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INTENSIFIED ROLE OF R&D IN TRANSFERRING FINNISH BIOENERGY KNOWLEDGE AND TECHNOLOGY TO CANADA
Case Sioux Lookout

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Abstract

The thesis applied a four-dimensional approach, which examined bioenergy knowledge and technology transfer from an economic, technical, ecological and social viewpoint. The case study of Sioux Lookout, analyzed in the light of existing literature, found that the barriers bioenergy projects face, are mainly related to public policy and funding, perceived or actual technology risks, and local capacity. Holistic view on energy, innovative collaboration, and interactive communication proved to act as success factors. Shortage of knowledge and technical proficiency was noticed to be a significant factor undermining project success at all four dimensions. It was thereby concluded that there must occur continuous knowledge transfer to enable successful technology transfer. Both the knowledge transfer and the technical solution must be planned according to and in collaboration with the receiving community to increase knowledge internalization.

Communication model of technology transfer was found useful to avoid falsifying the complex transfer process to chronologically ordered stages and one-way communication from expert to user. Quantifying and sharing the socio-economic and environmental benefits of bioenergy systems was noticed to be essential for furthering bioenergy knowledge and technology transfer. The four-dimensional analysis, however, revealed that there are no current mechanisms to incorporate these total benefits, which lowers knowledge articulability and thus also transfer success.

The thesis demonstrated that continuous R&D plays an important role in optimizing the required transfer activities, including those focused on assessing the embeddedness and articulability of the knowledge, those focused on accommodating and reducing differences and issues between the parties, and those focused on transferring the knowledge. It was also noted that stakeholder management and local presence are of paramount importance in long bioenergy transfer projects.

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1 INTRODUCTION

Increasing energy demand, environmental issues relating to greenhouse gas emissions and rising unpredictable fuel costs have led to an increasing interest about the use of forest biomass for energy in many countries (Röser 2012, 3). As a result, remote villages and communities around the world are beginning to transition from diesel generation to renewable energy which creates a demand for expertise, innovative products and integrated solutions (OECD 2018, 69).

Canada's largest environmental challenge is to reduce greenhouse gas emissions which are among the highest per capita in the OECD (The Organization for Economic Co-operation and Development) countries (OECD 2018, 68). Centralized electrical grids do not currently reach many remote areas and the majority of Canada’s almost 300 remote off-grid communities are electrified by diesel or natural gas or both and consequently lacking a reliable, cost-effective and efficient energy supply (Advanced Energy Centre 2015, 1). Reliance on diesel and other fossil fuels has negative economic, social and environmental impacts, and therefore, alternative clean energy provision solutions must be implemented (Advanced Energy Centre 2015, 1).

Small communities are well positioned for district heat distribution systems, especially those located in northern and remote communities (Canadian Counsil of Forest Ministers 2017, 13). Using forest biomass as an energy source has the potential to reduce electricity and especially heat costs, decrease greenhouse gas emissions and increase energy independence of remote communities. As a local renewable energy source, forest biomass can also create socioeconomic benefits which are significant especially in rural areas and peripheries. (Natural Resources Institute Finland & Karelia University of Applied Sciences 2018, 37.) These socioeconomic impacts are generated through the investment project often involved to establish a bioenergy system, employment effect of fuel supply and power plant operation, and the money circulated in local economy instead of paying it to nonlocal fossil fuel supply companies (Sikanen, Nivala & Prinz 2014, 2). As a cheaper alternative for consumers, bioenergy can also directly release more money into the local economy.

Despite above-mentioned drivers, there are various complex and systemic barriers inhibiting clean energy solutions from being deployed across Canada (Advanced Energy Centre 2015, 1). The aim of this thesis is to understand these barriers and the underlying dynamics of bioenergy knowledge and technology transfer. The thesis also examines the intensified role of R&D in furthering Finnish bioenergy knowledge and technology transfer to Canada. The research is conducted as a case study (Yin 2003) with Case Sioux Lookout as the subject. The study is based on self-produced materials and existing material analysis. Self-produced materials are comprised of interviews, discussions and observations at the project site and interpreted with the help of existing material analysis.

Case Sioux Lookout is a Finnish-Canadian bioenergy knowledge and technology transfer process taking place in the Municipality of Sioux Lookout and in the neighboring Lac Seul First Nation in North-Western Ontario (picture 1), which has shown signs of success (Natural Resources Institute Finland & Karelia University of Applied Sciences 2018; Valkeapää 2018; Blanchard 2018). The Finnish organizations taking part in the ongoing joint project are Karelia University of Applied Sciences, Natural Resources Institute Finland and Team Finland together with the Embassy of Finland in Ottawa. The thesis is commissioned by Karelia University of Applied Sciences and executed in collaboration with Team Finland Canada / the Embassy of Finland in Ottawa and Natural Resources Institute Finland.

The findings from Case Sioux Lookout are mirrored with earlier researches about knowledge and technology transfer and bioenergy technology implementation as well as with the previously identified barriers inhibiting clean energy solutions from being deployed in remote communities in Canada. Due to the intricacy of the barriers bioenergy projects face, it is essential to approach them through four dimensions - economic, technical, social and ecological dimensions - which together cover the aspects related to the current policy, technical solutions and local capacity.

Picture 1. Project location (Google Maps 2019).

The analytical framework of this study is set within the theory of systems engineering (Blanchard & Fabrycky, 1981) and innovation systems (e.g. Lundvall 1992) to understand the complexity of bioenergy knowledge and technology transfer process aiming to the establishment of a bioenergy heating system. An approach termed knowledge internalization is adopted in this study to evaluate transfer success. Knowledge internalization defines success as the degree to which a recipient obtains ownership of, commitment to, and satisfaction with the transferred knowledge (Cummings & Teng 2003, 42). Knowledge and technology transfer/innovation streams and transfer success are analyzed across four broad contextual domains that include knowledge context, relational context, recipient context, and activity context.

2 BIOENERGY KNOWLEDGE AND TECHNOLOGY TRANSFER

2.1 Establishment of a bioenergy heating system

Bioenergy is a key renewable energy resource derived from biomass, in other words from any organic material. According to Okkonen, the bioenergy systems are “designed for producing energy from renewable material that reuses the released carbon dioxide” (Okkonen 2009, 32). In addition, the use of biomass for energy contributes to rural development, energy independence, income, and employment in rural areas. At its best, when managed on a sustainable basis, bioenergy can serve as a decentralized energy production solution based on local fuels such as woody biomass. (Röser 2012, 8.) Woody biomass can consist of roots, wood, bark and leaves of living and dead woody trees and shrubs and be categorized as wood logs, chips, pellets and forest residues. Other types of bioenergy fuels are energy crops, agricultural residues and industrial residues.

Designing a biomass heating system requires thorough knowledge of each stage of the system (Röser 2012, 61). Okkonen defines the heat energy business system as a “subsection of wood energy production system” which includes “intertwined technological and economic parts” and “transformations such as the waste management and by-product systems” (Okkonen 2009, 38). The wood energy production system consists of several stages from harvesting of biomass from the forest ecosystem to processing the material for supply to the heating plant where the energy is converted and further transferred to customers (Okkonen 2009, 38). A careful investigation of the technology to be used and the needed know-how for its operation is a precondition in each operational environment. Timing and planning of the different operations and processes such as long-term supply of forest biomass, logistics and management of supply chains to the heating plant, and economic viability are essential to operational efficiency and project success. (Röser 2012, 70.) In addition, nationally and regionally varying regulatory requirements and incentives should be evaluated. Okkonen (2009) presents three stages required for the application of the heat energy business system that roughly summarized include defining targets, analyzing the operational environment, and surveying the possibilities for using external financiers, complementary partnerships, networks or subcontractors.

Successful bioenergy heating system installations depend on considerations of site-specific features and precise calculations of heat load to optimize the boiler sizing. Heating energy in buildings is utilized to produce domestic hot water (DHW) and to provide a comfortable indoor temperature (Natural Resources Institute Finland & Karelia University of Applied Sciences 2018, 11). The need for DHW is dependent on the consumption of warm water and the number of users. Heat consumption varies depending on the outside temperature and is linear to the change in temperature difference between outside and inside temperature. Therefore, to properly estimate the optimal boiler sizing, it is essential to know outdoor temperature profile and heating energy consumption of the project site (Natural Resources Institute Finland & Karelia University of Applied Sciences 2018, 11).

2.2 Framework for bioenergy knowledge and technology transfer

According to Blanchard and Fabrycky, a system can be defined as “an assemblage or combination of elements or parts forming a complex or unitary whole” (Blanchard & Fabrycky 1981, 3). Bioenergy knowledge and technology transfer that aims to the establishment of a new bioenergy heating scheme can be considered as a system, in which different actors are working together as a larger unit to reach a shared objective. The thesis topic touches on Blanchard and Fabrycky’s (1981) systems engineering, in other words “the engineering of human-made systems”. Systems engineering places its emphasis on the process of bringing systems into being. The process starts with the identification of a need and extends through requirements determination, functional analysis and allocation, design synthesis, evaluation and validation, operation and support, phase-out, and disposal. (Blanchard & Fabrycky 1981, 30.) As this thesis examines the intensified role of R&D in accelerating knowledge and technology transfer, it has also similarities to innovation system approach (e.g. the concept of national innovation systems by Lundvall 1992), which regards continuous interaction and interactive learning among actors involved in the exchange of knowledge to increase both absorptive and transfer capacity (Lundvall 1992, 23).

2.3 Communication perspective to technology transfer

Despite the various definitions of knowledge and technology transfer (KTT), there usually is an agreement that knowledge and technology transfer are highly interactive activities (Gibson & Smilor 1991; Gopalakrishnan & Santoro 2004; Lamberton 1991). Current literature on knowledge and technology transfer does not seem to provide a clear explanation on process levels and factors affecting the process, but appreciation for the human component directs us away from thinking knowledge and technology transfer as a linear process towards an interactive process with recurring back-and-forth exchange among parties over an extended timespan (Gibson & Smilor 1991; Lamberton 1991).

Technology transfer (TT) alone can be understood as a narrower and more targeted construct that often embodies certain tools for changing the environment, whereas knowledge transfer (KT) implies a wider, more inclusive construct that aims toward understanding the "whys" behind the process goals. Consequently, knowledge transfer can be considered as a key tool of technology transfer and technology transfer as the application of knowledge (Lamberton 1991; Gopalakrishnan & Santoro 2004). Knowledge and technology transfer is a complex process even when it occurs within a single company and challenges are amplified when crossing organization and especially nation boundaries. Therefore, to enable technology transfer, there must be a continual flow of knowledge transfer via one or more communication channels between involved parties. (Lamberton 1991, 1). Solely developing technical solutions without ensuring capacity for change within the receiving community will negatively contribute to project success.

Three models of technology transfer have been the most dominant: the “Appropriability Model”, the “Dissemination Model” and the “Knowledge Utilization

Model”. The “Appropriability Model” accentuates the significance of competitive market pressures together with the quality of research in achieving technology transfer, whereas the “Dissemination Model” concentrates on the dissemination of innovation to the potential users by the experts. (Devine et al. 1987, 28.) The “Knowledge Utilization Model”, which was developed in late 1980s, contains an underlying presumption that technology moves unilaterally from the experts to the users from “hand-to-hand” and becomes a product (Devine et al. 1987, 29). However, this presumption does not characterize the technology transfer process and researchers have thus blamed the model for linear bias, which falsifies the complex transfer process to chronologically ordered stages and one-way communication from expert to user. (Gibson and Slimor 1991, 290.)

Departing from the previous three models, several researchers have suggested “Communication Model” as a replacement of the earlier TT models. “Communication Model” emphasizes the importance of interpersonal communication between researchers and users and perceives technology transfer as an interactive non-linear process of exchanging ideas among the involved actors. (Williams and Gibson 1990, 13.) The model follows the network communication paradigm, according to which feedback is pervasive and all the participants in the TT process are transceivers rather than sources and receivers (Gibson and Slimor 1991, 290).

2.4 The role of R&D in increasing transfer capacity

Research and development (R&D) can be defined as an activity undertaken to develop new products, improve existing ones or discover new or more efficient processes. The term covers three activities: basic research, applied research, and experimental development. R&D activities result in a systematic creative work that produces new knowledge. The knowledge derived from R&D can be utilized in scientific and technological innovation, which, for its part, may be considered as the transformation of an idea into a new or improved product, into an improved operational process used in industry and commerce, or into a new approach to a social service. (OECD 2015, 45.)

Although the definitions of knowledge and technology transfer are not universally accepted or their flows yet fully understood, innovation literature provides a variety of analytical frameworks in which the flow of technology and knowledge can be contextualized. Innovation is often broadly associated with both the creation process and adoption of something new but the meaning of „new" varies among different fields (Gopalakrishnan & Damanpour 1997, 57). In other words, because conceptualization and practice of innovation is highly context dependent, it lacks a universally agreed definition. However, during the on-going transition towards more complex economies, innovation has been approached as a system (e.g. Lundvall 1992). When considered as a system, innovation is understood as "a set of institutions, which jointly and individually, contribute to the generation, diffusion and use of knowledge for the development, diffusion, and applications of new technologies". This innovation system approach emphasizes the continuous interaction between industry and R&D agents to increase both absorptive and transfer capacity, and to establish linkages between parties. (Lundvall 1992, 34.) It also recognizes policies as instruments of change and thereby the role of governments shaping the innovation system (Lundvall 1992, 152).

2.5 Barriers and drivers to bioenergy implementation

Despite their potential, bioenergy technologies often have problems establishing themselves on the energy market. An increased awareness of "nontechnical barriers" to bioenergy implementation has generated several workshops, conferences and projects to address the issue. (Roos 1998, 9.) Also studies to identify the common features of successful bioenergy projects have been conducted (e.g. Sanderson et al. 1996; Muehlenfeld et al. 1996).

The European Agriculture and Forestry Biomass Network (AFB-Nett 1995) is a European Union (EU) project that has identified barriers to the deployment of bioenergy systems. The principal barriers are lack of understanding, uncertainty regarding availability of biomass resources, low fossil prices, financial and regulatory mechanisms, and inconsistence in policy (AFB-Nett 1995). According to Muehlenfeld et al. (1996) common elements of successful individual biomass operations consist of access to low-cost biomass fuels, continuous on-site thermal energy requirements, access to special financing arrangements, special circumstances that precipitate conversion to biomass, and aggressive farsighted management. The factors that Sanderson et al. (1996) find important for successful bioenergy implementations correspond to some degree to the list given by Muehlenfeld et al. Also two Swedish studies by Hjalmarsson et al. (1996a & 1996b), which appoint factors behind the successful examples of biomass energy in local energy planning in Sweden, are aligned with the findings of Muehlenfeld and Sanderson.

Advanced Energy Centre has examined barriers inhibiting deployment of renewable off-grid energy solutions in Canada's remote communities. According to the study, the barriers are mainly related to public policy, technology, and local capacity. The study highlights that if innovative energy projects that fail to consider all these dimensions, they may produce poor results. (Advanced Energy Centre 2015, 4-6.) Roos (1998) however suggests that barriers and drivers to implementation of bioenergy are two complementary perspectives on the same reality and thus could be labelled more neutrally as “critical factors”. These critical factors should not be used as an absolute checklist without reflection but rather as a framework to examine the drivers and barriers of bioenergy technology implementation simultaneously for the analysis of bioenergy potential. (Roos 1998, 81.)

