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Carbon Policies in Canada: Implications for Biomass District Energy Systems

by

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Abstract

This study examines the impact of carbon policies on the implementation of biomass district energy (DE) systems within Canada. DE systems offer an energy efficient approach to providing heating, cooling, domestic hot water and sometimes electricity to residential or commercial buildings. Biomass and wood biomass is examined as an affordable fuel option for the DE systems. To reduce greenhouse gas (GHG) emissions, biomass DE systems can offer an affordable and stable option. This study examines how three systems across Canada are impacted by fuel charges or large emitter incentives and compares that to if they used only the fossil fuel most used in the province the system is located. It was determined by this paper that carbon policies increase these systems competitiveness in most circumstances. However, a dramatic increase in the cost for wood biomass or a drop in fossil fuel prices could render some systems economically inviable.

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Chapter 1: Introduction

Biomass district energy (DE) systems are offering Canadians a low-carbon source of heat and/or electrical energy that can be more reliable and efficient than other renewable sources. Biomass is a term used to describe renewable materials including solid wood or wood residues such as the by-products of the forestry industry, agricultural crop residues, aquatic plants, animal wastes and dedicated tree farms (Canada Energy Regulator, 2020). DE systems are comprised of a local source of energy generation equipment that connects multiple buildings in a community through underground piping. The local energy centre heats water that is pumped through pipes to local buildings for heating, cooling, and domestic hot water. DE systems can also produce electricity if cogeneration equipment is used. Canada has a total of 2 408-megawatts (MW) of installed biomass capacity as of 2015, with 70 biomass generating plants (Canada Energy Regulator, 2020). Biomass is considered carbon neutral, because the carbon dioxide (CO_2) released from burning or decomposing the biomass is roughly equal to the amount of CO_2 that trees remove from the atmosphere during their lifetimes (Canada Energy Regulator, 2020). This source of fuel can also generate power on demand for a base load or a community's fundamental power needs, while other renewable energy sources generally operate intermittently. As towns and communities progress towards a more sustainable energy grid, biomass DE systems can offer a promising alternative to traditional sources of energy. This is especially true for communities that have a readily available biomass fuel source, such as a local pulp mill or a strong forestry industry. Through the implementation of these systems, communities, especially remote ones, can create their own affordable and stable source of energy.

To bolster renewable energy projects within communities across Canada, opportunities, funding, and policy need to work in conjunction. Canada is committed to reaching the United Nations (UN) Sustainable Development Goals (SDGs) and adopted their agenda for 2030. This means that Canada is working towards achieving the seventeen goals outlined by the UN SDGs. These goals are: goal 7: affordable and clean energy; goal 9: industry, innovation and infrastructure and goal 11: sustainable communities. (Government of Canada, 2021a). To promote these goals, the federal Government of Canada has enacted policies that aim to increase companies' and communities' energy efficiency and offer more sustainable choices. Policies such as the federal carbon back stop program help further the development of sustainable energy projects.

The federal backstop program for large emitters is known as the output-based pricing system (OBPS). This system aims to incentivize reductions in greenhouse gas (GHG) emissions linked to industries and reduce them, while maintaining competitiveness (Government of Canada, 2021b). The other major policy is the federal fuel charge. The federal fuel charge came into place in 2019 and started at $20 a tonne. This price will increase $10 per tonne until $50 per tonne of carbon dioxide equivalent (CO_2e) in 2022 (Government of Canada, 2020b). By the year 2030, the fuel charge rate will be at $170 per tonne of CO_2e. Together the federal fuel charge and OBPS aim to encourage companies, energy providers and individuals to reduce their GHG emissions. They may also support sustainable infrastructure implementation. By using case studies, this paper seeks to analyze how these policies impact biomass DE systems that are already developed in Canada. Through this analysis, the impact of the OBPS and increases to the federal fuel charge on non-renewable energy compared to biomass produced energy will be presented.

1.2 Research Question and Objectives

The following is the research question that frames this study, **"how do carbon pricing policies affect the implementation of biomass DE systems within Canada?"** Other objectives this paper aims to explore include:

- The benefits of DE systems in communities
- What makes biomass DE systems a solution for decarbonizing heating systems in Canada?
- What policies, funding or incentives have helped biomass DE systems come to fruition?

1.3 Interdisciplinary Aspects and Scope

This project has a multidisciplinary approach that will focus on three areas: energy, policy, and economics. The energy aspect will be fulfilled by looking at biomass DE systems. Biomass is a type of renewable energy that can be used for heating. Communities can benefit from the use of biomass energy. It is a stable and renewable fuel source that can deliver a baseload for heating, which intermittent renewable energy cannot provide. This project will look at three different biomass projects that have been implemented across Canada. An overview of these projects will help create a better understanding of how these systems have been built successfully in the past and how current environmental challenges can further bolster their production.

Examining policy impacts will be an important part of this paper. By analyzing the implementation of biomass DE systems, local responses to different policies and the lessons learned from them will clarify which policies could benefit future projects. This paper will examine both provincial and federal policies. Since the three case studies are located in the provinces of British Columbia (BC), Quebec (QC) and Prince Edward Island (PEI), the relevant provincial carbon policies will be analyzed for them. These provinces each have their own carbon pricing programs that would impact the development of any new infrastructure. Through these three case studies, a robust analysis of the impacts these different policies have, both locally and nation-wide will be demonstrated.

Lastly, economics will be a major component of this project, as this paper will determine how various policies impact the cost of running biomass DE systems. Exploring how the price of carbon will impact the costs of the projects compared to without carbon pricing will help define these systems' competitive advantage.

Chapter 2: Literature Review

2.1 District Energy

DE systems distribute thermal energy for the heating and cooling of residential, institutional, commercial, and industrial facilities. A DE system often uses a central energy facility that generates the energy needed to provide heating and cooling for large square footage. From the centralized location, energy is transferred to hot water that is then piped through a network of insulated underground pipes to each of the buildings supplied by the network. The larger the system, the more pipe networks will be needed. The simplest pipe network will have one pipe that supplies hot water to the users and another which is used to return the water in a closed loop system (Gilmour & Warren, 2008). The thermal energy is transferred to the consumer through a heat exchanger (which transfers heat between one fluid or gas and another) to provide for their heating, ventilation and if possible, their air conditioning unit (Gilmour & Warren, 2008). After the heat exchanger, the system can have a forced air furnace that takes the heat from the heat exchanger, or, it could have in floor heating. The system normally consists of three subsystems: the collection and generation of thermal energy, the distribution of thermal energy through a network to the consumers and the transfer of thermal energy to the consumers (Gilmour & Warren, 2008). If the system is capable of cooling, the system would be referred to as district heating and cooling (DHC). The system can also provide electricity through what is known as cogeneration or combined heat and power (CHP). The most common system is a district heating (DH) system. DE systems can use multiple fuel sources to provide energy such as natural gas, coal, human waste, biogas, biomass, as well as solar and wind power. The systems are often capable of handling one or more types of fuels. This means that back up fuels can be used when needed (Gilmour & Warren, 2008).

There are several benefits to implementing a DE system. The adoption of a DE system can help reduce transmission losses through centralized energy generation, increase conversion efficiency, mitigate emissions, generate potential economic profits and increase the use of renewable energy sources (Sameti & Haghighat, 2017). Furthermore, the use of these systems can produce cost savings for the energy consumer (IEA Cogeneration, 2009). DE systems offer small communities an opportunity to retain more money and jobs within their communities by enabling the use of local renewable fuel sources, such as biomass, whereas traditional fuel systems often require the purchase of fuels that need to be imported.

DE systems can offer a great opportunity for Canada to decarbonize its heating systems. By connecting buildings to a more efficient means of heating and even energy production, the overall amount of emissions would be reduced, even if the fuel type was the same as for systems designed for individual buildings. The system could be even more sustainable if the DE system were to use a renewable fuel source. According to Gilmour & Warren (2008), if every residential and commercial building in Canada were connected to a CHP DE system, more than 57 million tonnes of CO_2 could be prevented from being released, eliminating 9% of the country's total CO_2 emissions. Furthermore, with new technology, air quality can be improved with modern pollution control systems. This is because centralized energy facilitates greater efficiency and can help reduce emissions by enabling the use of potential fuel sources that may already be generating pollution through their disposal. This is made evident when communities utilize the biomass they are already producing for energy, rather than treating it as a waste product and incinerating it without the benefits provided by a DE system. Overall, Canada has a total of 112 DE systems that serve mid-sized communities to large cities such as Montreal, Toronto, and Vancouver (Gilmour & Warren, 2008). The country's total DE heating capacity is 4 604 megawatts thermal (MWth) and a total cooling capacity of 1 144-MWth (SFU CEEDC, n.d). With a growing need to produce more sustainable energy and heat, the development of DE systems across Canada could help the nation achieve its climate goals.

