CASES

BIOENERGY ADVANCEMENT: PROGRAMS AND POLICIES

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Bioenergy Advancement: Programs and Policies

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ABSTRACT

Kelby Brinley: A COMPARITIVE ANALYSIS OF THE ADVANCEMENT OF BIOMASS ENERGY IN ALASKA, FINLAND, SWEDEN, AND CANADA

(Under the direction of Bram Noble)

The development of sustainable practices is growing substantially in several sectors, including that of energy practices. One such energy development is in the use of biomass. The focus of this paper is to review the key constraints and supporters of the development of biomass energy in four separate jurisdictions: Sweden, Finland, Alaska, and Canada. Topics of discussion include resource availability, operational facilities and current projects, and….. The main focus, however, will be on government policies. More specifically, it will review past and present policies that impact the development of biomass energy projects and look at what new policies and changes are being made. Furthermore, by comparing the four jurisdictions, it will look at where Canada stands in this sector and provide insight on why the country may be comparatively lagging.

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Finally, my sincere gratitude to my family for their continuous love, trust, and support. I am eternally grateful to my parents for both their mental and financial support throughout the entirety of my schooling. I am also thankful to my family for providing me with a large variety of experiences and opportunities that have helped shape the individual I have become.

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Literature Review and Research Question

This research project was completed as part of the Community Appropriate Sustainable Energy Security Partnership (CASES), with the University of Saskatchewan. The inspiration behind the project was to acknowledge the issue seen regarding energy in Northern remote indigenous communities. As seen in Figure 1, there are 1,492 off-grid settlements in the arctic region. Due to their remote locations, many northern indigenous communities are unable to be connected to the North American electricity grid and, therefore, often have to rely on diesel-generated electricity. Not only do these systems produce significant amounts of greenhouse gas emissions, but they are costly for the communities (Government of Canada, 2020). With the growing demand for and constant expansion of research on renewable energy systems, and the flaws of the current energy source in these communities, there has been a large amount of interest in shifting away from diesel-generated systems to renewable energy. Although wind and hydroelectric systems have been looked at as modes of doing this, the energy produced from biomass is also an opportunity to do so.

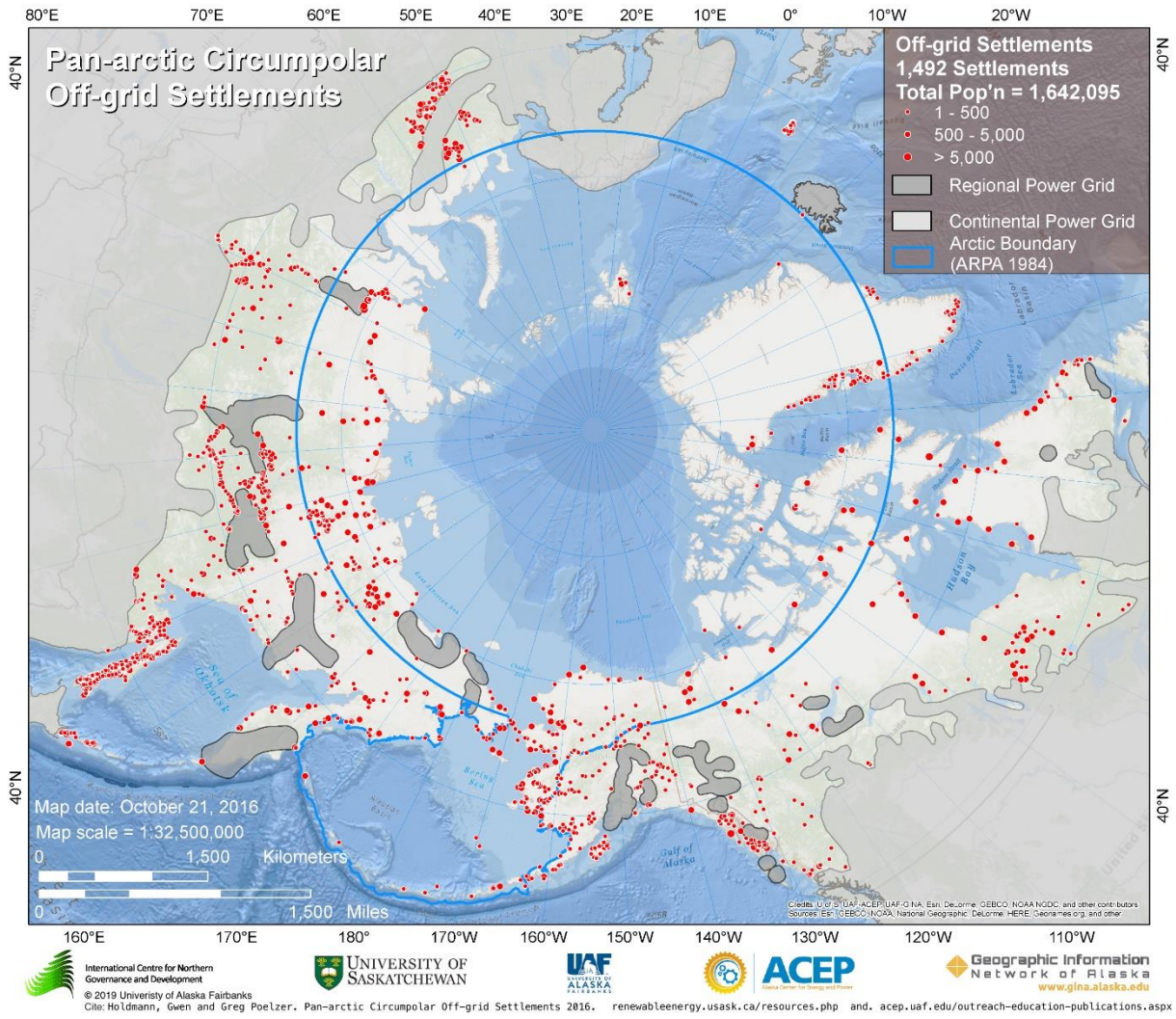

Figure 1: A map of northern off-grid settlements.

