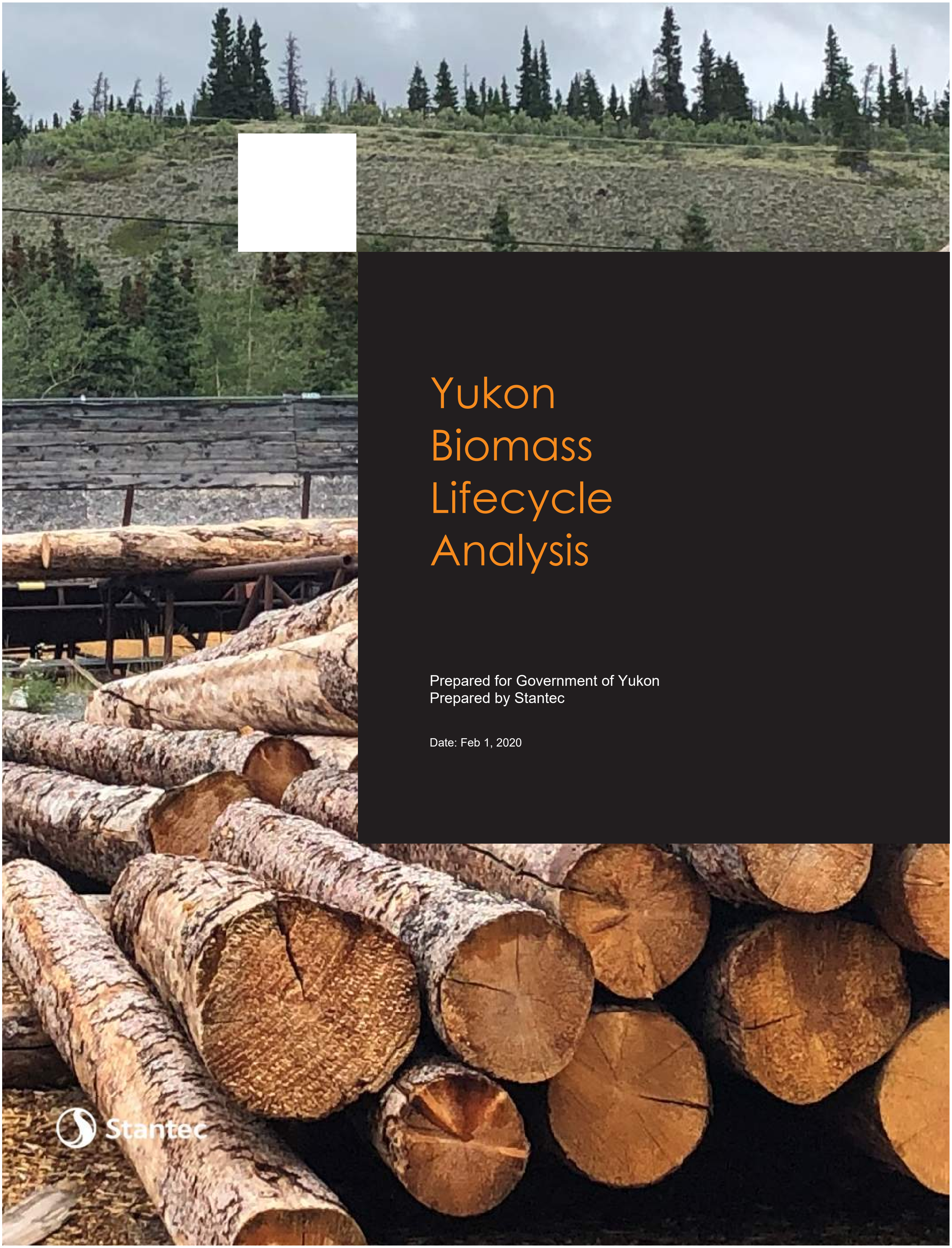

Yukon Biomass Lifecycle Analysis

Prepared for Government of Yukon
Prepared by Stantec

Date: Feb 1, 2020

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Executive Summary

The focus of this report is to conduct a lifecycle analysis of the biomass industry in Yukon and outline the environmental and economic benefit of a biomass fuel supply chain in the Territory. This report investigates the supply and demand sides of the industry and presents findings in the context of historical progress, current state of the industry and forward-looking projections. This study also presents the findings of a SWOT analysis that was completed during a series of interviews with industry stakeholders and presents a PESTLE analysis to identify risks and barriers to growth in the current environment.

The biomass supply industry assessment provides an overview of current harvest rates from the various harvesting activities to determine the existing demand for biomass fuel can be sustained by local sources alone. Presently, harvesting for cordwood is estimate at 13,000 t/ yr and harvesting for woodchip production is estimated at 1,600 t/ yr. Imports of densified wood pellets are estimated at between 2,000 and 3,000 t/ yr. There is currently no capacity for commercial scale pellet production in Yukon. The combined annual allowable cut for Yukon is approximately 146,000 t/yr from all regions with only approximately 10% utilized. Available wood from all sources, including FireSmart, highway and mine clearing and salvageable timber from fire and beetle kill is estimated at 2,840,000 t/yr. Growth of the biomass fuel supply industry is not expected to impact the sustainability of the forest resources within the evaluated time frame.

The current annual demand for biomass fuel in Yukon is estimated at approximately 300 TJ (18,000 t/ yr), of which 13,000 t/ yr is in cordwood and the remainder split between woodchips and wood pellets for biomass heating systems. The *Our Clean Future* strategy released in 2020 targets a reduction of 12,000 t in GHG emissions from building retrofits and fuel and 5,000 t GHG attributed to new buildings, which if accomplished entirely through biomass heating would result in an increase of 12,750 t/ yr of biomass heating fuel demand.

The jurisdictional review presents case studies of similar regions that have been successful in promoting growth of the industry through a variety of strategies, including financial incentives, training programs and education/information sessions. The primary drivers for industry growth have been identified as; GHG reduction goals, local energy security, lower cost ($/GJ) fuel costs, and local economic stimulation.

The economic analysis presents operating revenues and expenses for potential biomass facilities in the Yukon. Based on the stated assumptions, positive net present value was seen in the 800kW containerized chip plant, and the 1MW and 3MW district heating plants. A positive net present value was also seen from a 30,000 t/yr wood pellet processing mill with NPV of $17.6M at 20-years and $28M at 40-years.

Abbreviations

AAC	Annual Allowable Cut
AQI	Air Quality Index
AQMS	Air Quality Management System
BC	British Columbia
Biomass	Energy fueled by the combustion of organic material
CAD	Canadian Dollars
CHP	Combined Heat and Power
CO_2	Carbon Dioxide
EPA	Environmental Protection Agency
FFLTC	Fibre Forestry License to Cut
FMB	Forest Management Branch
FRPA	Forest and Range Practices Act
FSLTC	Fibre Supply License to Cut
FST	Forest Stewardship Plan
g/hr	Grams per hour

GHG	Green House Gas
GJ	Giga Joule
GW	Giga Watt
ha	Hectare
IPP	Independent Power Producer
Km^2	Square kilometers
kW	Kilowatt
kWh	Kilowatt hour
L/ yr	Litres per year
LCOE	Levelized Cost of Energy
m^3	Cubic Meters
MW	Megawatt
μm	Micrometers
NPV	Net Present Value
NSPI	Nova Scotia Power Incorporated
NWT	North West Territories
PEI	Prince Edward Island

PPEE	Program to Promote Energy Efficiency
PJ	petajoules
RFP	Request for Proposal
RPP	Refined Petroleum Products
SME	Subject Matter Expert
t	Metric Tonnes
t/ yr	Tonnes per year
tCO_2/ yr	Tonnes CO_2 per year
TSA	Timber Supply Analysis
TTC	Teslin Tlingit Council
YG	Yukon Government
yr	year
YT	Yukon Territory

Glossary

Annual Allowable Cut	The amount of timber that is permitted to be cut annually from a particular area.
Biodiversity	The variety, distribution and abundance of different plants, animals and micro-organisms, the ecological functions and processes they perform and the genetic diversity they contain
Biomass	Renewable organic material used for energy production.
Energy Efficiency	The ratio between input and output during an energy conversion process.
Feedstock	A feedstock is any biomass destined for conversion to energy or biofuel.
FireSmart	The process of addressing concerns related to wildfire in Canada is generally led by FireSmart Canada, and initiative which was originated by Alberta Forest Service –a department of the Alberta government now called Alberta Environment and Sustainable Resource Development. The FireSmart program helps protect residents, homes, communities, critical infrastructure, and vital natural resources from wildlife three seven disciplines: education, emergency planning, vegetation management legislation, development, interagency cooperation, and cross-training. Vegetation management associated with FireSmart activities focuses on fuel removal, fuel reduction, and species conservation.

Greenhouse Gas Emissions	Greenhouse gas, any gas that has the property of absorbing infrared radiation (net heat energy) emitted from Earth's surface and reradiating it back to Earth's surface, thus contributing to the greenhouse effect. Carbon dioxide, methane, and water vapour are the most important greenhouse gases. GHG emissions are often measured in mass of carbon dioxide (CO_2) equivalent. Gas emissions are converted into CO_2 equivalent by multiplying by the gas's Global Warming Potential (GWP). The GWP takes into account the fact that many gases are more effective at warming Earth than CO_2, per unit mass.
Moisture Content (% MC)	The amount of water in a given piece of wood. The weight of the water compared to its oven-dry weight (0% MC) Calculated by (weight of water / oven-dry weight of wood) x 100. Moisture content effects the caloric value (kWh/kg) and the particulate emissions of the wood when burned.
Particulate Emissions (PM)	The mixture of solid particles and liquid droplets found in the air. Some particles, such as dust, dirt, soot, or smoke, are large or dark enough to be seen with the naked eye. Others are so small they can only be detected using an electron microscope. PM_{10}: inhalable particles, with diameters that are generally 10 μm and smaller, $PM_{2.5}$: fine inhalable particles, with diameters that are generally 2.5 μm and smaller pose the greatest risk to health. PM_1: fine inhalable particles, with diameters that are generally 1 μm and smaller pose the greatest risk to health.
PESTLE Analysis	Political, Economic, Social, Technological, Legal and Environmental
SWOT Analysis	Strength, Weaknesses, Opportunities, Threats

1.0 INTRODUCTION

1.1 PROJECT BACKGROUND

Yukon's *Our Clean Future: A Yukon Strategy for Climate Change, Energy and a Green Economy* provides a 10-year action plan to address the climate change emergency and develop a new sustainable energy economy. This plan seeks to align Yukon CO_2 emission levels with Canada's commitment under the Paris Agreement by targeting a 30% emission reduction by 2030 relative to 2010 emission rates. This ambitious target relies heavily on developing local and renewable heat sources like biomass energy.

Biomass energy is derived from organic matter including wood, agricultural products, organic wastes, municipal solid waste, or other living cell materials. This report explores biomass energy in the context of using wood as the fuel source as Yukon has a large abundance of forest resources which historically have been sparsely utilized primarily for home heating. In recent years, a greater interest has developed in utilizing biomass heating systems on a wider scale to offset the use of imported fossil fuels and help meet the Territory's CO_2 emission reduction targets.

1.2 PURPOSE

The Yukon government Department of Economic Development commissioned this report to provide an analysis of the biomass industry in Yukon, its benefits, and potential for growth. This analysis will provide a critical investigation into the biomass industry as it currently operates in Yukon and will discuss opportunities and challenges facing the current industry stakeholders. The analysis will include forward looking estimates to identify biomass supply, demand and support industry growth and development opportunities, current and potential obstacles to growth, potential pricing pressure from external industry competitors, alternative fuel options and study into the environmental and social impacts of industry growth.

1.3 METHODOLOGY

This report intends to offer an objective view of the industry using a P.E.S.T.L.E. approach to identify internal and external influences and risks to the industry from Political, Economic, Social, Technological, Legal and Environmental factors. Specific action items will be recommended to identify a path to sustainable growth.

Research conducted during this analysis included a combination of quantitative methods focusing on review of previously published industry reports and reference documents, and qualitative methods focusing on interviews and questionnaires provided by industry stakeholders.

1.3.1 Stakeholder Interviews

A series of stakeholder interviews were conducted to gain input from active members in the Yukon biomass industry. The interviews followed a semi-structured format with an initial question framework that was adapted to the interviewee's background and area of expertise. This framework has been included in Appendix A Stakeholder Interview Guide for reference. The interviews sought to engage members from a cross-section of the industry to encourage a range of perspectives and identify opportunities and challenges throughout the industry. The interviewees included members of Yukon and First Nations governments, members of First Nations development corporations and representatives from private industry. A SWOT analysis was conducted with each interviewee to capture Strengths, Weaknesses, Opportunities, and Threats from the perspective of each stakeholder. Additional details of the interviews and the result of the SWOT analysis are provided in Section 4.0.

1.4 REPORT OUTLINE

This report has been organized as follows, to include all deliverables identified by the Yukon government in the project RFP, as described below.

Section 2.0 - Context of the biomass industry in Yukon

This section describes the historical context, current state, and future projections of the biomass industry in Yukon including technologies used, Yukon's energy profile, existing harvesting practices, and future supply and demand projections.

Section 3.0 - Jurisdictional review

This section reviews the biomass industry across Canada illustrating how it varies from Yukon's current state and considers case studies from active biomass industries in other regions. By reviewing the policies, guidelines, and regulations in other jurisdictions; a deeper understanding of why the differences experienced across Canada are seen.

Section 4.0 - Stakeholder engagement

This section describes results of stakeholders' interviews undertaken to inform the report and includes a review of key themes heard. Interviews were framed around a SWOT analysis process.

Section 5.0 - Political considerations

This section discusses the political climate and policy changes that could impact the biomass industry in Yukon.

Section 6.0 - Economic analysis

This section describes the main economic and employment growth opportunities for Yukon by providing a fuel cost comparison, considering the impact of economies of scale, future market rates, and evaluating the opportunity cost of the industry specific to not having a wood energy-based industry.

Section 7.0 - Social considerations

This section describes the current and anticipated social climate present in Yukon, to evaluate the level of community support for biomass as an industry and fuel source.

Section 8.0 - Technological review

This section discusses the technology used in Yukon's biomass industry identifying risks and opportunities for improvement.

Section 9.0 - Environmental considerations

This section explores the environmental risks and opportunities that may arise during growth of Yukon's Biomass industry.

Section 10.0 - Legislative considerations

This section describes key legislation and regulations impacting the biomass industry in Yukon.

Section 11.0 - Recommendations

This section provides recommendations and suggestions regarding how barriers to development could be eliminated or mitigated to grow the industry.

Section 12.0 - Conclusion

This section provides an overview conclusion of the existing and anticipated state of the biomass industry in Yukon including barriers to development and recommendations for improvement.

2.0 ROLE OF BIOMASS IN YUKON

Yukon is a proud user of renewable energy sources; approximately 94% Yukon's electricity comes from hydro resources with diesel used for communities off the electrical grid or where there is not enough hydroelectricity to meet the demand (Regulator, 2020); a small amount of electricity in Yukon comes from wind.

Although Yukon is widely provided by hydroelectricity, renewable sources are not as prominently used for heating because the demand for heat peaks in winter when hydro facilities are already operating at full capacity. When demand exceeds the hydro capacity, diesel generators are used to meet the increased demand. As outlined in *Yukon's Biomass Energy Strategy* and shown on Figure 2-1, heating oil and propane supplied approximately 75% of the heat used in Yukon in 2012 (Government of Yukon, 2016).

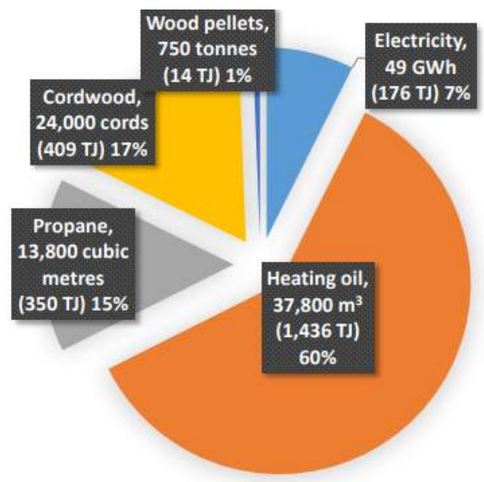


Figure 2-1 Estimated breakdown of energy use for heat in Yukon, 2012. Source: Energy Solutions Centre

2.1 HISTORIC ROLE

Yukon's Biomass Energy Strategy described Yukon's relationship with biomass fuel as follows,

> *"Yukon has a long history of using wood as a source of energy; the steamboats that plied Yukon's rivers 50-100 years ago were all powered with wood. Today, many Yukon people heat their homes with woodstoves, especially in communities where fuelwood is accessible.*
>
> *Approximately 13,000 cords (30,000 m^3) of wood are harvested annually in Yukon to heat homes and buildings. This accounts for approximately 17% of Yukon's total consumption of energy for heat. Most cordwood in the territory is currently harvested in the Haines Junction area from beetle-killed trees and trucked to the Whitehorse area, which accounts for approximately 75% of the territory's total heat demand."* (Government of Yukon, 2016)

In addition to Yukon's historic connection to using wood as a fuel source; with abundant forest resources, wood heating has been a fundamental heating method in Yukon. Traditionally, central wood stoves for home heating have been used alongside coal as the primary fuel source. Centrally distributed heating systems using steam, hot water, and heated air came into more widespread use in the 1940s and 1950s and fuel sources became more diversified including fuel oil, natural gas/ propane, and electrical resistance heating. Following these transitions to alternative fuel sources, wood and biomass heating was largely abandoned in larger commercial/ industrial sector buildings in favor of the oil and gas due to more easier handling and more efficient heat distribution systems.

2.2 FEEDSTOCK OVERVIEW

Yukon has a tradition of using wood as a source of energy. Many Yukon people heat their homes with woodstoves, especially in communities where timber is accessible. Between 1,480 and 1,624 homes use firewood as their primary heating fuel, representing between 13.6% and 14.9% of all homes (Thorp & Zanasai, 2015).

Approximately 30,000 m^3 of wood are harvested in the Yukon to heat homes and buildings (Yukon Government, 2016). This accounts for approximately 17% of Yukon total heat consumption.

Feedstock is a term that refers to the raw materials used as fuel in the production of biomass energy. In Yukon's wood biomass industry, there are three different feedstocks each described below with its own pros and cons.

Cordwood

Cordwood is widely used in for residential heating in Yukon with many Yukoners using wood as their primary method of home heating and many more using wood for supplemental or secondary heating. Split logs may be harvested by individuals using hand-tools.

Current production

At least 13,000 cords of firewood are consumed annually. Most cordwood comes from beetle kill in the Haines Junction area, with the second most common source of fuel from fire kill throughout the Yukon (Government of Yukon, 2016)

Pros

- Widely accessible.
- Can take advantage of local wood sources such as waste wood or excess wood from land clearing or FireSmart operations
- Less expensive than chips or pellets
- Low capital installation cost

Cons

- Producing cordwood is labour-intensive
- Lacks automated feedstock delivery
- Lower Energy Density compared to chips or pellets.
- Often higher particulate emissions due to fuel moisture content, or improper burn techniques.
- Seasoning required to control moisture content.

Chips

Wood chip feedstock are presently used on a limited basis in the Yukon. Chipped wood requires limited processing and is compatible with automatic feed systems, making it more conducive to large-scale applications.

Current production

Cordwood and chips are available locally within the Yukon; it is estimated that there are 1,600 t/ yr of woodchips produced in Yukon for use in Biomass facilities. Current production of chips includes approximately 600 t/ yr in Haines Junction area, and 400 t/ yr in the Whitehorse area that are generally sourced from Teslin fire kill (Roach & Berch, 2014). An additional 600 t/ yr is produced near Dawson City when the District Biomass System is in operation.