2.6 Operational environment

There are varying definitions for “operational environment” within different disciplines and sectors but they address the concept similarly. Operational environment of an organization can for example be described as a combination of internal and external factors that can affect the organizations future (Wheelen and Hunger 1995). In ecology, Mason and Langenheim (1957) defined operational environment as phenomena that have operational relevance. The concept of operational environment applied in this thesis consists of the political and policy framework in Canada and in the province of Ontario, ecological considerations, climatic conditions, working culture, the state of bioenergy knowledge and exposure to forest harvesting technology in Northern Ontario, as well as Finland-Canada relations and special features of First Nation communities.

2.6.1 Impacts of fossil fuel consumption in Canada's remote communities

Rural and remote communities face different challenges that can stimulate the regional economic growth (Canadian Counsil of Forest Ministers 2017, 13). Fossil fuel reliance has both long and short-term economic, social and environmental consequences that affect remote off-grid communities. One easily notable economic defect is that the prices of fossil fuels are often high and fluctuate according to supply and demand. Due to population growth and rising energy demand, all costs of supplying and storing diesel fuel constantly increase, especially when the existing system is at its capacity, aging, underperforming or in need of upgrades or replacements. In addition, the provision of electricity in remote off-grid communities is often highly subsidized, thus the costs do not always correspond to the actual usage. For example, in Ontario, the cost of producing off-grid electricity using diesel can be up to ten times higher compared to electricity within the primary electricity grid (Advanced Energy Centre 2015, 2). Reliance of fossil fuels supply is also problematic because of geopolitical and other risk factors.

In some cases, upon reaching nameplate electrical capacity, grid operators are prevented from connecting new loads. Load capacity limitations prevent construction of new housing stocks and limit development of infrastructure investments and upgrades, commercial operations and new tourism in remote communities. (Advanced Energy Centre 2015, 6). The use of fossil fuels for electricity production and the emissions associated with delivering the fuel cause GHG emissions and localized air pollution. There is also a risk of diesel spills both in-situ and in transit that can cause contamination of soil and ground water and have serious health implications for local residents.

2.6.2 Development of forest use and political framework in Canada

Forests have played a central role in Canada's history and been essential to the lives of Indigenous peoples, who created many innovative products from trees and shared their knowledge with European settlers upon contract. In the 17th century, settlers began logging to supply the shipbuilding industry. Wood products composed the basis of Canada's international trade throughout the 1800s. After the invention of techniques for making paper out of wood in the mid-1800s, pulp and paper products overtook sawmilling as the forest sector's largest output. In the 1930s, Canadian Forest Service pioneered innovative surveying techniques such as measuring forest inventories via aerial photography. The economic bloom after the World War II accelerated research on forest threats, such as pests and forest fires, through increased consumption and demand for new wood products. (Canadian Counsil of Forest Ministers 2017, 6.)

Hydro is currently the most extensive source of renewable energy in Canada forming about 67 % of Canada's total renewable energy production. In 2016, the share of solid biomass, e.g. wood and waste, was 22.6 % (Natural Resources Canada 2017, 93). The share of solid biomass can, however, be expected to increase because of the advantageous combination of biomass availability and technical capacity. According to the Canadian Counsil of Forest Ministers (2017), Canada represents 6.5 percent of the world's theoretical bioenergy potential and 9 percent of the world's forests by containing 347 million hectares of forests and the most biomass per capita in the world. In 2014, only 0.72 million hectares of Canada's forest area was harvested, which covers only two-thirds of the allowable cut.
Majority of Canada's forests, 94 percent, are on public lands ("Crown land"), and there has been a long tradition of cooperation between the federal, provincial, and territorial governments on forestry matters. In the late-20th century, Canada developed strong environmental standards in response to the growing

environmental movement. In 1995, the Canadian Council of Forest Ministers (CCFM) that consists of the 14 federal, provincial, and territorial ministers responsible for forests produced a national framework to support country's sustainable forest management (SFM). (Canadian Counsil of Forest Ministers 2017, 6.)

For Canada to meet its current greenhouse gas emission reduction targets under the Paris Agreement, there is a need for industry transformation and innovative forest management practices. Another driver for industry transformation is the decrease of Canada's markets for books, newspapers, telephone books and such products after digitalization. (Canadian Counsil of Forest Ministers 2017, 11-12). To support Canada's shift towards low-carbon and sustainable economy, CCFM has compiled The Forest Bioeconomy Framework for Canada which seeks to increase the use of forest biomass throughout the economy and ensure the vibrancy of Canada's forests for generations to come (Canadian Counsil of Forest Ministers 2017, 3). Together with The Pan-Canadian Framework on Clean Growth and Climate Change, it aims to address climate change, grow the economy, and sustain the forest industry's history of innovation, sustainability and competitiveness (Environment and Climate Change Canada 2016). One aim of The Forest Bioeconomy Framework is to review regulatory processes and ensure that they are appropriate and enable community-level bioheat and power projects. Regulations can affect the advancement of Canada's forest bioeconomy by acting as barriers to project development. For example, water and air emissions regulations regarding bioheat projects may be outdated and inappropriate for the technologies deployed, and thus, lead to project delays, increased costs and ultimately cause viable projects to fail. (Canadian Counsil of Forest Ministers 2017, 25.)

Canada is a federation of 10 provinces and three territories hence there are federal, provincial, territorial and municipal governments in Canada. Federalism allows different provinces to adopt policies tailored for their own populations and gives provinces the flexibility to experiment with new ideas and policies. The responsibilities of the federal and provincial governments are defined in the Constitution Act, 1867. The federal government is responsible for matters of national and international concern such as defense, foreign policy, interprovincial trade, criminal law and citizenship, whereas the provinces take responsibility inter alia for municipal government, education, health, natural resources, and property and civil rights. The federal government and the provinces also share jurisdiction over certain things, such as agriculture and immigration. (Government of Ontario 2019.) In the context of bioenergy technology implementation, federalism can cause incoherence in policy and increase regulatory barriers, but on the other hand, increase funding opportunities. However, funding structures for bioenergy implementation are often seen as complicated (Advanced Energy Centre 2015, 4).

2.6.3 Special features of First Nation communities

According to The United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) that Canada supports, Indigenous peoples have a right to inter alia freely determine their political status and pursue their economic, social and cultural development. They are entitled to autonomy or self-government in matters relating to their internal and local affairs as well as a right to own, use, develop and control their lands, territories and resources. Indigenous peoples have a right to be actively involved in the development of health, housing and other economic and social programmes affecting them, and to administer such programmes through their own institutions. In addition, they have an entitlement to establish and control their educational systems in a manner appropriate to their cultural methods of teaching and learning. (United Nations 2008.)

In the light of the previously mentioned studies by The European Agriculture and Forestry Biomass Network (1995), Muehlenfeld (1996), Sanderson (1996), Hjalmarsson et al. (1996), and The Advanced Energy Centre (2015), The United Nations Declaration on the Rights of Indigenous Peoples can positively affect bioenergy knowledge and transfer processes taking place in Canadian First Nation communities. Bioenergy technology implementation can theoretically face less regulatory barriers due to the autonomous position of Indigenous Peoples. The right of Indigenous Peoples to own, use, develop and control their lands and resources such as forests can increase biomass availability. Additionally, special financing arrangements may be available. However, inconsistence in policy, cultural differences, different educational systems and thus also varying stages of general knowledge may cause challenges.

2.6.4 Finland-Canada relations

As northern leading-edge information societies with bilingual parliamentary democracies, Finland and Canada have much in common. The two countries have similar geography, climate and natural resources and they share values in such areas as domestic policy, development, human rights and environmental issues. Finland and Canada work closely together in many areas multilateral organizations such as the United Nations (UN), the Organisation for Security and Cooperation in Europe (OSCE), the Organization for Economic Cooperation and Development (OECD), and the Arctic Council, an international forum that addresses the common concerns and challenges facing the governments of Arctic nations. Additionally, indigenous Sami people of Northern Finland have established regular exchanges with Canadian Inuit groups. (Government of Canada 2018.)

Bilateral trade flows between Canada and Finland are relatively modest, partly because the two countries compete in several resource-based sectors. Canada exports to Finland mostly ores and coal. Finland’s exports to Canada mainly consist of renewable fuels, machinery and machine parts, electronics and nickel ores. In 2017, imports from Canada to Finland amounted to 512, 731, 000 euros and exports to 568, 759, 000 euros. Trade balance in 2017 was hence +56, 029, 000 euros. In the provincial level, the most important trade partners of Finland were again Ontario, Quebec and British Columbia. (Finnish Customs 2019.)

Embassy of Finland to Canada, Team Finland, Natural Resources Institute Finland and Finnish companies have been working closely together for several years to open cleantech and bioenergy markets in Canada (Valkeapää 2018, Sikanen 2018). Finland is a good benchmark for Canada because of the similar climatic and natural conditions such as cold and snowy winters and primarily boreal coniferous forests. Both countries also have a tradition of harvesting forest resources for industrial purposes. (Karelia University of Applied Sciences & Natural Resources Institute Finland 2018, 7.) However, despite all the positive starting points, Canadian bioenergy and cleantech market is protective and new technological solutions are often blocked because of barriers related to permitting and certification (Valkeapää 2018, Sikanen 2018).

Comprehensive Economic and Trade Agreement (CETA) between the European Union and Canada aims to boost trade and help generate growth and jobs. CETA aspires to these goals inter alia by lowering customs tariffs and other barriers to trade between the EU and Canada and allowing for the mutual recognition of some qualifications. The agreement strives to uphold Europe's high standards in areas like food safety, workers' rights and the environment and to create predictable conditions for both EU and Canadian investors. It also has some of the strongest commitments ever included in a trade deal to promote labor rights, environmental protection and sustainable development. Therefore, CETA could theoretically cut EU exporters' costs and make it easier for EU firms to bid for Canadian public contracts, which would make European firms more competitive in Canada and benefit especially small and medium-sized EU enterprises. CETA entered into force provisionally on 21 September 2017, and already resulted to some modest increases in trade between Canada and the EU. (European Trade Commission 2018.) However, it is difficult to evaluate up to which extend this trend is caused by CETA. Even though the direction seems to be positive, it will most likely take years before CETA will have a significant effect on market boosting.

3 CASE SIOUX LOOKOUT

3.1 Background

There is growing research literature on the commonalities between northern regions of the world and the need for trans-national cooperation between them. The Boreal forest region of Canada and Northwestern Ontario itself are two of those regions (Lawrance 2018). Trans-national cooperation provides business opportunities and knowledge building for the provider countries and minimizes the growing pains in recipient countries.

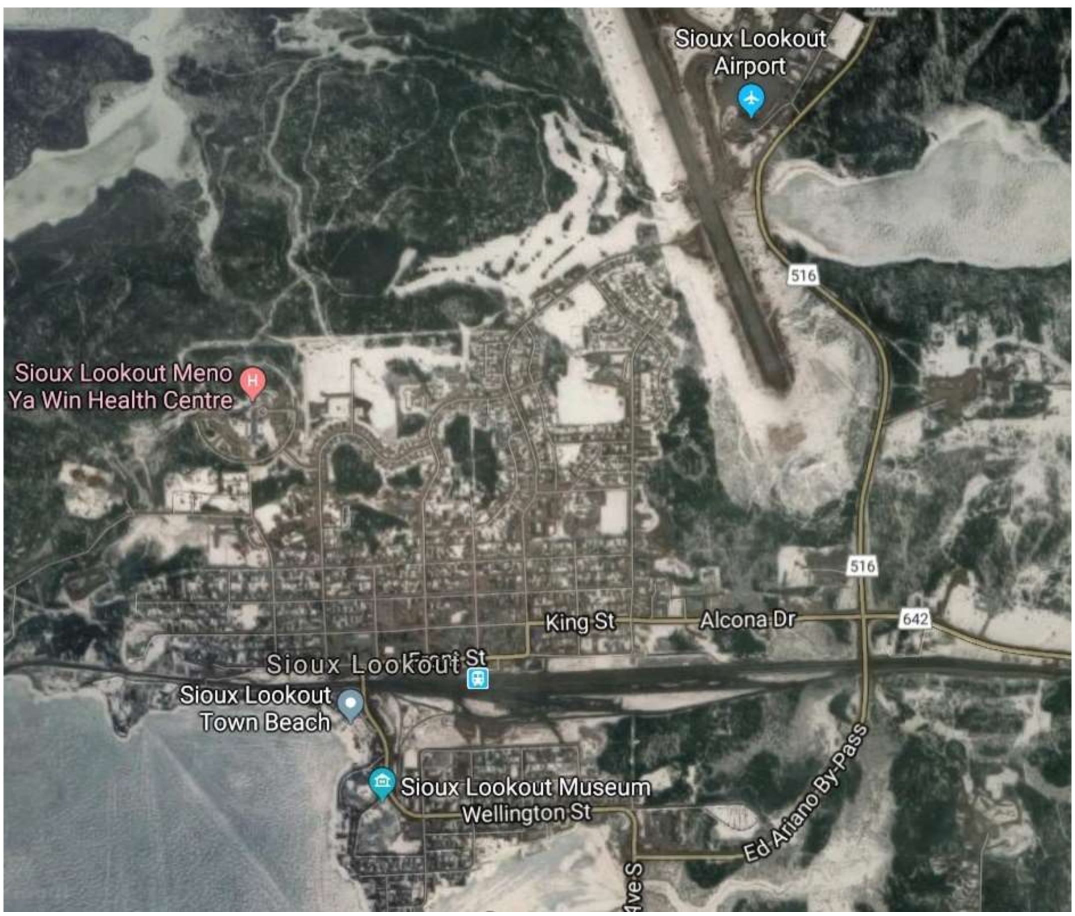
The Economic Development Office of Sioux Lookout has been working with regional partners to attract Foreign Direct Investment to Sioux Lookout with focus on the forest sector and bio-economy (Blanchard 2018). One driver has been the relatively high price of electricity. Current heating systems are run on fuel oil and electricity because the community has no access to natural gas, hence the municipality and different property owners are searching for more economic alternatives (Lawrance 2018). Simultaneously, the Embassy of Finland to Canada, Team Finland, Natural Resources Institute Finland and Finnish companies have been working closely together for several years to open cleantech and bioenergy markets in Canada and identified close to ten potential leads, mainly in the provinces of Ontario, Quebec and Yukon. One of the most promising cases is a bioenergy knowledge and technology transfer process aiming to the establishment of a forest biomass based ecological heat production in the municipality of Sioux Lookout and neighboring Lac Seul First Nation in North-Western Ontario (Sikanen 2018, Valkeapää 2018). This municipal-national co-operation speaks to the research suggesting this type of northern world collaboration is essential for sustainable development in the current era. According to the Mayor of Sioux Lookout, “Finland has much to offer through its’ northern experience in forest resource management and utilization, community development, and technological advances”. (Lawrance 2018.)