2.2 Biomass

Biomass is a broad term for plant or animal matter, and in this context, refers to materials that can be used to create fuel. Organic material such as solid wood or wood residues, agricultural crop residues, aquatic plants or animal waste can be used for power generation (Government of Canada, 2020a). Biomass can be either incinerated or gasified, then the resulting heat is used in a boiler to be turned into heating, cooling and/or used for electricity generation in the case of CHP systems. In 2014, there were 70 biomass power plants in Canada. These facilities total 2 408-MW of capacity (Government of Canada, 2020a). Most of these biomass plants utilize wood based or waste based fuels. Communities that have a large forestry industry can often benefit from biomass DE systems. Wood residue can be utilized as an energy source from conventional forestry operations. Provinces that see the greatest amount of forestry and thus, more biomass systems include Alberta, BC, Ontario, Quebec, and New Brunswick (Government of Canada, 2020a).

Biomass can be argued to be both carbon neutral and not carbon neutral. Biomass can be considered not carbon neutral because of the fuels that must go into the harvesting, transportation, processing, and removal of carbon sinks in our ecosystem (Johnson, 2009). However, many consider biomass carbon neutral. This is because the CO_2 released from burning or decomposing the biomass is equal or less than the CO_2 that the plants take out of the atmosphere during their lifetimes (Natural Resources Canada, 2020). Time frame also plays an important role in determining whether or not biomass is considered a carbon neutral fuel source. In the short term, biomass may not be considered carbon neutral due to the aforementioned requirements. However, if certain conditions are met —including whole stand rotation basis— and the trees are allowed to develop to maturity over a period of time, then the harvesting of these trees is carbon neutral (Natural Resources Canada, 2020). Ensuring that the forestry management establishes successful regeneration after harvesting is important to guarantee that the practice remains sustainable. For the purpose of this project, we will assume that biomass is carbon neutral. As the world increasingly relies on the use of bioproducts to replace energy sources based on fossil fuels, Canada's forest industry is set to see an increase in demand. This means that there may be a lot more wood residue being produced within Canada's forestry industry. Biomass such as wood pellets can help add value to what would otherwise just be waste. Since the use of beehive burners have been outlawed in many jurisdictions across Canada, responsible disposal of wood residues is important. Biomass DE systems can help in these circumstances.

There are many reasons why biomass is beginning to see an increase in use as a fuel source. Firstly, biomass is found all over the world and is consequently very easy to source locally. Secondly, it can be a diverse fuel stock and has multiple end uses. It can be turned into a solid, liquid, gas, or burned for power. Lastly, the uses of biomass are not limited to its function as a fuel source. Biomass can be a fertilizer, food, animal feed, medicine, or construction material (Tojo & Tadashi, 2013). However, compared to fossil fuels, biomass has less energy density and a less efficient energy conversion. It can also have high procurement costs and needs to be effectively monitored and controlled.

In order to be considered renewable, all biomass must be sourced in a sustainable manner. Canada is a world leader in sustainably developed biomass, possessing 46% of the world's certified sustainable forest (Stephen & Wood-Bohm, 2016). Canada uses three certification programs, the Canadian Standards Association, the Forest Stewardship Council and the Sustainable Forestry Initiative (Government of Canada, 2021 b). According to the UN Framework Convention on Climate Change (UNFCCC) (n.d), sustainable biomass needs to originate from land areas which remain forested, the level of carbon stock must not decrease over time and any national/regional forestry regulations must be consistently obeyed. If the biomass is produced from industry residues, it is sustainable if the use in the project activity does not create a decrease in carbon pools —such as dead wood, living wood or soil organic carbon— on the land where the biomass residues originated from. In 2003, it was estimated that residue streams from agriculture, forestry and urban sectors could provide an extra 1.5-2.2 Exajoules of energy, or 14% to 21% of Canada’s current primary energy supply (Stephen & Wood-Bohm, 2016). Furthermore, around 40 million dry tonnes of forest residue can be harvested annually from Canada’s forests while maintaining sustainable harvest regulations. If done in a sustainable manner, biomass could be part of Canada’s solution to reduce GHG emissions.

2.3 Carbon Policies

Carbon policies are implemented by provincial governments to help influence consumer and producer behaviour. Due to the importance of transboundary cooperation, the federal government works with the provinces to ensure there are relatively equivalent carbon policies nationwide. There are two main federal policies that impact the generation of heat, electricity, and the use of fuels. These are the OBPS back stop program and the federal fuel charge. The OBPS program started in 2019 and covers facilities that emit over 50 000 tonnes of CO_2e a year. Facilities that emit over 10 000 tonnes of CO_2e per year can opt-in to the OBPS system (Sullivan et al, 2021 a). The OBPS for emissions is set using an emissions intensity performance standard for the given product or industry (Government of Canada, 2021b). If a facility is over the standard they must provide compensation for the excess, whereas a facility under the standard can earn credits that can be saved or sold (Government of Canada, 2021b). For companies to remain competitive this pricing is determined by the risk of leakage or having the emissions transferred to another jurisdiction, within or outside of Canada. The OBPS for low to medium risk industries is set at 80% of the sector's average pollution intensity, while high risk industries are set at 90% to 95% of the average (Government of Canada, 2021b). The cost for exceeding these set standards is the same price as the federal fuel charge. Each province can produce their own regulations for heavy emitters instead of opting into the federal backstop program. Doing this would allow more local jurisdiction over regulation, although such programs must demonstrate equivalency with the federal benchmark. In 2019 the carbon pricing for the OBPS started at $20 per tonne of CO_2e and is set to increase to $50 per tonne of CO_2e in 2022 (Sullivan et al, 2021a).

The federal fuel charge is the second federal policy that could impact heating facilities in Canada. The federal fuel charge applies to 21 fossil fuels, including natural gas, gasoline, light fuel oil, and combustible waste such as tires (Government of Canada, 2020c). The rates correspond with global warming potential factors and emission factors (Government of Canada, 2020b). Starting in 2019, the fuel charge places a carbon pollution price of $10 per tonne. Every year, this price is set to increase $10 until 2022, when it will reach $50 per tonne (Government of Canada, 2020c). By creating these carbon pricing schemes, the Government of Canada hopes to cut carbon pollution by incentivizing innovation and more environmentally friendly practices (Environment and Climate Change Canada Estimated Results, 2018).

Each province can implement their own carbon pricing policies. This allows the provinces to adapt regulations to their circumstances, although some provinces choose to use the federal backstop program. BC implemented their carbon pricing programs in 2008. The province of Quebec has a cap-and-trade carbon pricing system that has been in place since 2013. Quebec and Nova Scotia are the only provinces in Canada with a cap-and-trade system. Emission units are sold at auction four times a year by the Quebec Government and the number of free allocated units are reduced every year to encourage emission reductions (Quebec, 2021). PEI has opted to use the federal government's back stop program. Understanding that each province can have its own set of regulations for carbon pricing is important because differences in policies determine whether certain emitters are able to opt-in to the carbon pricing programs. The ability to opt-in to carbon pricing programs can be critical as it allows companies within specific industries, such as heating or DE systems, to be taxed at a competitive rate.

2.3.1 British Columbia

The province of BC has implemented their own carbon pricing policies through their Greenhouse Gas Industrial Reporting and Control Act (GGIRCA) in 2009 and the Carbon Tax Act in 2008. The GGIRCA comprises of the Clean Industry Incentive Program (CIIP) which focuses on reducing industry emissions. The Carbon Tax Act sets guidelines for fuel charges. These programs were implemented well before the federal carbon pricing policies that were introduced in 2018.