Biomass is an organic material, from either plants or animals, that was recently living. Examples of biomass include wood and wood by-products, animal manure, municipal wastewater or human sewage, and crops and waste materials. Bioenergy is then a form of energy that is produced using these organic materials. It is also considered a renewable resource since, when used along with sustainable practices, there can be a constant supply of biomass materials.

The choice of policies and programs as the aim of this project was due to an interest in the role of the state with energy markets. Policies and programs are what industries, communities, and the overall working order within both small- and large-scale jurisdictions are run on. Thus, the implementation and use of these can largely support or constrain the advancement of the shift to biomass systems within Canada, including within the northern communities. Following preliminary research on the implementation of biomass systems, it was found that there are several limitations to bioenergy outside of policies. These include the availability of a resource, the economics and physical ability to harvest and transfer a resource, the economics and ease of building a new plant or converting a non-renewable plant, and the market for biomass in terms of demand. Based on these limitations, the research for this study was focused on policies and programs that are aimed at each of these as separate sub-sectors. Also from this preliminary research, eight categories of policies and programs were identified based on their goals and modes of accomplishing them. These categories include research and development, loans and repayable funds, program activities, financial incentives, procurement programs, demonstration programs, information and education programs, and standards and guidelines.

From the preliminary research of these topics, the research question for this study was: How does Canada compare to other jurisdictions in supporting bioenergy? It is important to address this question, as it is impossible to tell how well or poor a jurisdiction is doing in supporting bioenergy in terms of government policies and programs, without comparing its successes and failures to those of other locations with similar resources and systems. By looking at the policies and programs in jurisdictions similar to Canada, it is possible to distinguish where

the country stands in advancing its bioenergy market and to help allow the government of Canada to better its efforts.

Research Methods

The method used to gather data to answer the above research question was a qualitative comparative study. A qualitative comparative study is a form of analysis that allows an individual to analyse data on a case-based approach. To complete on of these are approximately six steps that should be taken. These are to develop a theory of change, identify cases of interest, develop a set of factors, score the factors, analyse the data gathered, and then interpret the data and revise the original theory (INTRAC, 2017). For this project, the research question was the theory of change, the jurisdictions looked at were the cases of interest, and the factors are the set of parameters that were determined previous to the core research being conducted.

Sources for this study included government policies, yearly energy reports, news articles, case studies, and previous studies conducted on bioenergy in each jurisdiction. Of these sources, the focus was placed on those that were peer-reviewed, scholarly documents. Sources that were not considered scholarly articles were avoided as data sources, unless absolutely no peer-reviewed sources were able to be found. Furthermore, when analyzed, non-scholarly articles were chosen carefully to ensure they came from news sources or organizations that are commonly deemed as commonly relied on mainstream media. All sources were found through the use of online libraries, government websites, and other search engines.

The jurisdictions reviewed in this study were Finland, Sweden, Alaska, and Canada. With Canada being the main country of focus, it was important to establish a base at which the other jurisdictions would be picked based on their level of comparability. Since the large majority of the country's bioenergy plants are currently run on wood fuel types, and Canada has an active forestry industry, wood-based fuels and forestry industries were made this base. Therefore, the countries of Finland and Sweden were chosen based on their large forestry industries. Due to these industries, both locations have a large supply of wood and wood by-products that work as the main fuel type for their biomass plants. They were also chosen based on their current levels of success within the bioenergy industry. Both Finland and Sweden are considered to be countries that have been successful in establishing their biomass industries. Thus, their support systems in terms of policies and programs can be considered good examples of what a successful system may look like. Therefore, both countries were chosen based on the combination of their similar forestry industries, wood resource bases, and their current levels of success in the market.

The jurisdiction of Alaska was chosen for similar reasons. Like Finland and Sweden, a large part of Alaska is covered in forest which not only provides the state with a significant forestry industry but also allows the majority of its bioenergy plants to be operated off of wood-based fuels. The reason this specific state was chosen to be focused on, however, over the entire country was due to its location. Communities in Alaska, especially those that are remote or off-grid indigenous communities, face many of the same challenges as the northern indigenous communities within Canada. Like the Canadian off-grid communities, many Alaskan communities rely on the use of non-renewable resource systems, such as diesel, to provide

citizens heat and power. Therefore, Alaskan was chosen both due to its available resources that are similar to those in Canada, Finland, and Sweden and based on its location and local challenges with energy.

The precise method used to conduct this research was to first pick the three jurisdictions that would best represent what this project was trying to determine in terms of answering the research question. The number of jurisdictions was chosen based on what number was thought to be the most efficient for this project. While one or two comparable jurisdictions did not seem like enough to accurately determine Canada's stance, more than four would have been an overwhelming amount of data that would likely have proven to be more of a hindrance than a benefit. The process of choosing jurisdictions was done by determining what countries have currently been deemed the most successful in implementing bioenergy, and of those, which two are most related to the systems and resources currently used within Canada. Next, was to choose a jurisdiction that was more closely related to those northern indigenous communities that sparked the interest for the project. Being that the state is directly attached to Canada's northern territories, and faces many of the same problems found within those territory's communities, it seemed like a valuable choice.

Once the jurisdictions were chosen, their current bioenergy markets and production levels, forestry industries, and policies and programs that fit into the predicted four subsectors and eight categories were researched one at a time. The focus started on Finland, and then moved to Sweden, followed by Alaska, and finally, Canada. After the data was collected and compiled, it was then determined what policies and programs appeared to be key in supporting each jurisdiction's advances in bioenergy. This was largely based on policies and

programs that directly targeted the bioenergy industry, but also considered those that supported renewable energy sources as a whole. The final step of each jurisdiction's data collection was to review case studies within each. By looking at case studies, the challenges and successes within each jurisdiction regarding support from programs and policies would be seen. Once this data was all collected, the results from each jurisdiction were compared and contrasted. This revealed common denominators in the policies and programs and also revealed what each jurisdiction lacked, in this sense, compared to the next. It also revealed Canada's stance among the other jurisdictions and allowed suggestions to be made that could raise its ranking, based on what was found.