Recently conducted feasibility studies (e.g. Natural Resources Institute Finland & Karelia University of Applied Sciences 2018) show the potential of wood in energy production in Sioux Lookout and neighboring Lac Seul First Nation community very clearly. The conversion to biomass will prove cost effective and environmentally beneficial over the fuel oil heating. Economic feasibility of the community heating project looks also promising. Sioux Lookout and neighboring Lac Seul First Nation are ideally located next to a relatively large forested area with appropriate infrastructure of roads to serve the operations of supply. There is also local experience and strong traditions of using forest biomass for energy in the region, albeit they primarily cover the use of cordwood for domestic heating. Even though the use of forest biomass does not yet cover centralized heating systems or the use of wood chips or pellets, existing forest harvesting systems can be utilized, which minimizes needed changes to the current workflow. Both communities also have a building mass enabling a good start up and offering potential for future growth. Employment effects at the first piloting phase are relatively small but can be expected to increase significantly with the upscaling of the bioenergy production in the future. (Natural Resources Institute Finland & Karelia University of Applied Sciences 2018, 39.)

Relatively seldom a customer seeking to implement green energy has all required resources. However, bioenergy projects speak to the demand for sustainable development in the current era hence there sometimes is external funding available (Sikanen 2018.) Funding bodies and regulations in Canada vary provincially, and thus, can appear as complicated (Advanced Energy Centre 2015, 4). Therefore, it is beneficial for project success that financial engineering supported by consults or other specialists (Sikanen 2018, Valkeapää 2018.) An interesting structure and an important procedure in financial engineering of public financing of projects is multiplying the money. Often, when someone puts in “seed money”, public financer responds by multiplying it. In Case Sioux Lookout the first investment also led to a multiplied project finance. (Sikanen 2018, Valkeapää 2018.)

3.2 Municipality of Sioux Lookout and Lac Seul First Nation

The Municipality Sioux Lookout (picture 2) is located in North-Western Ontario, halfway between Thunder Bay and Winnipeg, north of the TransCanada Highway. In addition to highways, the area is connected to a railway network and sustains its own airport. Sioux Lookout has a culturally diverse population of over 5,080 residents, on top of which it serves as the "Hub of the North" providing essential services to about 30,000 people in 29 remote First Nation communities. (Municipality of Sioux Lookout 2015A, 3). The Sioux Lookout Municipal Airport provides service to approximately 135,000 passengers travelling through the airport every year. (Municipality of Sioux Lookout 2015B, 25).



Picture 2. The Municipality of Sioux Lookout (Google Maps 2019).

Despite the turbulent global economic conditions of recent years, Sioux Lookout has maintained comparably good economic stability and continued growth, largely due to its position as the service hub for surrounding northern communities but also on account of its diverse economy. The economy of Sioux Lookout includes forestry, railroad, tourism, professional sectors, air transportation, retail, bulk fuel supply and delivery, construction and material supply, hotels, restaurants, government services, health care, social services, and First Nation's agencies (figure 1). Sioux Lookout has a labor force of 3,115 persons and relatively high labor participation and employment rates (72.2) compared to the provincial average (61.3). Correspondingly, the unemployment rate of Sioux Lookout (4.6) is lower than the average of Ontario (7.4). (Municipality of Sioux Lookout 2015B, 14.)

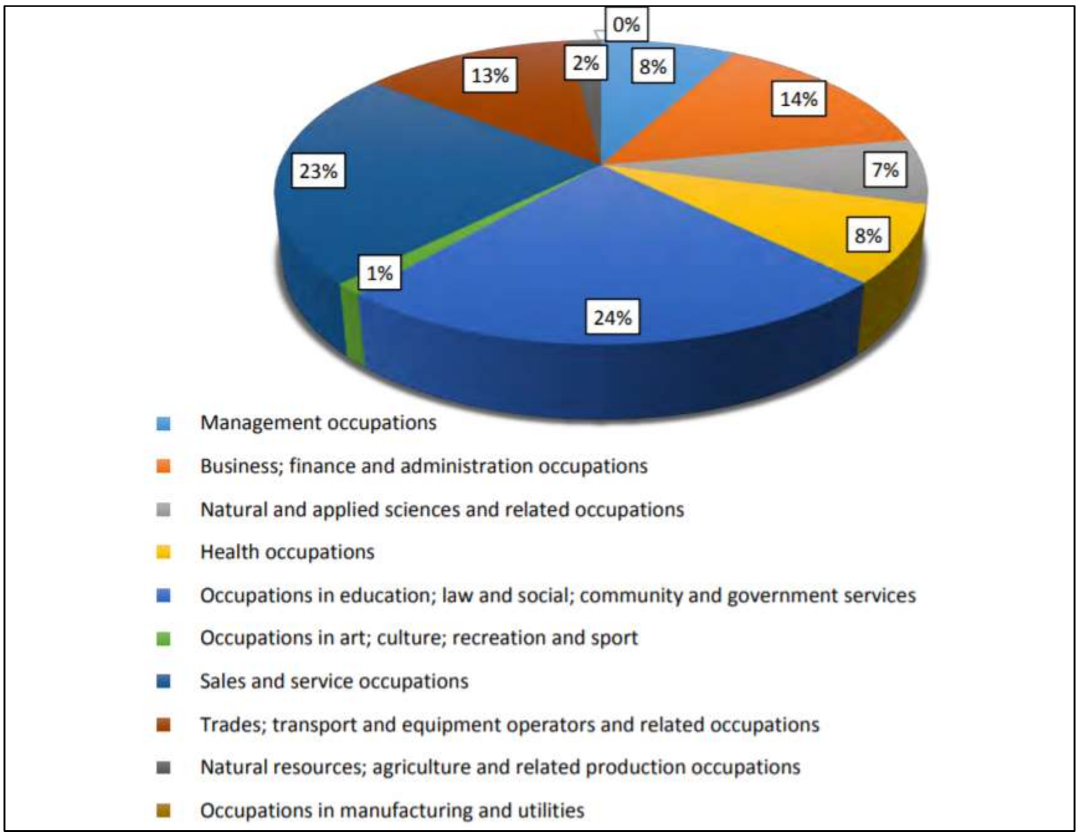


Figure 1. Labour force occupation in Sioux Lookout (Municipality of Sioux Lookout 2014).

Lac Seul First Nation (picture 3) is located about 40 km from the municipality of Sioux Lookout and it extends from the southeast shores of Lac Seul Lake southward to the north shores of Lost Lake. The community consists of three distinct settlements called Frenchman's Head, Kejick Bay, and Whitefish Bay.

The total area covers 66,248 acres of land with current on-reserve population of about 860 and total registered population of 3,372 (as of October 2015). (Lac Seul First Nation 2019). Lac Seul First Nation possesses the rights stated in the United Nations Declaration on the Rights of Indigenous Peoples (United Nations 2008), and thus, is entitled to decide also over the use and development of their forest biomass resources.

Picture 3. Lac Seul location (Google Maps 2019).

3.3 Participants of the project

NRCan Bio Fuel Demonstration Project involves many stakeholders and entities that overlap. This multi-lateral co-operation includes inter alia the Municipality of Sioux Lookout and the neighboring Lac Seul First Nation, National Resources Canada (NRCan), Embassy of Finland in Ottawa / Team Finland, Natural Resources Institute Finland (Luke), Karelia University of Applied Sciences (Karelia) and private Finnish technology. The first contracts for conducting feasibility studies of Local Heating Based on Forest Biomass in Sioux Lookout and Lac Seul were made between the municipality and Finnopool, a privatelyowned Canadian consulting company led by a Finnish President/CEO. The contracts further included Natural Resources Institute Finland and Karelia University of Applied Sciences as subcontractors. The data for the first preliminary listing of target buildings was collected by GCK Consulting and processed together with Karelia, Luke and GCK teams.

Team Finland is a network that brings together all state-funded business and internationalization services in Finland. The network consists of the Ministry of Economic Affairs and Employment, Ministry for Foreign Affairs, Ministry of Education and Culture, Business Finland, Finnvera, Tesi (Finnish Industry Investment), Centres for Economic Development, Transport and the Environment, Finnish Patent and Registration Office, Finnish-Russian Chamber of Commerce, Finnish-Swedish Chamber of Commerce, VTT Technical Research Centre of Finland, Finnfund, Finnpartnership and Finnish Cultural and Academic Institutes. With the country government reform in 2020, the network will also include private sector actors. Abroad, the Team Finland network is represented by more than 80 local teams that each gather together the Finnish authorities, publicly funded organizations, and other central actors representing Finland in the region. (Team Finland 2019.) State involvement brings credibility to local projects, which is important especially when applying for funding (Blanchard 2018; Valkeapää 2018).

3.4 Timeline

A simplified timeline of the Case Sioux Lookout is presented in the figure 2. starting from the introducing of Finnish solutions for the potential customers through road shows and seminars. The first Team Finland trip and tour around Lake Superior in Ontario was organized in 2014. The tour included visits in Sault Ste. Marie, Wawa, Marathon, Red Rock, and in Thunder Bay and led to participation of Naturallia - Canada's leading business alliance forum on natural resources - in Sudbury and later to Dr. Lauri Sikanen’s scholarship to Lakehead University in Thunder Bay. Sikanen joined Lakehead University from Natural Resources Institute Finland to become the New Chair of Finnish Studies. The second Team Finland delegation with Minister Mykkänen was arranged in 2017. (Sikanen 2018). The introducing of Finnish solutions for the potential customers was followed by finding concrete places where Finnish solutions could work. "In total, the preliminary work has taken approximately for a decade or more" (Sikanen 2018).

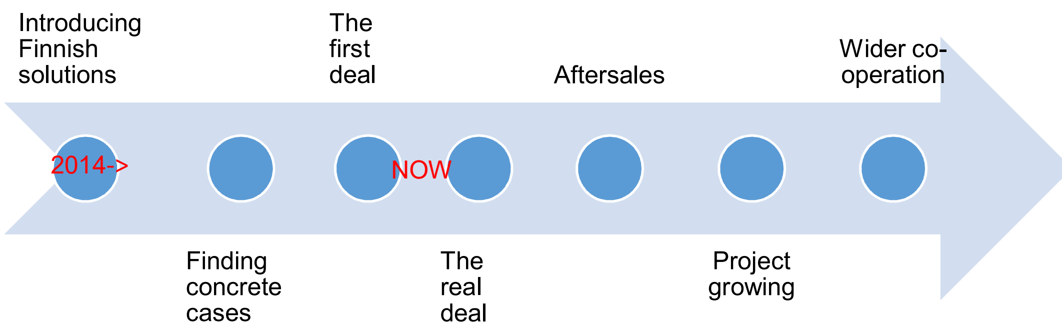


Figure 2. Timeline of Case Sioux Lookout.

Project Sioux Lookout and Lac Seul was started when the Economic Development Manager of The Municipality of Sioux Lookout Vicky Blanchard heard about the Finnish delegation in question in Thunder Bay and a meeting between Blanchard, Sikanen and Finnopool's CEO was arranged. First discussion led to the visit of Sikanen in Sioux Lookout in early November 2017. The Municipality introduced Dr. Sikanen to Obishikokaang Resources Corporation, the Lac Seul Forest Operations and the community of Lac Seul First Nation. Another delegation of companies representing Finland visited Sioux Lookout and Lac Seul First Nation on December 11th and 12th 2017.The first site tour was arranged in November 2017 and it resulted in the preliminary listing of the target buildings in Sioux Lookout and Lac Seul (Frenchman's Head and Kejick Bay). (Blanchard 2018; Sikanen 2018). The data for preliminary listing of target buildings was collected by GCK Consulting and listing of the most promising and viable bioenergy conversions done together with Karelia and GCK teams. The estimation of heat consumption was originally made by GCK Consulting according to the total energy consumption, which gave an estimate of heat production but needed to be extended to consider also facility connected specialties such as hot water consumption during summer time. (Natural Resources Institute Finland & Karelia University of Applied Sciences 2018, 8.)

To further examine public buildings in Sioux Lookout and neighboring Lac Seul First Nation for their viability to convert to biomass, the municipality of Sioux Lookout commissioned a feasibility study in partnership with the Natural Resources Institute of Finland and Karelia University of Applied Sciences. This first deal led to the arrangement of a second site visit to collect more detailed data for the calculations of the most promising sites in June 2018. (Blanchard 2018; Sikanen 2018.) In November 2018 Natural Resources Institute of Finland and Karelia University of Applied Sciences announced the findings of the final feasibility study conducted in collaboration with Obishikokaang Resources Corporation, GCK Consulting ltd. and Finnopool ltd. The study included results and recommendations of forest biomass-based heating concept on public premises of Lac Seul First Nation community and of selected locations in the Municipality of Sioux Lookout. (Natural Resources Institute Finland & Karelia University of Applied Sciences 2018.) The project is now waiting for the last funding decisions and the establishment of the concrete forest biomass-based heating system.

During the site visits, great potential for bioheating was also identified e.g. in the Sioux Lookout schools and the Meno Ya Win -health centre, all of which are currently using oil and propane for energy, as well as the local saw mill with the garage in Lac Seul. Consequently, Sioux Lookout community heating project is now growing towards a comprehensive sustainable housing project. The Municipality of Sioux Lookout has announced that Sioux Lookout and Lac Seul First Nation will organize a Northern Housing Summit together with Finnish partners in 2020 (Blanchard 2018). The summit will be accompanied with a Sustainable Housing Fair where affordable, ecological, socially and culturally sustainable houses are presented for public for one month in the form of an “Eco

Village". The idea is to demonstrate new housing concepts for sustainable and healthy living, such as, the use of local wood in buildings, biomass heating, advanced recycling and sewage systems.

According to the Mayor of Sioux Lookout, there are about two hundred new jobs in Sioux Lookout but a severe shortage of housing for newcomers. Vacancy rates are forever close to zero percent and this shortage of housing cuts across all sectors in both private and public housing. Additionally, there is also a lack of housing form, style, size, and type. "The ecovillage project comes at a time when Sioux Lookout's decades long perennial housing shortage is at a crisis level (Lawrance 2018)." In addition to the biomass heating and the eco-village projects, there is also a third aspect to project growing, which is the possibility for a deeper and wider cooperation between The Municipality of Sioux Lookout and Finland in the future.

3.5 Suggested solutions

The suggested supply chain, heat production technology, and sizing methods are based on proven solutions in Finland and elsewhere in Europe. To optimize boiler sizing, it is essential to know the outdoor temperature profile and heating energy consumption in the selected buildings. Figure 3, derived from YXL airport data, illustrates the daily outdoor temperature profile of YXL airport weather station during year 2017. The graph shows that there are less than 90 days per year when the average outside temperature is less than -10 °C, and less than 23 days when the temperature is below -20 °C thus below -20 °C outside temperatures can be considered as peak load area. (Natural Resources Institute Finland & Karelia University of Applied Sciences 2018, 12.)