Pros

- Requires less processing than wood pellets, chips can be easily produced using smaller scale processing operations such as wood chippers or grinders at smaller scales with much lower barriers to entry.
- Can take advantage of local wood sources such as waste wood or excess wood from land clearing or FireSmart operations
- Lower total cost per GJ than pellets.

Cons

- Quality of chips varies (e.g. size, moisture content)
- Requires trained personnel to monitor fuel quality and maintain feed and heating systems.
- Chips are commonly less energy dense than pellets due to moisture content and therefore require larger storage facilities or more frequent deliveries.
- Are more expensive to transport than pellets and therefore chip supply for facilities in Yukon would need to be sourced locally.

Pellets

The use of pellets as a feedstock is gaining increased usage but is still in its infancy in the Yukon; household use of pellets is increasing. In addition to the pros listed below, most modern pellet systems have a proven track record of being convenient, reliable, and efficient and have cleaner air emissions than chip or cordwood systems. Fuel handling systems are typically smaller and easier to maintain.

Current production

Bear Creek Logging in Haines Junction has recommissioned an older pellet manufacturing plant. Currently the operators are manufacturing test pellets with plans to expand production and sell the pellets commercially. Pellet use in Yukon is presently confined to individuals and supplied by retail outlets. It is estimated that 2,000 to 3,000 tonnes are consumed annually.

Pros

- Manufactured to more strict quality-control standards allowing more consistent quality and easier to verify and certify quality.
- Easy to transport and distribute.
- Consistently low moisture content and improved particulate emissions.
- Suitable for small and large-scale heating systems
- Less complex fuel storage and handling systems

Cons

- Generally higher total cost per GJ due to additional processing and shipping.
- Currently imported from British Columbia and large barrier to entry for local production.

2.3 TECHNOLOGY USED

2.3.1 Wood stoves

Figure 2-2 - Wood stove

Traditional wood fireplaces and stoves vary widely in design and construction, typically consisting of a single masonry or steel burn chamber and steel chimneys with little consideration given to burn efficiency and particulate emissions. Burn efficiencies were extremely low in early open fireplaces, often 10% or less. Closed wood stoves with designed convection systems achieved efficiencies of 30% to 40%. Modern wood stoves are still commonly constructed of cast iron or steel, but now include some form of secondary combustion to burn unburned gasses to improve emission and overall efficiency to 70% to 80%.

Catalytic combustor stoves use a honeycomb of steel or ceramic with a catalyst such as Platinum, or Palladium to reduce the combustion temperature of the flue gases and improve efficiency of the secondary burn chamber causing more complete combustion across a broader range of burn temperatures. New catalytic stoves typically offer emission rates of 2 g/hr or less and efficiencies of up to 80% (EPA-Certified Wood Stove Database, n.d.)

Non-catalytic wood stoves require higher combustion temperatures in the secondary burn chambers to achieve full combustion and so are capable of peak efficiencies similar to catalytic stoves under controlled conditions, but efficiencies diminish more quickly at low temperatures and with high moisture fuel. The EPA-Certified Wood Stove Database lists non-catalytic wood stoves with typical emission rates of 2 g/hr and less and efficiencies up to 80% however averaged operating efficiencies are estimated to be more commonly 65% to 75%.

Wood stoves and similarly constructed wood furnaces are used widely in Yukon for home heating with an estimated 15% of homes using these as their primary heating source and many more using them as a secondary/supplemental heat source.

2.3.2 Conventional outdoor wood furnaces

Figure 2-3 - Outdoor Wood Furnace

Small outdoor biomass boilers similar to the central boiler outdoor wood furnace system depicted in Figure 2-3 came into common use in the 1990s and 2000s. Their packaged design offered a simplicity of installation and operation and are primarily targeted at residential and small commercial sized installations. In some cases, these have been installed in small district heating systems such as at the Champagne and Aishihik First Nation carpentry and metal shops buildings in Haines Junction, YT.

These boilers operate similarly to single-stage wood stoves with a single primary burn chamber surrounded by a water jacket that captures and directs heat to the residence through buried insulated pipes which can then be utilized for space or water heating like a conventional hydronic heating system. These systems are primarily intended for use with cord wood; however, are versatile in fuel compatibility and could be used with wood chips, pellets or even scrap wood. These systems are typically not available with automated fuel feed systems so manual refueling is needed regularly. Boiler efficiencies are estimated between 50% and 60% and particulate emissions rates are estimated to be 15 to 20 g/hr based on similar technologies.

Although common, these boilers have not seen widespread adoption in the Yukon due to their relative inefficiency next to comparable high efficiency oil and gas boiler and furnace systems and the relative simplicity of electric resistance heating. The requirement for regular manual refueling was also seen as a deterrent.

2.3.3 Biomass heating plants

2.3.3.a Early systems

Two large biomass direct-combustion heating systems were installed in Whitehorse during the 1980s and 1990s at the Elijah Smith School and the Elijah Smith Federal Building; a third fluidized bed biomass gasification system was later installed at Yukon College. Each of these systems were generally viewed as failures due to frequent service disruptions caused by maintenance and operations issues as well as inconsistent fuel supply and quality. All of these initial systems have subsequently been taken out of service and are reported to have left a ‘lingering resentment’ toward the biomass heating industry that was seen as unreliable and prone to failures.

Yukon College

Figure 2-4 - Yukon College Biomass System

Feedstock: Chips or pellets, municipal solid waste, sewage sludge

In 1987, Yukon College in Whitehorse, YT, installed an air-blown fluidized bed gasifier to provide 2,000 kw of space heating for the campus buildings. The system was originally designed to use wood chips or pellets and would also be compatible to use combustible waste such as municipal solid waste and sewage sludge. The system encountered initial issues during commissioning due to inadequate controls and was eventually taken out of service in 1991 after multiple attempts to complete the system commissioning. Subsequent attempts to investigate the system and develop options to restore it to operation were made in 2004 and 2009.

In 2017, Yukon College purchased a Volter Micro Co-generation Combined Heat and power Biomass generator for use with the Yukon Research Centre. It is understood that operational issues were encountered with the Volter unit arising from fuel quality concerns and the unit has been removed.

It is noted that the gasifier and the CHP systems that have been trialed at the Yukon College bring unique operating constraints that differ significantly from the other examples listed in this section, and the challenges encountered here are not fully correlated with challenges at the heat-only plants.

Elijah Smith School

Figure 2-5 - Elijah Smith School Biomass System

Feedstock: Pellets

In 1991, the original construction of Elijah Smith School included a 1,000kW Apsco dual-fuel biomass/ propane boiler system with storage and feed systems intended for wood pellet handling. The system encountered numerous operational issues including component failures, length and troublesome fuel delivery loading and inconsistent fuel supply security through its life. It has subsequently been disconnected with the boiler operating in propane only mode through recent years. The boiler efficiency is unknown but is estimated to be approximately 70% based on similar technology of the era. In 2020, the Yukon Government launched a project to remove the existing Apsco boiler at the Elijah Smith School and install a new biomass boiler using modern technology for improved efficiency and maintainability.

2.3.3.b Modern systems

Dawson District Biomass Heating System

Figure 2-6 - Dawson District Biomass System

Feedstock: Chips

The Dawson district heating system project was completed in 2013 to install a new 720 kW Viessmann biomass boiler system, providing supplemental heat to the City's Reservoir Pumphouse and the City's Wastewater Treatment Plant building. The project installed 2,000m of buried distribution pipe and included future provisions for a Phase 2 expansion boiler and connection to the new nearby hospital which itself was under construction at that time. Fuel is stored in a below grade bunker and transferred using a combination of walking floor, and screw auger systems. Initial fuel handling problems were encountered with the inclined screw auger that was prone to jamming and required an eventual replacement in 2014. Fuel chipping has also been challenging due to chipper blade sharpening requirements.

This facility consumes approximately 540 t/ yr of locally harvested wood chips to offset an estimated 293,000 L/ yr of fuel oil and an estimated 800 tCO_2/ yr.

Teslin Biomass Projects

Figure 2-7 - Teslin Biomass Boiler

Feedstock: Chips

The Teslin District Biomass project initiated by the Teslin Tlingit Council to install a series of ten 100kW Hargassner wood chip biomass boilers distributed across three energy stations and supplying heat to ten buildings on the Teslin Tlingit First Nation Territories. The system was designed specifically to accommodate a wide variety of fuels and allow locally harvested chips with potentially higher moisture content. The fuel bays are designed with a woodchipper on site to directly accept chipped wood from locally harvested logs and are sized to allow an estimated 1 year of drying time with a goal of achieving 20% to 30% chip moisture content before supplying the boilers. The Teslin District Biomass system is estimated to consume 600 t/ yr of locally produced wood chips.

This project has been the subject of international attention as a successfully implemented district biomass system that supports local employment, reduces GHG emissions and offers energy security to the community. The TTC offers regular visitor tours of the facility throughout the summer and is developing plans for a phase 2 expansion that will install more boilers and expand the heat distribution system to potentially include nearby buildings belonging to the Municipality of Teslin and the Yukon Government.

Whitehorse Correction Center

Figure 2-8 - Whitehorse Correction Centre Biomass Boiler

Feedstock: Pellets

The Whitehorse Correction Center biomass heating system project was completed in 2011 to install a new 950 kW Viessmann wood pellet boiler at the existing correction center. This system uses a vertical silo for wood pellet storage and a series of screw augers for filling and transferring stored pellets. The boiler consumes approximately 680 t/ yr of wood pellets and is estimated to offset approximately 460,000 L/ yr of propane fuel and 980 tCO_2/ yr.

Although still operating, several operational issues have been managed through the course of the system's lifecycle. The installed 950 kW boiler is considerably oversized for the facility which has an estimated peak heat loss of 1,117 kW and as a result the annual duration of operation is reduced and maintenance issues arise from operating the boiler at low load for long periods. To address this, in 2020 the Yukon Government launched a project to convert the biomass heating system into a small district system by connecting the nearby Young Offenders and Takhini Haven Facilities. This project is scheduled for construction in 2021, will include approximately 800m of buried distribution pipe and is expected to result in additional offsets of 250,000 L/ yr of propane and an additional 770 tCO_2/ yr.

Raven Recycling

Figure 2-9 - Raven Recycling Biomass System

Feedstock: Chips

Raven Recycling partnered with ACS Mechanical Systems with support from the Yukon Government Department of Energy, Mines and Resources and the Cold Climate innovation Centre to install a 100 kW Hargassner Wood Chip boiler. This project completed in January of 2016 served as a pilot project to demonstrate the viability of small-scale biomass heating in Yukon. The project tested various sources of biomass and various size and quality of wood chips to help determine the optimal operating conditions.

The findings of the fuel testing trials were published to help advance the local knowledge base in biomass systems. In their Final Study Report it was noted that the boiler operators are generally pleased with the system operation and the support provided by the boiler suppliers, but some maintenance issues were encountered during the trial period. Also, the report details several fuel sources and fuel production methods, but none were noted to be fully optimized for the system with the primary concerns being inconsistent chip size and moisture content. Going forward the system consumption rate is estimated to be 60 t/ yr.

Yukon Garden's Biomass Boiler

Figure 2-10 - Yukon Garden's Biomass Boiler

Feedstock: Chips

The Yukon Garden newly expanded hydroponic greenhouse in Whitehorse, YT installed a 540 kW Viessmann wood chip boiler in 2019 to provide hydronic heat to the 2,000m² greenhouse and the nearby car wash. The biomass heating system has allowed increased vegetable harvest yields and increased the growing seasons from 6-months to 10-months. The system is estimated to consume 300 t/ yr of locally produced wood chips.

2.4 CURRENT STATE OF BIOMASS IN YUKON

2.4.1 Yukon's Energy Profile

As identified earlier in this section, most of the heat generated in Yukon depends on imported fossil fuels. Canada's Energy Regulator describes Yukon's energy demand based on 2017 figures as follows,

- *End-use demand for energy in Yukon was 7.9 petajoules (PJ) in 2017. The largest sector for energy demand was transportation at 58% of total demand, followed by industrial at 20%, commercial at 13%, and residential at 9%.*
- *RPPs [refined petroleum products], including gasoline, diesel, and jet fuel were the largest fuel type consumed in Yukon, accounting for 6.1 PJ (77%), electricity and natural gas accounted for 1.6 PJ (20%) and 0.2 PJ (3%) respectively.*
- *In 2017, annual electricity consumption per capita in Yukon was 11.1 megawatt hours (MWh).*

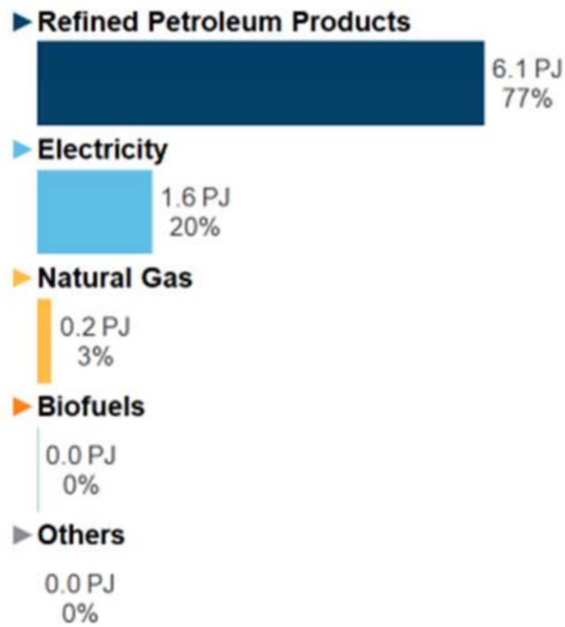


Figure 2-11 - Yukon End-Use Demand by Fuel, Source: CER Yukon Energy Profile

- *Yukon generates the majority of its electricity from hydro sources. In 2018, hydroelectricity accounted for 94% of total generation. Yukon has four hydro plants with a total capacity of nearly 95 MW (*Figure 3-1*). The largest is the Whitehorse Hydro Facility, which can supply 40 MW of power in the summer and 25 MW in the winter when water flow is reduced.*
- *Yukon's largest consuming sector for electricity in 2017 was commercial at 0.21 TWh. The residential and industrial sectors consumed 0.18 TWh and 0.05 TWh, respectively.*

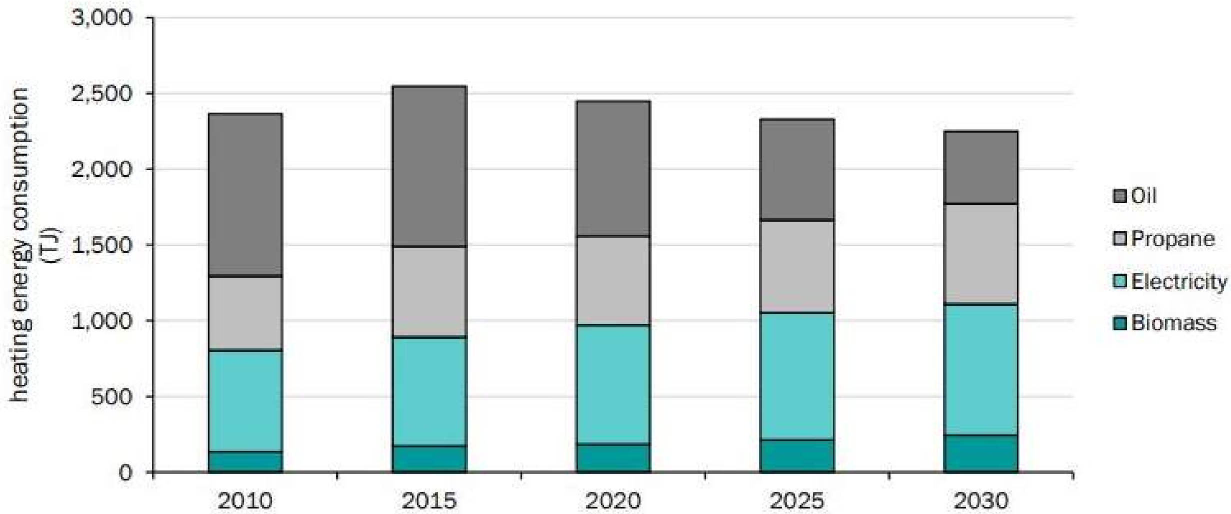


Figure 2-12 Heating energy consumption, existing policy forecast (TJ) (Navius Research Inc., 2020)

2.4.2 Feedstock sources

2.4.2.a Local

Cordwood and chips are available locally within the Yukon. Cordwood harvesting in Yukon is estimated at 13,000 cord/ yr (13,000 t/ yr). Local woodchip production is estimated at 1,600 t/ yr of woodchips produced within the Yukon for use locally in Biomass heating facilities. There is not currently a reliable large-scale pellet source available in Yukon although small scale pellet production has commenced at Bear Creek Logging near Haines Junction.

2.4.2.b Import

It is estimated that Yukon imports between 2,000 and 3,000 t/ yr of wood pellets for use primarily in residential systems and one larger-scale installation at the Whitehorse Correctional Center. Yukon imports pellets from outside jurisdictions such as British Columbia and Alberta which have more developed biomass supply industries. Importing feedstock from outside Yukon has several inherent advantages including assured supply and a known cost structure.

2.4.3 Supply-Side Review: Current Supply Market:

2.4.3.a Commercial Timber Harvesting

The total land area in the Yukon is 47.4 million ha (Yukon Bureau of Statistics, 2020) including 28 million hectares of forest land. Of the forested land, 8.1million ha (approximately 17%) can support timber harvesting activities (Roach & Berch, 2014). There are approximately 70 timber harvesting licensees in the Yukon; however, only four (4) licensees harvest more than 1,000 m^3/ yr and only one licensee harvests about 5,000 m^3/ yr. The combined Annual Allowable Cut (AAC) for the Yukon is greater than 250,000 m^3 but in 2010 only 27,000 m^3 were cut, of which 21,000 m^3 was for fuel wood (Government of Yukon, 2012).

Table 2-1 provides the total timber volume (78,068 m^3/ yr) for issued and applied licenses by region. Most of the wood for biomass is in Southern Yukon, with 57% of the total licensed timber volume within the Yukon Territory falling within the Haines Junction region.

Table 2-1 Total Timber Volume Under License (associated with applied and issued forestry licenses) by Region, as of February 2012

Region	Timber volume associated with issued licenses and applications for licenses (m^3/ yr)		
	Green Conifer	Dead Conifer	Green Deciduous
Carmacks	-	1,166	-
Dawson	4,700	5.918	900
Haines Junction	2,733	41,690	
Mayo	-	335	66
Ross River	-	-	-
Teslin	3,000	3,000	-
Watson Lake	3,190	1,395	-
Whitehorse	6,300	3,775	
Total	**19,923**	**57,179**	**966**

Source: (Dykshoorn, Tenures Forester, Forest Mangement Branch, Energy Mines and Resources, 2021)

Note: Numbers are current as of January 2021 but are subject to change.

Table 2-2 provides an estimate of annual cut for personal (11,595 m^3), commercial purposes (18,109 m^3) and total (29,793 m^3) by region cut in the Whitehorse Southern Lakes Region.

Table 2-2 Estimated Timber Volumes Harvested Annually (2011 to 2014) in Whitehorse Southern Lakes Regions

Region	Category	Number of Tenures	Timber volume associated with issued licenses and applications for licenses (m^3)
Whitehorse	Personal use	443	9,273
	Commercial use	3	934
Haines Junction	Personal use	146	2,325
	Commercial use	22	17,135
Carmacks/ Fox Lake	Personal use	0	0
	Commercial use	5	129
Total		**619**	**29,796**

Source: (Thorp & Zanasai, 2015), Timber Economy in the Whitehorse Southern Lakes Forest Resource Managing Planning Area

Forest biomass can be sourced from a variety of land and forest management activities. This includes salvaging wood from: commercial logging, forest fuel reduction, fire kill, insect infestation, roadside clearing, sawmill wood waste, aggregate resource extraction/ mining, or highway development. A review of each of these activities are provided in the subsections below.