A few limitations were present during this project. The first of which was that each jurisdiction had a different system of reporting its data on bioenergy. Where countries like Finland and Sweden had documents that were specifically designed to contain the bioenergy data from each year, Canada and Alaska had much broader methods of delivery. Data for Alaska and Canada in regards to production levels and resource availability had to be found in multiple locations, whereas the large majority of Sweden and Finland's was found within similar documents. Also, where Finland and Sweden had various styles of graphs to report specific aspects of their data, Canada largely focused its data on less specific line and bar graphs. Alaska, on the other hand, more often reported its data in writing rather than having bioenergy-related graphs. Another limitation was the levels of government that each jurisdiction uses to create its bioenergy policies and programs. Where Sweden and Finland largely implement theirs at the federal level, Alaska had many of its key policies at the state level. Canada was also complicated in this sense, as its policies and programs are also largely placed at the provincial/territorial

level. This meant that there was a much larger number of them to go through and made the country harder to compare.

Results

The data for this project is first shown for each jurisdiction. This is followed by more results created from the combined data.

Finland

The country of Finland has forest coverage of approximately 74% or 23 million hectares. Due to this, it has a large forestry industry that produces wood and wood by-products that can be used in biomass plants. The size of this supply has allowed for wood to be the main fuel base type within the Finnish biomass market. As seen in Figure 2, 28% of this jurisdiction's energy consumption in 2018 was from biomass. This made it the leading fuel type, followed by oil and nuclear fuels (IRENA, 2018).

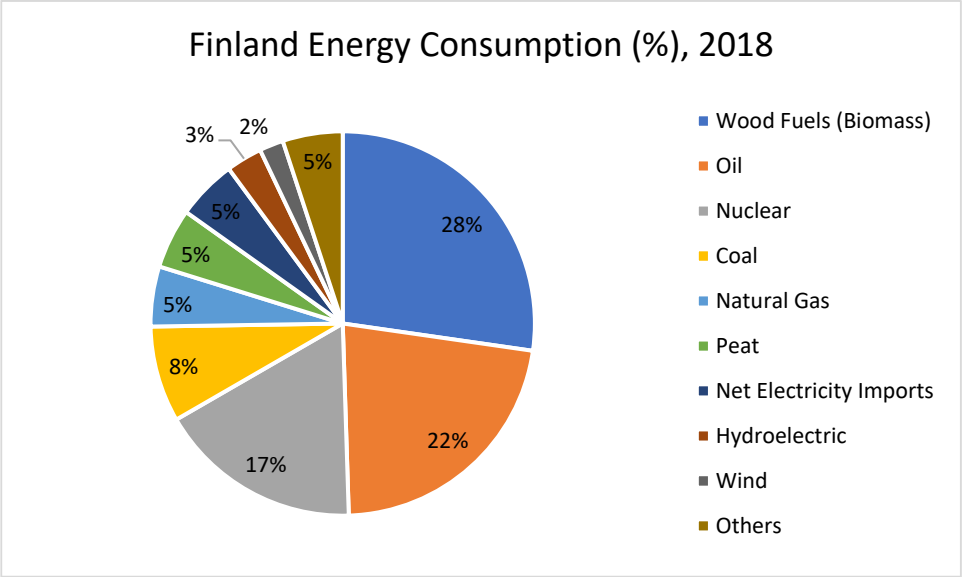

Figure 2: Finland's energy consumption in terms of source, 2018.

Bioenergy policies and programs in Finland are largely found at the federal level. This can be seen in Table 2, which shows where each one fits into each of the 4 sub-sectors and four of the 8 categories. Of the eight policies and programs, there are four that can be identified as key players in the support of biomass energy advancement. These are the Research and Development for Bioenergy technology, an exemption from the carbon tax, the Subsidy for Renewable Electricity Production and the Subsidies for Harvesting Wood Energy.

Table 1: Finland Biomass Policies and Programs

Target	R&D	PA	FI	SG
Availability			Forest Improvement Grants	
Harvesting and Supply Systems	Research and Development for Bioenergy Technology	National Wood Energy Technology Program	Subsidies for Harvesting Wood Energy, Forest Improvement Grants, Subsidies for Harvesting Wood Energy	
Conversion and Construction	Research and Development for Bioenergy Technology			
Market Development			Investment Aid, Exemption from Carbon Tax, Subsidy for Renewable Electricity Production	Action Plan for Renewable Energy Sources

R&D: Research and Development PA: Program Activities FI: Financial Incentives
SG: Standards and Guidelines

The Research and Development for Bioenergy Technology program were implemented in 1996 to increase the use of bioenergy that is environmentally friendly and economically profitable. As seen in Table 1, this program can be classified in the sub-sectors of conversion

and construction and harvesting and supply systems. Thus, it supports bioenergy by addressing two of the four limitations to introducing and advancing biomass systems by working towards developing new fuels, equipment, and biomass uses and transport systems. This program is key due to its specific aim at bioenergy technology, rather than an aim at all renewable resources as seen in other programs and policies (Taylor et al., 2003).

Implemented in the same decade, the carbon tax exemption was brought into play in Finland in 1990. The purpose of this exemption from the carbon tax, also implemented in 1990, was to encourage the use of renewable energy sources. Unlike the previous program, however, this program aims at the use of financial incentives over research advances. This was accomplished by exempting heat and electricity that was produced from renewable resources from paying the national tax. Along with wind, solar, and hydroelectricity, biomass was also identified as one of these renewable resources. Thus, it supports the advancement of bioenergy by providing producers and consumers with a greener solution at a competitive price to non-renewables (Taylor et al., 2003).