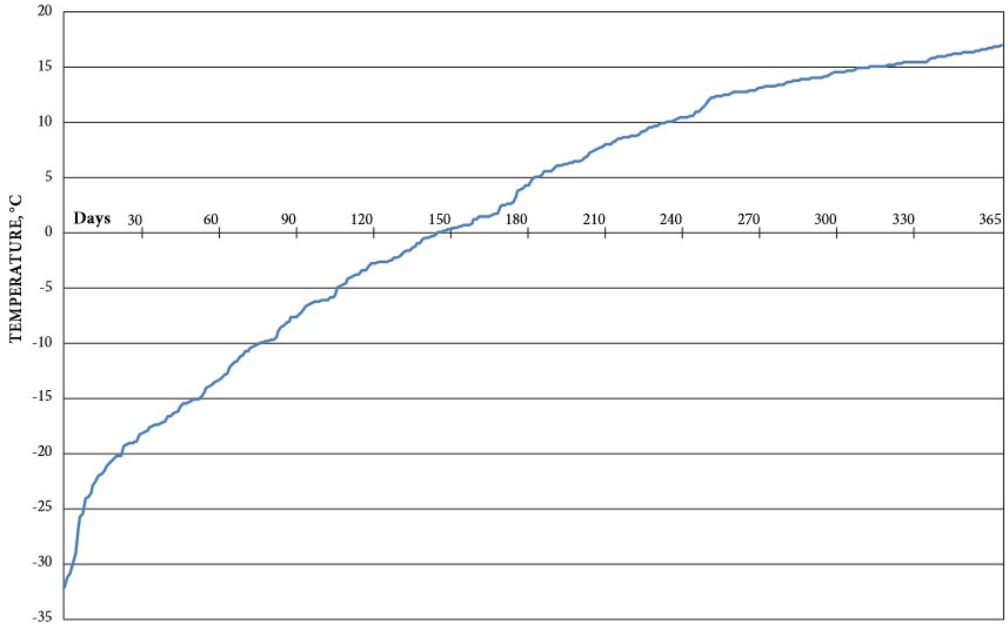


Figure 3. Temperature profile of Sioux Lookout (Karelia University of Applied Sciences and Natural Resources Institute Finland 2018, 12).

3.5.1 Selected sites and boiler sizing

Two sites, Public Works Garage and Firehall (picture 4), were selected from Sioux Lookout. Both buildings are used throughout the year and their combined average annual energy consumption is 522,532 kWh/a. The energy for the Public Works Garage, including both electricity and heat, is currently produced entirely with electricity. There are electric hot air blowers hanging from the roof construction (picture 5), electric heaters in the office rooms, and electric water heating for domestic heat water (DHW). The Firehall has hot air heating with oil burner / furnace of approximately 110 kW total capacity and electric heaters in the office room and in the kitchen. Fire Hall and Public Works Garage are located next to each other hence heat for both buildings can be provided with one centralized heating plant. It is estimated that there is no demand for space heating when the daily average outside temperature is 13 °C or above, which, according to Sioux Lookout's temperature profile, means that during the summer there are about 95 days when these sites will not be consuming any heat for space heating purposes. (Natural Resources Institute Finland & Karelia University of Applied Sciences 2018, 15.)

Picture 4. Firehall and Public Garage.

Picture 5. Hot air blowers in the Public Works Garage.

To estimate the net heating energy consumption of the buildings it is important to consider efficiency of the heat production system. Here it is assumed that all electrical heating equipment produce heat with 95% and all oil boilers with 85% annual efficiency. As the Fire Hall and the Public Works Garage will be served with one boiler, the boiler will not be inside either of the buildings, which will inevitably result to some heat losses to the ground when heat is transferred via pipes. These heat losses are estimated to be 10% of the net heating energy consumption, which presents an average heat loss for a small-scale heating network. The total heating energy needed from the boiler for these two buildings is thus 392,237 kWh/a. In addition to boiler house heat losses, wood combustion efficiency and fuel gas losses need to be considered. An annual boiler efficiency of 75% will be used in this study. (Natural Resources Institute Finland & Karelia University of Applied Sciences 2018, 14.) The peak heating power is only slightly below 160 kW for the Fire Hall and Public Works Garage combined. The most economically viable system is a 100-kW solid fuel boiler (SFB, wood chips) combined with a reserve fuel boiler (RFB, oil). 91% of the annual heating energy demand will thus be produced with the wood chip boiler and 9% with the solid fuel boiler, which will also serve as a reserve during possible emergencies.

Two buildings were selected also from Lac Seul, more specifically from Frenchman's Head. These two buildings, Events Centre arena and a school, are located approximately 130 meters from each other and can be covered with one centralized heating plant established between the buildings. The main selection criteria for these sites were energy consumption, favorable location of the buildings, and surrounding space for locating a wood fuel storage. Fuel deliveries are also easy to arrange without disturbances, which is important for the first reference sites. The combined average annual energy consumption in the buildings is significantly higher than in Sioux Lookout's case: 1,894,690 kWh/h. The share of heat was preliminary estimated to be approximately 571,846 kWh (30 %), and after applying the same 10% heat loss factor as in Sioux Lookout's case, the total demand for heat from the boiler will be 597,579 kWh/a. Additionally, similar combustion and fuel gas losses are being used, thus the annual boiler efficiency will be 75%. (Natural Resources Institute Finland & Karelia University of Applied Sciences 2018, 17.)

Both the school and the arena have a distinct seasonal break when they are not used for up to four months, meaning that there is essentially no heat load for up to 120 days. The school uses very little hot water during the heating season and there is already an electrical boiler installed to produce domestic hot water for occasional use. In the arena, however, ice conditioning machinery and showers depending on the number of people using them simultaneously, can cause a dramatic peak load. One single showerhead creates a demand for 30 kW heating power when the shower is running. The peaks can, however, be downgraded by accumulating and releasing heat when shower is turned on to slowly bring the water temperature back up again after showering. Arena is currently equipped with heat accumulators which will be utilized also in the future to take care of both the occasional showering peaks and the space heating peaks during the coldest days of the year. (Natural Resources Institute Finland & Karelia University of Applied Sciences 2018, 17.) As the heating season is shorter than in traditional sites, the heating energy consumption in colder periods is emphasized even more. DHW production is not considered when sizing the solid fuel boilers as the existing hot water accumulators will be kept as part of the process. The suggested solution is thus a 200 kW (or two 100 kW) solid fuel boiler (SFB, wood chips) combined with a reserve fuel boiler (RFB, oil). 93.3 % of the annual heating energy demand can be produced with the wood chip boiler and 6.7 % with the solid fuel boiler, which will also serve as a reserve during possible emergencies. Dimensioning the SFB according to the peak load is not feasible for it would be utilized only for one or two days. (Natural Resources Institute Finland & Karelia University of Applied Sciences 2018, 18.)

3.5.2 Supply chain

Local forest resources managed by Lac Seul First Nation with oversight by the Provincial Ministry of Natural Resources will be used as the source of the biomass in both Lac Seul and Sioux Lookout (Lawrance 2019). Based on the energy demand calculation above, it can be stated that the total need of biomass is relatively small. The aim is to create a reliable supply chain system which does not need large investments in technology. Existing harvesting practices and other related activities are utilized as much as possible to increase reliability of the system. The suggested supply chain is based on white birch which is currently cut down, piled and burned on roadside storages and thus already available for fuelwood purposes. (Natural Resources Institute Finland & Karelia University of Applied Sciences 2018, 24-25.)

The blocks are considered to be suitable for biomass harvesting if the volume of white birch is more than 300 m3 per block, distance to a road is less than 1 km road, transportation distance either to Lac Seul or to Sioux Lookout is less than 30 km, and if there is no waterbodies between the block and the road. Based on these criteria, the availability of forest biomass in Sioux Lookout is very good and existing harvesting planning close to the town offers much more biomass than is needed for the boiler in Public Works Garage and Firehall. In Lac Seul the white birch resource is more limited, and the available blocks are not very close to the boiler facility. The limitation is, however, not caused by the lack of forest resources but rather by the current harvesting scenarios and road infrastructure which is not as well developed as in other areas. Federal Reserve Land of Lac Seul has remarkable forest resources that are not actively used as a resource for either forest industries or for local energy solutions, except for cordwood. (Natural Resources Institute Finland & Karelia University of Applied Sciences 2018, 25.)

The weekly peak load consumption of fuel chips can be set as a target net volume of the fuel storage for each heating plant. It will cover the fuel demand of the heating plant even for the longest holiday weekends during the coldest days of winter. Smaller storages will increase the number of the machineries' cold starts during the coldest days and larger storages the risk of disturbances. The appropriate fuels storage capacities would thus be 25-30 loose-m3 for the heating plant of the Public Works Garage and Fire Hall and approximately 50 loose-m3 for the heating plant of Lac Seul school and arena. The most convenient way to organize the chipping of the biomass is to chip logs directly into the boiler silo with a farm tractor mounted disc chipper. (Natural Resources Institute Finland & Karelia University of Applied Sciences 2018, 31.) The tractor can be used also in other actions at the Lac Seul Sawmill and in the surrounding society and thus is an economically viable option.

4 RESEARCH OBJECTIVES

Current literature on knowledge and technology transfer does not seem to provide a clear explanation on the underlying dynamics of knowledge and technology transfer, its process levels or factors affecting the process (Gibson & Smilor 1991; Lamberton 1991). Some studies perceive technology transfer as the application of knowledge and knowledge transfer thus as a key tool to technology transfer (e.g. Lamberton 1991; Gopalakrishnan & Santoro 2004), which is also the starting point of this thesis. Although the definitions of knowledge and technology are not universally accepted or their flows yet fully understood, innovation literature provides a variety of analytical frameworks in which the flow of technology and knowledge can be contextualized. The thesis exploits innovation system approach, as well as the Communication Model of TT (e.g. Gibson & Slimor 1991; Lamberton 1991) which highlights the importance of communication between the transmitters participating the KTT process in increasing transfer capacity.

Despite their potential, bioenergy technologies often have problems establishing themselves on the energy market. An increased awareness of "nontechnical barriers" to bioenergy implementation has generated several workshops, conferences and studies (e.g. AFB-Nett 1995) to address the issue and to identify common features of successful bioenergy projects have been conducted (e.g. Sanderson et al. 1996; Muehlenfeld et al. 1996). Additionally, various researches have been conducted on bioenergy in Finland, in Sweden, and in other European locations (e.g. Okkonen 2009; Hjalmarsson et al. 1996a & 1996b; Röser 2012).

Finland is a good reference for Canada because of the climatic, geographic and natural similarities the two countries share. However, it is essential to consider the differences between the operational environments in Europe and in North America and design the product, here the bioenergy technology package, by the terms of the receiving community. This notion highlights the role of knowledge transfer as a key to technology transfer and the significance of R&D in transferring Finnish or European bioenergy knowledge and technology to Canada.

These research objectives can be posed as the following questions:

- What are the underlying dynamics and success factors of bioenergy knowledge and technology transfer?
- How can the knowledge derived from R&D be exploited in transferring Finnish bioenergy knowledge and technology to Sioux Lookout, Canada?

5 MATERIALS AND METHODS

5.1 Case study approach

The thesis is conducted as a case study (Yin 2003) with Case Sioux Lookout as a subject. Case study research approach answers to questions "how" or "why" and allows multifaceted explorations of complex issues. Case study is a suitable strategy in new topic areas and especially appropriate when there is a need to obtain in-depth understanding of an issue, event or phenomenon in its natural real-life context. (Yin 2003, 1.) Case studies can be based on any mix of quantitative and qualitative evidence and hence the case study strategy should not be confused with qualitative research (e.g. Eskola & Suoranta 1998).

This study utilizes mixed methods approach and therefore involves collecting, analyzing and integrating both quantitative and qualitative evidence. Qualitative research methods are used to gain an understanding of the underlying reasons, opinions, and motivations related to the case. Qualitative research methods provide information about "human" variables, such as behaviors, beliefs, opinions, emotions, and relationships of individuals, which can sometimes be contradictory (Eskola & Suoranta 1998). When used together with quantitative methods, qualitative research can help to interpret the implications of quantitative data and lead to a more comprehensive understanding of the given situation. The use of both quantitative and qualitative evidence enables a more complete and comprehensive understanding of the case than either quantitative or qualitative approach alone (Yin 2003, 14.)

The analytical framework of this study is set within the theory of systems engineering (Blanchard & Fabrycky 1981) and innovation systems (e.g. Lundvall 1992) to better understand the underlying dynamics of knowledge and technology transfer process aiming to the establishment of a bioenergy heating system in Sioux Lookout and Lac Seul. The findings from Case Sioux Lookout are mirrored with previously identified barriers inhibiting clean energy solutions from being deployed in remote communities in Canada. Due to the intricacy of these barriers, it is relevant to address them with a four-dimensional approach that covers economic, technical, social and ecological aspects. The outcomes of each dimension are compared with the results of earlier researches that examined drivers and barriers to bioenergy implementation (e.g. Sanderson et al. 1996; Muehlenfeld et al. 1996; Hjalmarsson et al. 1996a & 1996b). Based on this analysis, general success factors for bioenergy projects at each four dimensions are concluded.

5.2 Identification of success factors for bioenergy projects

Success factors of bioenergy knowledge and technology transfer at the economic dimension consider inter alia the costs of the new biomass heating system in comparison to the running costs of the current oil- and electricity-based heating system. Because a lack of clarity around cost estimates for reducing diesel consumption with renewable energy resources has been identified as one barrier to implementing clean energy solutions in Canada's remote communities (Advanced Energy Centre 2015, 5), the thesis will examine the importance of understanding the cost structure of these alternative energy systems in increasing receiving and transfer capacity is examined in the thesis.

A lack of understanding on technical feasibility of implementing renewables into remote off-grid systems among important stakeholders can act as a barrier to the deployment of these alternative energy systems for example through perceived technology risks (e.g. Advanced Energy Centre 2015; AFB-Nett 1995). Therefore, it is relevant to examine how these technology risks can be minimized and evaluate if the risks are valid or rather beliefs and opinions of different stakeholders. Technical feasibility is addressed by applying systems approach (Blanchard & Fabrycky 1981) to present the planned bioenergy heating solution as a system in order to make its implementation more comprehensible and hence more controllable.

Ecological success factors for bioenergy knowledge and technology transfer are considered by comparing emissions of burning wood biomass at a general level with air pollution caused by burning fossil fuels. The thesis also discusses the role of forest management and climate smart forest use in decreasing the risk of severe fire damages and transferring the forests from carbon source to carbon sinks. Additionally, by utilizing innovation system approach, the thesis examines the role of R&D and the significance of continuous interaction between R&D agents and other transceivers of KTT in communicating the ecological benefits of biomass-based energy systems and thus increasing transfer capacity.

The communication perspective to technology transfer (e.g. Gibson & Slimor 1991; Lamberton 1991) highlights the social dimension of bioenergy projects. Social dimension of the thesis examines stakeholder engagement and stakeholder management that are arguably very important ingredients for a successful project delivery, yet often regarded as a fringe activity. Behaviors, beliefs, emotions and opinions of different stakeholders and relationships between individuals are studied through interviews, discussions and observations. The role of national and local policy in advancing or hindering bioenergy projects is also discussed. The findings from Case Sioux Lookout are interpreted by mirroring them with existing literature about knowledge and technology transfer and bioenergy technology implementation as well as with the previously identified barriers inhibiting clean energy solutions from being deployed in remote communities in Canada.

