industry that has made use of bio-energy for years, and a small domestic consumer market that would lead successful industries to be export oriented.

Washington State uses a variety of deployment oriented policies to encourage Cleantech adoption amongst residential and commercial users. These include financial incentives such as grants for home owners that upgrade their energy efficiency, grants for consumers and businesses to install solar energy panels, tax rebates for manufacturers of solar technologies, and sales tax exemptions for users of renewable energy. Washington also has regulatory policies such as those requiring utilities to offer net metering for customers who produce excess electricity through private renewable energy sources, technology standards for new homes and appliances, and an RPS. This RPS has a mandate that by 2020, all electrical utilities must source 15% of their electricity from renewable sources such as wind, solar, geothermal, tidal, and others (Database of State Incentives for Renewables & Efficiency [DSIRE], n.d.).

Washington State created a Clean Energy Fund (CEF) in 2013 to help finance clean energy development in the state. Between the years of 2013-2017, the state has appropriated $76 million to fund a variety of programs including Energy Revolving Loan Fund Grants, Smart Grid Grants to Utilities, Federal Grant Matching Funds, Grid Modernization Grants to Utilities, Research Matching Fund Grants, and Credit Enhancement Grants. These funds are expected to leverage more than $200 million in matching funds from industry partners (Washington State Department of Commerce, 2016a).

Two CEF programs of interest are the Research, Development and Demonstration (RD&D) Match Program, and the Renewable Energy Manufacturing Program. The RD&D Match Program offers grant funding for clean energy projects that are at the demonstration or pre-commercial phase of development. Applicants must have non-State partners who will provide a minimum of 50% of the project funding. Projects must have an expected lifespan of 13+ years and be located within Washington State. The 3rd round of solicitations for this project closed on January 13, 2017, and had a potential USD 2.9 million available for disbursement (Washington State Department of Commerce, 2016b).

The Renewable Energy Manufacturing Program is offered by the Washington Department of Commerce in partnership with the Washington Economic Development Finance Authority (WEDFA). The program is intended to provide subsidized loans to companies that are looking to establish renewable energy manufacturing facilities or maintenance facilities to be used in conjunction with large renewable energy projects in Washington State. The program has two components. First, the WEDFA creates tax-exempt bonds that can be purchased by financial institutions (the purchaser), with the proceeds going to a clean energy project (the borrower). Because the bond is tax-exempt for amounts up to USD 10 million, it is expected that the financial institutions will offer a lower interest rate in return. The borrower of these funds is required to repay the bond and remain in good standing with bond repayments. The second part of this program is an Interest Cost Subsidy. This subsidy will involve the WEDFA reimbursing the

borrower up to 80% of the interest due on the qualifying loan. The effect of this program is ultimately to make it less risky for financial institutions to lend money to Cleantech companies, as the reduced income tax on the loans make them more profitable and thereby create a higher safety margin for the expenditure, and to reduce the cost for Cleantech companies to borrow money by subsidizing their interest payments (Washington Economic Development Finance Authority, n.d.).

Washington State has 10 Centers of Excellence that are located on post-secondary campuses and these have four focus areas: Economic Development; Industry Sector Strategy; Education, Innovation and Efficiency; and Workforce Supply and Demand. These centers issue project grants, fund research, and connect industry with academics and policy makers in their respective industries. The Pacific Northwest Center of Excellence for Clean Energy is located on the campus of Centralia College (Washington State Centers of Excellence, 2016). Additionally, the Washington State University and the University of Washington both have science institutes dedicated to Cleantech research. The state is also home to the federally funded Pacific Northwest National Laboratory (PNNL), which conducts research on Science, National Security, Energy and the Environment. One of the many services offered by PNNL is the Technology Assistance program that offers small tech businesses access to advice, consultations, and state-of-the-art research equipment free of charge. Small businesses that use this program may also be eligible for royalty-free licenses for technology developed through this program (Pacific Northwest National Laboratory, 2016).

Washington governor Jay Inslee attempted to introduce a cap-and-trade system in 2014 to reduce carbon emissions within the state, but this legislation failed to pass in 2015. In its place the state has mandated that all large industrial carbon emitters must reduce their emissions by 1.7% annually (Le, 2016).

5.4. Oregon

Much like Washington State, Oregon has been recognized over the past decade as being a leader in Cleantech in the United States (Clean Edge, 2016). Oregon also shares some traits similar to BC, such as the prevalence of hydro-electricity in its electrical grid and the lack of a strong domestic market that results in an export-focused economy. Oregon has a large number of policies in support of Cleantech deployment, which cover both financial incentives and regulatory policies. Financial incentives include various rebate programs for energy efficiency upgrades, personal and business tax credits, loan programs, and development grants. Regulations in support of Cleantech include mandatory net metering requirements for utilities, energy efficiency standards for buildings and appliances, and laws guaranteeing access to solar and wind energy resources for property owners. Oregon does not have a carbon tax or an emission trading system, but does have an RPS that requires large utilities to source 50% of their electricity from eligible renewable energy sources by 2040 (DSIRE, n.d).

The Oregon Built Environment and Sustainable Technologies (Oregon BEST) is a research center that focuses on testing, developing, and commercializing Cleantech opportunities such as solar systems, micro-wind turbines, and built innovations such as green roofs. Oregon BEST collaborates with three Oregon universities and has a network of nine research laboratories, each with a specific focus such as PV solar energy, green buildings, or green infrastructure. Oregon BEST offers not only research opportunities, but also grant funding for projects, commercialization funding for Cleantech start-up companies, industry access to seven research laboratories, and networking services that allow potential investors to learn more about Oregon BEST companies and explore financing agreements (Oregon BEST, n.d.).