Similarly, the subsidies for harvesting wood energy and renewable electricity production are also policies in the category of financial incentives. Although these are separate policies, the two work together to provide a large amount of support to the advancement of biomass as an energy source. The Subsidy for Renewable Electricity Production was first implemented in 1997 and then revised a year later. This policy provides monetary funds that allow renewable resources, including biomass, to be competitive against the non-renewable resources that originally dominated the market. The key to this policy is that as the prices of fuels have changed over the years since its implementation, the policy has been kept up to date with

subsidy rates increasing accordingly. By doing so, this policy has allowed renewable resources to remain competitive. Working alongside this policy, the Subsidies for Harvesting Wood Energy provided financial support that helped shift the energy industry towards harvesting more wood and less of other resources. While these were only in place from 1998 to 2002, the combination of these subsidies with the renewable electricity production subsidy made biomass very economically competitive. Thus, making them key to the support of biomass advancement (Taylor et al., 2003).

Looking at case studies, such as that at Järvenpää and Joensuu, the success of the Finnish policies and programs is evident. Located at Järvenpää is a Combined Heat Plant that was built in 2013. This site uses a flue gas condenser rather than the regular technology used in biomass systems as a means of making the plant more efficient (IRENA, 2018). This advanced level of technology is likely a result of the research and development policy previously mentioned. Furthermore, this system would not have been built if it was not economically competitive with other systems. This competitiveness would be a result of the financial incentives mentioned above. The tax exemption would have created a larger demand for this clean energy. The subsidies aimed at renewable energy and wood harvesting would be supporting the wood-based resource availability required for this project to be successful like it is, as well as making the project more affordable to build and run.

Joensuu also has a combined heat plant that runs on peat and wood sources. This project is also deemed successful as, not only does it provide a community with heat and electricity to the national grid, but there are plans to expand. This project is looking at adding a pyrolysis bio-oil production system to improve the plant's efficiency. This expansion is expected

to add approximately 50,000 tones of bio-oil to this site's outputs (IRENA, 2018). Based on these plans to expand, it is clear that the policies and programs in place have been successful in making biomass an affordable and feasible energy alternative.

Sweden

For Sweden, it was found that 70% of its surface area is covered in forest. This means that there are approximately 22.5 million hectares of trees that can largely be used as a biomass resource base. Thus, like Finland, the country was found to use wood and wood by-products as its main fuel base types. This jurisdiction, however, also moderately uses energy crops, waste products, and wet residues as resource bases. Looking at Figure 3, it was also found that approximately 37% of the country's energy consumption in 2016 was from bioenergy. This implies that it has a well-supported market and industry overall. The second most used energy source was oil with 25% of the consumption (IRENA, 2019).

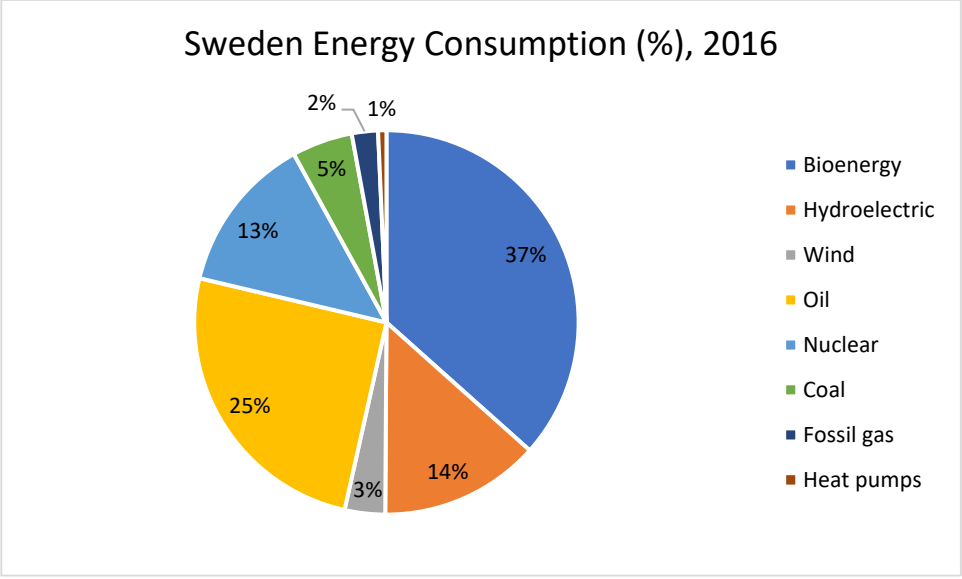

Figure 3: Sweden's energy consumption in terms of source, 2016.

Also similar to Finland, a large majority of the policies and programs in place in Sweden are found at the federal level of government. As of 2003, Sweden had approximately fifteen policies and programs, all of which were found at this level (Taylor et al., 2003). Table 2 shows how these policies fit into the sub-sectors and categories of this study. Furthermore, a few of the policies that were found to be key to supporting Sweden's bioenergy advances are the Green Certificate policy, the Biofuel-fired Combined Heat and Power Investment Grants for New Plants, and the Biofuel-fired Combined Heat and Power Investment Grants for Retrofitting Existing Plants.

Table 2: Sweden's Biomass Policies and Programs, 2003.