2.4.3.b Forest Fuel Reduction (FireSmart)

Figure 2-13 – Wildfire management harvesting

The process of addressing concerns related to wildfire in Canada is generally led by FireSmart Canada. The FireSmart program helps protect residents, homes, communities, critical infrastructure, and vital natural resources from wildfire through seven disciplines: education, emergency planning, vegetation management, legislation, development, interagency cooperation, and cross-training.

The Yukon government has recently allocated approximately $850,000 to communities and organizations for FireSmart activities. Forest fuel reduction activities have been an on-going activity around communities since the late 1990's. Initially treatments focused on the removal of deadwood but in 2006 to 2008 FireSmart prescriptions switched to not only removing dead wood but included creating fire breaks, thinning, live tree removal and pruning to reduce the hazards of wildfire. Vegetation management associated with FireSmart activities now focuses on fuel removal, fuel reduction, and species conservation. Community-scale FireSmart treatment prescriptions generally result in manual spacing of coniferous trees to three to four meter spacing, pruning limbs and removal of spruce less than four meters tall. Currently, cordwood larger than 12.5cm in diameter is cut into 4-foot lengths and stacked. This wood is usually left to be used by local residents (the public) for personal use. The remaining slash is generally burnt, unless where air quality is a known issue, in this case the slash is chipped on site.

Between 2012 and 2016 it is estimated that 390 ha were thinned in 133 areas, averaging approximately 3 ha per FireSmart thinning area (Tetra Tech, 2017). It was further estimated that approximately 30% of the stand volume was removed. It is unknown how much wood from the FireSmart program has been utilized as biomass by the public to date as there is no formal reporting mechanism on wood that has been collected or utilized for personal use.

In addition to the FireSmart program around communities, landscape level fuel management projects have been initiated in the past year further from communities by the Wildland Fire Management Branch. Two examples of such projects are the Copper Haul Road project (a Federal-Territorial partnership) and the Mary Lake Shaded Fuel Break (Yukon Government funded project). The treatment prescription for projects will likely result in a larger amount of merchantable wood and biomass.

2.4.3.c Fire Kill and Insect Damage Timber Salvaging

Figure 2-14 – Fire kill and insect infestation harvesting

Approximately 14,000 m^3 of the 18,157 m^3 commercially harvested per year is used for fuelwood (biomass) (Dykshoorn, 2021) Approximately 1,100 Personal Use Firewood (PUFW) permits are issued each year. These permits allow for the harvest of 25 m^3 of timber for heating. There are no reporting requirements after permits are issued; as such, it is not known how much wood is actually harvested.

Most fuel wood comes from beetle kill in the Haines junction area (Roach and Berch,2014). The second most common source of fuel is from areas burnt as a result of wildfires that have occurred throughout the Yukon (Roach and Berch, 2014).

The harvestable biomass volume available from the 45,000 ha Fox Lake Fire (burnt in 1998) and 60,000 ha Minto Fire (located north of Carmacks burnt in 1995) had estimated biomass volumes of 53,767 m^3 / yr and 116,118 m^3 / yr over a 20 year period (Morrison Herschfield, 2012). Furthermore, the approximately 40,000 ha French burn (burnt in 1998) had an estimated cut of 2,738 m^3 / yr over a 20-year period. More recently, the 40,000 ha Salmon burn (burnt in 2009) has an estimated cut of 4,005 m^3/ yr over a 20-year period (Morrison Hershfield, 2012).

Forest surrounding Haines Junction has been heavily impacted by spruce beetle infestation that began in 1990 (Morrison Hershfield, 2011). The total area impacted by spruce beetles is estimated to be 380,000 ha, and the contributing AAC from the infested areas is one million cubic meters over a 10-year period, starting in 2006.

Fire and insect damaged dead trees do not remain standing indefinitely and much of this volume is no longer available or useful. Firewood harvesting is still ongoing in areas such as Fox lake burn even though this area was burnt over 20 years The number of years beetle or fire killed trees will remain economically viable for timber harvesting or useful as a viable biomass source for fuelwood depends on a variety of factors.

2.4.3.d Roadside Residual Biomass

Figure 2-15 – Roadside residual biomass harvesting

Roadside residual biomass is comprised of tops and branches left on site of commercial forest operations. Generally standing trees are harvested and yarded to the roadside or landing and tree branches and tops are left at the roadside. It is estimated that 15 to 25% (Tetra Tech, 2017) of biomass harvesting is left on site because it is not economical or feasible to retrieve and transport. Approximately 10% of this biomass consists of needles, small branches, and deciduous trees and is not feasible and therefore it is estimated that an additional 15% of merchantable stand volume may be available as additional biomass (Tetra Tech, 2017).

Timber harvesting occurs on a small scale in the Yukon with only approximately 27,000 m^3 harvested per year and therefore approximately only between 4,000-6,750 m^3 would presently be available for biomass use based on the above estimates.

2.4.3.e Sawmill Wood Waste

Figure 2-16 – Sawmill wood waste harvesting

Sawmill wood waste comes in several forms including additional yard bucking, bark trimming, canter edges, and various cuts and shavings that occur during the milling process, which are usually converted into wood chips. Sawdust is another byproduct of the milling process. There are three sawmills in Yukon that cut approximately 2,500 to 3,000 m^3 a year. These sawmills generally feed wood waste into a biomass boiler. It is important to note that that sawmill production is not necessarily sufficient to produce a viable source of wood waste and there are doubts that pellets could be economically produced from the sawmill waste alone.

2.4.3.f Aggregate Resource Extraction/Mining

Figure 2-18 – Aggregate resource extraction/ mining

In 2015, an estimated 650 gravel pits were developed throughout the Yukon (Tetra Tech, 2017). New and expansion of existing pits is continual as this resource is developed to support development and road improvements and various resource development projects in the region. Aggregate resource extraction activities are administered through leases, designated public pits, highway pits, and private pits under Quarry Permits. The Yukon Government does not track aggregate resource extractive development on an annual basis.

Forest Resource Permits are usually issued to harvest timber or fuel wood for resource extraction purposes.

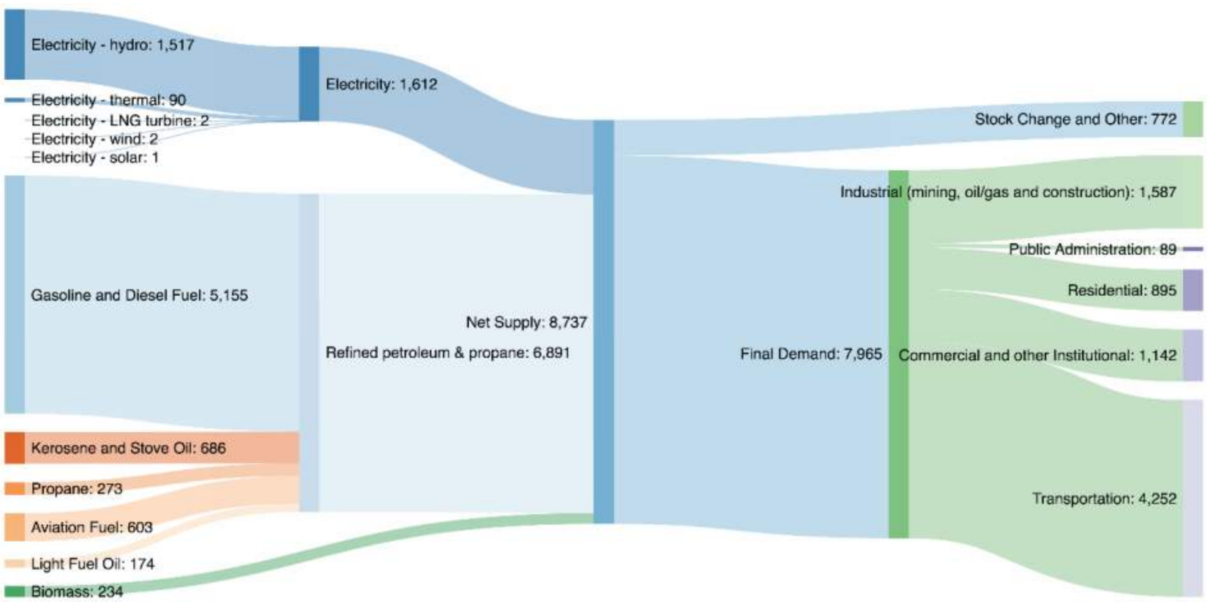
2.4.3.g Highway Development

Figure 2-19 – Highway development harvesting

Highway development (Tetra Tech, 2017) and improvement results in the clearing of forest land and available wood but the volumes produced through this activity are not published/available.

2.4.4 Demand-Side Review: Current Market Demand

In the context of utilizing biomass (wood fibre) as an energy source, it is important to understand the overall energy dynamic of the territory. An appropriate approach to depicting the energy use of the territory is using a Sankey diagram, where raw energy sources can be differentiated on the left, while their end-uses are categorized on the right. One such depiction prepared by Vector Research for the energy flows in 2015 is shown in Figure 2-20 (Vector, 2018). This highlights energy supplies on the left, noting that only hydroelectricity and biomass are locally supplied, and their end uses broken down on the right. One can see from the figure that transportation is the most significant energy consumer in the territory, followed by industrial, commercial/institutional, and residential uses (primarily electricity and heating consumption), respectively.



Source: adapted from Statistics Canada Cat. No. 57-003-X *Report on Energy Supply and Demand in Canada – 2015 Revised* and Yukon Energy, Mines and Resources, *Yukon's Energy Context* (2017).

Figure 2-20 – Yukon Energy Flow Sankey Diagram, Terajoules (TJ) (Vector, 2018)

From Figure 2-20, biomass used for space heating in 2015 only accounted for 3% of the territory's energy supply. Overall, the renewable sources only account for 20% of the total energy mix in 2015, with 87% of the renewables attributed to hydroelectricity, and 13% from biomass. Increasing biomass utilization in the Yukon will primarily focus on increasing its use for space heating, and potential options to support the renewable electricity grid.

From the Yukon GHG aspect, the same overall trend can be seen with transportation accounting for more than half of the territory's emissions, followed by building heating at 21% as shown in Figure 2-21 – Yukon's GHG Emission Sources, 2017 (Government of Yukon, 2020). Combining the relatively small part biomass currently plays in the overall energy supply for the territory, and that building heating accounts for over 20% of the GHG emission of the territory, biomass has a role to play in supporting fuel switching from fossil fuels to more renewable solutions.

Another on-going demonstration program through the Yukon Conversation Society is investigating the application of electric thermal storage for spacing heating. This allows for peak load shifting by using electricity to store energy in ceramic bricks. Although it does not reduce the amount of heating energy required, it will allow for improved use of hydro resources, and less fossil fuels to meet peak needs. Thermal storage of energy in this manner can be applied to biomass systems to further improve peak shaving as well.

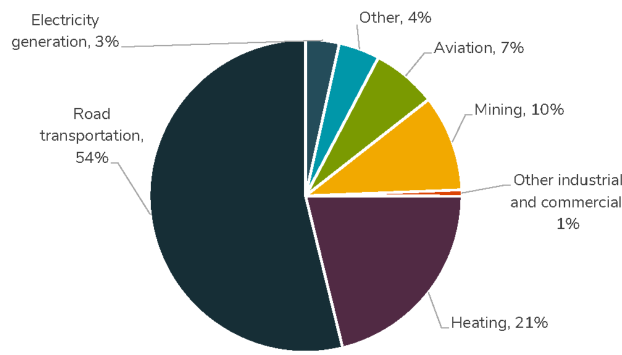


Figure 2-21 – Yukon's GHG Emission Sources, 2017 (Government of Yukon, 2020)

2.4.4.a Heating

Detailed, up-to-date heating statistics are not readily available for Yukon's energy mix. Data collected over the last ten years is routinely used as a basis to gauge territorial impacts of fossil fuel heating systems and reduction targets. Some individual communities, First Nations, institutions, and territorial government branches have commissioned studies to examine specific opportunities over this same period. Varying studies have placed the overall biomass energy consumption in the territory between 220 TJ to upwards of 450 TJ. The most common use of biomass in Yukon is the cordwood harvested and supplied locally by small operators servicing their local communities. This approach typically lends itself to small, forced air furnaces or wood stove appliances to convert the biomass to usable thermal heat in residences and small commercial buildings. It would be possible to use cordwood to heat a few dwellings/buildings using small outdoor cordwood boilers similar to those discussed in Section 2.3.2

According to the 2016 Census, there are roughly 15,215 residential dwellings in the territory and approximately 3,039 business operating in Yukon; this information is outlined in Table 2-3. Assuming 15% of the residential dwellings are using biomass as their primary heat source, according to Yukon statistical data in Table 2-4, the opportunity for increased market share becomes dependent on consumer preference, installed cost, fuel/operating costs, and environmental considerations.

Table 2-3 2016 Census Data for Number of Dwellings and Businesses (Government of Yukon Socio-Economic Web Portal, 2020)

Location	Dwellings	Businesses
Whitehorse	10,185	2,391
Dawson City	680	261
Watson Lake	485	84
Haines Junction	275	79
Carcross	155	29
Mayo	100	34
Teslin	125	26
Marsh Lake	345	41
Carmacks	200	15
Faro	175	16
Beaver Creek	40	6
Pelly Crossing	150	7
Ross River	130	10
Tagish	145	16
Burwash Landing	45	9
Old Crow	110	3
Destruction Bay	20	4
Other Yukon	1,850	5
Yukon Total	**15,215**	**3,039**

Table 2-4 Principal Heating Fuel, 2012, (Yukon Bureau of Statistics, 2013)

Fuel Type	Percentage of Residences Using Fuel Type as Primary Heat Source
Oil or fossil fuels	59%
Electricity	18%
Wood	15%

Apart from private dwellings and commercial properties, publicly owned buildings represent opportunities for larger installations and potential district heating. The Government of Yukon's assets include more than 500 government-owned buildings used by all departments. Of these, the Department of Highways and Public Works has 246 buildings (about 47 percent of all buildings). The Department of Education has 55 buildings (about 11 percent of all buildings), including 28 public schools that house over 5,000 students. The Department of Health and Social Services has 38 buildings (about 7 percent of all buildings), including health care facilities, seniors' residences, and residential care facilities" (Auditor General of

Canada, 2017). Yukon has made several attempts in recent years to begin the process of fuel switching on its buildings, as outlined in Section 2.3.3.b.

The Green Infrastructure Program is a multi-year capital investment program focused on reducing carbon emissions from Yukon government buildings/assets in support of the *Our Clean Future* targets. The primary objective of the program is the same 30% reduction in greenhouse gas emissions by the year 2030. To meet this target, the program tackles several areas of interest to the biomass industry including the promotion of renewable energy, biomass heating as well as district energy, and energy retrofit programs. Projects considered under the program are guided by the five pillars of their framework (Government of Yukon, 2021):

1. Reduce emissions:
   Complete projects to reduce carbon emissions by cutting down the use of fossil fuels or limiting how much methane or soot we emit.

2. Encourage long-term certainty:
   Projects must adapt buildings to changing climate conditions, help local supply chains develop, and improve the operation of Yukon government buildings in uncertain circumstances.

3. Show value for taxpayer dollars:
   Projects must have a proven business case, manage the cost of construction or building retrofits to keep spending low, and reduce operation and maintenance costs over the long-term.

4. Localize economic benefits:
   Projects make a contribution to community development by providing opportunities for local businesses.

5. Provide leadership and excellence:
   Projects demonstrate leadership by reducing emissions from our daily activities wherever possible, building partnerships among Yukon government departments, and building partnerships between the Government of Yukon and municipal or First Nation governments.

The program is managed by Strategic Initiatives Branch of the Department of Highways and Public Works. The branch aims to install renewable heat sources such as biomass energy in Government of Yukon buildings by 2030 to create long-term demand for renewable heating and contribute to a 30% reduction in greenhouse gas reductions.

2.4.4.b Electricity

Power generation and distribution in the territory is handled by two utilities, Yukon Energy Corporation, which is publicly owned, and ATCO Electric Yukon, a private entity, under the regulation of the Yukon Utilities Board. The Yukon power grid is an islanded system, meaning there are no major inter-territory transmission lines to facilitate the export and import of electricity. That is, Yukon is self-reliant on its own power generation to service the needs of the territory. The majority of grid-based power generation and transmission is the responsibility of Yukon Energy, with ATCO Electric Yukon looking after distribution along with five community based diesel systems (with no connection to the grid), one hydro facility, and several stand-by diesel units for grid reliability.

Like a few other Canadian provinces, Yukon is fortunate to have hydroelectricity as its primary source of electricity generation. By utilizing this resource across four hydroelectric plants, the Yukon grid was able to successfully achieve 94% renewable electricity generation in 2018. In 2019, this figure decreased to approximately 84% due to variations in water levels from the previous year but is generally considered to average out to 90% renewable generation over several years. The balance of electrical generation is accounted for with the use of fossil fuel plants - traditionally distributed diesel generators in the territory but also natural gas engines in Whitehorse since 2015. (Yukon Energy, 2019)

With a focus on the Yukon *Our Clean Future*, Yukon Energy released their 10-Year Renewable Electricity Plan in September 2020 to further increase the sustainable energy in the territory by 2030. The plan focuses on retiring all current diesel assets except for three diesel engines before 2030 by: increasing hydro generation capabilities, implementing pumped and battery storage, improved demand side management programs, as well as electricity purchases from Independent Power Producers (IPP) and the Micro-Generation Program. Contributions from biomass-based electricity generation would fall under the latter, in the form of an IPP generating standalone electricity, or a district energy/ commercial/industrial operation able to supply electricity.

In the current market, there is no biomass power generating facility in the Yukon. Biomass can support a reduction in the territory's electricity demand by providing an opportunity to switch building heating from electricity to a renewable source. By potentially filling the gap between installing more electric heating appliances, which in turn drive up electricity demand and therefore the need for additional generating assets, biomass can support an overall reduction in electricity demand/conservation.

2.5 FUTURE SUPPLY AND DEMAND PROJECTIONS

2.5.1 Supply-Side Review: Estimated Future Supply and Sustainability

A successful bioenergy industry needs secure and sustainable access to wood. The Yukon Government is committed to ensuring that forest development including bioenergy for both heat and power will be done based on sustainable timber harvesting. The following process has been put in place to accomplish this.

- Completing Regional Forest Resources Management Plans which involves working with the forest industry, First Nations, communities, interest groups and the public to ensure the sustainability of the forest resource throughout the territory.
- Completing Timber Supply Analysis (TSA) for forest regions throughout the territory. Ensuring that the Forest Resource Management Plans (FRMP) and the accompanying TSA are made public

including: Dawson FRMP (2013); Champagne and Aishihik FRMP (2005), and the FRMP for Teslin – Tlingit traditional territory (2006). A FRMP is currently being revised for the Whitehorse and Southern Lakes region. Preliminary information, and the status of the plan, is available from the Yukon Government, and is intended to be released to the public soon.

- Ensuring that social, environmental, and economic goals are considered in making annual allowable cut determinations, as per the requirements of the Forest Resources Act.
- Ensuring TSAs, including harvest levels related to bioenergy, are sustainable and account for social, environmental, and economic goals outlined in regional forest management plans.
- Ensuring biomass that could potentially be used for energy purposes is considered in timber supply assessments and annual allowable cut determinations.
- Ensuring timber tenures provide secure long-term access to wood for bioenergy development.
- Working with industry to allow for secure timber tenures that can access wood for energy projects.
- Encouraging and facilitating timber utilization that would not normally be used including the harvest of fire-killed wood and insect-killed wood for use as biomass.
- Working with proponents to ensure that projects that rely on local timber harvests are scaled so that they can operate successfully within locally acceptable harvest levels.
- Supporting pilot studies and demonstration projects to encourage the use of locally processed wood fuel products.

2.5.1.a Commercial

The AAC is calculated based on timber supply analysis and social, economic, and environmental considerations. The Annual Allowable Cut (AAC) is calculated based on timber supply analysis and social, economic, and environmental considerations. A redetermination of the AAC is made every five to ten years. Additional volumes to the AAC are allowed as the result of insect and or fire kill however these are non-replaceable and generally will not last for more than 20 years.