After a year of no incremental price increases due to the Covid-19 pandemic, the fuel charge in the province was raised to $45 per tonne of CO_2e in BC. In 2022 it will be increased to $50 per tonne (Government of BC, n.d a). This program is net neutral, as money is given back to low and middle-income families and households. In addition, there are other business incentive programs the carbon tax helps support. After 2022, the price of carbon in BC is expected to maintain the same price of carbon that the Federal Government sets. Although, if GHG emission targets are not being met, the government has the option to adjust the tax rate (Bumpus, 2015). It is estimated that the province's carbon pricing systems covers around 75% of the province's emissions. This is compared to the federal Greenhouse Gas Pricing Act which would cover around 62% of emissions with the fuel charge and cover an additional 21% of emissions with the OBPS (Dobson et al., 2019). This means that the province covers fewer emissions than the federal system and the backstop was not implemented. Despite these factors, the program was approved. Sectors that are exempt from fuel charges based on their emissions include controlled venting, fugitive emissions from mining or oil and natural gas production and distribution, non-combustion emissions from the waste sector and industrial process and product use (Dobson et al., 2019).

The CIIP is an incentive program open to companies that emit more than 10 000 tonnes of CO_2e emissions per year. Industrial facilities are given a set of emission intensities which they must aim to meet. If a facility has emissions that are below the emission benchmark intensity for its sector, it may be able to receive a payment equal to the amount of carbon tax paid in the previous year (Government of BC, n.d b). Low emissions slightly over the benchmark can receive a partial incentive on a sliding scale. There are numerous benefits for communities in BC to convert to DE and renewable sourced heating. If the system is large enough to emit over 10 000 tonnes of CO_2e emissions a year, they would be able to qualify under the CIIP program. This would allow the DE system to remain competitive amongst other energy suppliers. DE systems are easily transitioned to other energy sources, and they can reduce GHG emissions through advanced air pollution prevention technology.

2.3.2 Quebec

Quebec's carbon pricing system has been around since 2013 and takes the form of a cap-and-trade system, wherein GHG allowances are awarded to regulated parties (large emitters) with a cap. A cap-and-trade system is used to generate climate conscious decisions from large companies and emitters. Companies that emit more than 25 000 metric tons of CO_2 annually are subjected to a carbon allowance. This normally includes sectors such as oil and gas, industrial and electricity providers. Furthermore, if any company or individual would like to participate, they are free to do so even if there is no obligation. An emission allowance is equal to one metric ton of CO_2e (Quebec, n.d). A unique feature of the Quebec cap and trade program is that it is linked with the California cap and trade system under the Western Climate Initiative. Due to this agreement with an American jurisdiction, the system's units are imperial. The provincial government sets how many credits will be issued yearly and each year starting in 2015, these credits will decrease in quantity. The number of free permits will decline around 1% to 2% each year (Dobson et al., 2019). Industrial emitters are given the largest amount of carbon credits to prevent carbon leakage. Leakage occurs when companies move operations to areas without carbon pricing policies. Each year, there is a reduction of 1% to 2% for combustion emitters. It should be noted that oil and gas as well as electricity suppliers do not receive free credits as they can pass the cost on to consumers (Quebec, n.d). At the end of the year, emitters must be able to cover the number of emissions released through the emissions allowances obtained through auction or purchasing credits from other participants or offsets. To prevent manipulation, there is a maximum number of offsets allowed

The Quebec Government holds auctions four times a year with the price starting at $10.75 and increasing 5% plus inflation every year until 2020 (Quebec, n.d). In 2021 the cap on CO_2e emitted was 55.26 million and will decrease by 1.35 million tons of CO_2e emissions until 2030 when the cap will be 44.14 million (Sullivan et al, 2021. b). The cap-and-trade system is known for being flexible for industry compliance. Options include increasing their efficiency, reducing emissions to have a surplus of emission allowances, or buying credits on the carbon market if the company is not successful in reducing emissions. DE systems in Quebec are not largely impacted by the cap-and-trade program unless they emit over 50 000 tons of CO_2 annually. Most DE systems in Canada would not emit as many as 50 000 tonnes CO_2e per year, and so would not be impacted by the cap-and-trade system. Quebec also has a large amount of electricity that comes from hydropower. This means that their grid is already less GHG intense.

2.3.3 Prince Edward Island

The province of PEI implemented the federal OBPS system and their own carbon levy. In 2018, the province committed to enforcing the OBPS system but had no intention to implement a broad-based fuel charge. On the same day that the Greenhouse Gas Pricing Act was released from the federal government, the province agreed with the federal government on a two-year agreement to supplement the federal OBPS system with a tax on gasoline and diesel (Dobson et al., 2019). However, the Government of PEI also released their plan to reduce the excise tax on gasoline and diesel. This meant that the carbon tax impacted customers with an increase of one cent per litre in 2019 and two cents per litre in 2020 (Dobson et al., 2019). The agreement also included an exemption of carbon taxes on home heating fuels. The next round of carbon pricing agreements is anticipated to take place in the Fall of 2021. It is expected that home heating fuels will not be exempt in the next agreement. It is also predicted that the federal government will be stricter towards exemptions (Neatby, 2021). Due to these allowances, 47% of emissions in PEI are currently covered by the agreement (Dobson et al., 2019).

The details of this agreement have been scarce. The OBPS system has been implemented in the province and it should be noted that there is only one system within the province that surpasses 50 000 tonnes of CO_2e a year (Dobson et al., 2019). Facilities which emit more than 10 000 tonnes of CO_2e can voluntarily opt-in to the OBPS system. The province is largely unaffected by the requirements of this program. Stationary combustion emissions from the residential sector makes up 14% of these unpriced emissions (Dobson et al., 2019). Emissions from smaller industrial facilities, such as heating of service buildings, are not required to participate in the federal fuel charge or in the OBPS (Dobson et al., 2019). If the federal Greenhouse Gas Pricing Act was implemented in its entirety, 69% of the province’s emissions would be covered, as the federal benchmark requires the pricing on all combustion emissions. In PEI, 65% of homes are heated using heating oil. This accounts for around 40% of household energy expenses (Canadians for Affordable Heating, 2019). Transitioning residential homes and commercial areas to DE systems would be impactful in reducing the price of heating and electricity as the price of heating oil increases with carbon tax. Currently, the federal OBPS system does not include district heating as an industry that can opt-in to the OBPS system. Allowing district heating into the OBPS system would help keep or reduce the cost of heating for residents and businesses.

2.4 Sustainable Development Goals

The SDGs were produced by the UN in 2015 as a shared blueprint for peace and prosperity (UN SDGs, n.d. d). The SDGs are comprised of 17 urgent calls to action for countries who signed on to uphold them. Since 2015, 193 countries have signed onto the SDGs which indicates their commitment to the 17 goals and to each goal's respective calls to action. This project has been designed to focus on three SDGs. These goals are: goal 7: affordable and clean energy; goal 9: industry, innovation and infrastructure and goal 11: sustainable communities. Focusing on these goals is important because it helps address why biomass DE systems are an important technology that Canada can utilize to decarbonize heating.

Goal 7, affordable and clean energy, calls upon nations to increase their share of renewable energy, improve energy efficiency and enhance cooperation in clean energy research (UN SDGs Goal 7, n.d. a). Biomass DE systems can offer communities across Canada an option for renewable energy that is reliable enough for baseloads. Remote and small communities can find energy security using biomass and the DE system offers an energy efficient option that communities could invest in for long term benefits.

Goal 9, industry, innovation, and infrastructure recommends that nations develop reliable, quality infrastructure, support domestic innovation and promote retrofits to industries to make them more sustainable (UN SDGs Goal 9, n.d. b). Biomass DE systems can provide communities with quality infrastructure that will increase their sustainability. DE systems can be robust and cost effective. The UN District Energy in Cities Initiative supports the use of DE systems as a sustainable solution to heating, cooling, and electrical needs. They agree that DE systems are internationally recognized as the most sustainable and cost-effective way to provide energy and heating to population dense areas (UN Environment Programme, 2020). It is important to understand the feasibility of biomass DE systems within Canada and more importantly, within smaller communities. Towns and smaller cities with a strong forestry industry can take a pre-existing product which is typically considered waste and disposed of through incineration and instead turn it into heat and/or energy for their community. Understanding whether carbon pricing policies help increase the implementation of these systems is important to support future implementation.

Goal 11, sustainable cities, and communities aims to reduce the per capita impact of cities, increase affordability, and improve air quality (UN SDGs Goal 11, n.d. c). This goal encompasses the overall reasoning for implementing biomass DE systems in communities. By using wood residue from forestry and harnessing this energy, communities that implement these systems can improve their air quality by reducing their overall waste and fully utilizing what they produce. It can help create more affordable energy and heating options while reducing the impact on the environment that forestry-based communities have.