Target	R&D	FI	PRP	DP	SG
Availability	Sustainable Production of Forest Fuels Research Program, Bioenergy and Biological Diversity Research Program, Agriculturally Produced Solid Biofuels				
Conversion and Construction	Energy from Waste, Ethanol from Forest Raw Materials Research Program, Combustion and Gasification of Solid Biofuels for Combined Heat and Power Production, Alternative Motor Fuels			Ethanol from Forest Raw Materials Research Program	
Market Development		Biofuel-fired Combined Heat and Power Investment Grants for New Plants, Biofuel-fired Combined Heat and	Green Certificates		Consumption Target

		Power Investment Grants for Retrofitting Existing Plants, Pilot Project Tax Relief, Tax Break for Alternative Fuelled Employee Automobiles			

R&D: Research and Development FI: Financial Incentives PRP: Procurement Programs
DP: Demonstration Programs SG: Standards and Guidelines

Similar to the subsidies seen in Finland, the Biofuel-fired Combined Heat and Power Investment Grants for New Plants/Retrofitting Existing Plants were designed as financial incentives to expand to the production of at least 0.75 TWh/year from biomass. With both grants having the same goal and being implemented in 1997, they worked simultaneously to encourage the conversion of fossil fuel plants and the construction of new plants that relied on biomass. These grants covered up to 25% of the capital or retrofit costs, with a limit of $702 Canadian dollars per kilowatt of installed electricity (Taylor et al., 2003). Due to these grants, the cost of bioenergy systems was lowered and many companies decided to convert to biomass. An ethanol plant was also built due to these grants, which allowed for the introduction of liquid biofuels to the Swedish market (Andersson, 2015).

The Green Certificate policy system was put into place to support the development of bioenergy by replacing the previous investment grants with a system that created a market for energy from renewable resources. With this system, two things happened. The first is that consumers are now obliged to have a specified portion of their energy produced by renewable sources and electricity distributors are requires to have a portion of their electricity certified (Taylor et al., 2003). The other thing that came with this system is that companies are now

incentivized to switch from fossil fuels to renewable energy. This incentivization came from the introduction of certificates that are now awarded to companies, based on the type of renewable energy they use. The reason that this system can be recognized as significant is due to the resulting increases in bioenergy in the first few years of its operation. While wind energy was initially the fastest growing renewable resource, after the certificate policy came into place, bioenergy surpassed the wind-energy growth levels by approximately four times (Andersson, 2015).

The case studies reviewed for Sweden were Sodra Cell Varo and Jamtland county. Both of these cases are good examples of how policies and programs have supported the advancement of bioenergy. Originally constructed in 1972, the Sodra Cell Varo site is one of the world's largest softwood kraft pulp mills. Following a rebuild in 2016, this site is now entirely run off of the pulp produced by the mill. In addition to being self-sustaining, it also uses the excess from its 700,000 tonnes of pulp produced a year to produce 1.6Twh of energy annually and uses it to generate heat and electricity for surrounding communities (Sodra, n.d.). If it were not for the policies and programs that created the bioenergy market and provided monetary incentives, likely, this mill would still run off of fossil fuels.

Like Sodra, Jamtland county is also a success story resulting from the grants and certificate systems, along with others. In 2002, two logging companies partnered up to operate a combined heat and power plant that was able to receive construction funding from the biofuel-fired grants. As of 2015, the plant now runs on 99% biomass sources that consist of return wood, peat, and forest and logging residues. In addition to this plant, the county has also built several small-scale plants powered by animal manure to produce heat and electricity. Due

to the success of these builds between 2010 and 2015, the interest of farmers grew and sparked the potential for further growth (Berlina and Mikkola, 2017). These are just two examples of the bioenergy successes in the county that have resulted from good government support systems.

Alaska

Alaska was found to have a forest coverage of 35%, with 8.09 million non-commercial hectares of that forest owned by the state. Due to this large amount of forest, the main fuel again for this jurisdiction was wood and wood by-products, with support from fish by-products and municipal waste (U.S Department of the Interior, n.d., and Resource Development Council, n.d.) Although wood-based fuels are in abundance, biomass only accounted for 0.3% of the total energy consumption in 2018, as seen in Figure 4, and 2% of the total renewable energy produced, as seen in figure 7 (U.S. Energy Information Association, 2021).

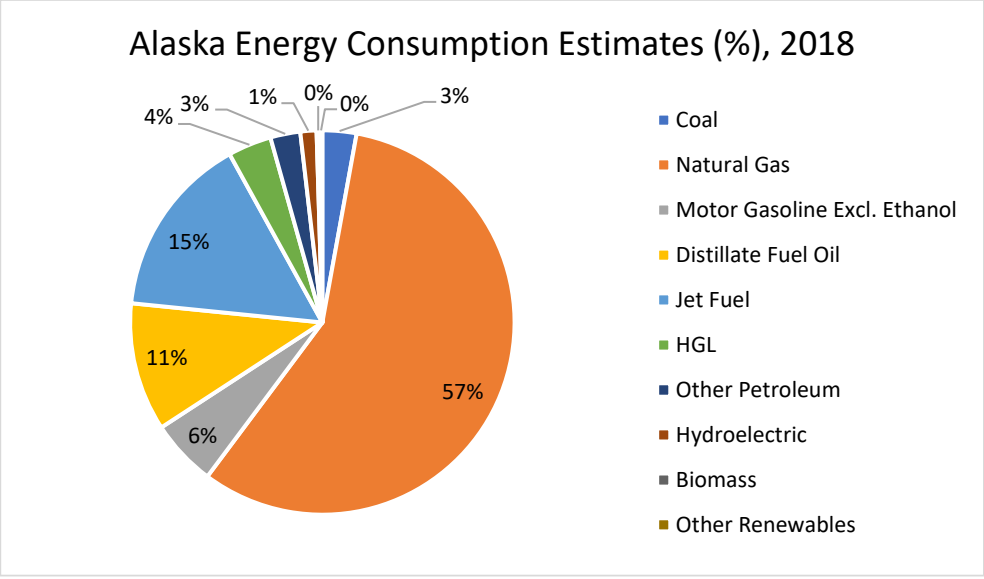

Figure 4: Alaska's energy consumption in terms of source, 2018.

Alaska was found to have policies at both the state and federal levels. As seen in Table 5, the United States has several policies that relate to bioenergy at the federal level. It was found, however, that majority of these policies relate to agricultural sources of biomass (Taylor et al., 2003). Due to Alaska having a growing, but not significant, agricultural industry due to its location, it was determined that the majority of the federal policies would not significantly impact the northern state. For this reason, the key policies and programs identified were all at the state level, as seen in Table 3.