5.3 Knowledge internalization defining knowledge transfer success

Social dimension extends to and is further analyzed through knowledge transfer success. An approach termed knowledge internalization is adopted in this study to determine transfer success. Knowledge internalization comes from institutional theory and defines success as the degree to which a recipient obtains ownership of, commitment to, and satisfaction with the transferred knowledge. Knowledge internalization is a perquisite for successful knowledge transfer because it defines how sufficiently knowledge is understood and adapted by the recipient. For knowledge to be re-created and ultimately used, recipient must first internalize it. (Cummings & Teng 2003, 42.)

Knowledge and technology transfer/innovation streams and transfer success are analyzed across four broad contextual domains that include knowledge context, relational context, recipient context, and activity context (figure 4). The first context, the "knowledge context", includes the transferred knowledge's embeddedness and articulability. The relational factors are organizational distance, physical distance, knowledge distance, and norm distance. There are also factors related to the recipient's receptiveness to learning new knowledge and to the extent of effort put forward to undertake transfer activities that can affect transfer success. (Cummings & Teng 2003, 40-41.)

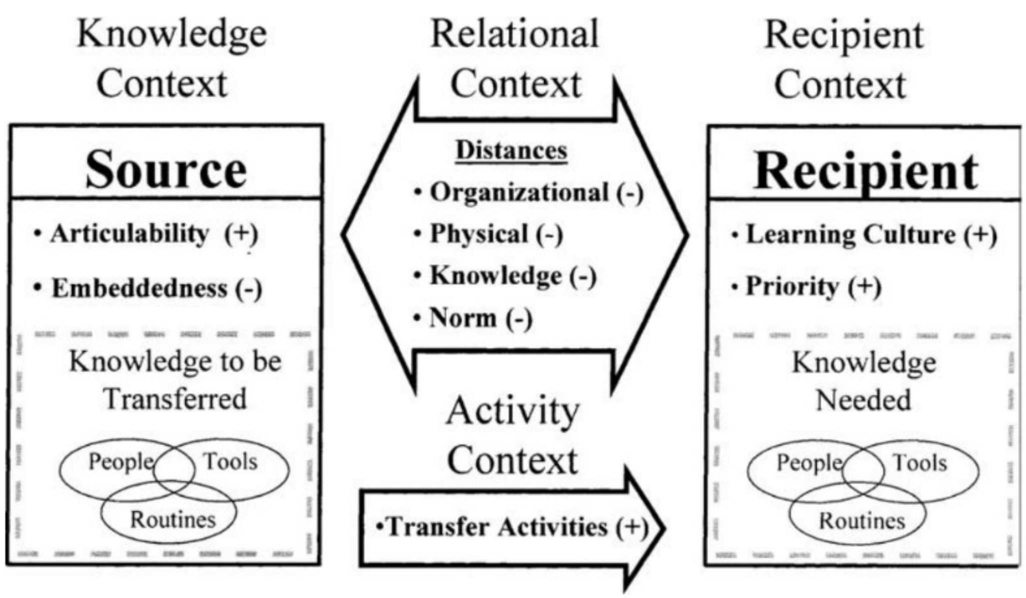


Figure 4 Research model (Cummings and Teng 2003).

5.4 Materials

The study is based on self-produced materials and existing materials analysis. Self-produced materials are comprised of interviews, discussions and observations in Sioux Lookout between 1st - 3rd of November 2018. The interviews were conducted during November and December 2018 as semi-structured interviews that followed a paper-based interview guide prepared in advance. The meetings consisted of open-ended questions that covered topics related to goals and objectives, drivers and barriers, risks, timeline, and each informant's personal understanding of the project. Semi-structured interview method was chosen to allow informants the freedom to express their views in their own terms. Another intension was to keep the discussion on relevant topics but still open for identifying new ways of seeing and understanding the case.

Observations were also made from a reception hosted by the Embassy of Finland and Natural Resources Institute Finland at Heritage Railway Station in Sioux Lookout on November 1st, 2018, where the cooperation between Sioux Lookout and Finland was officially launched. Additionally, a memo was written from a seminar held by the Economic Development Department of Sioux Lookout at Heritage Railway Station on November 2nd, 2018, where Natural Resources Institute Finland and Karelia University of Applied Sciences announced the feasibility study findings, results and recommendations of forest biomass-based heating concept of public premises of Lac Seul First Nation community and of selected locations in the Municipality of Sioux Lookout. The feasibility study presentation was followed by free discussion and questions asked by locals. Opinions and articles in the local newspaper Sioux Lookout Bulletin also provide information about the about the human side of the case.

Qualitative materials are integrated with quantitative data, such as energy consumption and heat demand in the target buildings, that is gathered from previous feasibility studies conducted of Case Sioux Lookout. Examination of the project's economic viability is also based on numeric data. The findings from Case Sioux Lookout are mirrored with the previously identified barriers inhibiting clean energy solutions from being deployed in remote communities in Canada and interpreted with the help of existing materials analysis.

6 RESULTS

6.1 Success factors for bioenergy deployment projects

6.1.1 Economic dimension

Adequate funding is a perquisite for a successful bioenergy project. However, the barriers bioenergy deployment project face, are to a large extent namely financial or regulatory mechanisms (AFB-Nett 1995). According to Muehlenfeld et al. (1996), is generally hard to find financing by banking institutions for bioenergy investments. The hindering effect of these institutional factors has been a challenging issue to resolve also in Canada, since provision of energy in remote communities is a multi-jurisdictional public policy issue that requires collaboration between the federal, provincial/territorial, and local administrative bodies. Funding streams in Canada are often complicated and incentive structures for clean energy alternatives thus seen as confusing. It is often experienced that the differing application processes, timelines and requirements for different funding programs make securing funding for renewable energy systems time-consuming and resource-heavy (Advanced Energy Centre 2015, 4). Provinces and territories also a lack viable contracting structure, such as a standard formula for 'avoided cost of diesel', which hampers decision-making and undermines business cases for alternative energy systems. What contributes to the lack of viable contracting structures and the existence of financial barriers is a lack of understanding on the cost of these alternative (AFB-Nett 1995; Advanced Energy Centre 2015). Developers require more mechanisms to quantify economic benefits, as well as examples and data from successfully deployed systems, to instill confidence and strengthen business cases for future projects.

Muehlenfeld et al. (1996) suggest that access to special financing arrangements increases bioenergy project success. For example, using internal funding or having a natural special financing party have led to successful bioenergy technology implementation (Muehlenfeld et al. 1996). Joint ventures may also increase funding options by satisfying various needs of a project. Joint ventures may include inter alia parties representing the feedstock supplier, energy customer, equipment vendor or operator, or financing and energy trading parties. (Sanderson et al. 1996.) Another success factor for bioenergy technology implementation is access to low-cost biomass fuels (Sanderson et al. 1996; Muehlenfeld et al. 1996). Having only few alternatives to oil available, other than biofuel, also contribute to successful establishment of new bioenergy systems (Hjalmarsson et al. 1996a & 1996b). Low and decreasing fossil prices, for their part, constitute a fundamental barrier to the large-scale introduction of biomass energy systems (AFB-Nett 1995). Very often there also are triggering economic factors, for example, oil chocks or the introduction of favorable tax treatments that help the managers decide to invest in bioenergy (Muehlenfeld et al. 1996).

In Case Sioux Lookout, a triggering factor that precipitated conversion to biomass was lack of access to natural gas and the relatively high price of electricity. The municipality was searching for a more cost-effective heating solution to substitute the current heating systems that are run on fuel oil and electricity (Blanchard 2018; Lawrance 2019). Another promotive factor is housing shortage: “There are two hundred new jobs in Sioux Lookout but a severe shortage of housing for newcomers. Vacancy rates are forever close to zero percent. This shortage of housing cuts across all sectors in both private and public housing.” (Lawrance 2019). Timing is also contributing positively because the current oil boilers are aging and would need to be replaced in the near future.

Correct boiler sizing plays a key role in economic viability of biomass heating solutions and is of paramount importance for small-scale systems. Oversizing has in general more negative effects than slight undersizing. Peak loads that last only for a few days at a time but demand the highest heating power of the whole year may be problematic for solid fuel boilers that require extensive investment. It wouldn’t be profitable to invest in a heating power reserve that is only utilized during few days in a year. Sizing the boiler according to the peak heating power demand would rather result in a low capacity factor and decrease the economic viability of the boiler unit. In traditional small-scale district heating systems, typically 80-90% of the annual heating energy is produced with biomass and the biomass boiler sized at 55-65% of the peak load (Karelia University of Applied

Sciences & Natural Resources Institute Finland 2018, 13). The peak loads are covered with oil fuel boilers that require less extensive investment but more expensive operating cost. The operating costs of biomass heating systems are low compares to oil- and electricity-based systems because the fuel, such as wood chips, used in biomass boilers is inexpensive, which increases the long-term attractiveness of the biomass heating investment.

Economic viability of bioenergy heating solutions can be quantified by comparing the fixed and variable costs of the new biomass heating system with the running costs of the current system. The fixed costs generally consist of the annual capital costs of the investment, administration costs and insurance costs of the plant. The typical lifecycle of a wood chip heating plant for the calculations is 15 years and the estimated technical lifecycle approximately 20 years (Karelia University of Applied Sciences & Natural Resources Institute Finland 2018, 20). The variable costs are equal to the annual running costs and include for example fuel costs, maintenance and repairs. In case Sioux Lookout, economic viability of the project was quantified by mirroring the suggested biomass-based heating solution with the current oil- and electricity-based heating system and communicated through a presentation of a feasibility study conducted by Karelia University of Applied Sciences and Natural Resource Institute Finland. The cost structure of the suggested solutions consists of the following components:

Fixed costs:

- Annual capital costs from the investment:
    - The plans and paperwork, permissions and licenses
    - The heating plant with the basis construction
    - The heat distribution pipelines
    - All the installations, including the connective works inside the buildings
- Administration
- Insurance:
    - The fire and water leakage insurances
    - Possible other insurances

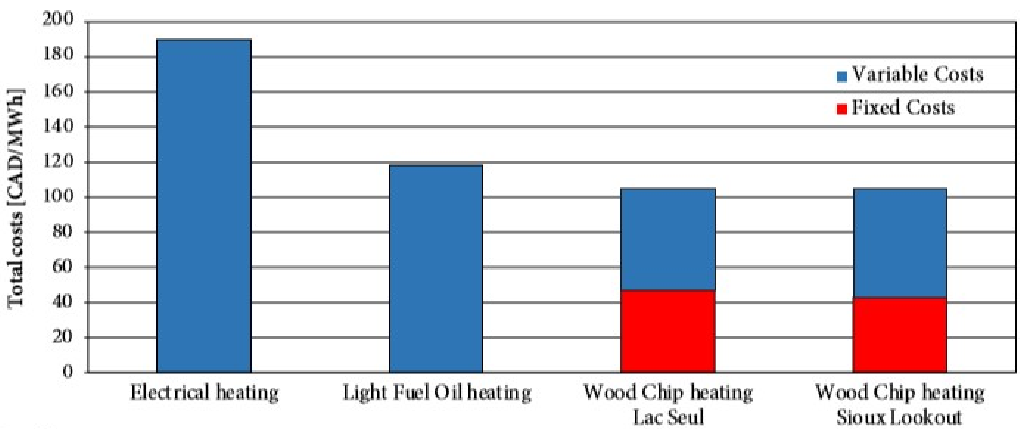
Variable costs:

- Fuel:
    - Wood chips for the solid fuel boiler
    - Oil for the reserve fuel boiler
    - Electricity consumption of the electrical reserve heating system
- Plant operating power:
    - The electricity needed for operating the solid and reserve fuel boilers
- Operating costs:
    - The basic maintenance work that is needed weekly/daily at the heating plant, e.g. boiler cleaning, ash removals
    - The replacement of consumables, conveyor and other repairing and handling of breakages, etc.
    - The 24/7 surveillance and emergency duty
- Spare parts

In the feasibility study, the calculations about economic viability were conducted by using a 5% interest rate and a 15-year payback time, after which there are no longer fixed costs. The cost of insurances was 1% of the total investment and spare parts 0.5% of the plant investment. Heating oil price was assumed to be 1 CAD/ltr/10kWh (average of 2017) and electricity prices in Sioux Lookout 0.18 CAD/kWh (average of 2017) and in Lac Seul 0.15 CAD/kWh (average from the electricity costs for heating the school and arena). The price of wood chips was assumed to be 25% of the heating oil price. Operating costs of the new system were estimated to be 25 CAD/h (3h/week), administration costs 1 CAD/produced MWh. (Karelia University of Applied Sciences & Natural Resources Institute Finland 2018, 20.)

Even though aging of the current oil boilers was not regarded, wood chip heating system proved to be economically the most viable solution when compared to the current electrical and light fuel oil heating (figure 5). If the finance required for the replacement of the current oil boilers were included in the calculations, economic profitability of the suggested wood chip heating system would further increase.

As a local renewable energy source, forest biomass can also create other socioeconomic benefits. These socioeconomic impacts are generated through the employment effect of fuel supply and power plant operation and the money circulated in local economy instead of paying it to nonlocal fossil fuel supply companies. Bioenergy also supports growth and economic potential of the community and as a cheaper alternative for consumers can also directly release more money into the local economy.



	Electrical heating	Light Fuel Oil heating	Wood Chip heating Lac Seul	Wood Chip heating Sioux Lookout
Variable costs	189.5	117.6	57.6	62.6
Fixed costs	0	0	46.9	42.3

Figure 5. Total cost comparison in Lac Seul and Sioux Lookout (Karelia University of Applied Sciences and Natural Resources Institute Finland 2018).

Carefully executed feasibility studies and correct dimensioning of the heat production system made by experts have been vital for financial engineering of case Sioux Lookout. According to Sikanen (2018) and Valkeapää (2018), it has also been beneficial for project success to have financial engineering supported by specialists (Sikanen 2018; Valkeapää 2018.) Additionally, state involvement through the Embassy of Finland in Ottawa can be seen to positively contribute to the project success by increasing credibility at the early stage (Valkeapää 2018; Blanchard 2018A). Based on existing literature analysis and case Sioux Lookout, it can thus be concluded that clear quantifying and effective communication of the economic benefits of bioenergy implementation are important success factors for bioenergy knowledge and technology transfer.

6.1.2 Technical dimension

Lack of understanding on technical feasibility of implementing renewables into remote off-grid systems among important stakeholders can act as a barrier to the deployment of these alternative energy systems for example in the form of perceived technology risks (e.g. Advanced Energy Centre 2015; AFB-Nett 1995). It is important to consider how these technology risks can be minimized and evaluate if the risks are valid or rather beliefs and opinions of different stakeholders.