Chapter 3: Methods and Assumptions

3.1 Methodology

This paper aims to answer the question, how do carbon pricing policies impact the implementation of biomass DE systems within Canada? To understand the feasibility of these projects in Canadian communities, three case studies were chosen. These case studies were selected for their differences in size, population density and overall community characteristics. The chosen case studies are in the provinces of BC, Quebec, and PEI; each of these provinces have different carbon pricing policies. This is important to the study because it demonstrates a broader picture of how carbon polices interact with the feasibility of biomass DE systems. This broad scope will help determine whether particular policies —specifically the federal fuel charge and the OBPS system— will encourage other communities to develop similar projects. To understand how different economic and social scenarios impact the development of these projects, the selected cases were developed before any carbon pricing policies were implemented. This is critical as it will help demonstrate the feasibility of biomass DE systems before carbon pricing policies.

Information gathered on the case studies included sources published from the communities and companies running the facilitates. Quantitative research was conducted by analyzing each of the communities DE systems and their respective outputs. Secondary research was also used for quantitative research. The economic viability of the projects was determined with carbon pricing and without carbon pricing.

The price of wood pellets is used for the biomass fuel cost because there are more consistent market and industry standards for wood pellets compared to saw dust and wood chips. The high price case cost of wood was determined by 2021-2030 global wood pellet predictions. The high pricing for wood is determined from the price of exporting wood pellets to Japan. This price is extremely high for domestic use and the case studies used have a local sawmill and an agreed upon price for wood residue. This high price is important to demonstrate the robustness of the wood biomass DE systems even without cheap wood residues.

The Oujé-Bougoumou (QC) community case study determined the amount of heating oil used by an energy basis. To determine the amount of oil used the energy in wood and oil was compared. The cost of heating oil was calculated from Quebec City pricing with transportation added on. The high and low heating oil costs were derived from the base price. Each case has its own fossil fuel pricing. Oujé-Bougoumou and Charlottetown (PEI) both use heating oil. Having different heating oil prices is important to understanding how location impacts prices, especially in rural communities. The price of wood remains the same throughout the three case studies. Since the communities all have local forestry industries, a pricing variation is less important. For the Charlottetown case study, the amount of oil used was calculated from the given tonnes of waste that included percentages of wood and municipal solid waste (MSW) used. Due to a lack of data on the waste to energy aspect of the Charlottetown case, the amount of waste and the cost of the fuel charge was determined but the cost of the tipping fee is not calculated into the case.

3.2 Assumptions

Due to limited and often older information on the community-based biomass DE systems selected, this paper makes many assumptions. All the cases presented in this study assume that wood biomass is harvested sustainably and is therefore carbon neutral. For this study, there is no carbon price applied to the combustion of wood biomass. It is also assumed that the case studies use wood pellets for biomass. Wood pellets cost more but they also have less moisture content, meaning that the heating value would be higher than that of wood chips or sawdust.

For the community case study in Oujé-Bougoumou, it is assumed that the quantity of fuel, whether that be heating oil or wood biomass stays constant throughout the 2021-2030 predictions. The assumptions that the system does not grow is also made since population change ultimately would not directly impact the size of the system if no other buildings are added on. Overall, there is an assumed 2% inflation rate on heating oil and a 2% inflation on the wood base case and low-price case.

The Charlottetown community case study maintains similar assumptions to that of the Oujé-Bougoumou case. A constant rate of fuel in both wood and heating oil is assumed, as well as a 2% inflation for heating oil rates and the base and low-price case for wood. Both The Charlottetown case and the Oujé-Bougoumou case use heating oil. The boiler efficiency for these cases is assumed to be 88% efficient for heating oil and 85% for wood biomass. Since PEI needs to negotiate a new carbon pricing agreement with the federal government, it is assumed that they will meet the federal backstop prices on heating oil. For simplicity, it is also assumed they did so in 2021.

The Revelstoke case study also assumes that the system and fuel demand will remain constant with 2% inflation. It is assumed that the system reaches 85% wood usage throughout the year and the remainder uses propane. This was their ideal fuel usage when implementing the system. Currently, BC is paying $5 more than the federal back stop program for a tonne of CO_2e. It is assumed that the province will reach the federal government's minimum price outlined in the back stop program. For this case it is assumed that after the community free wood residue contract expires, the community will have to pay for the biomass they need. Since this community uses propane for heating, it is assumed that the propane boiler operates at a 95% efficiency and the wood biomass boiler is assumed to run at 85% efficiency, equivalent to the other case studies.

Chapter 4: Case Studies

4.1 Revelstoke

Community Background

Revelstoke is a small city in the interior of the province of British Columbia. The total population reported in the 2016 census was 6 719 (Statistics Canada, 2016 b). The city is in the Columbia Mountain range on the Columbia River and is known as a transportation hub (City of Revelstoke, 2015). The city has gone through multiple dramatic shifts in both its industry and its population. The community started as a major transportation and supply centre for the mining industry. Following the construction of the Canadian Pacific Railway, the community experienced a significant growth of their forestry industry. In the 1960's when the Trans-Canada Highway was opened, the town experienced a boom in tourism (City of Revelstoke, 2015). A down turn in their industries happened when three hydro dams were developed in the region, flooding forests and agricultural land. After diversifying, the city focused on tourism and forestry. Forestry makes up 21% of the city's basic economic income as of 2006, while dam improvements have provided additional employment (City of Revelstoke, 2015). The community is home to three sawmills, one cedar shake and shingle mill, one pole yard and multiple wood manufacturing plants. Other industries within the community include tourism and hospitality. The community has also been focused on retaining jobs and money. They have done this through community studies and economic planning. Part of this work includes the implementation and growth of their biomass DE system.

Biomass System

The community of Revelstoke's biomass system is owned and operated by the Revelstoke Community Energy Corporation (RCEC). This system is the smallest of the cases studied in this paper. Development started in 2003 and the project was operable in 2005. It started with six buildings attached to its system but over the next five years, four more buildings were added to the system (Community Energy Association, 2013). The 3.25-MW system is powered with the Downie sawmill sawdust. Downie sawmill is located within the community. The Downie sawmill and RCEC agreed to share the cost of an operator if the sawmill provided 20 years of sawdust for a supply of steam for their dry kiln (Community Energy Association, 2013). The system contains a 1.5-MW biomass boiler with a 1.75-MW back up propane boiler. Steam is provided to Downie's dry kilns and hot water is piped through 2.3 km of pipe. 50% of the heat produced is used for the dry kilns, while the other 50% is used for heating and domestic energy for major buildings within the city (Community Energy Association, 2013). The goal for the biomass system is to use biomass for 85% Revelstoke's energy demands annually, while the remaining 15% of demand is met by propane, which is used for the coldest parts of the year, or during peak demand. RCEC is a wholly owned subsidiary of the City of Revelstoke, and the board of directors are appointed by the city (Community Energy Association, 2013).

Benefits

The initial goal of the project was to improve the air quality of the city. Since the city's major economic driver was the forestry industry, the city saw poor air quality due to the large amount of sawdust being incinerated. At the time, 70 000 tonnes of wood residue were being incinerated annually in a beehive burner at the Downie Sawmill (Community Energy Association, 2013). Beehive burners have since been phased out in BC. The DE system did not reduce the amount of wood being burned but helped reduce the amount of fossil fuels used for heating. Having a single source of emissions and the ability to implement air pollution control technology also helped reduce air pollution. The biomass system was proposed in the 1990's as a solution to the city's air quality issues and reliance on propane for heating. This system takes what would otherwise be wood waste and turns it into a value-added product which is processed locally. The biomass system uses 4 000 tonnes of wood residue from the Downie Sawmill (Revelstoke Community Energy Corporation, 2015). Through this system, the town was able to reduce their GHG emissions by 4-5% (Think Bright Climate Solutions, 2011). The RCEC was able to source biomass for free from the Downie Sawmill for 20 years. This means that until 2026, the community will be able to pay cheaper utility bills than they would using propane exclusively. Having a secure price for energy also protects the customers from fossil fuels' pricing uncertainties.