The Energy Trust of Oregon is an independent and non-profit organization mandated to help provide cost-effective clean energy solutions. It was created by the Oregon legislature in 2002 and is funded by a 3% levy charged to customers of four Oregon utility companies. The Trust reports to the Oregon Public Utility Commission. The Energy Trust operates by offering rebates and incentives to residential, commercial, and industrial customers to increase their energy efficiency and increase their usage of renewable energy sources. The Trust claims to have contributed $4.8 billion to the state economy and created more than 3,900 fulltime jobs. The Trust is focused on the deployment stage of product innovation and is not directly involved in R&D activities (Energy Trust of Oregon, n.d.).

5.5. United States Department of Energy

There are numerous programs throughout the United States, both federally and by individual states, intended to support Cleantech development and deployment but there are two programs at the US DOE that have been particularly successful. These programs are the Advanced Research Projects Agency-Energy (ARPA-E) and the Loan Programs Office (LPO). Recent changes in the US federal government may herald changes coming to these programs in the future, but any changes to these programs should not detract from the success they have achieved since their inception.

ARPA-E was created in 2009 with the intention of funding energy research in technology areas that were high risk and high reward in nature. The agency provides grant funding to companies engaging in applied research that are not yet in the commercial phase of their development, but past the concept or basic research phase. In the first 7 years of operation, ARPA-E provided more than USD 1.3 billion in funding to more than 475 projects. 36 of these projects have thus far started their own companies, 60 projects have continued their development through other government support, and 45 project teams have together attracted more than USD 1.25 billion worth of financing from private investors to bring their innovations to market. The agency invests in 30 different programs across four Cleantech subsectors: electricity generation; electrical grid and storage; efficiency and emissions; and transportation and fuel storage (ARPA-E, 2016).

The LPO operates a loan guarantee program whereby the federal government will guarantee commercial loans that are awarded to companies engaged in clean energy technology and advanced vehicle manufacturing for zero-emission vehicles. The program is designed to reduce the risk associated with deploying experimental technology for the first time and helps to fill the financing gap between RD&D activities and full commercial deployment and maturity. The LPO can guarantee up to 80% of eligible project costs but encourages companies to seek other co-financing opportunities in order to reduce this share (US DOE, n.d.). A report released in October of 2014 stated that the LPO had a loan loss ratio of around 2%, or USD 780 million. In the same period, the program received USD 810 million in interest payments from its loans, resulting in an overall net gain. The program committed more than USD 30 billion in loans, guarantees, and commitments and leveraged more than USD 50 billion of private sector financing for LPO projects (US DOE, 2014, p. 3-4).

5.6. Government of Canada

The Government of Canada has numerous programs intended to support Cleantech development in Canada, but only three programs will be discussed here as they are the most strongly related to the research findings of this report.

Sustainable Development Technologies Canada (SDTC) is an arms-length government program that provides funding, coaching, and networking to Canadian Cleantech companies. SDTC specifically tries to help companies overcome the "valley of death" between product demonstration and commercial deployment. The organization currently has more than $928 million invested in 320 projects, leveraging approximately $2.45 billion from private sector investors into Canadian Cleantech companies. SDTC has a mandate that explicitly directs it to accept high risk investments that other financial institutions are not willing to accept. Programs are divided into five different funds: the SD Tech Fund; the SD Natural Gas Fund; the NextGen Biofuels Fund; the SDTC Joint Fund with the Climate Change and Emissions Management Corporation (CCEMC); and the SDTC Joint Fund with Alberta Innovates Energy and Environment Solutions (AI-EES). These last two programs are joint ventures with the Government of Alberta. Programs cover a broad range of Cleantech fields including renewable energy, water treatment, energy efficiency, bio-products, and cleaner natural gas (SDTC, Jan 19, 2017).

The National Research Council of Canada Industrial Research Assistance Program (IRAP) provides technical assistance to Canadian SMEs through the entire innovation life-cycle, from start-up to commercialization. The program, which applies to all technology sectors and is not Cleantech specific, provides funding for innovation projects and youth employment, networking resources and advisory services. Advisory services are provided through Industrial Technology Advisors (ITA) that are located in offices across the country. These ITAs maintain working relationships with IRAP firms and help them grow their business, network with investors and potential partners, and gain access to government funding opportunities (IRAP, n.d.). IRAP also runs the Concierge service that provides a single point of entry for SMEs looking to find programs that can help them conduct

R&D or commercialize their innovation. The Concierge service allows users to search across Canada to find various funding opportunities and includes most federal government programs as well as those offered by the provinces. This service also has Industry Advisors located across Canada that are available free of charge to help SMEs grow their innovative businesses and access funding and other opportunities (Concierge, n.d.).

Export Development Canada (EDC) is a self-financing crown corporation that has a mandate to help Canadian SMEs pursue international business opportunities and grow their export potential. The EDC provides financial services to companies that intend to export their products internationally. They achieve this through providing insurance, financing, bonds and guarantees. The EDC can provide direct financing to companies and their customers, project financing, working capital financing, performance bonds that companies may be expected to put up as collateral for large projects, and financial guarantees that would cover loan losses suffered by lending agencies that provide finance for exporting companies (EDC, n.d.).

6. Findings

6.1. Company Profiles

Senior employees from 13 companies were interviewed for this research project. The cohort consisted of nine Chief Executive Officers (CEO), two Vice Presidents/Directors of Business Development, one Chief Technology Officer (CTO) and one participant equivalent to a Chief Operating Officer (COO). The technology areas of these companies were energy efficiency, cogeneration heat and power (CHP), industrial thermal combustion burners, coal fly-ash remediation and processing, hydrogen products, bio-products/energy, geo-exchange heating and cooling, mine wastewater treatment, and nuclear fusion. Hydrogen products were represented by two companies in this research, one involved in production and distribution and the second working on storage mediums and technologies. There were three companies involved with bio-products/energy, each in a different technology field. One company was involved in bio-mass combustion for electrical generation, a second company was involved in using bio-mass to produce high value specialty chemicals, and the third was involved in bio-methane recovery and production from landfill waste.