The TSA and AAC are calculated as part of the FRMP. The FRMP purpose is outlined in the Forest Resources Act and includes establishing the requirements for forest resource management, identifying areas in which forest resource harvesting may occur and establishing guidelines for harvesting in the area to which the plan applies. These plans consider multiple timber and non-timber forest values and identify acceptable timber harvest levels, including harvesting levels for biomass energy, that ensure maintenance of important forest values and long-term sustainability.

Less than ¼ of the forested area of the Yukon has been subject to regional management planning process and the accompanying TSA calculations.

Table 2-5 outlines the AAC for the various planning regions, as prescribed by the Yukon Forest Resources Regulation, and the amount of green coniferous timber volume already issued for licenses. The estimated combined coniferous and deciduous AAC cut for all regions in the Yukon is approximately

412,000 m^3/ yr which includes 200,000 m^3/ yr for a 10 year period (2006 to 2016) in the Haines Junction area and the Champagne and Aishihik Traditional Territory. Higher AAC's were established in these regions in part to salvage pest infected stands salvage opportunities. The uptick in AAC in these areas could well be revised in the near future. Approximately 19,923 m^3/ yr of the 412,000 m^3/ yr AAC has already been allocated to existing licenses. Tetra Tech estimated that a cubic meter of wood was the equivalent 373 to 376 kilogram of dry biomass (Tetra Tech, 2017). Using these assumptions approximately 146,245, tonnes/ yr would be available for the present non allocated AAC volumes. Approximately 72,664 tonnes/ yr would be available if the AAC values for Haines Junction region and the Champagne and Aishihik Traditional Territory are not included. It should be noted that all of the AAC is likely not economically viable and land use or social constraints will likely significantly reduce AAC availability for biomass.

Table 2-5 AAC for Forest Resource Management Planning Areas and Annual Limits for Timber Harvesting Areas (Yukon Forest Resources Regulations)

Region	Annual Allowable Cut[1]	Allocated Annual Allowable Cut of Green Coniferous Timber	Estimated Available Dry Mass Biomass Volume[2]
Beaver Creek, Burwash Landing and Destruction Bay Annual Limit Region	5,000 m^3/ yr of coniferous trees 2,000 m^3/ yr of deciduous trees		2,611tonnes/ yr
Carmacks Annual Limit Region	5,000 m^3/ yr of coniferous trees 2,000 m^3/ yr of deciduous trees		2,611tonnes/ yr
Dawson Annual Limit Region	5,000 m^3/ yr of coniferous trees 2,000 m^3/ yr of deciduous trees	4,700 m^3/ yr,	857.9 tonnes/ yr
Mayo Annual Limit Region	5,000 m^3/ yr of coniferous trees 2,000 m^3/ yr of deciduous trees		2586.4 tonnes/ yr
Old Crow and Peel Annual Limit Region	2,000 m^3/ yr of coniferous trees 1,000 m^3/ yr of deciduous trees		1119 tonnes/ yr
Pelly Crossing Annual Limit Region	5,000 m^3/ yr of coniferous trees 2,000 m^3/ yr of deciduous trees		2,611 tonnes/ yr
Ross River and Faro Annual Limit Region	5,000 m^3/ yr of coniferous trees 2,000 m^3/ yr of deciduous trees		2,611 tonnes/ yr
Watson Lake Annual Limit Region	128,000 m^3/ yr of coniferous trees 2,000 m^3/ yr of deciduous trees	3,190 m^3/ yr	47,300 tonnes/ yr

Region	Annual Allowable Cut[1]	Allocated Annual Allowable Cut of Green Coniferous Timber	Estimated Available Dry Mass Biomass Volume[2]
Whitehorse Annual Limit Region	10,000 m^3/ yr of coniferous trees. 2,000 m^3/ yr of deciduous trees.	6,300 m^3/ yr	2,126.1 tonnes/ yr
Haines Junction	1 Million m^3 over a 10 year period commencing in 2006 and ending in 2016 (100,000 m^3/ yr)	2,733 m^3/ yr	37,300 tonnes/ yr
Champagne and Aishihik Traditional Territory	1 Million m3 over a 10 year period commencing in 2006 and ending in 2016 (100,000 m^3/ yr)		37,300 tonnes/ yr
Teslin Tlingit Traditional Territory	25,000 m^3/ yr	3,000 m^3/ yr	8206 tonnes/ yr
Total (Excluding Haines Junction and Champagne and Aishihik Traditional Territory)	212,000 m^3/ yr combined coniferous and deciduous trees	17,190 m^3/ yr,	72,664.1tonnes/ yr
Total	412,000 m^3/ yr combined coniferous and deciduous trees	19,923 m^3/ yr,	146,244.76, tonnes/ yr

Table notes:

1. Annual Allowable Cut (AAC) limits set by Department of Energy, Mines and Resources, Forest Management Branch, Government of Yukon, for various regions in Yukon
2. Assumed 373 Kg of Dry Mass of Wood per m^3 of wood

2.5.1.b Forest Fuel Reduction (FireSmart)

The Yukon Government is looking to accomplish significant fuel abatement to reduce fire risk for Whitehorse. Some 4,000 ha are provisionally identified as meriting treatment.

Table 2-6 provides an estimate of the number of ha that is presently harvested around communities in the Yukon (Bibeau, 2020) and the volumes and dry mass of wood available from assumed ongoing FireSmart activities. FireSmart activities will treat approximately 94 ha per year and 35m^3/ha is filed for the Forest Resource Permits (Bibeau, 2020) and only one third to one half of merchantable wood is removed. If FireSmart activities yield 10 m^3/ ha then approximately 940 m^3/ yr of merchantable wood and an additional 142 m^3/ yr of waste wood will be available from FireSmart activities. It should be noted that forest stand chosen for FireSmart activities are based on reducing wildfire hazard to a community rather than generating timber volumes. The eventual goal of the FireSmart program is forest stand conversion. Once this is achieved the amount of merchantable wood from these stands will decrease over time. Even in the past year FireSmart activities around Pelly Crossing and Faro have focused on fuel clean up in deciduous stands rather than thinning of coniferous stands. Therefore, the volume of wood available from FireSmart activities will likely decrease over time.

Table 2-6 Estimated Volumes of FireSmart Biomass Volumes from Merchantable Timber and Waste Wood

Region	Treatment Area [1]	Estimated FireSmart Merchantable Volume [2]	Estimated FireSmart Biomass Waste Volume [3]	Estimated FireSmart Merchantable Volume	Estimated FireSmart Biomass Waste Volume	Estimated FireSmart Dry Mass of Merchantable Wood[4]	Estimated FireSmart Dry Mass of Waste Wood
	(ha/ yr)	(m^3/ ha)	(m^3/ ha)	(m^3/ yr)	(m^3/ yr)	(tonnes/ yr)	(tonnes/ yr)
Whitehorse	45	10	1.5	450	68	167.9	25.3
Watson Lake	7	10	1.5	70	11	26.1	4.1
Teslin	6	10	1.5	60	9	22.4	3.4
Haines Junction	6	10	1.5	60	9	22.4	3.4
Burwash Landing	2	10	1.5	20	3	7.5	1.1
Beaver Creek	2	10	1.5	20	3	7.5	1.1
Champagne & Aishihik	2	10	1.5	20	3	7.5	1.1
Dawson City	6	10	1.5	60	9	22.4	3.4
Old Crow	4	10	1.5	40	6	14.9	2.2
Mayo	2	10	1.5	20	3	7.5	1.1
Keno City	2	10	1.5	20	3	7.5	1.1
Carmacks	4	10	1.5	40	6	14.9	2.2
Pelly Crossing [5]	2	10	1.5	20	3	7.5	1.1
Ross River	2	10	1.5	20	3	7.5	1.1
Faro [6]	2	10	1.5	20	3	7.5	1.1
Total	**94**			**940**	**142**	**350.6**	**53.0**

Table notes:

1. Assumed that treatment hectares around communities will reflect the hectares treated recently.
2. Assumed 10 m^3/ha of merchantable wood from stands around communities. This will vary passed on stand characteristics and geographic location. For example: the merchantable wood available from thin stands at Watson Lake is likely different than Old Crow
3. Assumed 15% of additional waste wood volume from tops and branches
4. Assumed 373 kg of Dry Wood Mass per cubic meter of wood
5. Recent Pelly Crossing FireSmart activities consist of fuel management of deciduous stand. Thinning of coniferous stands are assumed to take place in the future
6. Recent Faro FireSmart activities consist of fuel management of deciduous stand. Thinning of coniferous stands are assumed to take place in the future

Table 2-7 provides an alternate assessment of FireSmart biomass volume estimates specifically within the Haines Junction and Teslin Areas. Tetra Tech assumed merchantable timber volume of approximately 113 m^3/ ha and 30% of this volume will be used in fuel abatement projects near Teslin (Tetra Tech, 2017). They assumed merchantable timber volume of approximately 100 m^3/ha and 60% of this stand volume would be removed in the Haines Junction area due to significant bark beetle damage. It was also assumed that all merchantable harvested volume would be devoted to biomass fuel and an additional 15% of biomass would be available from tops and branches. Based on these assumptions, it is estimated that approximately 15,840 m^3/ yr and 2,531 m^3/ yr of merchantable wood would be available from forest fuel reduction programs within the Haines Junction and Teslin Regions (Table 11.7). An additional 792 m^3/ yr and 51 m^3/ yr of waste wood (tops and branches) would be available from these two areas.

Table 2-7 Estimated Volumes of FireSmart Biomass Volumes from Merchantable Timber and Waste Wood within the 150 km of Haines Junction and Teslin Region (Tetra Tech, 2017)

Region	Treatment Area	Total FireSmart Merchantable Biomass Volume	Total FireSmart Waste Biomass (Tops and Branches)	Estimated FireSmart Merchantable Biomass	Estimated FireSmart Waste Biomass	Estimated FireSmart Dry Mass Merchantable Biomass	Estimated FireSmart Dry Mass of Waste Wood Volume
	(ha)	(m^3)	(m^3)	(m^3/ yr)	(m^3/ yr)	(tonnes/ yr)	(kg/ yr)
Haines Junction1	1,760	105,600	15,840	5,280	792	1,969.4	295.3
Teslin2	500	16,875	2,531	338	51	126.1	19.0
Total	**2,260**	**122,475**	**18,371**	**5,618**	**843**	**2,095.5**	**295.4**

Table notes:

1. Assumed average stand volume of 100 m^3/ha. Assumed 60% merchantable stand volume removal from FireSmart activities due to beetle activity and 15% waste wood for a 20-year time horizon (Tetra Tech, 2017)
2. Assumed average stand volume of 113 m^3/ha. Assumed 30% merchantable stand volume removal from FireSmart activities and 15% waste wood for a 50-year time horizon for treatments (Tetra Tech, 2017)

Table 2-6 was developed based on information for government staff and FireSmart operators and assumed that FireSmart activities yield 10 m^3/ ha areas and approximately 94 ha will be treated around Yukon communities. Table 11.7 assumed that FireSmart activities yield 60 m^3/ ha and 34 m^3/ha from the Haines Junction and Teslin regions, respectively. Approximately 1,760 ha of land will be treated in the Haines Junction area over a 20-year period (88 ha/ yr) and 500 ha of land in the Teslin area over a 50-year period (10 ha/ yr). Table 11.7 assumes an almost 2-fold increase in the hectares treated in Teslin area and a 14 fold increase in the hectares treated in the Haines Junction area in comparison to the 6 ha/ yr treated for these two areas in Table 11.6. In addition, it is assumed that a higher portion of volume will be removed from FireSmart treated stands. The approach employed by Tetra Tech provides what may be available to the future biomass industry if an aggressive fuel reduction program were implemented. This, however, would require substantial investment, organizational capacity, qualified people, and equipment. As mentioned previously FireSmart activities are presently based on stand conversion and reducing wildfire hazard to a community rather than generating timber volumes. Increasing timber volumes for biomass from a FireSmart treated area would require a change in the future strategic plan for this program and this require support, involvement and buy in from government, communities, and the forest industry.

2.5.1.c Fire Kill and Insect Infestation

Roach & Berch (2014) state that stand-replacing forest fires typically cover over 1,000 $km^{2.}$ (100,000 ha) of forests per year and significant beetle infestation kills over 2,200 km^2 (220,000) of forests per year. Annual forest fires result in enough dead trees to supply 600,000 tonnes of wood pellets which is tenfold more than required to supply the entire heating needs of the Yukon (Roach & Berch, 2014).

Yukon Government Reports (2016, 2016, 2017, 2018 and 2019) state that wildfire events burn an average of 197,559 ha (1,976 km^2) every year in the territory (Table 2-8). Table 2-10 provides an approximate volume of 6,915,000 m^3 (2,579,000 tonnes) wood available from the area burnt over a 5-year period from 2015 to 2019.

Table 2-8 Summary of Number of Fires and Area Burnt Over a Five Year Period (2015 to 2019)

Year	Number of Fires	Area Burnt (ha)
2015	18	156,048
2016	25	20,325
2017	40	433,412
2018	4	167,951
2019	38	210,059
Average per Year	**25**	**197,559**

Yukon government (2018 and 2019) reports that approximately 2,982 ha of forests were effected between 2009 and 2019 by Spruce Beetle (*Dendroctonus rufipennis*), Western Balsam Bark Beetle (*Dryocoetes confuses)* and Pine Needle Cast (*Lophodermelia concolor*) in Forest Health Zone 1 (Table 2-9), which encompasses the area around Teslin, Carcross, Whitehorse, and the area east of Haines Junction. Approximately 1,998 ha of forests were effected, between 2011 and 2019 by the same forest pests in Forest Health Zone 2 which encompasses the area around Carmacks, Pelly Crossing, Steward Crossing and Mayo. Table 2-10 provides an approximate volume of 174,000 m^3 of wood in only two southern Forest Health Zones effected by these dominant forest pests.

Other forest pests such as Aspen Serpentine Leafminer (Phyllocnistis populiella), Large Aspen Tortix (Choristoneura conflitana), Northern Spruce Engraver Beetle (Ips perturbotus), Spruce Needle Rust (Chrysomyxa spp) and Spruce Budworm (Choristoneura spp) are not included in the above estimates as their distribution and impact is not widespread and their damage is not known to kill large areas of entire coniferous forest stands in the Yukon at this time.

The volume estimates summarized in Table 2-10 assume that an average biomass volume of 35 m^3/ha available after a stand-replacing wildfire and/or pest infestation event. Forest stands in the Yukon range from non-merchantable stunted trees to productive stands in the southern Yukon that can have between 200 and 300 m^3/ha of merchantable wood. It is not yet clearly understood the minimum volume per ha required to economically harvest biomass and which are burnt, or pest effected stands would be feasible to harvest. However, as a general conservative estimate, even harvesting only 1/4 of the 197,559 ha of forest stands burnt annually (using the same value of 35m^3/ha used in Table 2-6) would yield 65,000 tonnes kg of wood which is more than adequate to supply wood consumed for biomass in the foreseeable future.

Table 2-9 Estimated Average Areas Impacted Insect/Pathogens in Forest Health Zones 1 and 2

Source	Forest Health Zone #1 (ha)				Forest Health Zone #2 (ha)			
	2009	2014	2018	2019	2011	2016	2018	2019
Spruce Beetle (*Dendroctonus rufipennis*)	3,130	2	1,196	709	48			54
Western Balsam Bark Beetle (*Dryocoetes confuses*)	1,465	2,790	1,816	34	6	27		10
Pine Needle Cast (*Lophodermelia concolor*)			780		7,116	85	17	629
Total	**4,595**	**2,799**	**3,792**	**743**	**7,170**	**148**	**17**	**693**
Estimated Average ha Impacted per year in Forest Health Zone #1 and #2	2,981				1,998			
Average ha for both Forest Health Zone #1 and #2	4,979							

Table notes:

1. Assumed biomass volume of 35 m^3/ha for all stands burnt or infected by major coniferous forest pests.

Table 2-10 Summary of Total Annual Biomass Potentially Available from Disturbed Forest Stands

Source	Area Burnt or Infested per Year	Assumed Average Biomass Volume[1]	Anticipated Volume of Wood	Anticipated Dry Mass of Wood
	(ha/ yr)	(m^3/ ha)[1]	(m^3/ yr)	(tonnes/ yr)[2]
Forest Fires	197,559	35	6,914,565	2,579,132.7
Forest Pests[3]	4,979	35	174,265	64,994.3
Total	**202,538**		**7,088,830**	**2,644,127.1**

Table notes:

1. Assumed volume of 35 m^3/ ha for potentially available disturbed forest stands.

2.5.1.d Sawmill Wood Waste Recovery

As mentioned previously, there are three 3 sawmills in Yukon that cut about 2,500 to 3,000 m^3 a year but the sawmill waste is already utilized.

2.5.1.e Aggregate Resource Extraction/Mining

A claim holder may only use timber cut on a mining claim for the purpose of working the claim, and not for any other commercial or personal use. If timber is cut on a mining claim, in most cases Yukon Government will issue a Forest Resources Permit for commercial use of this timber, with stumpage fees, or will allow the timber to be taken by the public for personal use.

The Yukon Government does not track aggregate reserve development on an annual basis, and it is unknown how much new aggregate resource reserve development is anticipated in Yukon in the next few years (Tetra Tech, 2017).

Tetra Tech conservatively estimated that 405 m^3/ yr (151.1 tonnes/ yr of dry mass wood waste) would be available from 47 active aggregate resource pits within a 150 kms radius of Haines Junction that were assumed to clear approximately 4 ha of forest land per year and 621 m^3/ yr (233,582 kg/ yr of dry mass wood waste) from 64 active pits within a 150 kms radius of Teslin that were assumed to clear approximately 5 ha of forest land per year (Table 2-11) (Tetra Tech, 2017). Alternately they employed another methodology and estimated 24,787 m^3/ yr (9,243.8 tonnes/ yr of dry mass wood waste) would be available from 88 aggregate resource pit dispositions within a 150 kms radius of Haines Junction that were assumed to clear 216 ha of forest land per year and 32,712 m^3/ yr (12,306.7 tonnes/ yr of dry mass wood waste) would be available from 130 gravel pit dispositions within a 150 kms radius of Teslin that were assumed to clear 253 ha of forest land per year. The clearing of active pits is a subset of aggregate pit dispositions.

Table 2-11 Biomass available from aggregate and mining development within the 150 km of Haines Junction and Teslin Region

Region	Source	Anticipated Area to be Cleared	Anticipated Volume of Biomass Wood	Anticipated Dry Mass of Biomass Wood
		(ha/ yr)	(m^3/ yr)	(tonnes/ yr)
150 km of Haines Junction	Aggregate Development (Method 1) [1]	4	405	151.2
	Aggregate Development (Method 2) [2]	216	24,787	9,243.8
	Mining Development [3]	30,301	23,231	8,663.4
150 km of Teslin	Aggregate Development (Method 1)	5	621	233.6
	Aggregate Development (Method 2)	253	32,719	12,306.8
	Mining Development	54,412	46,931	17,652.4

Table notes:

1. Aggregate Development Biomass Volumes from (Tetra Tech, 2017) for 150 km radius of Haines Junction and Teslin based on a conservative calculation for active pit land clearing.
2. Biomass volumes from (Tetra Tech, 2017) for aggregate resource pit dispositions with assumed clearing rates within a 150 kms radius of Haines Junction and Teslin
3. Mining Development Biomass Volumes from (Tetra Tech, 2017) for 150 km radius of Haines Junction and Teslin.

2.5.1.f Highway Development

The Yukon Government plans to upgrade a 200-kilometre stretch of Nahanni Range Road in the southeast part of the territory, construct a mining traffic bypass road in the Carmacks area, in the central part of the territory, upgrades to about 650 km of existing resource roads in the Dawson and Nahanni ranges and possible improvements to the North Canol Road.