For all remote systems, including energy supply, reliability is always the primary concern. For utilities operating in remote communities, concern over reliability is of paramount importance. Technology reliability risk of alternative energy systems in remote communities is generally experienced as higher than reliability risk of conventional diesel generators (Advanced Energy Centre 2015, 5). Utilities are often responsible for providing energy to all inhabitants and other industrial facilities in the area for reasonable prices and thus have a very low risk tolerance. In consequence, utilities often favor status quo and prefer to make long-term contracts for standard energy technologies (AFB-Nett 1995). It is thus evident that alternative clean energy systems must at least meet and preferably exceed the performance results of the existing diesel systems.

This risk aspect may often prevent implementation of bioenergy systems and bioenergy market growth at an early stage. One of the common concerns is uncertainty regarding availability of biomass resources. (AFB-Nett 1995.) Prediction of the sufficiency of the planned feedstock production is often experienced as challenging before a project or a market emerges, which makes the role of comprehensive feasibility studies essential for project success. As stated in the previous chapter, the feedstock supply should be abundant and of low cost (Sanderson et al. 1996). It is beneficial if fuels can be produced as byproducts on site (Muehlenfeld et al. 1996.) or if existing forest harvesting systems can be utilized to minimize changes to the current workflow. To minimize technology risks, the equipment should also have a proven track record (Sanderson et al. 1996).

In addition to these perceived and actual technology risks, The Advanced Energy Centre (2015) has identified that the current evaluation of local renewable energy projects in Canadian remote communities may not be holistic enough. The current project evaluation does not adequately examine the interface with local infrastructure, such as water purification plants, institutional facilities and road infrastructure, which lowers system performance and economic efficiencies (Advanced Energy Centre 2015, 5). It is beneficial for bioenergy project success if the planned business cooperates with other activities, for example with forestry or agriculture, and if synergy effects are exploited. Integration can concern any production factors including inter alia feedstock, equipment, infrastructure or knowledge. (Roos 1998, 83.) It is also fundamental for bioenergy projects that there is a continuous on-site thermal energy requirement (Muehlenfeld et al. 1996). Additionally, it is an advantage if there is a captive energy customer for the heat or steam (Sanderson et al. 1996).

According to the Advanced Energy Centre’s (2015) list of barriers to reducing diesel consumption in Canadian remote communities, deployment of alternative systems was made more difficult due to challenges associated with operating in remote northern regions, including snow, extreme cold, and the effects of remoteness. Reliability was also one of the main concerns among local stakeholders in case Sioux Lookout (Blanchard 2018). Finland is a good benchmark for Canada because of the similar climatic and natural conditions and long experience with biomass. The suggested supply chain, heat production technology, and sizing methods used in case Sioux Lookout are based on proven solutions in Finland and elsewhere in Europe, which increases technical reliability of the planned system.

To further improve reliability, the existing oil boilers will be preserved and used to cover peak loads and to serve as a reserve during possible emergencies. Risks were also minimized by through a feasibility study conducted by Karelia University of Applied Sciences and Natural Resources Institute Finland (2018). In the study it was noted that Sioux Lookout and Lac Seul are ideally located next to a relatively large forested area with appropriate road infrastructure to serve the operations of supply (Karelia University of Applied Sciences & Natural Resources

Institute Finland 2018, 7). United Nations Declaration on the Rights of Indigenous Peoples, according to which indigenous people possess a right to own, use, develop and control their lands, territories and resources (United Nations 2008.), positively contributes to biomass availability by allowing forest use. Possible future energy efficiency actions and renovations weren't however considered in the feasibility study simulations so far. Some energy efficiency actions may have a significant effect on the heat loads and therefore to simulation outcomes. There does however already exist a Five Year Energy Management Plan 2014-2019 for energy efficiency actions in Sioux Lookout, which shows some practical initiatives for different buildings. This kind of far-sighted community planning reflects holistic management style, which can be considered as a success factor for bioenergy knowledge and technology implementation. Sioux Lookout and Lac Seul both have suitable infrastructure to enable a good start up and to offer some potential for future growth but because biomass-based district heating or biomass boiler systems require hot water-based heat distribution for space heating inside the building, renovation of heat distribution methods in the selected buildings may be required.

6.1.3 Ecological dimension

Similarly to most industrialized countries, CO2 is the largest contributor in Canada's emissions profile. In 2016, CO2 emissions accounted for 79% of total emissions in Canada. Even though decreasing energy generation from coal and oil, accompanied by an increase in renewable and nuclear energy generation, was the largest driver of the 32% decrease in emissions associated with Electricity and Heat Production between 2005 and 2016, the majority of Canada's CO2 emissions still result from the combustion of fossil fuels. (Environment and Climate Change Canada 2018). It is thus apparent that the use of diesel and other fossil fuels for electricity or heat production inherently causes GHG emissions, as well as localized air pollution, in addition to those transportation related emissions associated with delivering the fuel.

A large, diesel-powered community produces over 10,000 tonnes of carbon dioxide per year (Advanced Energy Centre 2015, 3). According to the Government of Ontario, the estimated diesel consumption to generate electricity in diesel-based communities is about 215 million litres per year. Even though this estimated consumption excludes transportation and heating, it has almost double the ecological footprint compared to the Canadian emission average per capita. (Government of Ontario 2014.) Lengthy distances and deficient storage also significantly increase the risk of spills, which can cause contamination of soil and groundwater. Diesel contamination is also a significant risk for local population's health. According to The Advanced Energy Centre, there are multiple cases whereby communities have reported illnesses within the surrounding population following diesel contamination incidences. Polycyclic Aromatic Hydrocarbons, for example, are a group of toxic compounds associated with diesel contamination, which are proven to cause cancer with prolonged exposure. One example happened in 2006 at Canadian Forces Station Alert when a fuel line broke and spilled 22,000 litres of diesel, which caused serious contamination of surrounding lands. The diesel concentration in the surrounding soil was over 2000 parts per million (ppm), which is 800% more than the 260ppm accepted by federal guidelines. (Advanced Energy Centre 2015, 3.)

The environmental benefits of bioenergy compared to fossil fuels are inevitable. As a local renewable energy source, forest biomass reduces greenhouse gas emissions associated resulting from both combustion and transportation of fuels. However, there is no current mechanism to incorporate environmental and socio-economic benefits of implementing bioenergy solutions (Advanced Energy Centre 2015, 4), thus positive externalities are not accounted for. Furthermore, the negative environmental externalities for fossil technologies are difficult to assess correctly. Comparisons between fossil and bioenergy technologies are therefore often left out, which disadvantages biomass technology implementation (AFB-Nett 1995).

To increase bioenergy technology transfer success, the ecological benefits of biomass-based energy systems should be communicated better. It is also important to acknowledge that some biomass production systems may contain real or perceived environmental risks (AFB-Nett 1995), which should also be evaluated and discussed. Weather the environmental risks are real or perceived, continuous knowledge transfer advances their minimization. The state of bioenergy knowledge within the receiving community should be evaluated and considered during both planning and executing bioenergy knowledge transfer. In other words, it is essential for project success that there occurs continuous R&D and interaction between R&D agents and other transceivers participating in the knowledge transfer project.

The ecological benefits of bioenergy implementation are apparent also in case Sioux Lookout. The current heating systems are run on fuel oil and electricity, hence conversion to biomass would lower greenhouse gas emissions. The suggested supply chain for bioheat production is based on white birch, which is currently cut down, piled and burned on roadside storages. Chipping and controlled combustion of chipped wood in the planned bio boilers would thus also decrease the environmental risks related to the current practice. However, opposition in Sioux Lookout has mostly been related namely to ecological aspects. It has been written in the local newspaper, The Sioux Lookout Bulletin (appendix 1), that the planned supply chain operations are “exploitation and unsustainable use of our natural resources” and stated that “burning wood biomass emits as much, if not more, air pollution than burning fossil fuels”. Bioenergy has also been seen as “a danger to public health”. Similar topics, although not as straightforwardly, were also discussed at a seminar held by the Economic Development Department of Sioux Lookout at Heritage Railway Station on November 2nd, 2018, where Natural Resources Institute Finland and Karelia University of Applied Sciences announced the feasibility study findings, results and recommendations for the planned forest biomass-based heating project in Sioux Lookout and Lac Seul.

In case Sioux Lookout, the environmental risks can be stated to be perceived. Also according to the Mayor of Sioux Lookout “the opposition is based largely on lack of knowledge” (Lawrance 2019). In the feasibility study (Karelia University of Applied Sciences & Natural Resources Institute Finland 2018, 25), white birch blocks are considered to be suitable for biomass harvesting only if the volume of white birch is more than 300 m3 per block, distance to a road is less than 1 km road, transportation distance either to Lac Seul or to Sioux Lookout is less than 30 km, and if there is no waterbodies between the block and the road. Planned biomass harvesting can thus be stated to be sustainable use of natural resources. Furthermore, updating the harvesting plan of Federal Reserve Land of Lac Seul, which has remarkable forest resources that aren't currently utilized as a resource for either forest industries nor local energy solutions, except for cordwood, would decrease the risk of severe fire damages caused by forest fires and thus prevent rather than cause deforestation.

Increased forest management and harvesting care would also lower greenhouse gas emissions and help to transfer the forests from carbon source to carbon sinks. According to Natural Resources Canada (2018), if both the absorption and emission of CO2 are considered, Canada's forests have not been a net carbon sink since 2001. Due largely to forest fires and insect infestations, the trees have added to the country's greenhouse gas emissions for each of the past 15 years on record. (Natural Resources Canada 2018, 34-37). Figures 6 and 7, reported in megatonnes of CO2 equivalent. demonstrate the importance of forest management and harvesting care in reducing the net carbon emissions of Canada's managed forests. Positive values demonstrate net emissions and negative values net absorption.

Figure 6. CO2 emissions of all areas (Natural Resources Canada 2018. Modified by Robson Fletcher / CBC).

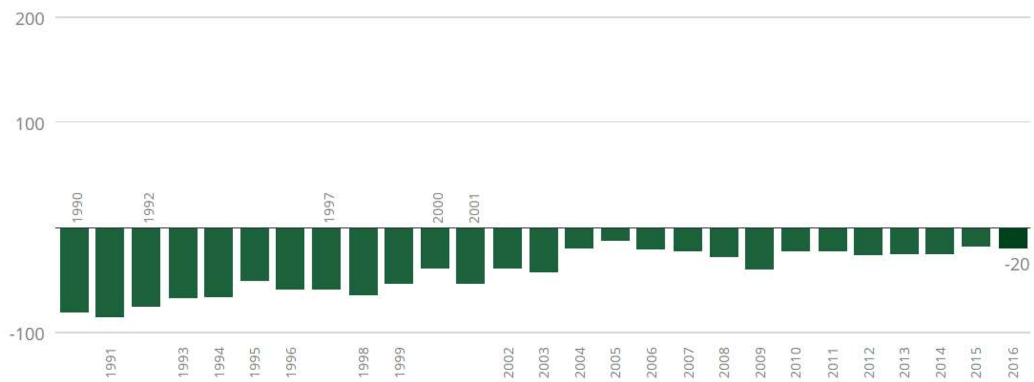


Figure 7. CO2 emissions of areas with forestry activity (Natural Resources Canada 2018. Modified by Robson Fletcher / CBC).

Based on the reactions among locals, it can be stated that environmental benefits and risks should have been included in the feasibility study. The role of forest management and climate smart forest use in decreasing the risk of severe fire damages and transferring the forests from carbon source to carbon sinks should also have been communicated. On the grounds of existing literature analysis and case Sioux Lookout, it can thus be concluded that clear quantifying and effective communicating of the economical benefits of bioenergy implementation are important success factors for bioenergy knowledge and technology transfer success.

6.1.4 Social dimension

According to the European Agriculture and Forestry Biomass Network report (1995), many of the barriers bioenergy implementation projects face are institutional factors that could be removed if the policies were stable and farsighted. Policy affects to the deployment of bioenergy systems both at national and at local level for example through inconsistencies and the lack of synchronization between policy instruments. Bioenergy investments are specifically sensitive to changing policies because the projects are often slow and include long time scales associated with activities necessary to growing a bioenergy crop, harvesting, and operating a plant (IEA 1993). According to the AFB-Nett report (1995), however, it is not possible to prescribe one policy measure to remove all institutional barriers. Efforts should rather be planned based on the analysis of each operational environment in question (AFB-Nett 1995). Efforts should inter alia be focused on optimizing the project schedule. Permitting, for example, can be time-consuming and applications should thus be submitted as early as possible in the planning process (Sanderson et al. 1996). When permitting is taken care of on time, project delays are prevented. Additionally, when timespan of project activities shortens, sensitivity to changing policies decreases.

Regulations can hamper bioenergy technology transfer projects by acting as barriers to project development. For example, water and air emissions regulations regarding bioheat projects may be outdated and inappropriate for the technologies deployed and thus lead to project delays, increased costs and ultimately cause viable projects to fail. To support Canada's shift towards low-carbon and sustainable economy, CCFM has compiled The Forest Bioeconomy Framework for Canada (2017) which seeks to increase the use of forest biomass throughout the economy and ensure the vibrancy of Canada's forests for generations to come. One aim of The Forest Bioeconomy Framework is to review these above-mentioned regulatory processes and ensure that they are appropriate and enable community-level bioheat and power projects. Together with The Pan-Canadian Framework on Clean Growth and Climate Change, it aims to address climate change, grow the economy, and sustain the forest industry's history of innovation, sustainability and competitiveness. (Canadian Counsil of Forest Ministers 2017; Environment and Climate Change Canada 2016.)

At local level, successful biomass projects are often associated with an active management style and local ambition to create employment in the region (Muehlenfeld et al. 1996). It is also essential for project success that the main players such as municipalities, utilities, and industry manage to coordinate their efforts (Sanderson et al. 1996). Support from policymakers and public opinion naturally make the introduction of bioenergy business easier and there ideally exists a high degree of interest and engagement among policymakers and solution providers (Hjalmarsson et al.1996a & 1996b). Public opinion and local policy are often dependent on the state of general knowledge and awareness about bioenergy systems (e.g. Advanced Energy Centre 2015; AFB-Nett 1995). If key persons such as creditors, local policymakers, and investors, lack understanding about bioenergy and show a low interest in these technologies, misconceptions about bioenergy systems can prevail, which prevents fair assessments of the technologies' advantages and disadvantages are never conducted (AFB-Nett 1995). Additionally, as stated in the earlier chapter, there is no current mechanism to incorporate environmental and socio-economic benefits of renewable energy systems, which affects the public opinion and local policies.

Favorable attitude by local population positively contributes to project success. However, lack of knowledge and understanding at different levels may cause opposition among the public. Additionally, as stated earlier, bioenergy implementation projects are often long and therefore attitudes are more prone to change. This notion highlights the importance of continuous knowledge transfer and stakeholder management. Lack of knowledge also affects local capacity regarding operational considerations (Advanced Energy Centre 2015, 6). According to Sanderson et al. (1996) trained and qualified personnel should be employed to run the bioenergy plants thus it is essential that there are enough training opportunities available to acquire skills and knowledge within communities.