Nearly the entire cohort reported that their company began operations in BC due primarily to the founders being from the region originally, with only one company stating that they purposefully setup operations in BC in order to be near to an already established technology cluster of companies and research infrastructure. Several companies indicated that there were contributing reasons for continuing business in the Metro Vancouver region such as the proximity to a technology cluster, local networks of researchers and the established Cleantech investment community. Twelve of the 13 interviewed companies stated that their business goals are primarily based around an export model, with only one company reporting that most of their business is in BC.

6.2. Exporting Goals and Challenges

The Cleantech companies that participated in this research had diverse goals for exporting their products to other markets. The US and the rest of Canada were the two most common markets that companies expressed interest in doing business with. This matches what has been observed by other researchers (Analytica Advisors, 2016), that Canadian companies do most of their business in Canada, followed by the US. Six companies identified China as part of their future export goals, however these are typically long-term goals and come with several conditions required to overcome challenges before moving into these markets.

Concerns about IP rights are the most common barrier to exporting the other locations, especially in reference to China. Eight companies specifically stated that they had IP concerns in dealing with

China because it was possible for Chinese firms to simply copy their technology and reproduce domestically. These companies intend to employ several means of dealing with these concerns. Many companies are seeking to partner with either large multinational companies or large domestic Chinese companies who will have a vested interest in defending the IP within the Chinese market. In order to attract these kinds of senior partners, these companies intend to develop their business in safer markets in order to expand their market cap, which will then give them more leverage in developing the strategic partnerships that will be necessary for them to grow into more aggressive markets like China. The second most commonly cited challenge in exporting is a lack of experience in operating in foreign markets, with six companies making this observation. Lack of financing is also seen a challenge that inhibits growth in export markets.

"Going in (to China) and coming out with your shirt on is the tricky thing"

6.3. BC Barriers to Growth

Challenges in acquiring financing were seen as the largest barrier to Cleantech growth in BC. Companies are finding not only that there are few VC funds available to Cleantech projects, but that these funds are very risk-averse. Financial institutions are not interested in investing in Cleantech projects due the risks inherent in Cleantech ventures. Cleantech companies often take 5-10 years to reach commercialization, whereas many investors are only interested in projects that offer a return in 3-5 years. There is also a high degree of technological risk involved in these types of investments. There is the possibility that the technology will fail to deliver expected results, that costs will increase over the life of the project, that a competitor may release a superior product, or that government policy will change over time and significantly impact the success of the business model. These factors combine to create an atmosphere in which financing is expensive for small Cleantech companies, as financial institutions expect a higher rate of return in order to offset the higher risk.

"Natural resources, sure, but as soon as you get into technology, (financing) is much more conservative"

Only one company received financing through the BCRCF. The consensus is that BC needs VC capital that is open to a higher level of risk, a broader range of technology types, and longer time frames in order to assist BC Cleantech companies. The ICE fund has been a source of funding for several companies that were interviewed for this research, but ICE has not held an open Call-for-Applications since 2010. Several companies commented that the ICE fund seems only interested in particular types of technologies and excludes other technology areas. The mandate for ICE covers innovative clean energy, which means it does not include areas such as wastewater treatment, soil remediation and other Cleantech areas not involved in energy production (BC Ministry of Energy and Mines, 2014).

Several companies expressed a need for a loan guarantee program in order to help them develop project financing. These companies have been required to post large bonds or performance guarantees as part of their project contracts. These companies have had difficulty raising these funds due to their small size and limited assets, and in some instances have had to walk away from potential business due to these financial requirements.

6.4. Research Centres

Formal partnerships with universities are common in the Cleantech industry in many locations around the world. Here in BC however, these formal partnerships are few and far between. Only two companies in our research cohort had any kind of formal partnership with universities in BC. Many companies expressed that they made use of informal connections with universities for recruiting employees after graduation, hiring co-op students, and for networking directly with professors. The two primary reasons for not pursuing partnerships were that companies felt the institutions were too expensive to warrant using their facilities, and that concerns regarding IP ownership made collaboration unattractive. Several companies stated that they had no interest in paying large usage fees to develop IP that would then belong to the university. These companies feel it makes more financial sense to conduct their own research at a lower cost and not have to share IP rights or pay licensing fees to the institution.

"We always found the national research centres are extremely academic and very expensive. We can do it ourselves for half as much and it will be a more commercial application"

There is also a feeling amongst many companies that their technology is "not a right fit" for what is being done at these research institutions. Several participants said they felt the research being done at these institutions is primarily academically focused and not aligned with industry problems and goals.

6.5. BC Cleantech Programs Compared to Other Jurisdictions

Companies participating in this research overwhelmingly said that provincial Cleantech programs are difficult to apply for or to find information on. Only one company said that BC programs were easy to navigate, although this company was, by their own admission, not applicable for many of the programs. Many companies stated that it was very difficult to find information about various programs.

Program applications, such as for ICE, were found to be very difficult and unpredictable. There is a lack of communication with stakeholders about the future of the ICE program and Calls-for-

Applications are often released with very short application deadlines. These short application windows have prevented some companies from applying for funding. The ICE program is also structured in a manner that makes many Cleantech companies ineligible for the program. ICE is specifically designed to support renewable energy products and technologies and does not consider other environmental technologies that are being developed in BC. For instance, bio-energy products such as bio-mass combustion projects are eligible for ICE, but bio-products such as high value chemicals made from biological materials are not. There are various Cleantech sectors in BC that are not eligible for ICE, such as soil-remediation, wastewater treatment and others.

"To move the dial on emissions worldwide is not going to be done with what BC is doing"

When asked to compare BC to other regions and how they support the Cleantech industry, several participants felt the Government of Canada did a good job of supporting the industry. Two programs specifically mentioned as being very successful are Sustainable Development Technologies Canada (SDTC) and the National Research Council's Industrial Research Assistance Program (IRAP). Both programs have consultants that are responsible for advising stakeholders and keeping them up-to-date on programs that might benefit them and on application deadlines. These advisors are located across Canada, including offices in BC, and maintain working relationships with BC Cleantech companies in order to help them grow and take advantage of government programs. The provincial government has no equivalent to these positions. One interview participant actually stated that BC does not seem to be interested in working with companies.