Policy and Funding

The project cost almost $7 million. Of that amount, $3 million was spent on the central plant and equipment, $2 million was spent on construction, $1.1 million was spent on the installation of energy transfer states and $900,000 was spent on construction financing and developer fees (Community Energy Association, 2013). Around $2.1 million came from grants, $1.35 million came from loans and the rest came from a combination of debt and equity. The grant funding was provided by the Federation of Canadian Municipalities' Green Municipal Fund, while other funds came from the city Reserve Fund, Revelstoke Credit Union, and the Community Forestry Corporation (BC Climate Action Toolkit, n.d). Revelstoke has since looked at options to increase the size of their DE system, but opportunities for expansion depends on where new development within the city occurs.

Lessons Learned

Since the implementation of the Revelstoke biomass DE system there have been many lessons that future projects can learn from. The first issue that has come to light over multiple years relates to design flaws that have created operational challenges. Some of the issues that have been documented include the original heat exchangers failing and needing replacement and water for heating being contaminated with thermal oil because of leaking tubes in the steam generator. The plant also experienced steam generator and combustor pipe corrosion despite following the required water procedures (Community Energy Association, 2013). The plant has had three fires since opening. The most damaging fire was in 2015 with $1.6 million worth of damage and revenue lost (BC Local News, 2021). To get the system working again, the RCEC had to upgrade their sprinkler system, increase maintenance and cleaning and update operating protocols. The most recent fires took place in November of 2020 and February 2021. The fire in November happened in the combustor area and affected some nearby ductwork.

The damage was subsequently fixed. The cause of February’s fire has yet to be released but may have resulted from an equipment flaw in the original design (Orlando, 2021).

Other issues that RCEC found while implementing this system was the challenge of hiring qualified staff and backup staffing. Considering the city’s smaller size, this process was difficult, and having project champions, an informed community and strong hiring practices would have alleviated some of these challenges (Community Energy Association, 2013). At the time of implementation, DE systems were new to both the federal and provincial governments of Canada. With an increase of DE systems within the province, regulatory requirements are now in place. Since the project was first designed, multiple buildings have been added onto the system. This further complicated the project and cost more. It was advised that to improve cost efficiency and ease, all buildings should be added at the same time (Community Energy Association, 2013). Lastly, the project has experienced issues with competitiveness and scalability. In 2019, FortisBC aligned its home propane pricing to that of natural gas, making heating more affordable in Revelstoke (Orlando, 2021). This meant that RCEC competitiveness was decreased dramatically. Extending RCEC’s utilities to homeowners has been deemed non-viable, as it would cost the same for the infrastructure as it would be to add a large building (Harrap, 2019). This means that the return on investment would be higher with a larger building. Overall, the RCEC has faced numerous issues. Considering its early implementation in conjunction with the city’s smaller size and rural nature, the system should be considered a success as it led the way for numerous other DE systems to be developed within BC.

Carbon Pricing

The province of BC’s carbon pricing policies for large emitters, the CIIP, is for facilities that emit over 10 000 tonnes of CO_2e. Since the Revelstoke case emits under 1 000 tonnes of CO_2 they are unable to join this program. This means that the RCEC biomass DE system would be subject to the provincial fuel charge for propane that they use. Having to pay the fuel charge would mean that the cost of heating for the system's customers would rise with carbon pricing. Adding buildings onto the system afterwards has been proven costly but BC’s carbon policies are generally more beneficial towards large DE systems. Funding for clean technology sponsored through carbon pricing could help justify the cost of adding onto the system in the future. Currently, the community's propane costs are being subsidized. This subsidization came into place well after their biomass DE system was implemented and it greatly impacted the RCEC competitiveness against propane suppliers. If propane remains subsidized, the base price of wood pellets at $60 per tonne will only remain competitive if there is a fuel charge (see chart 1). However, if the fuel charge were to not increase as predicted or be removed altogether the base price of wood pellets would not be competitive (see chart 1). If the propane costs are no longer subsidized, the price of wood pellets will regain their advantage (see chart 2).

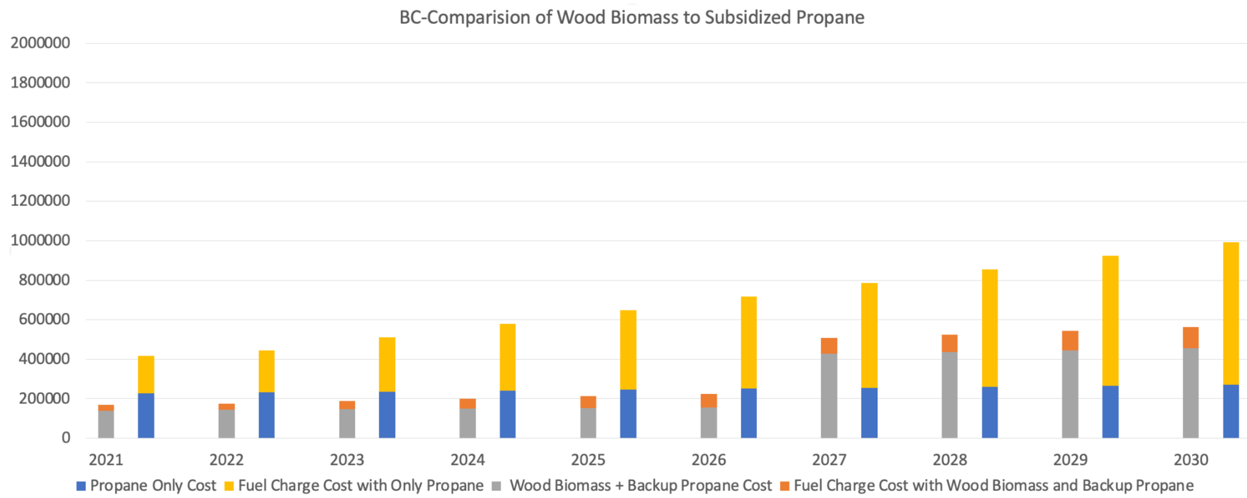
Biomass DE System Overview

Table 1: Revelstoke Biomass DE System Overview

Date	• **2003-2005**
Cost/ Funding	• **$7 million**
Ownership	• **The City of Revelstoke: Revelstoke Community Energy Corporation**
Fuel source	• **Biomass (85%)** • **Propane (15%)**
Capacity	• **1.5-MW biomass boiler** • **1.75-MW propane back up boiler** • **11 buildings, 600,000 sq ft**
Energy Provided	• **Heating** • **Hot water** • **Steam for kilns**
Benefits	• **Reduced GHG emissions by 4-5%** • **4 000 tonnes of wood residue used instead of incinerated without any benefit** • **Better air quality**

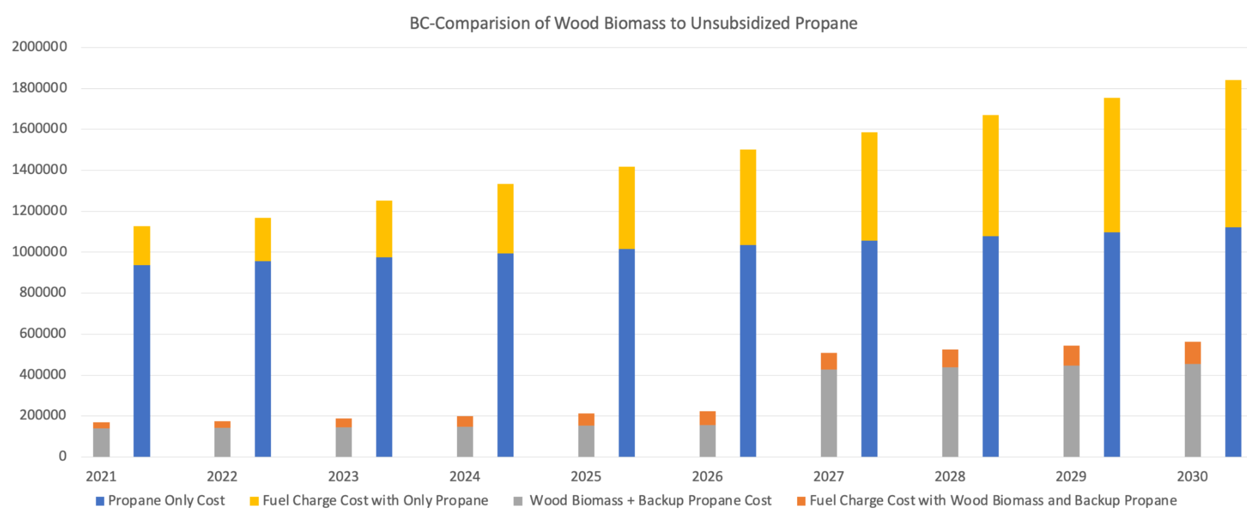
Note*:* Data from Community Energy Association (2013) and Community Energy Association (2013)

Figure 1: Revelstoke biomass DE system compared to only using subsidized propane.