The hectares cleared for this planned highway development and associated wood biomass from these clearing activities was not estimated.

2.5.1.g Summary of Available Biomass

Table 2-12 summarizes the total potential wood biomass available from different resource activities and disturbance events throughout the Yukon Territory. Approximately 7,373,000 m^3/ yr (2,750,307 tonnes/ yr) to 7,635,000 m^3/ yr (2,848.060 tonnes/ yr) is potentially available from AAC, FireSmart treatment activities, forest fires, insect and pest damaged stands, aggregate resource development and mining development. These estimates are based on existing and available information on AAC calculations, fire disturbances across the Yukon, existing FireSmart programs near communities, stands effected by major forest pest in specific Forest Health Zones, and forest clearing for aggregate resource and mining development in the Haines Junction and Teslin areas. These estimates are approximate and based on underlying assumptions with varying degrees of uncertainty. Specifically, available volume estimates that can be feasibly harvested from wildfire and pest damaged stands, and volume estimates from areas cleared for aggregate resource, mining, and highway development are particularly ambiguous until further data becomes evident. Nonetheless, in spite of these uncertainties the information gathered on current and future wood biomass indicates that the largest potential supply of biomass is from fire effected stands (6,914,585 m^3/ yr), followed by non-allocated annual allowable cut (194,810 to 392,077 m^3/ yr) and theni insect/pest damaged stands in the southern Yukon (174,265 m^3/ yr). Any one of these could meet expected future demand for the development of a bioenergy industry based on wood biomass in the Yukon Territory.

Table 2-12 Summary of Total Potential Annual Available Biomass by Source

Source	Anticipated Volume of Wood (m^3/ yr)	Anticipated Dry Mass of Wood (tonnes/ yr)
Annual Allowable Cut [1]	194.810	72,664
Annual Allowable Cut [2]	392,077	146,245
FireSmart Treatment activities [3]	1,082	403.6
FireSmart Treatment activities [4]	6,461	2,390.9
Forest Fires [5]	6,914,565	2,579,132.7
Insect/Pest [6]	174,265	64,994.3
Aggregate Development [7]	1026	384.7
Aggregate Development [8]	57,506	21,550.6
Mining Development [9]	70,162	26,315.8
Total[10]	7,161,295	2,743,985.1
Total[11]	7,615,036	2,840,629.3

Table notes:

1 Annual Allowable Cut (AAC) Volume (m^3) from Yukon Forest Regulations (O.I.C. 2010/171) for all regions of the Yukon.

2 Annual Allowable Cut (AAC) Volume (m^3) from Yukon Forest Regulations (O.I.C. 2010/171) for Yukon except for Haines Junction Region and Champagne and Aishihik Traditional Territory all regions of the Yukon.

3. FireSmart activities biomass Volumes based on recent treated hectares. Assumed 11.5 m^3 /ha (including Tops and Branches) of wood available from FireSmart treated areas.

4. FireSmart activities Biomass Volumes from Tetra Tech (2017) for 150 km radius of Haines Junction and Teslin. Assumed 35 to 63 m3 /ha (including Tops and Branches) of wood available from FireSmart treated areas. Biomass Volume of Wood for merchantable and waste wood (Tops and Branches)

5. Forest Fire Biomass Volumes based on an assumed volume of 35 m3 of wood for all burnt lands

6. Forest Pest Biomass Volumes based on an assumed volume of 35 m3 of wood for two southern Forest Health Zones only
7. Aggregate Resource Development Biomass Volumes from Tetra Tech (2017) for clearing of active pits for 150 km radius of Haines Junction and Teslin based on a conservative calculation.
8. Biomass volumes from Aggregate Resource Pit dispositions land clearing within a 150 kms radius of Haines Junction and Teslin
9. Mining Development Biomass Volumes from Tetra Tech (2017) for 150 km radius of Haines Junction and Teslin.
10. Estimate of Biomass volumes assuming AAC values excluding Haines Junction Region and Champagne and Aishihik Traditional Territory, FireSmart activities with assumed treatment volumes of 11.5 m^3 /ha and a conservative estimate of land cleared for Aggregate Resource Development
11. Estimate of Biomass volumes assuming AAC values for all of the Yukon, FireSmart activities with assumed treatment volumes of 35 to 63 m3 /ha and land cleared for Aggregate Resource Pit dispositions.

2.5.2 Demand-side review: Estimated Future Market Demand

With the introduction of the *Our Clean Future* strategy, there is a clear push from the Yukon Government to support the conversion of energy sources from GHG intense fossil fuels to renewables. The focus of the strategy, from the biomass perspective, is correctly focused on the Yukon heating market. This would include existing and new residential, commercial, institutional, government, and industrial buildings.

As outlined in Table 2-4, approximately 15% of Yukon homes are currently heated by biomass while 59% are serviced by fossil fuels (balance by electricity). The combustion emission factors for biomass heating compared to oil on a kWh basis of energy, excluding transportation, are outlined in Table 2-13 from a Yukon community energy study. With an approximate 92% reduction in GHG emissions, each home converted will support the *Our Clean Future* strategy. Based on an average of expected home heating requirements of 30,000 kWh (Table 2-14), converting to biomass from oil will reduce GHG emissions by almost seven tonnes annually. With the average Yukonite emitting 18 tonnes per year, biomass represents a significant avenue to reduce GHG intensities.

Table 2-13 Emission Factors Adapted from (Pembina, 2013)

Greenhouse gas emission (kgCO2e)	Biomass	Oil
Per kWh of energy	0.021	0.26

Table 2-14 Typical Home Heating Loads, kWh, Adapted from (NRCAN, 2002)

City	Old Detached	New Detached	New Semi-Detached	New Townhouse
Whitehorse	43,000	32,000	23,600	16,700

As each home is unique, it is difficult to assign a one size fits all to biomass conversion technologies. For the purpose of this study, economic analyses were carried out on a 25 kW_{th} wood burning appliance to provide an indication of installation viability - results are presented in Section 6.0. For reference, *Our Clean Future* is anticipating building heating efficient retrofits and fuel switching to account for a 12,000 tonnes reduction in GHG by 2030 (a further 5000 tonnes will be attributed to requiring new buildings to be more energy efficient). If the reduction were solely to be accounted for by fuel switching, it would require the conversion of 1,714 appliances. As this is a significant undertaking, an alternative approach where heat users are located close together, is to implement a district heating system. In this case the furnace or hot water boilers are located in a central location and heat is transferred to multiple users through underground distribution lines as depicted in Figure 2-12. This approach has seen success in Dawson and more recently in the community of Teslin and at the Whitehouse Correction Centre as described in Section 2.3.3.b. Both installations are consuming around 600 tonnes of biomass per year and are responsible for reductions of approximately 800 tonnes of GHG annually. Combining potential future district energy systems with individual residences doing their part, will support achieving the *Our Clean Future* target of 12,000 tonnes by 2030.

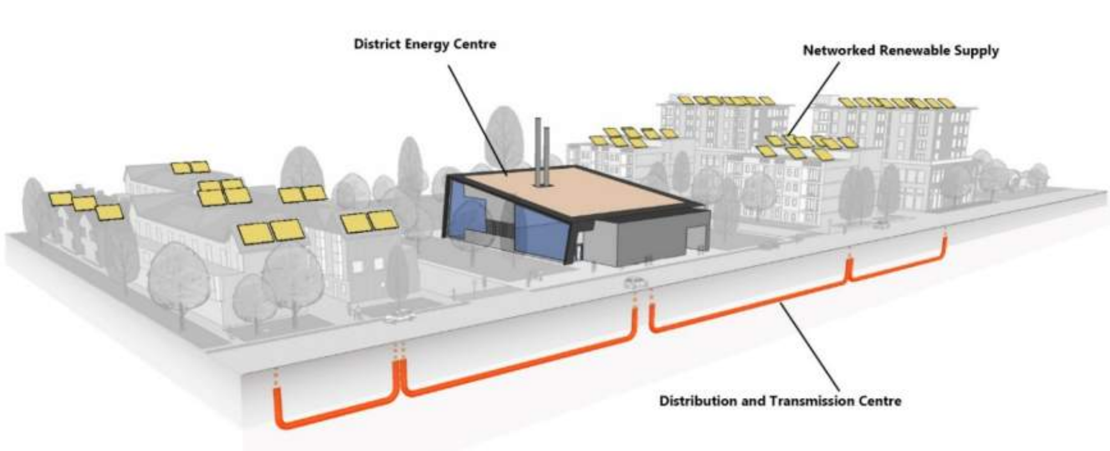


Figure 2-22 – District Energy, www.energyexplorer.ca/energy101

One of the key commitments made in the strategy is "conducting energy efficiency retrofits and installing renewable heating systems in Government of Yukon buildings" to reduce the government's GHG emissions by 8,000 tonnes. This can be approached in a similar fashion to residential and commercial buildings by installing a district energy system to service multiple users or install a single appliance on a standalone building. The Whitehorse Garden operation is an example of a single boiler servicing a single load. With almost 500 public buildings throughout the territory, the primary challenge will be assessing which should be converted first. Conversions of this nature are significantly larger in size than the residential option, therefore require more space and feedstock handling/storage equipment. Typical installations in the Yukon and throughout NWT use packaged pellet/chip hot water boilers and either a silo for fuel storage or require a fuel bunker as is the case in Dawson. The boilers themselves can be installed in existing mechanical rooms or can be standalone in a containerized enclosure and piped to the building - sample photos in Figure 2-23. As with the future residential analysis, no one size will fit every building, therefore two sizes of 400 kW_{th} and 800 kW_{th} containerized boiler packages are assumed for this study's economic assessment. Every installation needs to be assessed to understand boiler capacity required, space available, and how to integrate with existing building systems and operations.

Figure 2-23 – Standalone Units

Along the same lines, for the purposes of this study, a district energy system with capacities of 1 MW_{th} and 3 MW_{th} are considered. The smaller size is consistent with existing systems in Dawson, Teslin, and Whitehorse Correction Centre, but these systems have or are currently undergoing expansions to increase their capacity and/or distribution network. District heating systems will vary by community with smaller systems falling closer to the 1 MW_{th} capacity, while systems in the larger centers like Whitehorse, can far exceed 3 MW_{th} in size depending on the buildings included (business case viability). With all the larger options, GHG reductions become dependent on the number of buildings included in the network, a 3 MW_{th} could achieve reductions of approximately 2500 tonnes per year.

With a focus on Whitehorse, several studies have been conducted over the years investigating district energy opportunities. Systems are typically phased for development over an extended period of time and given the large capacity of such a system, offer the opportunity to incorporate electricity generation along with heat. This cogeneration approach allows for displacement of heat throughout the city and providing renewable electricity to the power grid. Systems this large take extensive planning and a bankable business case to proceed; therefore, are less common and require significantly more financing, permits, assessments, and environmental/social approvals. Given the capacity required to generate electricity with a district energy system, a biomass boiler plant with the capacity around 8-10 MW_{th} would have to be deployed with a steam turbine or Organic Rankine Cycle unit with an electrical generation capacity of 1-2 MW_e. Given the capital and capacity this type of installation would require, it is not assessed as part of this study.

3.0 JURISDICTIONAL REVIEW

3.1 GENERAL POLICY OVERVIEW ACROSS CANADA

Policies and guidelines relating to woody biomass harvesting are found at the provincial and territorial rather than federal level in Canada. The Canadian Federal Government in forestry is focused on management of the limited federal land area, science and technology, international relations, trade and investment, industrial and regional development, national statistics, climate change, and protecting water. Use of woody forest biomass from harvesting as an alternative energy source has much appeal in government and industry in Canada, although the biomass industry has not taken off in a big way at this point. Despite this enthusiasm, the potential environmental, ecological, logistic, and economic concerns mentioned in the Introduction are a consistent theme brought up by these and other organizations (e.g., environmental groups).

Legislation and guidelines that were developed for conventional logging apply to biomass harvesting (e.g., guidelines for riparian areas and soil disturbance). For most jurisdictions, the policies and recommended procedures are entrenched in an array of different documents, which are not all in one place, making it hard to pull together all the relevant information relating to biomass policy.

3.1.1 Climate Action Plans and Energy Initiatives and Policies

Canadian provinces and territories have Climate Change Action Plans or related policy that includes greenhouse gas (GHG) emission reduction targets. In those plans, replacement of fossil fuels with “renewable” or “green” energy sources is identified as a strategy to help achieve the targets. In addition to the Climate Change Action Plans, other provincial or territorial strategies, plans, policies, and acts related to energy have been developed. Forest biomass is often mentioned as a new renewable energy source, along with agricultural biomass, solar, tidal, wind, and geothermal power. None of the plans or strategies place legal requirements on generation of a certain amount of energy from forestry biomass. However, several of the provinces (e.g., Ontario, Quebec, Nova Scotia, New Brunswick) have targets for a certain amount (or percentage) of energy generated in the province to come from renewable sources (not necessarily forest biomass) by a certain year.

3.1.1.a British Columbia

B.C. Climate Change Action Plan

The British Columbia government established targets for GHG reductions in the province and made them law through the *Greenhouse Gas Reduction Targets Act* (Province of British Columbia 2007b). This would encourage the development of new energy sources with lower emission levels than traditional energy sources, such as forest biomass.

B.C. Energy Plan

The BC Energy Plan promotes the use of new renewable energy sources and reflects the province's increasing interest in using forest biomass.

Bioenergy Strategy

The BC Bioenergy Strategy addresses the commitments laid out in the BC Energy Plan including funding for a provincial Bioenergy Network that seeks to support greater investment and innovation in bioenergy projects and technologies.

3.1.1.b Quebec

The Forest Biomass Heating Assistance Program

The Forest Biomass Heating Assistance Program, started in 2009 under the Climate Change Action Plan, gave funding assistance for building managers to use residual forest biomass for their heating needs.

Developing the Value of Forest Biomass–An Action Plan

This action plan encourages the startup and development of energy production from forest biomass with the basic goal of eliminating 1.1 million tons of GHG emissions by replacing fossil fuel energy with renewable energy, specifically biofuels (Québec Ministère Développement Durable, Environnement, et Parcs 2011). The action plan indicates that certain conditions must be met if forest biomass is to be used as an energy source: forest biomass availability must be sustainable, precautions must be taken to protect fragile soils, regulations effecting airborne particulate emissions must be complied with, and the impact of harvesting woody biomass on forest ecosystems must be monitored. It also states that at least 30% of woody material must be left on the site during harvesting.

The four primary objectives and policy instruments of the action plan are summarized below:

1. Make the resource available (Forest Biomass Allocation Program for Public Lands)
2. Encourage the replacement of fossil fuels (Heavy Oil Consumption Reduction Program)
3. Support investment Measure 15 is to support programs for manure processing and for the energy valorization of agricultural, forest, and municipal biomass. Forest biomass will play an important role Support innovation
4. Support innovation - The goal of the Program to Promote Energy Efficiency (PPEE) is to provide financing to stimulate demand for forest biomass

For a Green and Prosperous Quebec: A Development Strategy for Quebec's Environmental and Green Technology Industry

Thirty-seven (37) million dollars was provided to promote the growth of environmental and green technology companies by supporting investment projects of companies that specialize in the environment and green technology, contributing to setting up a venture capital fund of about $100 million, and raising the financial community's awareness of the environment and green technology sector in order to facilitate access to financing.

The Quebec Energy Strategy 2006–2015: Using Energy to Build the Quebec of Tomorrow

This strategy includes an assistance fund for new energy technologies and the promotion by government of renewable fuels, with the use of forest and agricultural biomass and urban waste given priority over grain corn. This is recognized as being technologically difficult, but research will be supported to address this. A task force will be created to better identify potential sources of feedstock and identify the business model best suited to maximize the spin-offs from it.

Quebec and Climate Change, a Challenge for the Future, 2006–2012

Measure 15 of the Climate Change Action Plan was an allocation of $124 million to support programs for manure processing and for the energy valorization of agricultural, forest, and municipal biomass. Measure 20 was intended to implement a $135 million program to support technological research and innovation for the reduction and sequestration of GHGs. Forest biomass was specifically mentioned.

3.1.1.c New Brunswick

Electricity Act

The Electricity from Renewable Resources Regulation (Statutes of New Brunswick 2006) issued under the *Electricity Act* requires NB Power to acquire 10% of its electricity supply from new renewable sources by 2016. Wind, solar, biomass, small hydro, landfill gas, and ocean are eligible.

Climate Change Action Plan (Province of New Brunswick 2007)

In June 2007, the New Brunswick Government launched its Climate Change Action Plan, which outlined a series of actions to reduce provincial GHG emissions, to adapt to impacts of climate change, and to encourage participation of communities and citizens. The plan calls for a reduction in New Brunswick's GHG to 1990 levels in 2012 and further reductions of 10% below 1990 levels by 2020. A commitment to implement a Crown land forest biomass policy was included in the policy actions to achieve these goals.

3.1.1.d Nova Scotia

Renewable Energy Standards (Province of Nova Scotia 2007)

Legal requirements are that by 2013, Nova Scotia will generate at least 18.5% of its electricity through renewable energy sources—wind, tidal, biomass, solar, and hydro. By 2015, Nova Scotia aims to generate 25% of its electricity with renewables and 40% by 2020.

Environmental Goals and Sustainable Prosperity Act (Statutes of Nova Scotia 2007a)

This act includes the target of 10% less GHG emissions than 1990 levels by 2020.

Towards a Greener Future: Nova Scotia's Climate Change Action Plan

Outlines 68 climate-change actions with two main goals:

1. Reduce the Province's GHG emissions; and
2. Prepare for climate change. Nova Scotia has aimed to reduce GHG emissions by at least 10% from 1990 levels by 2020. The greatest single reduction was to be achieved by imposing caps on emissions from Nova Scotia Power Incorporated (NSPI), which produces 46% of the Province's GHG emissions. The caps were to take effect in 2010, 2015, and 2020. The two most cost-effective means of reducing emissions from power generation in Nova Scotia were described as straightforward: generating less electricity and generating it from clean, renewable sources.

Toward a Greener Future: Nova Scotia's 2009 Energy Strategy

A companion to the Climate Change Action Plan, this strategy set out the following policies and strategies: increase energy efficiency in the province by 20%, using less imported coal and more diverse sources of clean, local, and renewable energy, encourage more renewable electricity energy, encourage onshore and offshore exploration and development for petroleum, consult widely and seek advice on sustainable energy policy, support the participation of Nova Scotians in the energy industry, and keep Nova Scotia's energy markets open for imports and exports. The energy strategy identified biomass (wood, wood waste, fast-growing grasses and trees, and construction waste such as lumber) as an emerging option for energy, but indicated that biomass resources need evaluation for supply, sustainability, and cost, which were being studied by the Province, NSPI, and other stakeholders. Biomass was recognized as having the potential to displace coal and supply firm, predictable amounts of electricity. It was also considered an attractive economic opportunity to use Nova Scotia's fuel sources to lessen dependence on foreign coal. Nova Scotia Power proposed to meet some of the Renewable Energy Standard targets with biomass power from independent producers. Biomass could also be mixed with coal and used in existing plants.

3.1.1.e Prince Edward Island

Renewable Energy Act

Specifies that beginning January 2010 every public utility in Prince Edward Island shall obtain at least 15% of the total amount of electric energy that it sells during a year from renewable energy sources.

Prince Edward Island Energy Strategy. Securing Our Future: Energy Efficiency and Conservation

This strategy was intended to reduce dependence on fossil fuel energy sources through improved energy efficiency and increased reliance on wind power and renewable biomass from forestry and farming operations. Timelines included that by 2010 utilities must acquire at least 15% of electrical energy from renewable sources. By 2013 there shall be a 50% increase in biomass use, leading to 10 mw of new electricity generation capacity. The province's renewable energy portfolio standard shall double from 15% to 30%. By 2020 they are aiming for a 10% reduction in GHG emissions below 1990 levels. By 2025 they plan to reduce the amount of CO_2 emitted per megawatt hour of electricity use by 20% of current emissions.