"BC is a black hole for finding information on Cleantech programs"

When asked about jurisdictions outside of Canada that succeed in supporting Cleantech development, there was no consensus from the research data. Many jurisdictions were named, but there was no clear winner and the reasons why these locations were considered successful varied greatly. This is likely due to the diverse nature of our cohort, which included many different technology types and companies that are focused on a variety of geographic regions. Energy producing companies favoured policies such as RPS' and deployment incentives, whereas other companies favoured technology forcing regulations such as Zero Emission Vehicle requirements for auto companies or stricter emission regulations for wastewater treatment. One commonality for this question was that successful jurisdictions all take a whole-of-government approach to supporting Cleantech instead of piecemeal policies spread across different government departments.

6.6. Carbon Tax

The BC carbon tax is generally seen by the interviewees as not having a significant positive impact on Cleantech companies in BC. Only two companies that were interviewed stated that the BC

carbon tax has directly benefitted their company, and one of these companies stated that since the price of natural gas has fallen in recent years, the carbon tax no longer has an impact on their business because the cost savings from lower fuel prices have offset the expense of the carbon tax. The 11 other companies all stated that the BC carbon tax, at its current price of $30/tCO2*e*, does not significantly benefit their company. All the respondents agreed in principle with the tax and felt it was an important tool at reducing GHG emissions, but that its current price was too low to impact their business model.

6.7. Scientific Research & Experimental Development

The SR&ED tax credit program applied to 12 of the companies in our research cohort, and all those eligible companies expressed support for the program. Many indicated that SR&ED funding was an essential part of their business plan and allowed them to continue conducting R&D when they otherwise may have shifted funding to other business areas such as marketing and sales. Specific features of the program that are seen as beneficial are the predictable nature of the program that allows companies to budget SR&ED funding into their business plans, and the grant portion of the program that allows them to receive funding before they are generating sales revenue.

"SR&ED has a vital role in small companies thriving. A bad company won't live or die if SR&ED is better, but a good company may live because SR&ED is bigger or better"

One company in our study was not eligible to receive SR&ED support because the company was a publicly traded small-cap company, and the program is only open to Canadian Controlled *Private* Corporations (CCPC). Companies that become publicly traded on a stock exchange lose their SR&ED eligibility. This company expressed frustration at not being able to apply for the program, given that they are a small R&D company that is Canadian controlled and not yet generating net income.

6.8. Carbon Neutral Government Program

Most of the companies involved in this study were not eligible for the Carbon Neutral Government program because their products were not ready for deployment or because their technology was not directly involved in reducing GHG emissions. Of the two companies that were applicable for this program, one stated that the buying price for carbon credits, $8.50/tCO2*e,* was too low to generate significant interest on their part, and the other stated that the application process was written in a "risk-averse manner." This risk aversion makes incumbent technology preferable and makes innovative Cleantech too risky to be considered. "No one ever got fired for buying an IBM" was a comment heard in several interviews, meaning that companies and purchasers could be blamed for the failure of an innovative new product, but that no one gets in trouble for purchasing an accepted incumbent technology.

6.9. SWOT Analysis

Strengths	Opportunities
• BC has several mature Cleantech sectors such as hydrogen products and bio-products. • BC has a strong post-secondary system with world class research institutes. This provides for strong networking opportunities, numerous tech start-ups, and highly skilled researchers. • BC has a highly skilled workforce.	• Large potential markets in the rest of Canada and the US that are easy to access for BC companies. • Large potential Cleantech market in China, despite significant barriers to entry. • Location on the Pacific Rim presents excellent opportunity for overseas trade. • Integrating BC Cleantech programs with Government of Canada programs would simplify the applications processes, help attract federal funding to BC companies, and provide assistance throughout the innovation life-cycle.
Weaknesses	**Threats**
• Risk-averse financial institutions, both private and public. • Poor communication from the BC government about Cleantech programs and their future. • Government support for Cleantech in BC is focused on renewable energy production and neglects non-energy related Cleantech sectors. • University research is academic focused and is not well integrated with industry when compared to other systems around the world.	• Lack of financing, especially expansion capital, results in BC companies being bought out. BC could be limited to being a Cleantech incubator wherein our most successful innovations are acquired and relocated elsewhere. • Stagnant growth at the commercialization phase could result in technology competitors becoming established and dominating the market to the detriment of BC companies and economic growth. • Regulatory changes in trading partners could result in BC companies failing before they become commercially viable. • Over-reliance on the BC carbon tax as a vehicle for innovation may result in political complacency. Additional policies are needed in addition to increasing the price of carbon.

7. Discussion

7.1. Financing

The Cleantech industry in BC faces financial challenges in many forms, with the one common feature being a general risk-aversion amongst financial institutions. The higher level of risk for Cleantech comes from many sources such as regulatory changes, technological challenges, supply chain problems, and uncertain market demand to name a few. An example of this risk can be seen with Endurance Wind Power, a company that received funding from the BCRCF through Yaletown Capital and from the EDC. The company was based out of Surrey, BC and was investing heavily in the UK market for small and medium scale wind turbines. A change of government in the UK brought with it a 65% reduction in the feed-in-tariff for certain energy technologies, which triggered the company into declaring bankruptcy in late 2016 when one of its lenders pulled their financing from the company (Bennett, 2016).

Bankruptcies like this are causing lending agencies to reduce their exposure to high risk Cleantech ventures. Government agencies can help make up the funding gap, but in BC the main vehicle for Cleantech grant funding, the ICE program, has suffered from uncertainty about where its funding will come from due to changes in the tax levy that supported it. The application process for ICE is also considered by some stakeholders to be poorly communicated and too narrow in its eligible technologies.