Note: *(Author,2021) This figure demonstrates the RCEC competitiveness against propane suppliers if the system was run completely on propane. The propane only cost demonstrates what this would cost the facility without a fuel charge. When the fuel charge for only propane is added on top, the final price is determined up to 2030.*

Figure 2: Revelstoke biomass DE system compared to only using unsubsidized propane



Note: *(Author,2021) The wood biomass with propane backup is what the current system would pay without the fuel charge on the propane backup. The fuel charge price is added separately for propane the system uses.*

4.2 Oujé-Bougoumou

Community Background

The community of Oujé-Bougoumou is a Cree Nation located in Northern Quebec's James Bay area, 960 kilometers (km) North of Montreal. The James Bay and Northern Quebec Agreement (JBNQA) was signed in 1975 by Cree representatives, Inuit representatives, the Government of Quebec and Canada (Government of Canada, 2014). In 1978 the Naskapi Band of Schefferville signed the Northern Quebec Agreement (NEQA) with the Government of Quebec, Canada, the Société de développement de la Baie James, the Société d'énergie de la Baie James, Hydro-Québec, the Grand Council of the Crees (of Quebec) and the Northern Quebec Inuit Association (Government of Canada, 2014). These agreements are important because they were the first comprehensive land claim agreements signed in modern times. They comprised of some self-government components and helped to build better relationships between the provincial and federal governments, the Cree, Inuit and Nakaspi (Government of Canada, 2014). The agreements also defined rights to resource management, economic development, policing and administration of justice, health care, social services, and environmental protection (Government of Canada, 2014). The territory covered in these agreements (JBNQA and NEQA) comprise of one million square kilometers within Quebec.

The Oujé-Bougoumou Cree Nation were not a part of these agreements as they wanted to settle their own land claim with the Quebec Government and Canada. The Oujé-Bougoumou signed a complementary agreement to the JBNQA which incorporated them under the Cree-Naskapi (of Quebec) Act to act as a local government (Government of Canada, 2017). The Nation resides on land which has vast mineral deposits. Over many years, the area saw a lot of resource development. The Nation of Oujé-Bougoumou went through seven forced relocations of their village within fifty years (Oujé-Bougoumou Cree Nation History, n.d). These relocations were involuntary and done through coercion from the mining industry and the Quebec and Canadian Governments. In the 1980's the Nation started land claim talks with the Quebec and Canadian Government. In 1989 the Quebec Government agreed to fund the relocation and construction of a new village and acknowledged the Oujé-Bougoumou as a local government with a degree of jurisdiction over their territory (Oujé-Bougoumou Cree Nation History, n.d). It was not until 1992 that the Canadian Government agreed to help fund part of the new village. The Nation still has unresolved land claim issues with both the Quebec and Canadian Governments (Oujé-Bougoumou Cree Nation History, n.d). Due to the community's remote location and the high price and volatility of oil, the community rebuilt the village with energy efficiency and affordability in mind. They implemented a district energy system with energy being supplied through biomass. The Nation is neighboured by the Barrette-Chapais Sawmill that can supply an abundant source of energy in saw dust form.

Biomass System

The biomass system implemented following the village's relocation was deemed to be the best option to provide affordable, reliable energy for the community. The sawmill was previously having difficulty disposing of their large amount of forestry waste (Biocap Canada & EnergyNet, 2006). When the village was rebuilt, they implemented a central, woodfired heating plant and district energy to heat the entire community. The system connected 140 homes and 20 public buildings with 12 kilometres of pipe (Biocap Canada & EnergyNet, 2006). The heating plant was constructed with a 1-megawatt (MW) biomass boiler and an 1-MW oil boiler and in 1998 a 1.7-MW biomass boiler was added to account for the community's growth. The system now consists of a 2.7-MW biomass boiler capacity and 2 oil boilers with a capacity of 2.5-MW. The peak winter heating capacity was 2.5-MW in 2000 (Biocap Canada & EnergyNet, 2006). High temperature resistant plastic piping is used to connect smaller buildings while insulated, thin wall, steel pipping is used for core pipes. The water temperature is 85° Celsius at peak rates and during the summer it is 65-70° Celsius, which is all that is needed for domestic hot water (Biocap Canada & EnergyNet, 2006).

Benefits

The district energy and biomass project at the Oujé-Bougoumou aimed to give residents affordable, sustainable, and stable heating. This project aimed to incorporate both sustainability and the Nation's traditional way of life. The Nation achieved this goal using sawdust, which was otherwise considered waste. The sawdust was formerly being stockpiled by the sawmill located 26 km from the village. Previously, the community was reliant on heating oil as an energy source. The price of heating oil in 2000-2001 reached 54 cents per litre before it settled back down to 44 cents per litre (Biocap Canada & EnergyNet, 2006). In 2021, the cost of heating oil is 1.208 per litre. In the winter of 2000-2001, the cost per MWh(th) to run a boiler using heating oil would have been $96 whereas using heat from biomass cost around $11 per MWh(th) (Biocap Canada & EnergyNet, 2006). In 1999-2000 the system burned 3 025 tonnes of sawdust and it took two truckloads a day to maintain the fuel supply during the winter. There is a $6 per tonne loading charge. During 1999-2000, biomass supplied 90% of the village's heat while 10% came from oil (Biocap Canada & EnergyNet, 2006).

The biomass system is not only important for keeping heating costs low, but it also helps keep money in the community. Oujé-Bougoumou offers a unique housing option for its members. There is a home ownership program and a rental program. Ownership is encouraged, while the rental program is for fixed income or low-income residents (Natural Resources Canada, 1998). Under the homeowners' program, the owner is expected to pay back 50% of the construction cost and they are responsible for maintenance and utilities. The program is designed so these costs will be no more than 25% of the family's disposable income (Natural Resources Canada, 1998). By keeping utility costs low, families were able to put more money towards paying off the construction costs. This led to the housing program becoming self-sufficient and more houses being built.

Policy and Funding

The community of Oujé-Bougoumou is a unique case, as the community developed their DE system while they were rebuilding their village. When applying for funding, the community was deemed ineligible for funding, as the community was supposed to be developed near an already existing hydroelectric grid (EnviroChem Services, 2006). At the time of the community's development, costs to produce one megawatt-hour (MWh) of heat from Hydro Quebec's electricity rates would be around $72, while biomass from the local sawmill would cost around $2.50. Since the community received socio-economic based government funding, they decided to put a large portion of that money towards the project. Natural Resources Canada (NRCan) contributed a large amount of technical services and expertise as well as $100 000 and Hydro-Quebec contributed around $300 000. Recently in 2019, the community updated their biomass boilers with a contribution of $2.7 million from the federal government (Church, 2019). They are also upgrading some of the system's pipes and modernizing the control panels. Through the community's interest in biomass DE systems, this project was feasible. Funding from the federal government and Hydro-Quebec was also used. However, policies around funding for energy efficiency programs would not have allowed the community to optimize the best system for them as a biomass DE system was deemed feasible but was not supported through grant eligibility.

Lessons Learned

For this project to be successful, the community of Oujé-Bougoumou started making early decisions about installing this system in 1986 after witnessing a similar system being installed at a military base (EnviroChem Services, 2006). The community first did a prefeasibility study conducted by an engineering firm, which concluded that this system would be not feasible (EnviroChem Services, 2006). After getting a second opinion from the Natural Resources Laboratory (now the CANMET Energy Technology Centre), the project was deemed feasible. This discrepancy in opinions is attributed to the engineering firms lack of technical knowledge regarding biomass DE systems (Biomass Energy Research Centre, 2010). Ensuring that hired companies possess a robust knowledge of these systems is key to gaining a better understanding of project feasibility. When Oujé-Bougoumou's system was being developed biomass DE systems were generally new to Canadian communities. The Natural Resources Laboratory was a division of NRCan, which helped share the costs of the new study (Biomass Energy Research Center, 2010). This involvement from the federal government, as well as the determination of the community helped this project come to fruition. The community's desire for a sustainable, long term solution helped ensure that this project happened. The leaders of the Nation wanted to develop a community which was based around Cree values, sustainability, self-sufficiency, community participation and economic development. Using local resources and having a community-based energy centre has helped keep money within the Nation.