Lack of knowledge and technical proficiency within the communities can also act as a significant barrier to developing more holistic collaboration models. The Advanced Energy Centre (2015) has noted that communities currently lack adequate opportunities to collaborate on an equal footing with public utilities and private developers, in terms of deploying, operating and maintaining renewable energy systems. This situation is compounded by limited energy literacy amongst community members and lack of training opportunities available to acquire the skills and knowledge needed within the community, which prevents integrating the community into the planning process for energy system renewals. Additionally, there often occurs a poor clarity on innovative collaboration models for new partnerships which does not sufficiently focus on local benefits and long term economic and social prosperity (Advanced Energy Centre 2015, 6).

Based on this existing literature analysis, it can be concluded that adequate state of knowledge within the receiving community is essential for bioenergy technology transfer success. Another important success factor at the social dimension is holistic and far-sighted management both within the transfer project and within the receiving community. Additionally, it can be stated that bioenergy projects benefit from innovative collaboration models. Case Sioux Lookout, as a municipal-national co-operation, can be noted to support this statement. The social dimension and knowledge transfer success of case Sioux Lookout are further analyzed in the following chapter 6.2.

6.2 Evaluation of knowledge transfer success in Case Sioux Lookout

As indicated earlier, an approach termed knowledge internalization is adopted in this study to define transfer success. As presented in the figure 4, knowledge and technology streams and knowledge transfer success are analyzed through four contextual dimensions. The dimensions include knowledge context, relational context, recipient context, and activity context.

6.2.1 Knowledge context

Knowledge transfer success is affected by embeddedness and articulability of the transferred knowledge. Embeddedness is a recognized characteristic of knowledge, which designates how many knowledge elements and related sub-networks will need to be transferred, absorbed, adapted and adopted by the recipient to allow the knowledge to be successfully transferred. Highly embedded knowledge is expected to be more difficult to transfer than less embedded knowledge. Articulability refers to the extent to which knowledge can be verbalized, written, drawn or otherwise articulated. Research has shown that the more articulable the knowledge is, the more easily it can be transferred, whereas tacit knowledge is often deeply rooted in action and hard to communicate. (Cummings & Teng 2003, 43-44.)

Embeddedness of knowledge related to bioenergy systems is generally relatively high because they generally include a long chain of stages from the initial growing of the stock to the final energy customer. Likewise, in case Sioux Lookout, the transferred knowledge includes know-how related to harvesting, transportation, storage and chipping of the biomass, production and distribution of heat, as well as operation and maintenance of the system. It is beneficial for knowledge transfer success that there are local experience and traditions of using forest biomass for energy in the region and that existing forest harvesting systems can be utilized. Utilization of current systems reduces the number of needed changes to the current workflow and thus also embeddedness of the knowledge by lowering the number of knowledge elements needed to be transferred. However, current practices primarily cover the use of cordwood for domestic heating, whereas the use of wood chips, pellets, or centralized heating systems, have not been implemented locally. It is therefore important to ensure the availability of training opportunities to acquire the needed skills and knowledge within the community. There however already is a new initiative underway to establish an "Innovation Station" – Knowledge Hub in Sioux Lookout (Blanchard 2018), which will increase knowledge adoption and positively contribute to knowledge transfer success.

As discussed earlier, there is no current mechanism to incorporate environmental and socio-economic benefits of implementing bioenergy solutions. Given multiple funding streams, it is also rational that no organization alone can justify implementing alternative solutions, given that total benefits and avoided costs do not accrue to that same organization. This increases the complexity and challenges associated with tracking performance metrics and measuring the impact of these alternatives and thus prevents the environmental and socio-economic benefits of implementing bioenergy solutions from being quantified. Without mechanisms to evaluate the total impacts of bioenergy systems, articulability of the knowledge related to them remains low, which decreases knowledge transfer success. The feasibility study conducted by Karelia University of Applied Sciences and Natural Resources Institute Finland (2018), however, relatively comprehensively considered total impacts and socio-economic benefits of the planned bioenergy heating system. A seminar held at Heritage Railway Station on November 2nd, 2018, where Natural Resources Institute Finland and Karelia University of Applied Sciences announced the feasibility study findings of the planned forest biomass-based heating project in Sioux Lookout and Lac Seul, further increased articulability and thus portability of the knowledge being transferred.

However, because the development of forest use in Finland has a long tradition, some of the knowledge may be deeply rooted in action. This tacit knowledge can be challenging to transfer and even recognize because parts of it have become general knowledge in Finland. It is thus important to analyze the operational environment to avoid falsely considering important parts of transferred knowledge self-evident. In case Sioux Lookout, as discussed in the chapter 6.1.3, it would, for example, have been advantageous to include environmental aspects into the feasibility study. Behind the knowledge gap between the transfer parties regarding environmental aspects of bioenergy systems is inter alia the effect of various drivers on the development of forest biomass for energy in Finland during the past decades. Shortly, the development of forest in Finland and in Europe has a long tradition whereas North America has had more significant deposits of fossil fuels and less political and regulatory pressure. This issue of knowledge distance is further discussed through relational context in the next chapter 6.2.2.

Because the knowledge source in case Sioux Lookout consists of multiple Finnish actors such as Karelia University of Applied Sciences, Natural Resources Institute Finland, Team Finland together with the Embassy of Finland in Ottawa and private Finnish companies, it is essential for knowledge articulability that these main knowledge endorsers manage to coordinate their efforts. Lack of internal communication and association among the source can negatively affect articulability of the knowledge being transferred and thus hinder transfer success. Based on observations, physical distance may hinder internal communication because some Finnish actors are located in Finland and some in Canada, which for its part can be stated to decrease coherence among the source. It can thus be concluded that the strength of social ties, free-flow of communication, consistency in administrative controls, and levels of trust are essential success factors also among the source, not just between the source and the recipient.

6.2.2 Relational context

The relational context of knowledge transfer includes organizational distance, physical distance, knowledge distance, and norm distance. “Organizational distance” measures the degree of organizational integration between the parties to a transfer. Research has found that transferring knowledge from related parties is more effective than transfer from outsiders. Transfer success can thus be expected to decrease when organizational distance between source and recipient increases. Additionally, the strength of social ties, free-flow of communication, consistency in administrative controls, and levels of trust between the source and recipient contribute to transfer success. Research has also found that face-to-face meetings are superior to other meetings or transfer formats in the transfer of strategically important matters. (Cummings & Teng 2003, 45-46.) This raises the question of “physical distance”, which refers to the difficulty, time requirement, and expense of communicating and getting together face-to-face.

“Knowledge distance” is the degree to which the source and recipient possess similar knowledge. Knowledge distance is an important aspect to consider in R&D knowledge transfer for the R&D output of the source is often the R&D input of the recipient. (Cummings & Teng 2003, 46.) Due to this starting point, the knowledge distance between the source and the recipient can be quite significant and learning thus more problematic. However, it has also been argued that a knowledge gap too small may burden the recipient with unlearning old knowledge prior to learning any new knowledge. Inter alia, a report concerning the biomass power industry in the United States notes that in some occasions information and education may needed to correct common misconceptions among the public and decision makers (NREL 1994). Therefore, it has been suggested that there may be a curvilinear relationship between knowledge distance and transfer success (Cummings & Teng 2003, 46-47).

Research on technology transfer has shown that differences in work values and organizational cultures can significantly impair knowledge transfers, whereas similar cultures and value systems allow for a smooth working relationship between the knowledge transfer parties (Cummings & Teng 2003). This notion touches the context of “norm distance”, which regards to which extent knowledge transfer parties share the same organizational culture and value systems. Because knowledge is embedded in cultures and routines, transfer success often decreases as norm distance between source and recipient increases. (Cummings & Teng 2003, 47-48.)

Physical distance between Finland and Canada is significant, about 6000km, but because both countries are leading-edge information societies, information and communication technologies can be utilized to bring internationally dispersed parties taking part in the transfer process together. While such technologies can be effective at facilitating the transfer of codified knowledge, they have been noticed to be insufficient in transferring related sensory information, feelings, intuition, and non-verbal communications (Cummings & Teng 2003, 40). Therefore, to achieve the knowledge’s ultimate implementation needed for successful technology transfer, face-to-face meetings, which have been noticed to be superior to other meetings or transfer formats in the transfer of strategically important matters (Cummings & Teng 2003, 46), must occur.

Face-to-face meetings and local presence have been important factors also in case Sioux Lookout. For example, the role of the Embassy of Finland in Ottawa, cooperation between consulting company Finnopool and the municipality of Sioux Lookout, as well as expert visits from Karelia University of Applied Sciences and Natural Resources Institute Finland, have played an important role in so far project success. Additionally, the preliminary work taken place over the past decade, such as Team Finland and other delegation visits together with Dr. Lauri Sikanen’s scholarship to Lakehead University in Thunder Bay, have positively contributed to the establishing of linkages between Finland and Sioux Lookout. Ministerial visits and state involvement have further increased levels of trust. It can thus be concluded that this establishing of linkages and strengthening of social ties through both technology and face-to face-meetings has increased the degree of organizational integration between the parties to the transfer.

Finland is a good reference for Canada because of the climatic, geographic and natural similarities the two countries share. However, it is essential to consider the degree to which these two countries possess similar knowledge. There can be recognized differences in attitudes and practices related to forest biomass use for energy between the source and the recipient. Bioenergy development in Finland has been promoted by insignificant deposits of fossil fuels combined with vast amounts of available forest resources, fluctuation of fossil fuel prices and the oil crisis in 1973. In consequence of these drivers, the number of installed community heating plants and combined heat and power plants has increased rapidly during the last decade. There has also been constant public support to develop the use of forest biomass for industrial and energy purposes in Europe, whereas North America has had more significant deposits of fossil fuels and less political and regulatory pressure. Due to inter alia these reasons, the operational environment in Europe is somewhat different compared to North America especially when it comes to human variables, such as politics, opinions, emotions, believes and tacit bioenergy knowledge.

All in all, knowledge distance between the source and recipient in case Sioux Lookout may be considered to be relatively ideal. A smaller knowledge gap might burden the recipient with unlearning old knowledge prior to learning any new knowledge. A larger knowledge gap, for its part, might increase embeddedness of the knowledge and thus make the transfer more difficult. It is however important to remember that the norm distance between the source and he recipient should be evaluated constantly and the product, here the bioenergy technology package, designed according to the capacity of the receiving community. This notion highlights the significance of R&D in transferring Finnish or European bioenergy knowledge and technology to Canada and approaching the transfer as an interactive non-linear process of exchanging ideas among the involved actors.

This Communication Model of TT highlights the importance of communication between the transmitters participating the KTT process in increasing transfer capacity (Lamberton 1991). By designing the knowledge according to the receiving community, the degree to which the recipient obtains ownership of, commitment to, and satisfaction with the transferred knowledge can be increased.

It is beneficial for knowledge transfer success of case Sioux Lookout that the norm distance between Finland and Canada is relatively small. As northern leading-edge information societies with bilingual parliamentary democracies Finland and Canada have much in common. In addition to similar geography, climate and natural resources, the two countries also share values in such areas as domestic policy, development, human rights and environmental issues. Finland and Canada work closely together in many areas multilateral organizations such as the United Nations (UN), the Organisation for Security and Cooperation in Europe (OSCE), the Organization for Economic Cooperation and Development (OECD), and the Arctic Council, an international forum that addresses the common concerns and challenges facing the governments of Arctic nations. Additionally, indigenous Sami people of Northern Finland have established regular exchanges with Canadian Inuit groups. (Government of Canada 2018.) Comprehensive Economic and Trade Agreement (CETA) between the European Union and Canada may further decrease the norm distance between these parties if it succeeds to remove barriers to trade between the EU and Canada and allow for the mutual recognition of some qualifications.

6.2.3 Recipient context

Transfer success can also be affected by factors related to the recipient's predisposition for learning new knowledge and to the extent of effort put forward to undertake transfer activities. When the priority of the knowledge transfer project for the recipient is high, the recipient will have greater motivation to support the transfer than if the project is seen as less significant. Thus, transfer success can be expected to increase as project priority increases. However, even when knowledge is transferred to a motivated recipient, the knowledge will need to be retained, nurtured and further developed to ensure transfer success. To facilitate knowledge transfer, there is a need for learning competencies designed to retain and nurture transferred knowledge among the recipient. When the recipient's degree of learning culture increases, transfer success can be expected to increase, too. (Cummings & Teng 2003, 48-49.)

Knowledge internalization defines transfer success as the degree to which a recipient obtains ownership of, commitment to, and satisfaction with the transferred knowledge (Cummings & Teng 2003, 42). According to Kostova (1999), three factors appear to be related to knowledge ownership. First, greater discretion over the knowledge can allow a recipient to invest more of their own ideas and personal style in the knowledge. Second, the intensity of the recipient's association with the knowledge can affect its feeling of ownership. Lastly, knowledge ownership also relates to the degree that an individual invests energy, time, effort, and attention in the knowledge. (Kostova 1999, 313).

Some past unsuccessful renewable energy projects in Canada have lacked meaningful collaboration with locals and missed out on opportunities to include the community in critical decision-making processes (Advanced Energy Centre 2015, 6). Shortage of knowledge and technical proficiency within the receiving community can inhibit community engagement in planning, design, deployment and operation of clean energy systems and thus decrease the recipient's discretion over the transferred knowledge. Lack of technical proficiency also evokes operational concerns about local capacity to manage the planned bioenergy heating plant operations and heat distribution. Therefore, to facilitate knowledge transfer, it is essential that that there are enough learning competencies designed to retain and nurture transferred knowledge among the recipient.

Case Sioux Lookout, however, looks promising. Local engagement and labor participation in Sioux Lookout are provincially comparably high. Sioux Lookout's employment rate, for example, is 72.2, whereas the provincial average in Ontario is 61.3. (Municipality of Sioux Lookout 2015B, 14). Additionally, there already is a new initiative underway to establish an “Innovation Station” – Knowledge Hub in Sioux Lookout (Blanchard 2018), which will offer training opportunities to acquire skills and knowledge within community and thus increase the community's absorptive capacity. Training opportunities can also be expected to increase the intensity of the recipient's association with the knowledge by increasing the number of interactions involving the knowledge and thus positively contribute to knowledge transfer success through increased feeling of ownership within the community.

Sufficient state of knowledge is a perquisite for commitment, which is the second aspect of knowledge internalization. Individuals develop knowledge commitment to the extent that they put value on the knowledge, develop competence in using the knowledge, maintain a working relationship with the knowledge, and are willing to put in effort to work with the knowledge. Project priority can be considered as a form of commitment. In Case Sioux Lookout, project priority can be stated to be high among the key actors. The Municipality of Sioux Lookout Economic Development Office has been working with regional partners to attract Foreign Direct Investment to Sioux Lookout with focus on the forest sector and bio-economy. According to the Mayor of Sioux Lookout "it is exciting at a municipal level to be engaged in a municipal-national co-operation" (Lawrance 2019). These observations can be concluded to indicate active, farsighted and holistic management style and local ambition to create employment in the region, which are all associated with successful bioenergy projects. Additionally, high project priority and commitment give a promising prediction for the expected transfer success.