VC in BC is not only limited in quantity, but has a preference for safer and more predictable business sectors such as Internet Technologies. As one interview participant put it, "there is no adventure in venture capital here in BC." A shortage of VC financing for Cleantech is a common problem across Canada and is not unique to BC. A report by SDTC concluded that Canada has an equity financing environment that is not conducive to the scaling up of independent Cleantech companies in Canada. Most VC investments in Canada are much smaller than comparable investments in the US, and the largest rounds of financing in Canada typically involve foreign investors (SDTC, 2016, p. 26).

"BC has announced a $100 million for the BCTech fund, but it's *impossible* to get. Nobody in [the BC Cleantech] sector is happy about it. Zero probability. What they will do is fund more IT sector, more of what they are already doing"

The BCTech fund will contribute some much needed VC to the BC region, but it is uncertain how much of this $100 million fund will be allocated to Cleantech companies as the fund will be distributed across four technology sectors. A VC fund that had a specific mandate to consider higher-risk Cleantech ventures would significantly benefit companies in BC.

Cleantech companies entering the commercialization phase do not need VC or grant funding, but instead need access to debt and expansion capital. Once again, the high-risk nature of Cleantech makes obtaining this financing more challenging in this sector than in conventional industries. Interestingly, the SDTC has found that US organizations, such as the DOE, are some of the largest providers of debt to *Canadian* Cleantech companies. The SDTC report (2016, p. 28) concluded that there are no Canadian equivalents, public or private, to agencies such as the DOE to provide large amounts of debt to Canadian Cleantech companies.

"Companies are looking to be bought out. They are unable to come to market because they are not financed enough, they don't have the runway, so the best they can hope for is to be bought out."

Programs such as the DOE LPO have been very successful at reducing the risk of lending to Cleantech projects and could be recreated here in BC. A provincial loan guarantee program, whereby the government would provide a financial backstop for commercial lenders that provide loans to Cleantech companies, would help local companies bridge the gap between technology demonstration and commercial deployment. Doing so would leverage additional private capital into the sector without requiring significant spending from the government. In the case of the LPO, the program provided a net profit for the DOE after subtracting project losses from interest payments made by applicants.

In addition to the need for growth financing, Cleantech companies also have difficulty posting financial bonds for large projects in export markets. EDC provides several financial instruments that help Canadian exporters provide performance bonds and guarantees for large projects. Such a program could be instituted in BC specific to Cleantech companies and could be partnered with the EDC programs. The provincial program could provide matching loan guarantees in addition to those provided by EDC. Doing so would help reduce the financial risk of these projects, as the liabilities would be spread between the provincial lending agency, the EDC, and the underlying financial institution. This would also add an additional layer of oversight, as potential projects would have to meet the eligibility requirements of all three organizations.

These kinds of subsidized financial instruments are used by other governments to help their Cleantech companies, such as loans made by the Swedish Energy Agency, the Danish Green Investment Fund and the Danish Growth Fund, Washington State's CEF, and the LPO program in the US. The role of all these organizations is not to replace private financial institutions, but to augment them by reducing financial risk and to help correct for the "knowledge as a public good" market failure inherent in Cleantech development.

Concerns about financing for Cleantech companies have been voiced by other stakeholders in the Cleantech sector. The Canada Cleantech Alliance released a letter signed by 200 Cleantech CEOs that contained several policy recommendations that they feel would help the industry. These recommendations include a $1 billion loan guarantee program, a $500 million VC fund for Cleantech ventures, and a recapitalization of SDTC to turn it into a global flagship of Cleantech

development (BC Cleantech CEO Alliance, 2016). The SDTC found that on a per-capita basis Canada lagged significantly behind the US in terms of both VC and debt financing (2016, p.6), and Analytica Advisors recommended that public capital be deployed to help backstop risk for buyers and sellers of clean innovation (2016, p. xix).

Problems with Cleantech financing may be partly attributed to a misunderstanding of how innovation works in this sector. If stakeholders are using a traditional model of innovation, as discussed in section 4.2.1, then investors can expect a linear progression of innovation leading to predictable timelines. However, if the iterative model of innovation is used, it can be better understood that timelines are difficult to establish due to the non-linear progression of innovation.

7.2. Export Growth

The client for this project had a particular interest in how to support BC Cleantech exports to emerging markets like China. Six companies specifically mentioned China in their future growth plans. As discussed in the findings sections, most companies were seeking large strategic partnerships in order to help them access the Chinese market. These partnerships will help them overcome challenges pertaining to IP protection and experience in dealing with foreign markets, which were the two most commonly cited challenges to export growth.

In order to make these partnerships viable, companies are seeking to prove their technologies in safer markets and to grow their business in places like the US, Europe and Canada. Once the companies have proven track records in these more accessible markets, they will have an established business model to offer strategic partners. Most of these companies do not expect to become successful by exporting to China; they expect to become successful *and then* export to China. Efforts to improve export growth should focus on supporting businesses in general in order to give them a solid foundation that can be used to attract strategic partners.

7.3. University Collaboration

There is a strongly established connection between innovative companies and knowledge networks such as universities and other research bodies. Our interview findings indicate that this is true for BC Cleantech companies just as it is elsewhere in the world. Cleantech companies in BC make regular use of universities for hiring new graduates and coop students, and send existing staff back to school to continue development in their field.

Informal connections to professors and the resulting networking opportunities are an important part of innovation in BC, however, BC does not see the types of formal collaborations that are seen in other parts of the world. Expensive usage fees and restrictive IP agreements make these partnerships unattractive to many companies. Our research did not indicate that companies are harmed by this lack of collaboration, but the success of such collaborations in other regions

indicates that BC could be missing an opportunity to better integrate research infrastructure with commercial ventures.