Carbon Pricing

The benefit of using a biomass DE system in Quebec under the province's cap-and-trade policy is that the system provides the community with an economically stable fuel source. Carbon pricing policies and their impact on Indigenous communities varies greatly across Canada. There are no direct exemptions for Indigenous communities or peoples (Environment and Climate Change Canada, 2021). However, carbon pricing policies do not impact the Oujé-Bougoumou's DE system. This is because their system does not produce over 50 000 tonnes of CO_2e. The pricing may indirectly impact the price of fossil fuels over time. The economic benefits of this system are independent from the carbon pricing system, as it enabled the community to re-invest the money saved. Wood pellets are a cheaper fuel source for the community of Oujé-Bougoumou compared to heating oil. Even at the base price of $60 per tonne of wood pellets, the community will pay drastically less than if they used heating oil in their DE system (see chart 3). Overall, this example shows that biomass DE systems can be a cost-effective and sustainable option for remote or rural communities where forestry or other biomass sources are available.

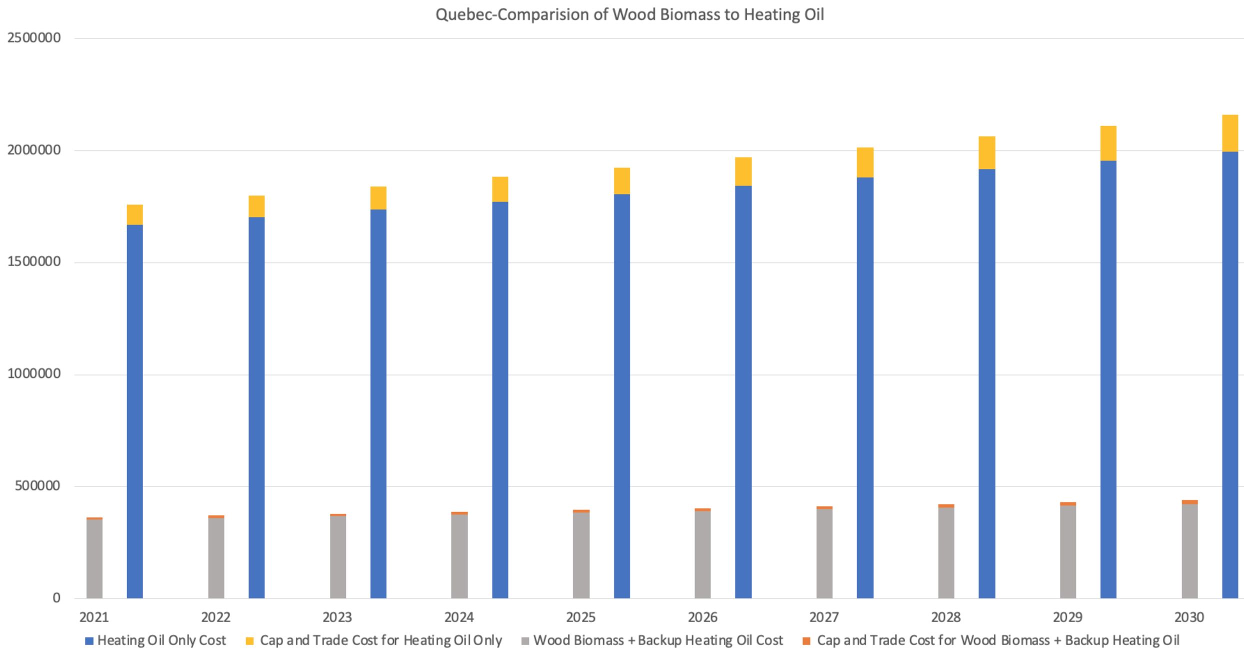
Biomass DE System Overview

Table 2: Quebec Biomass DE System Overview

Date	• **1991-1993**
Cost/ Funding	• **$46 million** • **Part of the resettlement agreement** • **$2.4 million going towards the DE system** • **$2.7 million for 2019 biomass boiler upgrade**
Ownership	• **Oujé-Bougoumou Cree Nation**
Fuel source	• **Biomass (90%)** • **Heating oil back up (10%)**
Capacity	• **2.7-MW biomass boiler** • **2.5-MW oil boiler** • **140 homes, 20 public buildings**
Energy Provided	• **Heating** • **Hot water**
Benefits	• **Stable fuel prices, more affordable heating** • **Local jobs**

Note*:* Data from Biocap Canada & EnergyNet (2006), EnviroChem Services (2006) and Church (2019)

Figure 3: Quebec biomass and backup heating oil compared to heating oil only cost



Note*: (Author,2021) The heating oil only cost demonstrates what the cost of running the DE system only on heating oil would be. The cap-and-trade cost for heating oil is added on top of the cost to demonstrate the difference. The cap-and-trade cost was determined independent of allowances for both the heating oil only example and the actual project costs. The wood biomass and backup heating oil costs are the calculated cost of the real system.*

4.3 Charlottetown

Community Background

The community of Charlottetown implemented a DE system utilizing biomass in 1980. It is Canada's longest running, privately owned, biomass-fired DE system (Canadian Urban Institute, n.d). The city of Charlottetown is on Prince Edward Island (PEI) which is located on Canada's East coast. The city is the capital of PEI and is full of rich history. It was the birthplace of Canada's Confederation in 1864 (City of Charlottetown, 2021a). In the 2016 census the city had 44 739 residents (Statistics Canada, 2016 a). Charlottetown has a diversified economy that is composed of numerous industries, including advanced manufacturing, biotechnology, finance, information technology and tourism (City of Charlottetown, 2021b). In the past and in recent years, the community has had a major focus on diversifying their energy and making their grid more sustainable. In 2015, the city produced a study documenting their GHG inventories. The City of Charlottetown's goal is to achieve 100% renewable energy by 2050 (City of Charlottetown, 2018). Their plan is to have a grid that is 30% solar, 50% wind, 9% nuclear, 5% biomass, 5% municipal solid waste (MSW) and 1% biogas by 2050. Creating a diversified grid has been one of Charlottetown's energy goals for decades. The community uses imported heating oil to meet their heat and electricity needs. Moving away from this energy source will help reduce costs and increase energy stability.

Biomass System

The biomass DE system in Charlottetown serves over 125 buildings which includes residential, commercial, and institutional customers (Canadian Urban Institute, n.d). The system uses wood waste and MSW as fuel sources with oil as a backup source. The fuel ratio is 41% MSW, 42% residual sawdust and 17% oil (Natural Resources Canada, 2009). Three small DE heating plants were constructed by the provincially owned PEI Energy Corporation between 1981 and 1989 (Canadian Urban Institute, n.d). The system was later bought by Trigen Energy Canada INC in 1995 and the production was centralized at a core plant at the centre of Charlottetown. During this transition, Trigen upgraded a heat recovery boiler, and a highly efficient biomass plant was also integrated (Canadian Urban Institute, n.d). The overall system has a capacity of 72-MW and 1.2-MW for electricity (Natural Resources Canada, 2009). The system provides heating, electricity, and hot water for 4.5 million square feet of area. The DE system is connected through 17 km of thin wall steel piping (Canadian Urban Institute, n.d). The finances of the original biomass system were not published but the cost to upgrade the system in 2007 was $28 million (Canadian Urban Institute, n.d). Each building has two heat exchangers, one for heating which pumps 80^{o} Celsius water and another for domestic hot water that pumps 50^{o} Celsius water. The size of this system and its age make it an interesting success story for biomass DE systems.