Table 3: Alaska State Level Bioenergy Policies and Programs.

Target	FI	SG
Harvesting and Supply Systems		
Conversion and Construction	Alaska Renewable Energy Fund	
Market Development		Southeast Alaska Integrated Resource Plan, House Bill 306

The Alaska Renewable Energy Fund was established in 2008 and later extended in 2012. This fund between 2008 and 2015, provided $257 million in grants to support renewable energy projects. Thus, it is a program that provided financial incentives to help companies pursue renewable energy sources. Of this $257 million, $27.5 million was granted to biomass projects (BallotPedia, n.d.) Next, House Bill 306 was a bill passed in 2010 within the state. The purpose of the bill was to set the goal for Alaska to achieve having 50% of its energy produced from renewable resources by 2025 (The Alaska State Legislature, 2020).

Finally, the Southeast Alaska Integrated Resource Plan was established in 2012. While not specifically a program or a policy, this plan strongly supports the advancement of biomass

use in Alaska. Within this plan is qualitative data for each of the potential renewable energy sources and systems that could be used to replace non-renewable energy systems in the state's communities. This data includes the identification and descriptions of current policies and research taking place and information regarding what systems would be most practical in the different regions of Alaska. The plan explains the benefits and a few key issues of a variety of biomass fuel types. In doing so, it strongly promotes the use of bioenergy in northern regions as a replacement for diesel and oil systems (Black &Veatch, 2012).

For case studies, the main two analyzed were Delta Junction and the community of Dot Lake. Both of these projects have wood-based systems. The Delta Junction project is run by a logging and milling company that uses the system to power its business. Due to the nature of the business, the source of fuel is sawmill residues, 95% of which is sawdust. This study was a good example of small-scale systems currently in place in Alaska that have the potential to grow with proper government support. The community of Dot Lake was analyzed to see what a larger scale bioenergy system could look like in Alaska. Here a wood-fired system that runs on large firewood to small sawdust particles heats a laundromat and seven homes. The wood fuel is sourced from the surrounding local area, including a local sawmill (Nicholls, 2009).

Canada

The country of Canada has a surface coverage of forests of 38%. Of this 38%, 75% of it is found in the boreal zone. An equivalence of 307 million hectares of forest. With this, Canada also has a very active forestry industry in several of its provinces that produce large amounts of wood and wood by-products. These wood-based resources are the main biomass fuels

currently used on the 70 Canadian biomass systems. In a few locations, such as Edmonton, Alberta, some plants run on landfill gas (Government of Canada, 2017). Figure 5 is a graph that was formed from data found on the Government of Canada website and represents the energy consumption sources for the year 2019. In 2019 Canada's consumption of bioenergy was not significant enough to make it into the represented data. The biomass portion for the country is included in the "Other" portion of the graph, which consists of 3% of the overall total (Government of Canada, 2020). Furthermore, looking at Table 4, there are approximately twelve federal policies that relate to biomass and bioenergy at the federal government level (Taylor et al., 2003). Like Alaska, Canada creates the majority of its biomass-related policies at the provincial/territorial level. While many of these were reviewed, the key policies identified for the jurisdiction were all at the federal level. These included the Northern Responsible Energy Approach for Community Heat and Electricity Program (Northern REACHE), a collaboration with Finland, and the Canadian Forest Service Biomass for Energy program.

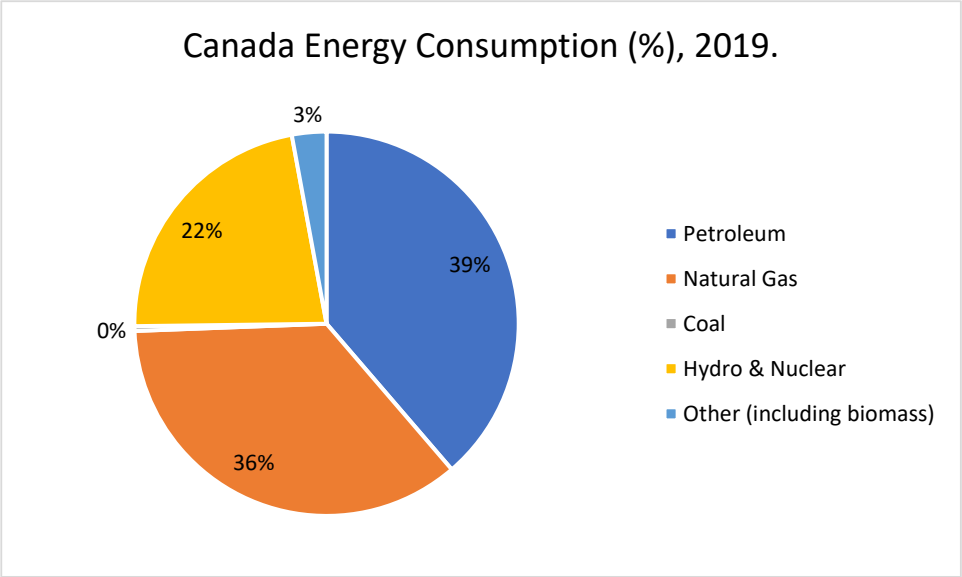

Figure 5: Canada's energy consumption in terms of source, 2019.

Table 4: Canada's Federal Level Bioenergy Policies and Programs.