Experimenting with different IP agreements or usage fee structures, such as is seen in countries such as the US and Denmark and is discussed in the Smart Practices section of this report, could provide a boost to the BC Cleantech sector. Both the US and Denmark have research facilities that can be used by select companies free of charge, as well as lenient IP arrangements that allow companies to commercialize the IP resulting from the research.

7.4. Carbon Tax

The literature review for this report suggested that a carbon tax, while being instrumental at reducing GHG emissions, would have a negligible effect on innovation without an unfeasibly high price for carbon. The results of the interviews for this report also support this position, as only one of the participating companies indicated that the BC carbon tax had a positive impact on their product innovations. While the carbon tax will remain an integral part of BC's efforts to reduce GHG emissions, and is essential for signalling the province's commitment to supporting Cleantech policy in general, it will likely be insufficient to induce innovation amongst BC Cleantech companies without additional supporting polices, even with the expected increase to $50/tCO2*e* by 2022. As per the findings of our literature review, government support in the near future should focus on direct support of R&D activities, with the carbon price increasing over time to encourage the use of new technologies as they become cost effective in the long-term.

7.5. Navigating Cleantech Policies in BC

Companies that participated in this research were nearly unanimous in the feeling that provincial government programs for Cleantech are difficult to access and that BC in general is difficult for Cleantech companies to operate in. BC needs to create an organization that functions like SDTC or ARPA-E that will nurture innovations in all Cleantech sectors, not just renewable energy, and that will provide consistent programs and be a single point of contact for Cleantech companies looking to access provincial support. Even in the absence of such a single program, industry consultants should be created to help companies navigate the existing Cleantech ecosystem here in BC. These consultants should be modeled after similar positions in place with IRAP, SDTC, and the Concierge service.

ICE could be given an expanded mandate to encompass all clean technology types and to provide a single point of contact for Cleantech stakeholders looking to access provincial government programs. The reformed agency should also pursue partnership opportunities with federal bodies such as IRAP and SDTC. Such partnerships are being undertaken by Alberta and would simplify the process for companies to get access to support from multiple levels of government.

8. Conclusions

8.1. Policy Recommendations

Recommendation #1: Restructure the ICE fund into a broad Cleantech supporting agency.

BC Cleantech programs and policies are difficult to navigate, poorly communicated, and suffer from a high level of uncertainty stemming from a lack of political buy-in and inconsistent source funding. The ICE program should be restructured to encompass the entirety of the Cleantech sector, be given a consistent source of funding that will not fluctuate year-over-year, have regularly scheduled Calls-for-Applications, and its programs should be aligned and partnered with those of the Government of Canada such as SDTC and IRAP. This restructured agency should serve as the central point of contact for the BC Cleantech industry.

Recommendation #2: Create additional financial instruments to support the provision of debt financing for Cleantech companies.

BC Cleantech companies need additional financial support in order to overcome the inherent high-risk nature of Cleantech development. Provincial efforts to financially support Cleantech companies have typically been through grant funding such as ICE or through VC funding such as the BCRCF. These funding sources are important and have played a vital role for many BC Cleantech companies, and will continue to be vital to the next iteration of Cleantech start-up companies, but the incumbent sector is reaching a stage where they need access to debt financing to help expand their markets and to pursue export opportunities that require performance bonds and guarantees.

The province needs to create financial instruments such as loan guarantees, concessional loans, lines of credit and investment bonds to address the lack of debt financing available to the sector and explore options for partnering with other levels of government to help provide this financing. The goal of these financial instruments should be to help reduce the risk to private financial institutions in order to leverage additional funding into the sector. This will allow companies to expand their business and grow their operations without requiring they be acquired by larger corporations.

Recommendation #3: Increase the VC funding available for Cleantech companies and give this funding a mandate to accept investments that have higher risk profiles and longer timelines.

Cleantech development is inherently more risky than other types of technology development due to technological, market, and political risks. Creating a VC environment that is open to these risks is necessary to support the industry. It is especially important for Cleantech companies that they be given timelines in the 5-10 year range instead of the 3-5 year range as is typical for VC investments. The $100 million investment in the BCTech fund is an important contribution to the VC landscape in BC, but it will be important to make sure that the funding is equally distributed to its four target sectors and that Cleantech is not left out.

Recommendation #4: Develop and employ industry advisors to provide consultation and support to Cleantech stakeholders in BC attempting to access programs across all levels and branches of government.

Creating a single point of contact for stakeholders will help to ensure that they are up-to-date on application timelines and requirements, that they are aware of new programs they may be eligible for, and will create a dependable avenue for consultation between the industry and the government. These advisors should be managed through the reformed ICE program, but could also be managed through another government department.

Recommendation #5: Clean Energy Canada should work with members of the BC Cleantech sector to develop a government relations strategy to help improve consultation between industry and government.

The Cleantech industry in BC is currently in need of an organized strategy for communicating with the provincial government. Clean Energy Canada should work with members of the Cleantech industry and other NGOs to develop a coordinated communications strategy for engaging with various levels of government so as to effectively communicate the needs and concerns of the industry to relevant policy makers.

8.2. Recommendations for Further Research

Area for further research #1: Strategies for increasing industry participation with academic research institutions that could result in better optimization of research infrastructure in BC should be explored.

BC universities play an important part of the BC Cleantech sector for recruitment, training, and networking opportunities; however the research infrastructure in BC is largely academically focused and does not serve to help SME Cleantech companies with their research needs as is the

case in other jurisdictions around the world. While it is difficult to say if the BC Cleantech industry is negatively affected by the current system of post-secondary research, examples from other parts of the world indicate that alternative arrangements could be beneficial for all stakeholders. While encouraging the informal connections between industry and the academic Cleantech sectors, BC should explore new ways of encouraging research collaboration between these two groups of stakeholders.

Area for further research #2: The needs of Cleantech start-ups should be further explored.