There have however been opposition among the public, mostly related to environmental aspects (appendix 1), as discussed in chapter 6.1.3. Opposition raises a question of satisfaction with the knowledge, which is the third aspect of knowledge internalization. According to the Mayor of Sioux Lookout, while the bioenergy heating project "is generally welcomed in our community, as is the case in most jurisdictions, there are those who will oppose change." (Lawrance 2019.) Recipient satisfaction with knowledge is important because it can reduce the recipient's stress and resistance levels in adapting and using the knowledge (Cummings & Teng 2003, 42). Only when a recipient internalizes knowledge can it be sufficiently understood and adapted by the recipient to allow for its effective re-creation and, ultimately, its use. However, in case Sioux Lookout, as the Mayor (Lawrance 2019) also states, “the opposition is based largely on lack of knowledge” and therefore it is likely that “the questions and doubts can be resolved” with improved knowledge transfer. It is important to note that bioenergy projects are often long and sensitive to changing attitudes, hence knowledge transfer should be continuous.

6.2.4 Activity context

The fourth domain across which knowledge and technology streams and knowledge transfer success can be evaluated is the ‘activity context’, which refers to the different forms of knowledge transfer activities. These activities include those focused on assessing the embeddedness and articulability of the knowledge, those focused on accommodating and reducing differences and issues between the parties, and those focused on transferring the knowledge. Earlier researches suggest that the greater the involvement of the parties to a knowledge transfer through different transfer activities, the greater the likelihood that the recipient will be able to internalize the knowledge. (Cummings & Teng 2003, 50.)

In case Sioux Lookout, knowledge transfer activities after preliminary work have included inter alia a pre-feasibility study, site and data collection visits in both Lac Seul and Sioux Lookout, an evening reception held in Sioux Lookout to officially launch the municipal-national cooperation, a final feasibility study, and public seminar held in Sioux Lookout to announce to findings of the study. Knowledge transfer has been interactive and continuous. R&D has played an important role in optimizing the transferred knowledge correcting the occurred shortcomings. An answer to the writing in the local newspaper was for example written after noticing that environmental aspects of the planned bioenergy system should have been included into the feasibility study or otherwise communicated better. Additionally, local presence, strengthening of social ties, and state involvement have played an important role.

7 DISCUSSION AND CONCLUSION

7.1 Evaluation of the results

The research is conducted with a permission from Karelia University of Applied Sciences, Team Finland, Natural Resources Institute Finland, and The Municipality of Sioux Lookout. The confidentiality of commercial secrets is ensured, and the participation of the interviewees is voluntary. The liability of the research is analyzed through the four categories Yin (2003) presents for evaluating the research designs: construct validity, internal validity, external validity and reliability.

The construct validity means the formation of correct operational measures for the objects being studied (Yin 2003, 34). The construct validity was established by using multiple-sources of evidence to form relevant research questions, to link data to propositions, and to choose correct criteria for interpreting the findings. The critical factors for bioenergy knowledge and technology transfer were examined through a four-dimensional approach consisting of economic, technical, social and ecological aspects. None of the factors alone was not considered to be defining the total transfer capacity but overall evaluations were made based on the cooperative action of the factors. The multiplicity of evidence was ensured by mirroring the data collected from Case Sioux Lookout with existing literature analysis. The analysis included also one study conducted namely about Canadian remote communities to ensure compatibility between the analysis and the case in question. Consequently, the draft case study report was reviewed by key informants.

Internal validity is a concern for causal and explanatory case studies, in which the goal is to determine whether event x led to event y. The concern over internal validity of case studies may also be extended to the broader problem of making inferences. Basically, a case study involves an inference each time an event is observed indirectly for example based on interviews and documentary evidence. (Yin 2003, 35.) The internal validity is established with "pattern-matching" which is a technique of relating the data to the propositions, even though the entire study consists of only a single case. The theoretical proposition used is case Sioux Lookout was that knowledge transfer positively contributes and can be considered as a key tool to technology transfer. Consequently, an approach termed knowledge internalization was adopted to evaluate transfer success. Knowledge internalization defines success as the degree to which a recipient obtains ownership of, commitment to, and satisfaction with the transferred knowledge (Cummings & Teng 2003, 42). Knowledge and technology transfer, innovation streams and transfer success were analyzed across four contextual domains that included knowledge context, relational context, recipient context, and activity context. To further improve internal validity, direct observations were made at the project site in addition to interviews and secondary evidence.

External validity has been a target of criticism in doing Case studies. Critics typically claim that single cases offer a poor basis for establishing a domain to which findings of a study can be generalized. However, such criticism indirectly contrasts case studies to survey research by creating an analogy to samples and universes. This is incorrect because survey research, in which a "sample" often readily generalizes to a larger universe, relies on statistical generalization, whereas case studies as well as experiments rely on analytical generalization. In analytical generalization a previously developed theory is used as a template with which to compare the empirical results of the case study. In other words, the case study, like the experiment, does not represent a "sample" nor does it aim to enumerate frequencies. Therefore, analytic generalization can be used whether the case study is a single-case or a multiple-case study. The generalization is not automatic, however, but the theory must be tested through replications of the findings in a second or even a third case. (Yin 2003, 36.) If two or more cases are shown to support the same theory, replication may be claimed. In case Sioux Lookout, analytical generalization can be used by comparing the empirical results from this case study to the results from previous researches about knowledge transfer as a key to technology transfer. However, this study is quite case specific thus no direct application of the results to other regions can be conducted. To claim a replication, other similar projects between Finnish and Canadian parties need to be studied as they emerge.

Yin (2003, 33) summarizes reliability as replicability of the operations of a study, such as the data collection procedures. The goal of reliability is to minimize the errors and biases in a study. Reliability of the results was established by choosing a four-dimensional approach and using multiple-sources of evidence. Biases were minimized by choosing the interviewees from different sides of the transfer process and by observing the general operational environment in Ontario approximately for a year before conducting this report. However, during the research it was noticed that grass root opinions related to community development projects are not easily accessible. For example, opinions and viewpoints specifically from Lac Seul were accessed only through different moderators.

The aim of the thesis was to investigate the underlying dynamics of bioenergy knowledge and technology transfer and the role of R&D in improving the transfer success of Finnish bioenergy knowledge and technology. The thesis demonstrates that the chosen four-dimensional approach, which included economic, technical, social, and ecological perspective, was practical to investigate the complex multi-lateral co-operation between Finland and the Municipality of Sioux Lookout. Additionally, addressing the planned bioenergy facility as a system and utilizing the communication model of technology transfer advanced the understanding of the underlying dynamics affecting the bioenergy transfer success in case Sioux Lookout.

Knowledge about different operational environments is beneficial to generate new and innovative knowledge about organizing bioenergy knowledge and transfer. Therefore, the identified underlying dynamics and success factors of bioenergy knowledge and technology transfer in case Sioux Lookout may be valuable knowledge for next possible Finnish-Canadian bioenergy projects. It is, however, important to note that Case Sioux Lookout is still in progress, hence the final analysis of the transfer success should be conducted later. If the timeline of the project is seen to move from the introducing of Finnish solutions for the potential customers towards a wider co-operation between the transfer parties (figure 2), it can be evaluated that only about 25% of the transfer process has been completed so far. If Case Sioux Lookout is considered as an independent bioenergy project consisting of feasibility studies, financing, and construction of the new bioenergy system, approximately 50% of it can be seen to be completed. Consequently, to eliminate possible false inferences and to ensure application of the results to other regions, replication of the study should be conducted with other bioenergy knowledge and technology transfer projects. This report serves as a requisite for allowing the study to be repeated.

7.2 Future perspectives and research needs

Quantifying and sharing the socio-economic and environmental benefits of bioenergy systems is important for the project success of future bioenergy knowledge and technology transfers. However, the four-dimensional analysis has revealed that there is no current mechanism to incorporate these total benefits. Furthermore, given multiple funding streams, no current organization in Canada can justify implementing bioenergy solutions, given that total benefits and avoided costs do not accrue to that same organization. This increases the complexity and challenges associated with tracking performance metrics and measuring the total impacts of these alternative energy systems and thus prevents the environmental and socio-economic benefits of implementing bioenergy solutions from being quantified and communicated. Without mechanisms to evaluate the total impacts of bioenergy systems, articulability of the knowledge related to them remains low, which decreases bioenergy knowledge and thus also bioenergy technology transfer success. Therefore, further research about different mechanisms to concretize the socio-economic and environmental benefits of bioenergy systems can be considered as a key piece in strengthening the business case for future bioenergy systems.

It is important to examine ongoing transfer processes to understand the underlying dynamics of bioenergy knowledge and technology transfer and the role of R&D in improving the transfer success, as was done with Case Sioux Lookout. However, the four-dimensional analysis has highlighted that more data also from successfully deployed systems is required to instill confidence and strengthen business cases for future projects. It would thus be beneficial to conduct another research about Case Sioux Lookout when the knowledge and technology transfer process has been completed and the planned bioenergy system deployed. Additionally, to strengthen the reliability of the results of this study, the intensified role of R&D in other similar projects between Finnish and Canadian parties should be studied as they emerge.

7.3 Conclusions

The aim of the thesis was to investigate the underlying dynamics of bioenergy knowledge and technology transfer and the role of R&D in improving the transfer success of Finnish bioenergy knowledge and technology. It proved to be beneficial to combine the findings from Case Sioux Lookout with existing literature analysis and evaluate the results and knowledge transfer success through knowledge internalization -approach. The thesis demonstrates that the chosen four-dimensional approach, which included economic, technical, social, and ecological perspective, was practical to investigate the complex multilateral cooperation between Finland and the Municipality of Sioux Lookout. Additionally, addressing the planned bioenergy facility as a system and utilizing the communication model of technology transfer increased understanding and controllability of the underlying dynamics affecting the bioenergy transfer success in Case Sioux Lookout.

The thesis aimed to answer to the following questions:

- What are the underlying dynamics and success factors of bioenergy knowledge and technology transfer?
- How can the knowledge derived from R&D be exploited in transferring Finnish bioenergy knowledge and technology to Sioux Lookout, Canada?

The case study and existing literature analysis demonstrated that if innovative energy projects fail to consider prerequisites and underlying dynamics of bioenergy deployment projects at all four dimensions, they may produce poor results. It was noticed that the barriers these projects face, are mainly related to public policy and funding, perceived or actual technology risks, and local capacity, whereas holistic view on energy, innovative collaboration, and interactive communication act as success factors. Shortage of knowledge and technical proficiency was noticed to be a significant factor undermining transfer success at all these dimensions. It was thereby concluded that there must occur continuous knowledge transfer to increase both absorptive and transfer capacity and thus enable successful technology transfer. The existing literature analysis, however, demonstrated that there is no current mechanism to incorporate the socio-economic and environmental benefits of bioenergy projects. Without mechanisms to evaluate the total impacts of bioenergy systems, articulability of the knowledge related to them remains low, which decreases knowledge transfer success. It was thus concluded that quantifying and sharing these total impacts is a key piece in strengthening the business case for bioenergy systems.

The study highlighted that because bioenergy projects are often long and sensitive to changes in politics and opinions, continuity of knowledge transfer, stakeholder management and local presence are of paramount importance. It was also noticed that knowledge transfer, as well as the technical solution, must be planned according to and in collaboration with the receiving community to increase knowledge internalization. Communication model of technology transfer, which highlights the importance of continuous interaction between transceivers participating the transfer, was found useful to avoid falsifying the complex transfer process to chronologically ordered stages and one-way communication from expert to user. The study noted that continuous and interactive R&D plays an important role in optimizing the knowledge through transfer activities, including those focused on assessing the embeddedness and articulability of the knowledge, those focused on accommodating and reducing differences and issues between the parties, and those focused on transferring the knowledge. It was concluded that the lower the embeddedness and the higher the articulability of the knowledge is, the better transfer success can be expected. Small organizational, physical, knowledge, and norm distance between the transfer parties and high knowledge ownership, commitment and satisfaction within the receiving community proved to be advantageous. It was also found that the greater the involvement of the parties to a knowledge transfer through different transfer activities, the more effective the knowledge and thus also technology transfer success.

It is important to examine ongoing transfer processes to understand the underlying dynamics of bioenergy knowledge and technology transfer, as was done with Sioux Lookout. Therefore, the identified underlying dynamics of and success factors for bioenergy knowledge and technology transfer in case Sioux Lookout may be valuable knowledge for next possible Finnish-Canadian bioenergy projects. However, more data from successfully deployed systems is required to instill confidence and strengthen business cases for future projects. It would therefore be beneficial to conduct another research about Case Sioux Lookout after the ongoing knowledge and technology transfer process has been completed and the planned bioenergy system deployed. Additionally, to claim a replication and more specifically determine how knowledge derived from R&D can be exploited in advancing bioenergy knowledge and technology transfer, the intensified role of R&D in other similar projects between Finnish and Canadian parties should be studied as they emerge. This report serves as a requisite for allowing the case study to be repeated.

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Letter to the Editor. The Sioux Lookout Bulletin 15.1. & 5.2.2019.

Letter to the Editor

Biomass

The proposal to use wood burning biomass plants in Sioux Lookout and Lac Seul is misleading as stated in the article in the Sioux Lookout Bulletin dated Wednesday, December 19, 2018. Live standing Birch trees are to be cut, chipped and hauled to the biomass plants for use in the two communities.

The definition of biomass when used for energy production is left over waste from forestry / logging and agricultural farming. If anyone is interested in seeing this kind of biomass I recommend you take a drive behind Hudson, the Kathlyn Lake Road, Highway 642 east, and Highway 17 east from Dinorwic to Thunder Bay. Those piles of wood waste on the side of the road from forestry/ logging are real biomass. We should not be cutting live Birch trees to create biomass. This is exploitation and unsustainable use of our natural resources. The Boreal forest is the largest carbon sequestering sink in the world, thought by many scientific minds and naturalists to be the lungs of the planet. How fortunate we are as Canadians that a large portion of it is located in Canada. If we are going to move forward to a green future should we not be putting a value on a live standing tree in the forest rather than a dead tree in a chip pile?

Remi Lorteau

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Letter to the Editor

Biomass - The Inevitable Impacts

The risks associated with the location of the proposed biomass plant in Sioux Lookout near our health care center, three of our schools and a large portion of our residential area should be of great concern for many of our citizens.

Burning wood biomass emits as much, if not more, air pollution than burning fossil fuels - particulate matter, nitrogen oxide, carbon monoxide, sulfur dioxide, lead, mercury and other hazardous air pollutants. The American Heart Association and the American Lung Association have called this a danger to public health, produces respiratory illness, heart disease, cancer and developmental delays in children.

Depletion and deforestation of our natural forest, acidification of our fresh water lakes, unrepairable damage to wildlife and bio diversity should be a real concern.

This project must require an environmental assessment on the health and welfare on human wellbeing and impacts on our forest and wildlife, and also an LCCA (Life Cycle Cost Analysis) on the proposed biomass plant in Sioux Lookout. If you have any concerns with this project, now would a good time to contact our Mayor and Council members.

Remi Lorteau