Target	R&D	L/RF	FI	PRP	DP	SG
Harvesting and Supply Systems	Bioenergy Development Program, Canadian Forest Service Biomass for Energy Program					
Conversion and Construction	Bioenergy Development Program, Advanced Combustion Technologies, Renewable Energy Technology Program		Northern REACHE Program			
Market Development	Finland Collaboration	Future Fuels Initiative	Tax Exemptions for Ethanol Fuel and Biodiesel, Renewable Energy Development, Accelerated Capital Cost Allowance for Class 43.1, Market Incentive Program	Refuelling Stations, Green Power Procurement Program	Refuelling Stations	Consumption Target

R&D: Research and Development L/RF: Loans and Repayable Funds FI: Financial Incentives PRP: Procurement Programs DP: Demonstration Programs SG: Standards and Guidelines

The Northern REACHE program is a program created by the federal government to fund renewable energy projects in its northern communities. It was specifically designed to help northern

communities move away from diesel-powered systems for electricity and heating. The budget for this program changes on an annual basis, with the last recorded budget being $53.5 million for 2018-2019. This program is key to supporting the jurisdiction's biomass industry as it provides a financial incentive to all varieties of renewable projects, including biomass heating (Government of Canada, 2020).

While not an official program yet, the University of Northern British Columbia's collaboration proposal with Finland for biomass expertise is key to the country's support of advances in bioenergy. This proposal states that the province of British Columbia would like to learn from Finland new techniques for supporting and growing the bioenergy industry within the province, and eventually the country (Canada Energy Regulator, 2020).

Finally, the Canadian Forest Service Biomass for Energy Program is a research and development program that was established in 2000. It was created to assess the biomass resources in the forestry and agriculture industries, in hopes of increasing the supply of biomass. It also aims to develop efficient harvesting and supply system methods and to demonstrate the sustainability of biomass systems. Thus, it applies to three of the four sub-sectors in supporting bioenergy (Taylor et al., 2003).

The case studies for Canada were located in Revelstoke, British Columbia, and Ouje-Bougoumou, Onatario. Both of these were chosen for there own unique influence from Canadian policies and programs while using wood by-products as their fuel type. In Revelstoke, a portion of the town is heated by a combined heating and power plant. This plant has faced and overcome the challenges of resource availability, and economic affordability. The one issue it has not yet overcome though is its restriction from the Government of British Columbia. The British Columbia Government currently has a policy in place that limits how much the

Revelstoke system can expand, as once it reaches a certain size the provincial law states that a staff member must be on site at all times. Due to this regulation, the plant is unable to expand, as the project then becomes too costly (Biomass Energy Resource Center, 2017). This is a good example of how policies can restrict, rather than support the biomass industry.

The case study in Ontario is Canada's largest containerized wood biomass boiler. As of 2019, the community had had the its biomass boilers for thirty years and were in need of a upgrade that would not only make the system more efficient, but supply more jobs to the community. When analyzing this project's upgrade it was found that it would not have been possible without an investment of $2.7 million from the federal government and funding from Natural Resources Canada's Clean Energy for Rural and Remote Communities Program (Church, 2019). Thus, this case study was a good example of how the Canadian government is taking steps towards better supporting its biomass industry.

Combined

Combining the data from the four jurisdictions, Table 5 comparatively shows which of these jurisdictions have policies in the different sub-sectors and categories. From this, it is clear that program activities, and information and education programs are the least used as methods of supporting bioenergy advancement. It also shows that research and development and financial incentives are the most commonly used categories.

Table 5: A compilation of the policies found within each jurisdiction regarding the 4 sub-sectors and 8 categories identified at the beginning of the study.

Target	R&D	L/RF	PA	FI	PRP	DP	I&EP	SG

Availability	Sweden, Alaska/ USA			Sweden, Finland, Alaska/ USA				
Harvesting and Supply Systems	Finland, Canada, Alaska/ USA		Finland	Finland				
Conversion and Construction	Sweden, Finland, Canada, Alaska/ USA			Alaska/ USA		Sweden, Alaska/USA		
Market Development	Alaska/ USA	Canada, Alaska/ USA		Sweden, Finland, Canada, Alaska/ USA	Sweden, Canada, Alaska/ USA	Canada, Alaska/ USA	Alaska/ USA	Sweden, Finland, Canada, Alaska/ USA

R&D: Research and Development L/RF: Loans and Repayable Funds PA: Program Activities
FI: Financial Incentives PRP: Procurement Programs DP: Demonstration Programs I&EP: Information and Education Programs
SG: Standards and Guidelines

Also from the combined results, it was found that Sweden has had the most success in both renewable energy production and bioenergy production. Finland ended up being in the middle of the spectrum with high levels of renewable energy and bioenergy production as seen in Figures 6 and 7. It is considered the middle spectrum, however, since Sweden has surpassed Finland by over 10%. Also from these graphs, it is clear that Canada and Alaska are comparatively near the lower ends of the spectrum.

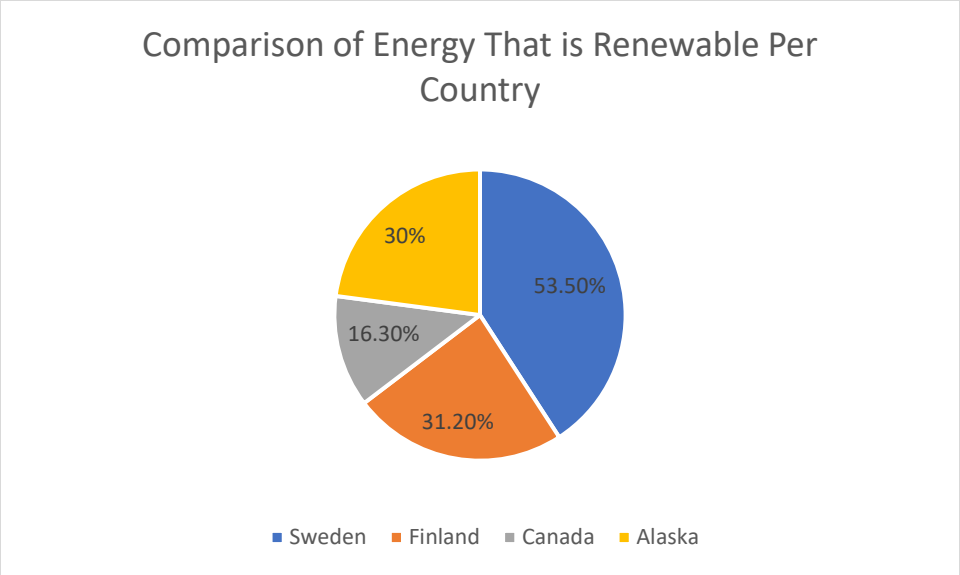

Figure 6: A comparison of the renewable energy production in each jurisdiction.