The needs of companies in the start-up phase of development, which is a much earlier phase than the companies included in this research are in, could provide information about Cleantech needs at the concept R&D stage, patent development, and company formation. Start-ups are often created to commercialize the findings of university research, and as such this research may also provide additional insight about how best to utilize post-secondary research infrastructure.

8.3. Additional Conclusions from the Research

The BC carbon tax has been widely considered a success for its part in reducing provincial GHG emissions, a role it will continue to play in the coming years, but its impact on innovation is difficult to ascertain. Support for the BC Cleantech sector should not rely on the carbon tax in isolation.

The Carbon Neutral Government program, while an important part of reducing GHG emissions from government sources, does not seem to have a significantly positive impact on supporting innovative Cleantech companies here in BC. As the literature review indicated, this is likely because market-based instruments such as carbon taxes and emission trading schemes incentivize technologies that are already cost-competitive and do not impact those requiring significant innovation and development before being ready to deploy. Since many of the companies interviewed in this report did not yet have products ready for market deployment, it is not surprising that they could not make use of this program. It is possible that if this research had been focused on Cleantech that was ready for commercial deployment, instead of innovation and product development, that market-based instruments like carbon taxes and the Carbon Neutral Government program would have been more influential.

The SR&ED program, offered conjointly by the provincial and federal governments, is an important program for supporting Cleantech companies in BC. This program should continue to support innovative companies, with possible consideration being given to increasing the grant portion of the tax credit that directly affects many Cleantech SMEs that are not yet generating revenue.

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Appendix 1: Invitation to Participate

Invitation to Participate in a Research Project

Project Title: Cleantech Policy in British Columbia: A stakeholder perspective on what role the provincial government should play in encouraging innovation.

Primary Investigator: Darryl Hoefsloot, Masters of Public Administration student.
Academic Supervisor: Dr. Jim McDavid, professor Public Policy at UVic.
Client Organization: Client Energy Canada - Jeremy Moorhouse.

To (participant), of (company name),

Your company is invited to participate in a research project being carried on behalf of Clean Energy Canada by myself, Darryl Hoefsloot, a graduate student at UVic. The topic of investigation is government Cleantech innovation policy in British Columbia.

Why have you been approached?
Your company has been identified as a member of the Cleantech community here in BC. This research intends to interview representatives of BC companies that are involved in researching and developing new and innovative technology in the Cleantech sector.

What is the project about?
Broadly speaking this project is about how provincial government policies impact your company and its business of developing Cleantech products. This project intends to include perspectives from at least 10 different companies in the BC Cleantech sector. The policies that are identified as the most effective will be recommended to the provincial government and could be implemented to help the BC Cleantech sector grow and develop.

Why is this research relevant?
The BC Climate Leadership Team's report in 2016 included a recommendation that the government assemble a taskforce to research B.C.'s competitive advantages and potential growth areas in a low-carbon economy, both within and across sectors, and to develop recommendations on stimulating these areas. Findings from this project will be submitted to the provincial taskforce to help guide the development of future policy in the Cleantech sector.

If I participate, what will be required of me?
You, or a representative of your company, would participate in a 45 minute interview with 10 to 15 questions regarding BC Cleantech policies. Interviews can be conducted over the phone, in person at your workplace, at a public location such as a library, or over the internet via Skype – whichever method is most convenient. The interviews will be recorded and the results will be used to draw conclusions about the strengths and weaknesses of provincial policies. Information obtained in

these interviews will remain confidential and your specific answers will remain private within the research team. You will be provided a copy of the interview questions beforehand so you may give complete answers and avoid any surprises; however, the interviews will be open-ended and therefore the discussion may deviate from the interview guide. Once the interviews are over you may request to have your responses removed from the project, up until the point of time when the project is deemed ready to defend before my professors at UVic.

This research project will utilize snowball sampling, wherein participants may suggest other potential individuals who may be interested in partaking in the project. As such, if you know of any individuals or companies that may be interested in participating in this project you are encouraged to forward a copy of this invitation to these parties, even if you and your company decline to take part in this research. Interested parties should contact me at DHoefsloot@Outlook.com to be included in the study.

Who is involved in the project?
I am conducting this research as a Masters of Public Administration student at the University of Victoria and this Capstone project will serve as my final requirement prior to graduating with a Master's of Public Administration. Dr. Jim McDavid will be the academic supervisor.

I hope this research project is of interest to you and I look forward to hearing your reply.

Sincerely,

Darryl Hoefsloot
UVic MPA Candidate.

Appendix 2: Participant Consent Form

Participant Consent Form

Cleantech Policy in British Columbia: A stakeholder perspective on what role the provincial government should play in encouraging innovation.

You are invited to participate in a study entitled "Cleantech Policy in British Columbia: A stakeholder perspective on what role the provincial government should play in encouraging innovation" that is being conducted by Darryl Hoefsloot. My client for this project is Clean Energy Canada, a climate and clean energy think tank within the Centre for Dialogue at Simon Fraser University that conducts original research, hosts dialogue, and aims to guide policy leadership on renewable energy topics.

Darryl is a graduate student in the School of Public Administration at the University of Victoria and you may contact him if you have further questions by email at DHoefsloot@Outlook.com.

As a graduate student, I am required to conduct research as part of the requirements for a master's degree in Public Administration. It is being conducted under the supervision of Dr. Jim McDavid. You may contact my supervisor at 250-472-4293.

Purpose and Objectives
The purpose of this research project is to examine provincial government policy intended to support innovation in the Cleantech sector in BC. This project will interview industry representatives and provide our client with on the ground perspectives about government policies and will ultimately lead to recommendations being made to the provincial government on how to improve the current situation.

Importance of this Research
Research of this type is important because Cleantech is a rapidly growing sector in BC and Canada and has the potential to significantly reduce environmental impacts from human activity, as well as providing significant economic benefits to local economies. Both the federal and provincial governments have identified the Cleantech sector as one of growing importance in government policy and the economy.