Climate Change Strategy

The province's Climate Change Strategy recommended increased emphasis on renewable energy and wind. The provincial government committed to four actions related to biomass (wood, sawmill residue, and municipal waste):

1. Review and improve codes and regulatory barriers preventing the sustainable development of biomass fuel and biogas facilities.
2. Lead by example in demonstrating biomass and biogas technologies in public buildings and facilities.
3. Promote the use and encourage the installation of biomass heating systems in homes and businesses through loans, tax breaks, and other financial incentives.
4. Undertake feasibility studies for the use of biomass and biogas in urban and local community district heating systems and for the potential for co-generation facilities with the Island.

Biomass Heat on PEI: A Path Forward

In 2010 the Government of Prince Edward Island established a Joint Working Committee to review how the province might effectively meet the targets set out in the 2008 Energy Strategy. The Environmental Advisory Council and Public Forest Council Joint Working Group on Biomass Heat considered that the expansion of biomass heat on Prince Edward Island was an opportunity for economic development, revitalization of rural communities, job creation, and new alternatives for the forest sector, which would also reduce greenhouse gas emissions and decrease dependence on fossil fuels. They felt that abundant fuel sources in Prince Edward Island combined with the province's energy needs justify the expansion and exploration of biomass technologies and recommended greater use of biomass for heat. They recommended that at least six 5-year test pilot projects be established across the province to provide initial information to validate the expansion of biomass heat. The projects should represent the three primary biomass feedstock sources on Prince Edward Island: forestry, agriculture, and construction and demolition. They recommended that sustainable and environmental well-being be the most important consideration in analysis of the test pilot projects; economic cost of the energy was considered a less important factor during the testing phase. Proponents would be responsible for the capital costs of installation and operation of the heating units, but the provincial government should participate by purchasing heat from the operations. The facilities must be monitored by the Department of Environment, Energy and Forestry for emissions, sustainability of feedstock, maintenance and construction of facilities, and environmental concerns. Biomass feedstock must be harvested within recognized sustainability guidelines, with harvesting done from properties with a current and registered Forest Management Plan prepared according to the standards of the Ecosystem-based Forest Management Manual. They also recommended that provincial forest policy provide more specific definitions of acceptable methods of forest biomass harvesting.

Charting our Electricity Future

The Prince Edward Island Energy Commission was mandated by the Government of Prince Edward Island to provide advice on ways to reduce and/ or stabilize the high cost of electricity on the Island over the long term. In its final report, Charting Our Electricity Future (Prince Edward Island Energy Commission 2013), the commission declared that wood biomass generation could not compete economically with low-cost natural gas and its feasibility would also depend upon the sustainability of a long-term local fuel supply.

3.1.1.f Newfoundland

Charting our Course, Climate Change Action Plan

Goals of the Climate Change Action Plan include reducing GHG emission levels in Newfoundland and Labrador to 10% below 1990 levels by 2020 and 75–85% below 2001 levels by 2050. The strategic framework of the Climate Change Action Plan includes identifying and maximizing opportunities such as development of the province's clean energy resources and developing new technologies, although the plan does not specifically mention the use of forest biomass as an energy source. Forestry is mentioned in the context of the importance of forests as carbon sinks.

3.1.1.g Northwest Territories

Energy for the Future: An Energy Plan for the Northwest Territories

This plan maintains that while the government supports renewable energy, these energy sources, with the exception of hydroelectric power, will only represent a relatively small share of the total energy supply for the Northwest Territories in the short and medium term. The reliability of fossil fuels, their superior economics for energy production, and the presence of existing capital infrastructure to deliver power will limit the impact of renewable energy solutions in the Northwest Territories and many other parts of Canada.

Energy Priorities Framework

This document includes several priority initiatives aimed at reducing dependence on imported diesel for energy. One priority is a commitment to expand the use of biomass, including for electricity generation, building on the past success of wood pellet boilers.

NWT Biomass Energy Strategy

It is recognized in this strategy that because the forest industry operates at a very low level and there is therefore no low-cost supply of waste wood, trees would have to be harvested to produce pellets. In addition, wood chips would be available from residues of road building and maintenance, forest thinning for community protection, forest fire burn areas, and pipeline or seismic line cutting from cardboard, paper, or construction and demolition waste, and from fast-growing willow or poplar.

Among the 12 actions recommended in the strategy are: encourage a stable and economic supply of pellets in all the Northwest Territories communities; work with the private sector and Aboriginal development corporations to identify viable business models to produce pellets and/ or wood chips in the Northwest Territories; evaluate and quantify wood resources around select communities and determine potential harvesting areas; and install a combined heat and power pilot project in one community by 2012

3.1.2 Natural resource legislation

3.1.2.a British Columbia

Waste Assessment Policy and Logging Residue and Waste Measurement Procedures Manual (British Columbia Ministry of Forests, Mines and Lands 2011)

Licensees in British Columbia must pay a penalty for merchantable timber that is not removed during harvesting, so the maximum amount of coarse woody debris left on a site is influenced by the timber merchantability specifications. However, depending on markets, licensees may choose to leave more woody biomass, and market forces rather than utilization standards may be the main force dictating the maximum amount of woody debris that remains after logging (Roach & Berch, 2014).

Fibre Recovery Tenures (British Columbia Ministry of Forests, Lands and Natural Resource Operations, 2012)

In 2012, the Ministry of Forests, Lands and Natural Resource Operations announced new provisions in the Forest Act for two timber tenures intended for use in accessing road and landing waste not utilized by the person who conducted the original harvesting. These two fibre recovery tenures are the Fibre Supply License to Cut (FSLTC) and the Fibre Forestry License to Cut (FFLTC). Once harvesting is completed on a specific block, the primary harvester is required to provide notice whether or not the waste remaining on the block will be utilized. If not, the rights to the fibre may be allocated to the holder of one of these tenures. Along with these new tenures came amendments to regulations under the *Forest and Range Practices Act* (Forest Planning and Practices Regulation, see below) and the *Wildfire Act*.

Forest and Range Practices Act (FRPA)

This is a major piece of legislation guiding forestry operations on Crown land in British Columbia, setting out requirements that must be adhered to including sustainable management of forest resources and the requirement of an approved Forest Stewardship Plan (FSP) before any harvesting is done. The FSPs must state intended results or strategies to achieve the objectives set by government in the act or its regulations and if not complied with, measures may be taken that could include monetary fines. Forest biomass harvesting is not specifically mentioned in FRPA.

Forest Planning and Practices Regulation

In their plans, tenure holders must state how they will address government objectives for timber, soils, water, fish, wildlife, biodiversity, visual quality, and cultural heritage resources. This requires:

- Conserving productivity and hydrologic function of soil
- Conserving sufficient wildlife habitat in terms of area, distribution of areas, and attributes of those areas for the survival of species at risk, the survival of regionally important wildlife, and the winter survival of specified ungulate species,
- Conserving, at the landscape level, water quality

3.2 CASE STUDIES

3.2.1 Northwest Territories

Similar to Yukon, the Northwest Territories (NWT) was traditionally dependent on biomass cordwood as the sole source of heat prior to the arrival of fossil fuel fired heating appliances. Although residential wood stoves remained common, fuel oil largely replaced biomass as the primary fuel source for most buildings due to its reliability of operation, availability, and ease of use. The rising costs of fossil fuels and increasing concerns of climate change over recent years has led to a renewed interest in biomass which along with the development of new biomass heating technologies made biomass a reliable option for broader adoption in NWT. This aligned well with the Government of the Northwest Territories (GNWT) 2007 Energy Plan, which identified three main goals:

1. Reduce the use of imported diesel fuel for energy generation.
2. Reduce greenhouse gas emissions.
3. Reduce the cost of living in NWT communities.

Following this in 2010, the GNWT developed their NWT Biomass Energy Strategy, which identified four primary objectives:

1. Increase education and awareness of biomass as a heating option for residents and businesses,
2. Promote biomass heating options,
3. Promote greater stability in the supply of biomass in the NWT including locally produced biomass, and
4. Promote combined heat and power technologies.

The first commercial wood pellet heating boiler in the NWT was installed at the North Slave Correction Facility in 2007. This was installed as a privately owned and operated system with a heating supply agreement with the GNWT that has benefitted both parties and is still in operation today. This initial 1,500 kW system was estimated to displace 560,000L of fuel oil per year and served as a successful demonstration of the viability of the technology.

Through efforts from both Private and Public sector investors, the installed capacity in NWT grew steadily to an estimated 21,900 kW installed capacity and 30,000 t/ yr pellet consumption rate in 2015 at which time it was estimated that 9% of all NWT's heating needs were provided by wood pellets or cord wood.

In a retrospective interview in 2015, GNWT Environment and Natural Resources Minister Michael Miltenberger said, "For me, the plan was two steps: build the market and then once you do that, build the industry. We've spent the last eight years building the market. We've encouraged people to get into it, but as a government, we've made a very significant investment in converting our own buildings".

NWT Biomass Energy Strategy 12-Step Action Plan

1. Deliver "Burn-it-Smart" workshops to encourage proper wood burning techniques.
2. Promote wood pellets for residential use at fairs, trade shows and information sessions.
3. Sponsor woodstove and wood pellet appliance installation and maintenance training.
4. Develop air quality guidelines for biomass burning based on EPA standards.
5. Promote efficient biomass burning technologies through the Energy Efficiency Incentive Program.
6. Continue to expand the implementation of biomass systems in GNWT facilities.
7. Work with communities to assess the potential of new biomass district heat system.
8. Encourage a stable and economic supply of pellets in all NWT communities.
9. Work with the private sector and aboriginal development corporations to identify viable business models to produce pellets and woodchips in NWT.
10. Work with communities to establish their own wood marshalling yard.
11. Evaluate and quantify wood resources around select communities and determine potential harvesting areas.
12. Install a combined heat and power pilot project in one community by 2012.

The results in terms of GHG reduction are evident. The goal adopted in the 2007 GNWT Energy Plan to reduce corporate emissions by 10% below 2001 levels was overshot by a significant margin, achieving 30% reductions compared to 2001 levels within 4 years.

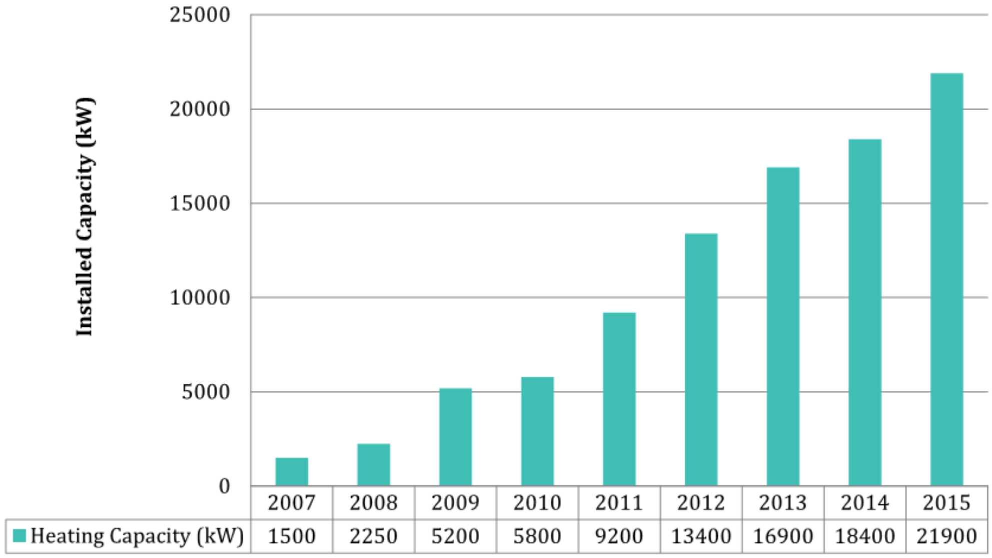


Figure 3-1 Total Capacity of Wood Boilers in the NWT

The Northwest Territories has seen dramatic growth in the biomass heating industry since its first steps in 2007. Along with a growth in installed biomass heating systems has been a growth in supporting services including; pellet delivery services, installers, maintenance services, and pellet boiler and stove sales. Despite this, local production of fuel pellets has not yet been established. The relatively limited scale of the forestry sector in NWT which exists primarily in the South Slave Region is not able to address the growing demand for wood pellets. A proposed pellet mill near Hay River, NT on a 320 ha site has met political opposition on numerous fronts, but recent reports indicate that the project may proceed in 2022. Currently wood pellets are imported from the La Crete pellet mill in northern Alberta.

The Government of the NWT identified biomass as a preferred substitute for conventional heating fuels and has invested heavily through the last decade to establish the industry. This is done primarily through investing in biomass heating technology for a large portion of Government owned buildings and through incentivizing private investment biomass heating systems through territorial government funding opportunities. Their focus has been largely on creating a demand for biomass heating fuel to support growth of a privately operated fuel supply chain.

The primary economic drivers that led to the current biomass industry in NWT are;

- heavy dependance on fossil fuels with limited local fuel security,
- high fuel and electricity prices,
- small existing forestry industry,
- increased desire to reduce GHG emissions,

- unsuitable conditions for alternative renewable energy options such as wind, solar and geothermal,
- ready access to imported wood pellets from northern Alberta

In comparison, Yukon shares a similar dependance on imported fossil fuels although benefits from a more robust hydro-electricity system that accommodates a higher proportion of the Territory's electricity demand. However, hydro-electricity systems have reached peak capacity and further electrical load is being accommodated by diesel and natural gas generation and so there is a desire to avoid increased dependance on fossil fuels. Electricity prices in Yukon are lower than NWT although still high in comparison to competing fuel sources. Unlike NWT, Yukon benefits from more accessible forest resources, but a similarly underdeveloped forestry industry. This presents the option for future development of a biomass fuel supply industry, but without the benefit of a pre-existing industry with expertise, equipment, policies and useful residual biproducts that it would afford.

3.2.2 British Columbia

British Columbia benefits from an abundance of low GHG emitting renewable energy sources in comparison to other regions of Canada. On per capita basis, British Columbia is the sixth largest consumer of energy but is one of the lowest emitters of Greenhouse Gases at 36% below the national average. Fossil fuels accounted for approximately 66% of energy consumed in 2017, while electricity and biofuels combined accounted for 32% of the 2017 energy demand. Approximately 98% of electricity generated in BC is produced from renewable sources, of which 91% is hydroelectricity, and the remainder is a combination of biomass, wind and solar generation. (Canada Energy Regulator, n.d.)

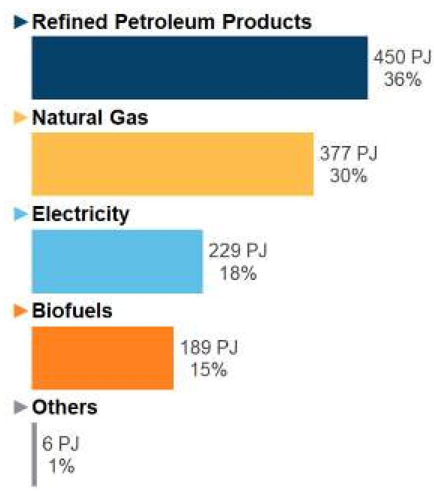


Figure 3-2 - BC Energy Demand by Fuel

Energy consumption for space heating in BC's commercial sector comes largely from natural gas at 83% and electricity at 14%, while space heating for the residential sector comes from 56% natural gas, 24% electricity, and 12% from combination wood/electric heating units.

Biomass fuel is widely available in British Columbia as a residual byproduct of the established sawmills and timber mills accounting for 90-95% of wood pellet production in BC. Wood pellet production in BC is largely exported with approximately 1.6 million tonnes of wood pellets exported to global markets, primarily UK, Japan, and Belgium (Statistics Canada, n.d.) compared to approximately 460,000 tonnes consumed locally in 2017 (Natural Resources Canada, n.d.).

The hydroelectricity and natural gas production industries in British Columbia has allowed access to inexpensive, locally produced, renewable energy. The Government of BC 2018 Climate Action Strategy commits to reducing emissions from buildings through increasing building efficiency standards, incentives for home efficiency upgrades and electric heat pumps, and implementing minimum requirements on renewable content in residential natural gas. Biomass energy is noted only as a minor part of the overall strategy as a means of reducing diesel dependency in remote communities.

With these mature industries in place, there is much less incentive to invest heavily in the biomass sector and less political and social will to develop in this area.

The primary economic drivers that led to the current biomass industry in BC are;

- Abundant hydro-electricity and natural gas provides inexpensive and relatively low GHG energy sources resulting in smaller incremental gains from fuel switching.
- Other more cost effective options for high efficiency and renewable energy systems such as air sourced heat pumps and wind are available.
- Relatively high capital cost of installation for biomass systems with relatively low ROI from environmental and financial benefits.
- Large and mature forestry industry with relatively easy access to residual wood fibre for pellet production. Larger profit margins for suppliers supporting export rather than local consumption.

In comparison, Yukon has fewer options for cost effective renewable energy systems and does not benefit from low-cost electricity and natural gas.

3.2.3 Quebec

Like British Columbia, Quebec benefits from abundant natural resources that provide relatively inexpensive access to renewable energy in the form of Hydroelectricity. In 2018, Quebec generated 213.7 TWh of electricity accounting for approximately one third of all electricity produced in Canada and accommodating 95% of Quebec's electrical demand for that year while allowing for substantial electricity exports. The remaining electrical demand in Quebec is produced by Wind at 4% and natural gas, diesel and biomass producing the final 1% primarily in remote off-grid communities. This low-cost source of electricity is also the primary method used for home heating in Quebec. (Canada Energy Regulator, n.d.).

Across all sectors, an estimated 633 TWh of energy was consumed in 2018, of which 51% was produced from imported oil, natural gas and coal, while 49% was produced from hydro, biomass and wind. (Chair in Energy Sector Management, HEC Montreal, 2019).

	Source	PJ	Percentage of total (%)	Equivalence
Imports = 51%	Oil	826	36	137 million barrels
	Natural gas	325	14	8.4 billion m³
	Coal	13	1	0.6 million tons
Local = 49%	Hydro	818	36	227 TWh
	Biomass	170	7.5	
	Wind	126	6	35 TWh
	Total	**2,278**	**100**	

Sources: EIA, 2018; TEQ, 2018 (preliminary data); OEE, 2017; Statistics Canada, 2018.

Figure 3-3 - Primary Energy Sources in Quebec

The total GHG Emissions from Quebec in 2017 was 77.8 MT CO_2e, which represented a 9% decline from 1990. Quebec's emissions per capita are the lowest in Canada, approximately 52% below the national average.

Quebec's 2030 climate change target includes a reduction in overall greenhouse gas emissions by 37.5% below 1990 levels. Further reductions in GHG emissions will come largely from transitioning from Oil and Natural Gas to renewable synthetic fuels. Oil consumption in Quebec is used almost entirely for Transportation, while Natural Gas and Coal are largely used for heating in the industrial sector and commercial buildings to a lesser extent. To achieve the GHG emission reduction target, Quebec' 2017-2020 Action Plan includes replacement of 40% of the 4,758,000 gasoline-fueled vehicles currently in use with Electric Vehicles, and to implement a new regulation requiring 2% renewable biofuel content in diesel and 5% in gasoline. To offset the use of coal and oil in the industrial sector, the Action Plan aims to promote the production of synthetic bio-oil and bio-coal which is produced from biomass fuel through gasification. (Chair in Energy Sector Management, HEC Montreal, 2019)

Like British Columbia, Quebec has a long history of forestry with a mature logging industry. Diverting residual biomass waste from the established sawmills and timber mills will offer a ready supply of inexpensive biomass fuel to promote growth in the developing biomass industry. Most biomass power and heating plants are privately owned, and the Quebec Government is incentivizing private sector development through funding programs to subsidize installation and operating costs. However, the value of these funding programs has been relatively limited in past years at between $20 million and $50 million which has been quickly depleted.