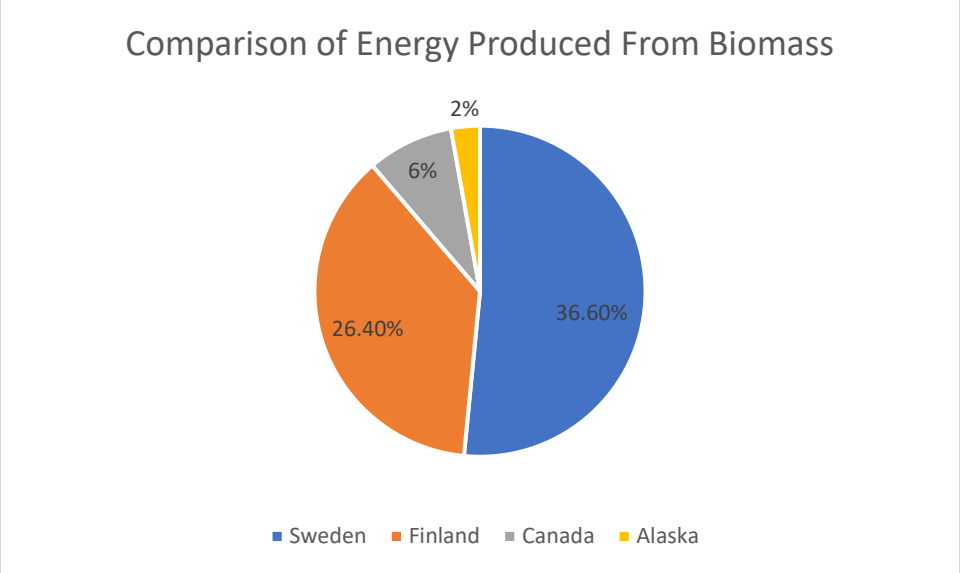

Figure 7: A comparison of bioenergy production amounts from each jurisdiction.

Discussion

Looking at the data, the largest similarity between each of these jurisdictions is the influence of their forestry industries. These industries supply the jurisdictions with wood-based

fuel types that are the current backbone of their bioenergy developments. This can be recognized not only from the percentage and hectare values given, but also from the several case studies mentioned that mainly run on woodchips, pellets, logs, or other forms of wood by-products. While this is currently the case, the overall ratio of forest to surface area varies greatly. Where Sweden and Finland are over 70% forest, Canada and Alaska are only in the range of 30%. Being that Canada is a significantly larger country, it likely would not be able to solely run on the use of wood and wood by-products like Finland. It would also likely require more supporting fuel types than that of Alaska and Sweden as well. In northern communities, however, wood would be the most abundant source of biomass and, with the right conditions created by policies, could have a significant role in replacing diesel-powered systems.

Also, from the data biomass energy is greatly lagging in North America, especially in Canada. As previously mentioned, Figures 6 and 7 show how Canada has significantly lower production percentages of both renewable energy and biomass energy. While Alaska is also found to be drastically behind Finland and Sweden, its low numbers are still comparatively more significant than those of Canada. Not only does Alaska have around double of its energy produced by renewable sources, but as a state that faces the challenges of northern communities, its percentage of biomass production is not much smaller than that of Canada's as a whole.

Furthermore, the results of this research have largely found that there are policies and programs that both help and hinder the development of the biomass energy industries in each jurisdiction. As seen in Table 5, Sweden, Finland, and Alaska all have financial incentives directly aimed at biomass availability and in place to support all 4 sub-sectors that were identified as

crucial to the success of implementing these systems. Canada, however, does not share this level of policies. The financial incentives offered in Canada focus on the use of grants and tax exemptions for market development. Additionally, Sweden and Alaska also place a heavy focus on research and development policies and programs. This can be seen not only from Table 5's data but also from Tables 1 through 4 that show Alaska and the USA having nine policies and Sweden having eight policies that target this sub-sector. In comparison, Finland has one policy and Canada has four policies that target research and development.

Conclusions

From this data, it is clear that Canada's bioenergy industry is comparatively less advanced than that of Sweden and Finland. This lag is likely due to a lack of policies and programs that are specifically aimed at bioenergy, rather than renewable resources as a whole. Referring back to the previous discussion, Finland and Sweden both have federal government policies and programs specifically focused on the advancement of biomass as an energy resource. Canada at the federal level, however, has significantly fewer direct ones in place. Additionally, it was found that Alaska is also taking steps and advancing at a slightly faster pace than Canada in terms of bioenergy. While Canada currently produces three times more of its energy from biomass sources as Alaska does, the American state appears to have more policies and research in place that are specifically aimed at the expansion of the use of bioenergy. The reason that the results in Alaska from these policies and programs are not yet more significant is likely due to how new they are. While Finland and Sweden also have newer policies, they have had well-established bioenergy support systems for a significantly longer period. Thus,

Alaska will likely advance at a much quicker pace now that its policies and programs are beginning to age and get more traction.

While government support is growing within Canada, there are a few potential solutions that can be offered as a result of this project. The first of which is the better implementation of incentives towards biomass availability, conversion and construction, and harvesting and supply systems. Another potential solution could be to create a policy with direct financial production support. Such a policy could take the form of a set dollar amount per kilowatt-hour produced and could perhaps gain funding from the current carbon tax that has been implemented in Canada. The final suggestion from this research could be to implement a system similar to the green certificate program found in Sweden. This system would automatically create a larger demand for green energy sources and could help increase the economical competitiveness of biomass as a source.

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