Participants Selection
You are being asked to participate in this study because your company has been identified as an important member of the Cleantech community here in BC. This research intends to interview representatives of BC companies that are involved in researching and developing new and innovative technology in the Cleantech sector.

What is Involved
If you consent to voluntarily participate in this research, your participation will include a 45 minute interview with 10 to 15 questions regarding BC Cleantech policies. Interviews can be conducted over the phone, in person at your workplace, at a public location such as a library, or over the internet via Skype – whichever method is most convenient. The interviews will be audio recorded and the results will be used to draw conclusions about the strengths and weaknesses of provincial policies. Information obtained in these interviews will remain confidential and your specific answers will remain private within the research team. You will be provided a copy of the interview questions beforehand so you may give complete answers and avoid any surprises; however, the interviews will be open-ended and therefore the discussion may deviate from the interview guides. Once the interviews are over you may request to have your responses removed from the project, up until the point when the project is considered finished and ready for submission to UVic. Participants who wish to have their response removed will receive confirmation via email that these answers have been removed. This confirmation will also be emailed to the project supervisor and the client.

This research project will utilize snowball sampling, wherein participants may suggest other potential individuals who may be interested in partaking in the project. As such, if you know of any individuals or companies that may be interested in participating in this project you are encouraged to forward a copy of this invitation to these parties, even if you and your company decline to take part in this research. Interested parties should contact me at DHoefsloot@Outlook.com to be included in the study.

Please be advised that information about you that is gathered for this research study, such as the recordings of your interview sessions, may be stored online in servers located in the U.S. As such, there is a possibility that information about you may be accessed without your knowledge or consent by the U.S. government in compliance with the U.S. Freedom Act.

Inconvenience
Participation in this study may cause some inconvenience to you, including the loss of time involved in the interview process, as well as any travel time that may be required.

Risks
There are no known or anticipated risks to you by participating in this research.

Benefits
The potential benefits of your participation in this research include a better understanding of the policies being studies, leading to an improvement on the state of knowledge for these policies that may benefit Cleantech companies operating in BC. These improvements may help the development of new technologies that may potentially benefit society at, both locally in BC and at an international level.

Compensation
There will be no compensation offered for your participation in this research.

Voluntary Participation
Your participation in this research must be completely voluntary. If you do decide to participate, you may withdraw at any time without any consequences or any explanation. If you do withdraw from the study your data will only be used with your permission. The information from your interview may be removed from the study prior to the study's completion.

Anonymity
In terms of protecting your anonymity, answers will remain anonymous in the final report, with specific answers not being attributed to an individual or their company. Interview answers will be stored in a central computer location by the primary researcher. Complete anonymity will not be possible, as the primary researcher will know which participants have given which answers, however these answers will remain confidential within the research team. The project client, Jeremy Moorhouse, will not have access to specific answers by specific participants.

Confidentiality
In terms of protecting your confidentiality, answers will not be referred to individually in the final report, with specific answers not being attributed to an individual or their company. Interview answers will be stored in a central computer location by the primary researcher.

Dissemination of Results
It is anticipated that the results of this report will be shared with others in the following ways: the project will be defended before a board of professors at UVic once it is completed; the final report shall be emailed to the client (Clean Energy Canada) as well as all the individuals and companies that participated; a copy of the report will be stored and be publicly available on the UVic website; and lastly a copy of the report will be sent to the provincial government in order to contribute to policy development in the Cleantech sector.

Disposal of Data
Data from this study will be disposed of by deleting interview recordings once the study has been completed and publicly released.

Contacts
Individuals that may be contacted regarding this study include Darryl Hoefsloot at DHoefsloot@Outlook.com, as well as Uvic professor Dr. Jim McDavid at jmcdavid@uvic.ca.

In addition, you may verify the ethical approval of this study, or raise any concerns you might have, by contacting the Human Research Ethics Office at the University of Victoria (250-472-4545 or ethics@uvic.ca).

Your signature below indicates that you understand the above conditions of participation in this study, that you have had the opportunity to have your questions answered by the researchers, and that you consent to participate in this research project.

Name of Participant	*Signature*	*Date*

Appendix 3: Interview Questions

Cleantech Policy in British Columbia: A stakeholder perspective on what role the provincial government should play in encouraging innovation.

1. Can you tell me a little about your company and your role within it?

2. What market is your company/product focused on? Are you focused on Domestic or Export deployment?

3. Where do you see the largest potential for growth in deployment for your products? Canada? The United States? Japan? China? Korea?

4. What are some of the barriers in BC that your company is facing in growing your Cleantech business? For example, legal/regulatory barriers, lack of demand for new products, constrained supply of skilled workers, lack of capital financing?

5. Has your company made use of any of the government sponsored Venture Capital funds (Innovative Clean Energy fund [ICE], BC Renaissance Capital fund [BCRCF]) to provide financing for your operations?

a. How does the supply of venture capital in BC affect your company's development? Has the growth of your company been constrained by lack of financing?

6. Does your company partner with any of the Centres of Excellence in BC, such as PICS (UVic), Centre for Energy Systems Applications (BCIT), or the Centre for Interactive Research on Sustainability (UBC)? If not, why?

7. Has your company made use of government procurement programs to test products prior to marketization? Examples of these programs include the Carbon Neutral Government program.

8. What is more beneficial for your company; tax credits such as the provincial and federal Scientific Research and Experimental Development tax credit (SR&ED), or direct research assistance such as the Centres of Excellence in BC?

9. Do you find that in BC the government programs that support Cleantech development are easy to navigate and understand? Is it straightforward and easy to find and apply to the programs you need, or is it confusing and difficult to navigate? How does it compare to other jurisdictions (such as the Government of Canada)?

10. What policies are being done in other locations that you would like to see done in BC?

11. What kind of an impact do broad domestic climate policies, such as carbon taxes, cap and trade systems, or renewable portfolio standards, have on your business?

12. What would you like to see the BC government do to help support your business?