To meet its 2030 GHG reduction goals, Quebec's Action Plan focuses largely on offsetting fossil fuel consumption by leveraging its abundant potential for electricity and biofuel production and is less focused on direct-fired biomass heating and power generating systems.

The primary economic drivers that led to the current biomass industry in Quebec are;

- Abundant hydroelectricity provides inexpensive and relatively low GHG energy sources resulting in smaller incremental gains from fuel switching.
- Access to relatively inexpensive natural gas allows a more cost-effective transition from oil and coal heating to a more clean natural gas source.
- Relatively high capital cost of installation for biomass systems with relatively low ROI from environmental and financial benefits.
- Mature forestry industry with relatively easy access to residual wood fibre for pellet production.

3.2.4 Prince Edward Island

The final jurisdiction investigated was Prince Edward Island (PEI), as it shares some similarities with the Yukon Territory. PEI trucks in the majority of its energy sources, has limited utility infrastructure connections with other provinces, and became a champion for biomass as an avenue to reduce dependency on oil/reduce GHGs while creating a market for biomass byproducts from forestry operations.

Prince Edward Island has a long history in biomass, with its first major infrastructure project taking place in the early 1980's. PEI Energy Systems (now owned by Enwave) developed Canada's largest district heating system at the time providing service to the City of Charlottetown. Burning biomass, solid waste, and fuel oil, the 33 MW_{th} facility heats over 145 buildings in Charlottetown, including the local hospital, university, residences, as well as commercial and government buildings. The plant can also generate 1.2 MW_e of electricity and is currently undergoing a major $37M retrofit to improve throughput, reduce local landfilling of solid waste, utilize Island biomass, and further decrease GHGs/dependency on oil.

In early 2000, PEI began to make a push to decrease oil dependency by installing wood burning units on government buildings using locally derived biomass feedstock. Due to technology limitations in attempting to eliminate the need for stationary power engineers, the initial installations were not successful. To ultimately improve the opportunity for installations to incorporate the latest technology, the provincial chief boiler inspector (Steven Townsend) championed regulation changes to allow for the installation of boilers meeting the European Pressure Equipment Directive (P.E.D.) standards. This, along with other regulatory improvements, facilitated installation of biomass boilers meeting EN 303-5 up to 300kW_{th} and EN 12953 for those above. Although more and more boiler suppliers are meeting American Society of Mechanical Engineering (ASME) standards, acceptance by provincial inspectors for P.E.D. codes and standards greatly increased the success of PEI's biomass heating market development.

By 2015, the province had successfully procured and installed 13 biomass units on government properties. The procurement initially focused on locally sourced wood chips as a feedstock but made later attempts to incorporate wood pellets; however, this proved cost prohibitive. All feedstock supplied to the new installations had to be sustainably harvested on the Island, although some supply did come from neighboring New Brunswick. By 2018, the number of public buildings converted to biomass heating systems reached 29, with four companies operating the units in the province.

Today, PEI continues its push to a greener economy through its "A Climate Change Action Plan for Prince Edward Island (2018-2022)." By recommitting that "government, together with residents, businesses, and industries, will reduce provincial greenhouse gas emissions by 30 per cent below 2005 levels by 2030", they continue to strive to meet new targets. Although transportation and agriculture account for almost three quarters of the Island's GHG emissions, their policies and incentives provided through efficiency PEI (their government body committed to providing energy efficiency rebates for biomass heating devices in the home) have helped significantly reduce dependency on furnace oil for heating. The new Action Plan also commits to install 20 more heating system with an estimated GHG reduction of 4,000 tonnes CO2 eq. with four new installations approved for 2020-21. Figure 3-4 highlights PEIs success in reducing furnace oil usage through the introduction of their biomass heating strategy.

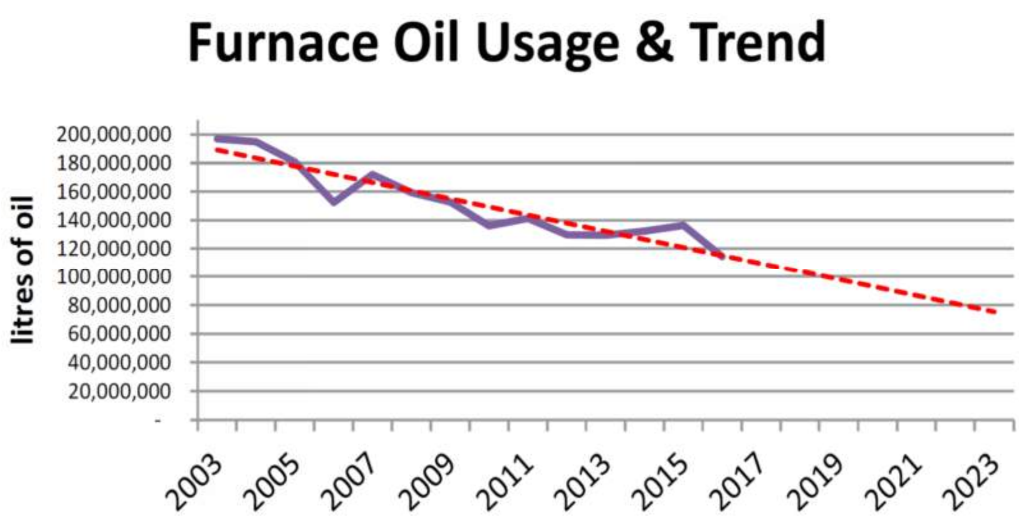


Figure 3-4 – Furnace Oil Usage - A Climate Change Action Plan (2018-2022)

The primary economic drivers that led to the current biomass industry in PEI are;

- heavy dependance on fossil fuels with limited local fuel security,
- high fuel and electricity prices,
- mature existing forestry industry with available byproducts,
- increased desire to reduce GHG emissions,

4.0 STAKEHOLDER ENGAGEMENT

4.1 APPROACH

Stakeholder engagement was used during the completion of this analysis to gain deeper insight into the existing context of the biomass industry in Yukon. Prior to the outbreak of COVID-19, a collaborative stakeholder workshop was proposed which was to include representatives from biomass suppliers, regulators, users, stakeholders, and the consultant team. During the workshop, the intent was to facilitate an in-person SWOT analysis session that would assist in identifying gaps, challenges, and opportunities to advance the biomass industry in Yukon. Unfortunately, the restrictions associated with the outbreak of COVID-19 did not permit such a workshop to take place; as such, one-on-one interviews were instead used to gather the information. This change was approved by YG as a suitable alternative to in-person engagement.

4.2 STAKEHOLDERS ENGAGED

One-on-one interviews were held with representatives from the following organizations or governments:

- Yukon Government
  - Forestry Branch
  - Energy Branch
  - Economic Development
  - Community Services (Wildland Fire Management)
  - Highways and Public Works (Strategic Initiatives)
- Yukon Conservation Society
- Yukon First Nation's Wildfire
- Bear Creek Logging
- Yukon Wood Products Association
- Yukon Chamber of Commerce
- Biolive DCD Energy
- ACS Mechanical
- Champagne and Aishihik First Nations
- Kwanlin Dun First Nation
- Nihtat Energy [Nihtat Gwich'in First Nation]
- Yukon Energy Corporation
- Yukon Development Corporation
- Arctic Inland

4.3 FEEDBACK RECEIVED

A structured stakeholder interview guide was used to guide conversations during the interviews; however, interviewers remained flexible to allow conversations to shift toward specific areas of interest and expertise.

4.3.1 SWOT: Strengths, weaknesses, opportunities, threats

Throughout all interviews, respondents were asked to identify the strengths, weaknesses, opportunities, and constraints to the biomass industry in Yukon; the results of those conversations are included below.

Table 4-1 Stakeholder engagement feedback - SWOT

Strengths	Weaknesses
• There is a lot of wood available through fire smarting, beetle kill, road clearing, and fibre/ trees not suitable for other uses – There are large scale fire reduction programs starting in Yukon • There is a strong cordwood industry existing • There is a history of biomass in Yukon, since the Gold Rush • There is social acceptance for renewable energy • Will help support energy security/ sovereignty • Will help supports fire risk reduction • Decreases our carbon footprint • Currently has Territorial-support • All Yukon communities are situated in the Boreal Forest	• There is a lack of technical expertise in this industry: – installing and maintaining boilers – planning and permitting large forest harvesting – wood delivery operations • There are no primary wood industries in Yukon; the logging industry is not as mature or experienced as compared to other jurisdictions in Canada • No model for required economies of scale, break even cost or the profit margin for biomass payback • Supply is not available in all locations • Supply price is high/low profit margins • Operates at a small scale • Scale required • Presently low demand for biomass • No substantial existing market for pellet or woodchip supply • No social license • Difficult to access feed stock • Short term supply contracts • Short term harvesting permits

Opportunities	Threats
• First Nation Governments and Development Corporations are interested in energy projects – IPP's • One or two projects could have a major impact • Yukon government as a customer (retrofitting buildings for biomass heat) • Government incentives • There are potential customers that could influence: e.g. construction companies, apartment building owners, public, Yukon Housing • Fibre available from roadway clearing • Yukon government forest fire reduction program can produce sufficient fibre/ fuel supply and there may be some cost subsidies from this program • Local economic and employment benefits • Capital investment dollars available for First Nation Governments	• Yukon Energy does not include biomass generated electricity in 10-year renewable electricity plan • Lack of capacity and expertise • Lack of interest/capacity by harvester/suppliers to grow the industry • Forest planning • YESAA • Secure wood supply • Concern that those doing the feasibility studies have a vested interest (e.g. selling boilers) • Greenhouse gas emission levels • Quality produced in Yukon may not meet that available from Alberta or British Columbia • Cheaper alternative fuel sources (e.g. diesel) • Change in government priorities • Must be located close enough to buildings to deliver and sell the heat • Past failures

4.3.2 Key themes

There were a few key themes that were consistent in the interviews. The respondents **support and recognize the benefits** of growing a biomass industry in Yukon while also identifying several challenges. The key themes include.

4.3.2.a Lack of social license

Social license is marginal. More work needs to be done by the industry and government to promote the benefits of biomass and a forest industry. There is opposition to larger harvesting programs in the territory. Yukoners are concerned about visual aesthetics, new roads and access and loss of habitat.

4.3.2.b Cost

'The cost of stump to dump is expensive'. The biomass heating industry is competing against electricity in Yukon and not diesel or propane as is the case in other northern jurisdictions. Although there may be a perception of high cost of biomass fuel it is typically much lower than competing fuels. Current prices for biomass in Yukon is $305/t for woodchips and $396/t for wood pellets, which approximately corresponds to $24.9/GJ and $23.4/GJ respectively. In comparison, energy costs of oil, propane, and electricity are $30.5/GJ, $49/GJ and $41.7/GJ respectively. In light of this, it would be more accurate to say that the capital installation cost of biomass heating systems is high in comparison to equivalently sized electric systems.

4.3.2.c Capacity

The forest industry is small. The supply industry would need to scale up to supply the fuel demand identified in Yukon government's *Our Clean Future's* strategy. Some members of the supply industry have acknowledged an interest to grow and invest in equipment to supply biomass. There are a couple key projects in the planning stage that have the potential to meet future demands.

For many of those involved in the supply of biomass fuel there is a preference to remain small and harvest manually.

4.3.2.d Forest Management

All interviewees were asked what they thought were the strengths, weaknesses, opportunities, and threats for growing the biomass industry in Yukon using an interview guide as included in Appendix A Stakeholder Interview Guide. The following are the results of the SWOT analysis.

4.3.2.e Barriers to Development

- Definition of a carbon-neutral renewable source in the Clean Energy Plan
- Emission standards
- Canada is not recognizing European boilers/ vessels
- Social license
- Harvesting costs are high
- Biomass heat is competing against electric heat
- Operational risk due to a lack of significant infrastructure to support private investors.

4.3.2.f Opportunities for Success

- Find champions
- Build technical and managerial skills
- Assist local businesses in achieving profits, making it worth their while to enter the market; offer incentives
- Incentivize building owners to use biomass for heat

5.0 POLICY CONSIDERATIONS

Our Clean Energy Future – A Yukon strategy for climate change, energy, and a green economy, released September 14th, 2020 should have a significant impact on growing the biomass industry in Yukon. The Yukon government has set the target to reduce greenhouse gas emissions by 30% for 2030. To reach the 30% GHG reduction target Yukon has set an additional target that by 2030, 40% of the heating needs in Yukon will be with renewable sources, specifically increasing the use of biomass.

The strategy focuses on supporting Yukon businesses, communities and individuals with financial incentives, innovative projects, economic opportunities and explicit actions and targets. The actions include:

- Support local governments, businesses, and organizations to install 20 commercial and institutional biomass heating systems
- Install biomass energy systems in Yukon government buildings
- Provide financial incentives and low interest loans to install biomass heating systems for commercial, residential, and institutional uses
- Support First Nations to study the feasibility of installing and operating biomass systems
- Regulatory improvements to the Forest Resources Act
- Amendments to the Air Emissions Regulations to minimize air pollutants; and to
- Examine forest management techniques and harvesting techniques that will guide sustainable and low carbon biomass use.

The government of Canada's, ***Clean Energy for Rural and Remote Communities (CERRC),*** delivered through NRCAN is a program Yukon government, First Nation and IPP proponents are using to access planning and capital dollars in support of biomass heating.

Yukon government, First Nation governments and municipal governments have declared climate emergencies.

5.1 RISKS

5.1.1 Biomass Heating Greenhouse Gas Emissions

Biomass fuel has traditionally been considered nearly carbon neutral as an energy source. Carbon that is contained in biomass fuel was relatively recently absorbed from atmospheric carbon during the growth cycle of the fuel source (trees) and so is already accounted for in current atmospheric carbon balance. This differs from carbon in fossil fuels which has been trapped in geologic formations for millennia and is therefore considered a new source of carbon with respect to the atmospheric carbon balance. In theory, carbon emissions from biomass fuel combustion are absorbed by the next generation of trees, creating a closed carbon cycle and a net zero rate of carbon emissions.

However, a positive carbon emission rate is produced during secondary processes of this industry, such as harvesting, processing, transporting fuel and then reforestation efforts which are often dependent on fossil fuels. In recognition of this biomass fuel is now considered to be “low carbon” when harvested sustainably however there are significant challenges in accurately quantifying the true emission rates over the lifecycle of the fuel. For the purposes of calculations in this report, an emissions factor value of 0.065 kg CO_2/kg is carried. (adapted from Pembina, 2013)

The view that biomass is “low carbon” is coming under increased scrutiny due to a lack of consensus on how to accurately account biomass carbon emissions over the lifecycle of the fuel. The lifecycle carbon emission can vary widely depending on numerous project specific factors such as harvesting methods, processing methods, distance transported, combustion methods, regrowth methods, and the timeframe of the analysis.

Currently there is a wide variety of opinions on this matter. As this field and knowledge base matures, a consensus emission factor for biomass may emerge that could dramatically alter its understood effectiveness in reducing carbon emissions.

The generally accepted position nationally is that biomass fuel is a low carbon emitting renewable energy source, making it an effective path to reduce carbon emissions. However, if in the future the YG were to adopt a more conservative non-zero GHG emission rate for biomass, it could have a large and immediate effect on the industry and the technologies that are accepted for use in reducing GHG emissions.

5.2 OPPORTUNITIES

5.2.1 Government Building Heating Retrofits

In recent years, the Yukon Government has initiated several projects to retrofit existing Government-owned buildings with biomass heating systems in Whitehorse and Watson Lake. A similar policy should be considered that requires all new Government buildings to include a biomass heating plant as a baseline requirement of construction. This policy has been successfully implemented in the Northwest Territories to help drive demand for wood pellets and supporting biomass related services.

Update Note; in the time since the draft submission of this report the YG Strategic Initiatives Branch has launched an RFP requesting proposals to complete feasibility studies to implement Renewable Energy Heating Systems at 12 YG sites in Whitehorse, Dawson, Mayo and Haines Junction. At each site, the studies will investigate the options for District vs. Stand-alone systems and consider biomass as a leading option along with Geo-thermal, Geo-exchange, micro-hydro and air sourced heat pumps. The proposed sites and buildings represent a potential to offset 10 kt of GHG annually which if fully implemented would exceed Yukon’s 2030 carbon reduction commitments for Buildings of 8 kt.

6.0 ECONOMIC ANALYSIS

6.1 ASSUMPTIONS

To estimate the operating revenues and expenses for potential biomass facilities in the Yukon, several assumptions have been made, with all dollars in 2020 CAD. These include:

- Capital costs are for:
  - 3 MW_{th} DES stoker central heating plant
  - 1 MW_{th} DES stoker central heating plant
  - 0.8 MW_{th} containerized stoker central heating plant
  - 0.4 MW_{th} containerized stoker central heating plant
  - 0.025 MW_{th} single, residential unit
  - 30,000 tonne/ yr pellet mill.
- Capital costs include the cost of equipment.
- Assuming 8,760 hours/ yr, operating 60% of the time, and an 80% capacity factor for each facility.
- 30% moisture for chips, or 3.4 kWh/kg (Krajnc, 2015)
- 10% moisture for pellets, or 4.7 kWh/kg (Krajnc, 2015)
- Annual energy produced by the various sizes of facilities and feedstock required are:

Table 6-1: Energy Production Per Facility

Facility	kWh_{th}/ yr	tonnes woodchips/ pellets consumed (produced)
3 MW_{th} DES chips	13,140,000	3,865
1 MW_{th} DES chips	4,380,000	1,288
800 kW_{th} chips	3,504,000	1,031
800 kW pellets	3,504,000	746
400 kW pellets	1,752,000	373
25 kW_{th}	109,500	23
Pellet Mill	N/A	(30,000)

- Inflation is assumed at 2%, between Canada's target inflation range of 1% - 3% (Bank of Canada, 2020).
- Cost of debt is assumed at 5%.
- Discount rate is assumed at 5%.

- Debt amortization period is assumed to be 25 years.
- Building and equipment useful expected life is 20 – 40 years, as per table below:

Table 6-2: Facility and Equipment Lifespan

Equipment	Lifespan (years)
Boiler	20
Distribution Piping	40
Organic Rankine Cycle (ORC)	20
Building	40
Containerization & smokestack	40
Backup oil fired boiler	20
Bunker storage	40
Silo storage	40
Backup diesel generator	20
Pellet mill	20
Hammer mill	20
Pellet mill building	40
Pellet mill storage	40
Dryer	20
Screeners	20
Pellet mill generator	20

- Capital costs and assumptions are from Stantec subject matter experts (SMEs).
- 2.5% - 5% annual facility construction capital renewal costs (assumed 40 or 20-year lifespan), with capital renewal reserve fund accumulation beginning in the 1st year of service.
- Construction period is 1-year.
- For the purpose of the study, operation is assumed to begin in 2021.
- No escalation beyond inflation is assumed.
- $0 cost for utilities connection is assumed.
- $0 land purchase price, environmental remediation, etc. is assumed beyond the stated costs.
- No additional revenues or expenses are assumed other than those noted in the tables below.
- Debt payments begin in 2021.
- 50% of capital costs are assumed to be funded through government grants.
- $0 is assumed in operating grants.