Benefits

The city of Charlottetown has made it a priority to find a local fuel source for heat and electricity. Most of the city's oil and electricity is imported. Using biomass and waste for fuel makes use of sources which can be found locally. This means that products that were previously deemed waste are now being utilized for everyday essentials, such as heat. The implementation of this new fuel source for the city also meant that they were less reliant on imported oil. By using waste and wood as biomass to replace fossil fuels, more money is retained by the community. For every dollar spent on biomass fuel, 70 cents stay within the local economy, compared to 10 cents if oil was being used (Natural Resources Canada, 2009). Furthermore, as Charlottetown has a limited amount of space, utilizing wood and waste for useful purposes means that the city can decrease the amount of space needed for their garbage. The system burns 6 000 tonnes of waste materials, including wood waste and municipal waste (Canadian Urban Institute, n.d). Overall, the system also reduces the GHG emissions being released into the atmosphere and helps improve the community's air quality. The system reduces CO_2 emissions by 48 900 tonnes annually and sulphur dioxide (SO_2) emissions by 135 tonnes annually (Natural Resources Canada, 2009). Having a centrally located place for stack emissions makes it easier to implement emission controls. Charlottetown's biomass DE system has benefited the community by supporting the local economy, providing stability, and improving the environment.

Policy and Funding

The first part of the project was developed in the 1980's by the City of Charlottetown. This was done by the provincial Crown corporation, the PEI Energy Corporation. This first project consisted of three systems; one in the University of PEI, one in the Queen Elizabeth Hospital and another system incorporating other buildings (Canadian Urban Institute, n.d). This initial system does not have easily accessible or widely published information on costs and funding. The system was later sold in 1995 to Trigen Energy Canada. Energy efficiency upgrades happened in 1998. The total cost of upgrades was reported to be around $28 million (Canadian Urban Institute, n.d). Similarly to the original project, funding for past upgrades are not easily accessible or are unpublished. Charlottetown's system is now privately owned by Enwave after multiple transfers of ownership. Currently, Enwave plans to update and expand their system. The federal government has contributed $3.5 million for the upgrade, which will include a larger furnace, a heat recovery boiler and advanced air pollution controls (Nicholson, 2019). The full upgrade will cost around $37 million, and anything not covered by the federal government will be paid for by Enwave. This upgrade will focus on improving the system's waste to energy abilities.

Lessons Learned

Since Charlottetown's biomass DE system was one of the first biomass systems in Canada, there were a lot of lessons that were learned. DE offers small communities a strong growth strategy and economic retention. If the community is experiencing little to no growth, DE systems offer a strategy to help businesses find a competitive advantage with the cost of operations (Canadian Urban Institute, n.d). DE systems can offer a more cost effective and efficient means for heating, cooling, and electricity.

This project experienced regulatory hurdles that created unplanned "work around" expenses. Levies and fees can increase the cost of a project when applied to private or municipal right of ways for the pipping (Canadian Urban Institute, n.d). These issues should be looked for in pre-feasibility reports to reduce additional costs. Furthermore, engaging stakeholders, regulatory bodies and the public from the start can help support and minimize the number of issues that may arise with these types of projects. Lastly, it is important to look at the system's ability to grow, for more buildings to be added onto the DE system and the ability to hire trained professionals.

Carbon Pricing

The Charlottetown case study demonstrated that larger systems could retain competitiveness through the utilization of different fuel sources. Although this system still uses heating oil to help generate the amount of heat and electricity needed, it still retains its economic incentives. PEI may end up with the full federal OBPS in the coming years. This program does not include district heating amongst the industries allowed to take part, although any facility over 10 000 tonnes of CO_2e could opt-in. Being able to opt-in is important if there is a thermal heat benchmark that the facility is below. This would allow them to generate credits. With PEI's current carbon pricing policies, DE systems are not as competitive as they could be. This is because the province currently does not have a fuel charge on heating oil. If this changes, alternative forms of heating and energy will be more appealing. Even with the federal OBPS, DE systems are not as favourable as they could be. Recognizing DE systems would encourage their implementation. The DE system remains a competitive option for heating and electricity with or without a federal fuel charge (see chart 4).

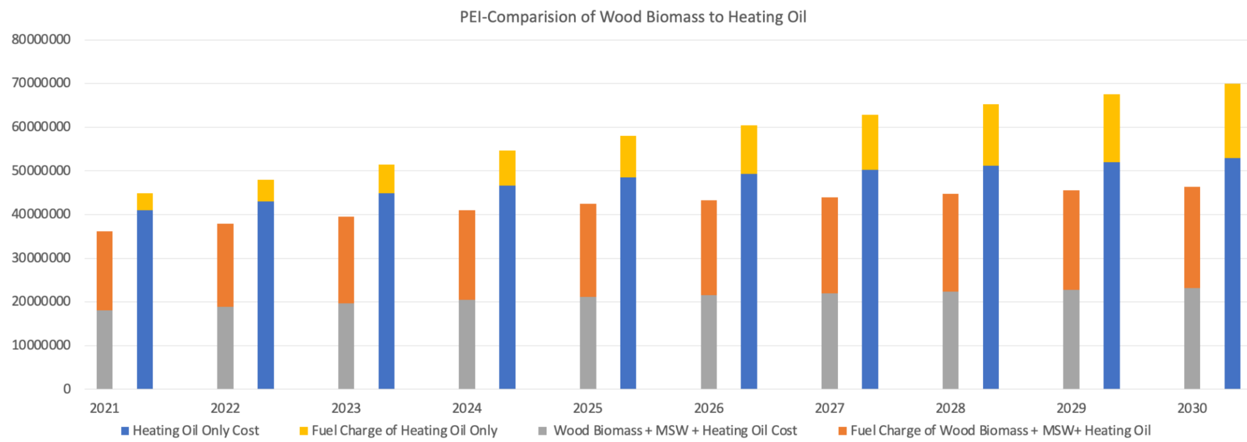
Biomass DE System Overview

Table 3: Charlotte Town Biomass DE System

Date	• **1981-1983 original small DE plants developed** • **1995 centralized plant developed**
Cost/ Funding	• **$28 million for upgrade, original cost not published**
Ownership	• **Private** • **Enwave Energy Corporation**
Fuel source	• **MSW (41%)** • **Biomass (42%)** • **Oil (17%)**
Capacity	• **72-MW heating** • **1.2-MW Electricity** • **125 buildings, 4.2 million sq ft**
Energy Provided	• **Heating** • **Electricity** • **Hot water**
Benefits	• **48 900 tonnes of CO_2 emissions reduced** • **135 tonnes of SO2 emissions reduced** • **Every dollar spent on biomass, 70 cents remain within the community**

Note: Data from Canadian Urban Institute (n.d) and Natural Resources Canada (2009)

Figure 4: PEI wood biomass DE system compared to heating oil only



Note: *(Author,2021) The heating oil only bar shows the cost of only using heating oil for this system. The fuel charge for this example is added on top to demonstrate cost with a fuel charge and without one. The wood biomass, MSW and heating oil cost is the calculated price of the system. The fuel charge is calculated based on heating oil and MSW combustion to get the total cost with carbon pricing.*

Chapter 5: Conclusion

5.1 Discussion

Carbon pricing policies in Canada are a patchwork of federal and provincial programs. This patchwork has made certain provinces more and/or less receptive towards clean energy technology, depending on their existing industries and the political climate. DE systems can offer impressive energy efficiencies and a reduction in CO_2 emissions while biomass can offer a carbon neutral renewable source of power. Together, a biomass DE system can provide a baseload power supply for communities. This typically makes the systems a reliable source for power and heating.

The results of these case studies demonstrates that DE systems are a viable option, now more than ever. Even without carbon pricing policies in place, the cases demonstrated that they were still able to remain competitive when comparing the overall cost of fuel. Carbon pricing policies such as fuel charges will increase the price of using fossil fuels which makes sustainability sourced wood biomass a more reasonable fuel option. However, not all carbon policies are beneficial to the implementation of biomass DE systems. Large emitter incentives either don't apply or DE systems are not recognized as a facility that is eligible. The case studies chosen for this project were all implemented before carbon pricing was. This is because biomass and DE systems have been proven to be beneficial for these communities even without incentives. Wood biomass has validated itself as an option for an affordable and stable fuel supply for rural communities or communities with a strong forestry sector. Wood residue and wood pellets are an under-utilized source of power within the country and many more communities could benefit from using them.

There is a lot of further research that could be done regarding carbon pricing policies and their impact on biomass DE systems in Canada. More research with new data on current biomass DE systems in Canada would be beneficial to understanding their problems and benefits. Current data would help future research understand how these systems could be optimized. While it has been determined that biomass is a worthy choice of fuel for remote communities or places with a local forestry industry, more research is needed to understand the feasibility of wood biomass systems in larger urban centres. This would improve understanding of how feasible these systems are for urban communities which may not have easily accessible wood residue fuel stocks.

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