- For the purpose of this study, $0 is assumed for GHG credits and other operating cost incentives, other than a carbon tax variance, which is assumed to be $0.107[3]/litre ($40/tonne) of fuel oil in 2021 and $0.1341/litre ($50/tonne) from 2022 onward. 32.75 litres of fuel oil is assumed required to produce 1 GJ of energy at an 80% efficiency factor.
- Revenue from the sale of thermal energy is assumed to be consistent with the cost of heating from fuel oil, at $0.15[3]/kWh based on the following calculation:

$$\frac{\$1.30}{1L\ fuel\ oil} * \frac{32.75L}{1GJ} * \frac{1GJ}{277.8kWh} = \frac{\$0.153}{kWh}$$

- Operating expenses include raw material costs, transportation costs, collecting, harvesting, chipping, loading, transportation and unloading, stumpage fee and return for profit and risk, energy costs, labour costs, and costs of chemicals & water, and ash disposal costs.
- Labour expense is assumed at a per-employee burden rate of $125,000/ yr, with the number of employees required per facility as detailed below:

Facility	# of FTE employees
3 MW_{th} DES	2
1 MW_{th} DES	1
800 kW_{th}	0.5
400 kW_{th}	0.5
25 kW_{th}	0

- Maintenance expenses include cost of spare parts, service, regular and preventive system maintenance, labour costs in maintenance. The frequency of breakdowns increases significantly with low quality fuel and is a notable concern for biomass systems. Maintenance costs are assumed at 1% annually. This does not account for the additional capital renewal maintenance assumed and noted in Appendix B Operating Expenditures – Imported Chips/ Pellets and Appendix C Operating Expenditures – Locally Produced Chips/ Pellets.
- Cost of chemicals and water is assumed at $5,000/ yr for the 3 MW_{th} and the 1 MW_{th} facilities, and $0 for the smaller biomass facilities.
- Insurance expense is assumed at 0.5% of total capital cost.
- Equipment costs are assumed at $0/ yr in addition to capital, capital renewal, and maintenance expenses.

6.2 CAPITAL COST

Capital cost estimates for various biomass facility size options are provided in the tables below, and include larger district energy systems (DES) for 3 MW and 1 MW facilities, as well as size options for 800 kW, 400 kW, and 25 kW facilities, and a 30,000 tonne pellet mill (presented in Section 6.5.1).

Table 6-3 Capital Cost - 3 MW_{th} DES, Stoker Central Heating Plant

Element	Cost	Comment
Boiler (Woodchip)	$2,000,000	20-yr life
Distribution Piping	$2,000,000	40-yr life
Installation	$1,000,000	20-yr life
Building	$1,000,000	40-yr life
Soft costs (engineering design, etc)	$500,000	40-yr life
Bunker storage	$250,000	40-yr life
Total Capital Cost	**$6,750,000**	

Table 6-4 Capital Cost - 0.8 MW_{th} Containerized Stoker Central Heating Plant

Element	Cost	Comment
Boiler **(woodchip or pellet)**	$310,000	20-yr life
Installation	$60,000	20-yr life
Containerization & smokestack	$120,000	40-yr life
Soft costs (engineering design, etc)	$180,000	40-yr life
Silo storage	$130,000	40-yr life
Total Capital Cost	**$800,000**	

Table 6-5 Capital Cost - 0.025 MW_{th} Single, Residential Unit

Element	Cost	Comment
Boiler (pellets) & smokestack	$20,000	20-yr life
Installation & engineering	$10,000	20-yr life
Storage (with automatic feed)	$10,000	40-yr life
Total Capital Cost	**$40,000**	

Table 6-6: Capital Cost - 1 MW_{th} DES, Stoker Central Heating Plant

Element	Cost	Comment
Boiler (Woodchip)	$667,000	20-yr life
Distribution Piping	$400,000	40-yr life
Installation	$200,000	20-yr life
Building	$334,000	40-yr life
Soft costs (engineering design, etc)	$167,000	40-yr life
Bunker storage	$83,000	40-yr life
Total Capital Cost	**$1,851,000**	

Table 6-7: Capital Cost - 0.4 MW_{th} Containerized Stoker Central Heating Plant

Element	Cost	Comment
Boiler **(pellet)**	$194,000	20-yr life
Installation	$60,000	20-yr life
Containerization & smokestack	$90,000	40-yr life
Soft costs (engineering design, etc)	$180,000	40-yr life
Silo storage	$98,000	40-yr life
Total Capital Cost	**$622,000**	

Table 6-8 Capital Cost - 30,000 Tonnes/yr Pellet Mill

Element	Cost	Comment
Pellet Mill	$1,500,000	20-yr life
Hammer Mill	$750,000	20-yr life
Building	$500,000	40-yr life
Storage	$500,000	40-yr life
Dryer	$250,000	20-yr life
Screeners	$250,000	20-yr life
Total Capital Cost	**$3,750,000**	

6.3 OPERATING EXPENDITURES USING LOCALLY PRODUCED PELLETS/CHIPS

Operating revenues and expenditures using imported woodchips or pellets for the various size options are detailed in Appendix B Operating Expenditures – Imported Chips/ Pellets below, for locally produced woodchips or pellets in Appendix C Operating Expenditures – Locally Produced Chips/ Pellets, and for a 30,000 tonne/ yr pellet mill in Appendix D Operating Expenditures – Pellet Mill, and utilize the following assumptions:

6.3.1 Biomass Facility

- Feedstock is woodchips for the 3 MW_{th} DES, 1 MW_{th} DES, and 0.8 MW_{th-} chips size options.
- Feedstock is pellets for the 0.8 $MW_{th-pellets}$, 0.4 MW_{th}, and 0.025 MW_{th} size options.
- Cost of feedstock including transportation is $305/ tonne for imported woodchips and $396/ tonne for imported pellets.
- 50% of the above cost of imported feedstock is assumed to be attributed to the cost of transportation (i.e.: cost of feedstock only is assumed to be $152.50/ tonne for chips and $198 /tonne for pellets).
- Transportation costs for locally produced feedstock (both woodchips and pellets) is assumed at $3/ tonne.
- Auxiliary load requirement is assumed to be 5% of the facility's generated kWh/ yr, at an assumed expense of $0.11/ kWh.
- Labour expense is assumed at $125,000/ yr per FTE (full-time equivalent) employee. The number of employees per facility size is:

Facility Size	Number of FTEs
3MWth DES	2
1MWth DES	1
800kWth	0.5
400kWth	0.5
25kWth	0

- Chemicals and water expenses are assumed at $5,000/ yr for the 3MW DES and 1MW DES systems, and $0/ yr for the remaining options.
- Ash disposal expense is assumed as follows:

Facility Size	Ash disposal expense
3MW_{th} DES	$7,500
1MW_{th} DES	$2,500
800$kW_{th-chips}$	$2,000

800kW$_{th\text{-}pellets}$	\$1,500
400kW$_{th}$	\$700
25kW$_{th}$	\$45

- Annual maintenance expense, not including capital renewal, is assumed as follows:

Facility Size	Maintenance expense
3MW$_{th}$ DES	\$132,000
1MW$_{th}$ DES	\$44,000
800kW$_{th}$	\$36,000
400kW$_{th}$	\$18,000
25kW$_{th}$	\$1,000

- Insurance expense is assumed at 0.5% annually of the total capital cost for each size facility.
- Capital renewal is assumed at 2.5% for items with an assumed 40-year lifespan, and 5% for items with an assumed 20-year lifespan.
- Debt payments are based on 50% of the capital cost being grant-funded, the remaining cost funded through debt. The debt is assumed to have a 25-year amortization with annual payments at the end of period, and 3% interest on debt.
- Revenue from the sale of thermal energy (heat) is assumed at \$0.153/ kWh.
- As outlined in the *Yukon Government Carbon Price Rebate*, benefit from carbon tax variance is assumed to be \$0.107[3]/ litre fuel oil displaced in 2021, and \$0.1341/ litre in 2022 (Government of Yukon, 2019).

6.3.2 Pellet Mill

- Revenue for a 30,000 tonne/ yr pellet mill is based on the sale of 25,000 tonnes of pellets per year at \$198/ tonne.
- Feedstock expense is assumed at \$40/ tonne.
- 1.8 tonnes of feedstock are required to produce 1 tonne of pellets.
- Energy costs to operate the pellet mill are assumed as follows:

$$\frac{\$0.10}{kWh\ (industrial)} * \frac{1{,}740.4MJ}{tonne} * \frac{1{,}000{,}000kWh}{3{,}600{,}000MJ} * \frac{25{,}000tonnes}{year}$$

- Annual maintenance expense is assumed to be \$450,000.
- Insurance expense is assumed to be \$37,500/ yr.

Note that the annual cost of the displaced fuel oil that could alternatively be used for heating is shown in Table 6-11 (in Section 6.6.2) below.

6.4 NET PRESENT VALUE (NPV)

Table 6-9: 20- and 40-year NPV per option, with wood chips/ pellets produced locally

Description	NPV
20-year NPV: 3MW$_{th}$ DES	$10.3M
40-year NPV: 3MW$_{th}$ DES	$17.1M
20-year NPV: 1MW$_{th}$ DES	$3.1M
40-year NPV: 1MW$_{th}$ DES	$5.2M
20-year NPV: 0.8MW$_{th\text{-}chips}$	$3.8M
40-year NPV: 0.8MW$_{th\text{-}chps}$	$6.0M
20-year NPV: 0.8MW$_{th\text{-}pellets}$	-$3.9M
40-year NPV: 0.8MW$_{th\text{-}pellets}$	-$6.0M
20-year NPV: 0.4MW$_{th}$	-$2.6M
40-year NPV: 0.4MW$_{th}$	-$4.0M
20-year NPV: 0.025MW$_{th}$	-$0.1M
40-year NPV: 0.025MW$_{th}$	-$0.2M
20-year NPV: Pellet Mill	$17.6M
40-year NPV: Pellet Mill	$28.0M

Table 6-10: 20- and 40-yearNPV per option, with wood chips/ pellets imported

Description	NPV
20-year NPV: 3MW$_{th}$ DES	\$1.8M
40-year NPV: 3MW$_{th}$ DES	\$3.9M
20-year NPV: 1MW$_{th}$ DES	\$0.3M
40-year NPV: 1MW$_{th}$ DES	\$0.8M
20-year NPV: 0.8MW$_{th\text{-}chips}$	\$1.5M
40-year NPV: 0.8MW$_{th\text{-}chps}$	\$2.5M
20-year NPV: 0.8MW$_{th\text{-}pellets}$	-\$6.0M
40-year NPV: 0.8MW$_{th\text{-}pellets}$	-\$9.3M
20-year NPV: 0.4MW$_{th}$	-\$3.7M
40-year NPV: 0.4MW$_{th}$	-\$5.6M
20-year NPV: 0.025MW$_{th}$	-\$0.2M
40-year NPV: 0.025MW$_{th}$	-\$0.3M

6.5 IMPACT OF ECONOMIES OF SCALE FOR PELLETS NEEDED

6.5.1 Commercial Pellet Manufacturing

Currently, wood pellets consumed in Yukon must be brought in from outside the territory. As the current visions to increase biomass consumption in the territory are realized, interest in suppling this fuel source locally is always questioned. Like many industrial processes, the 'first' cost for installing all the infrastructure around a mill or process are typically quite high. Once these costs are accounted for, an incremental increase in capacity has a significantly lower cost. With this in mind, the installation of a new pellet mill in the territory would have to be planned around installed demand for the pellets with a sufficient quality to satisfy a business case. For most pellet mill operations, a minimum size is between 30,000 – 50,000, with most in the southern provinces targeting well above this capacity to ensure profitability.

The NWT has been pursuing the installation of a pellet mill in their territory as demand for pellets has increased over the years. Early studies in 2009, put the minimum capacity for economic viability at 30,000 tonnes/ yr, while the latest estimates surrounding the Aurora Wood Pellets plant in Enterprise, NWT put the potential size at 120,000 to 200,000 tonnes/ yr. The study *NWT Wood Pellet Pre-Feasibility Analysis* reviewed the pellet consumption in Yellowknife at the time, approximately 12,000 tonnes/ yr, and concluded although technically feasible to install a pellet mill matching this capacity, economics were challenging (BW McCloy & Associates Inc., 2009). Financial viability only improved at a capacity at or in excess of 30,000 tonnes/ yr, and is the capacity carried for this study's assessment.

As current demand for pellets in the Yukon is approximately 2,000 – 3,000 tonnes per year, the current market is too small for a large-scale commercial pellet operation. As the territory installs more containerized size units, increasing consumption by 400 – 800 tonnes/ yr each, and the market grows, a detailed study on the financial viability of a pellet mill in the 20,000 – 30,000 tonnes/ yr range should be explored. Having long term fuel contracts associated with the larger containerized installations will further support the pellet mill's development and business case, supplemented with potential residential customers.

6.6 FUTURE MARKET RATES

6.6.1 Fossil Fuels

Based on the historical average monthly cost of furnace oil in Whitehorse from 2007 – 2020 from the Government of Yukon Socio-Economic Web Portal (Yukon Bureau of Statistics, 2020) and from the variation in current fuel oil prices in the below communities from the *Yukon Fuel Price Survey September 2020*, (Yukon Bureau of Statistics, 2020), the future market rates and associated total displaced cost of fuel oil were assumed for low, expected, and high costs of fuel oil. The expected cost of fuel oil is assumed at $1.30/ litre, with the assumed low- and high-cost per litre being $0.90/ litre and $1.70/ litre, respectively. The variation in price was looked at over the following communities:

- Whitehorse
- Beaver Creek
- Burwash Landing
- Carcross
- Carmacks
- Dawson City
- Destruction Bay
- Faro
- Haines Junction
- Marsh Lake
- Mayo
- Pelly Crossing
- Ross River
- Stewart Crossing
- Tagish
- Teslin
- Watson Lake

6.6.2 COST COMPARISON OF BIOMASS AND FOSSIL FUELS FOR HEAT

The table below illustrates the potential annual consumption and cost of fuel oil that could be displaced for each of the various biomass facility sizes. The annual cost of displaced fuel oil assumes that 32.75 litres of fuel oil are required to produce 1 GJ of energy, and the assumed facility energy outputs as illustrated in the table below.

Table 6-11: Potentially Displaced Annual Consumption and Cost of Fuel Oil

Facility	Energy produced (GJ)	Fuel oil displaced (litres)	Cost of fuel oil (CAD/litre)	Annual cost of displaced fuel oil (CAD)
3 MW_{th} DES	47,300	1,549,075	$0.90	$1,390,000
			$1.30	$2,010,000
			$1.70	$2,630,000
1 MW_{th} DES	15,767	516,369	$0.90	$465,000
			$1.30	$671,000
			$1.70	$878,000
800 kW_{th}	12,613	413,076	$0.90	$370,000
			$1.30	$540,000
			$1.70	$700,000
400 kW_{th}	6,307	206,554	$0.90	$186,000
			$1.30	$269,000
			$1.70	$351,000
25 kW_{th}	394	12,904	$0.90	$10,000
			$1.30	$20,000
			$1.70	$20,000

Fuel oil for heating also carries a cost for carbon tax. This cost is assumed to go up to $0.1073/ litre on fuel oil in 2021, increasing to $0.1341/ litre in 2022.

Table 6-12: Potential Annual Consumption and Cost of Biomass Produced Locally

Facility	Energy produced (GJ)	Feedstock (tonnes)	Cost of chips/ pellets (CAD/tonne)	Annual cost of Feedstock
3 MW_{th} DES	47,300	3,865 woodchips	$100	$386,500
			$150	$579,800
			$200	$773,000
1 MW_{th} DES	15,767	1,288 woodchips	$100	$128,800
			$150	$193,200
			$200	$257,600
800 $kW_{th-chips}$	12,613	1,031 woodchips	$100	$103,100
			$150	$154,700
			$200	$206,200
800 $kW_{th-pellets}$	12,613	746 pellets	$130	$97,000
			$165	$123,100
			$240	$179,000
400 kW_{th}	6,307	373 pellets	$130	$48,500
			$165	$61,500
			$240	$89,500
25 kW_{th}	394	23 pellets	$130	$3,000
			$165	$3,800
			$240	$5,500

Producing heat from a local biomass source would reduce the Yukon's dependence on fossil fuel imports and shift from funds being spent outside the Yukon and Canada to dollars invested within the local economy.

6.7 ECONOMIC COST OF THE LOST OPPORTUNITY IF NO BIOMASS INDUSTRY IN YUKON

In addition to providing benefits such as:

- energy security,
- economic diversification,
- environmental improvements through reduction in GHG emissions,
- regional and community pride,
- an option for off-grid energy supply, and
- a productive use for beetle-killed and fire management plan cut trees,

An active biomass industry in the Yukon would additionally provide economic benefits in the form of employment opportunities. For example, a single 3 MW_{th} DES facility is assumed to require 2 full-time equivalent (FTE) positions, at an assumed average cost of labour of $125,000 per FTE. Creating such local employment opportunities within the Yukon would both contribute to decreasing unemployment in the Yukon and increase the need for skilled labour jobs locally.

Furthermore, using the 2016 within-territorial multiplier showing the total sum of the direct, indirect, and induced effects from the project are shown in the table below for both the capital and annual operating costs assumed utilizing locally sourced woodchips and pellets.

Table 6-13: Economic Opportunity Per Facility, Local Production

Facility	Description	Total Multiplier	Effect (CAD)
3 MW_{th} DES	Effect of capital cost of non-residential construction industry on GDP within the Yukon	0.735	$5,000,000
	Effect of capital cost of non-residential construction industry on labour income within the Yukon	0.365	$2,500,000
	Effect of capital cost of non-residential construction industry on taxes on production within the Yukon	0.012	$80,000
	Effect of annual operating expenditures of forestry and logging industry on GDP within the Yukon	0.700	$770,000
	Effect of annual operating expenditures of forestry and logging industry on labour income within the Yukon	0.335	$370,000
	Effect of annual operating expenditures of forestry and logging industry on taxes on production within the Yukon	0.012	$10,000
1 MW_{th} DES	Effect of capital cost of non-residential construction industry on GDP within the Yukon	0.735	$1,400,000
	Effect of capital cost of non-residential construction industry on labour income within the Yukon	0.365	$700,000
	Effect of capital cost of non-residential construction industry on taxes on production within the Yukon	0.012	$20,000
	Effect of annual operating expenditures of forestry and logging industry on GDP within the Yukon	0.700	$290,000
	Effect of annual operating expenditures of forestry and logging industry on labour income within the Yukon	0.335	$140,000
	Effect of annual operating expenditures of forestry and logging industry on taxes on production within the Yukon	0.012	$5,000

800 $kW_{th\ chips}$	Effect of capital cost of non-residential construction industry on GDP within the Yukon	0.735	$590,000
	Effect of capital cost of non-residential construction industry on labour income within the Yukon	0.365	$290,000
	Effect of capital cost of non-residential construction industry on taxes on production within the Yukon	0.012	$10,000
	Effect of annual operating expenditures of forestry and logging industry on GDP within the Yukon	0.700	$200,000
	Effect of annual operating expenditures of forestry and logging industry on labour income within the Yukon	0.335	$95,000
	Effect of annual operating expenditures of forestry and logging industry on taxes on production within the Yukon	0.012	$3,000
800 kW_{th} pellets	Effect of capital cost of non-residential construction industry on GDP within the Yukon	0.735	$590,000
	Effect of capital cost of non-residential construction industry on labour income within the Yukon	0.365	$290,000
	Effect of capital cost of non-residential construction industry on taxes on production within the Yukon	0.012	$10,000
	Effect of annual operating expenditures of forestry and logging industry on GDP within the Yukon	0.700	$190,000
	Effect of annual operating expenditures of forestry and logging industry on labour income within the Yukon	0.335	$90,000
	Effect of annual operating expenditures of forestry and logging industry on taxes on production within the Yukon	0.012	$3,000
400 kW_{th}	Effect of capital cost of non-residential construction industry on GDP within the Yukon	0.735	$460,000
	Effect of capital cost of non-residential construction industry on labour income within the Yukon	0.365	$230,000
	Effect of capital cost of non-residential construction industry on taxes on production within the Yukon	0.012	$10,000
	Effect of annual operating expenditures of forestry and logging industry on GDP within the Yukon	0.700	$120,000
	Effect of annual operating expenditures of forestry and logging industry on labour income within the Yukon	0.335	$57,000
	Effect of annual operating expenditures of forestry and logging industry on taxes on production within the Yukon	0.012	$2,000

25 kW_{th}	Effect of capital cost of non-residential construction industry on GDP within the Yukon	0.735	$29,000
	Effect of capital cost of non-residential construction industry on labour income within the Yukon	0.365	$15,000
	Effect of capital cost of non-residential construction industry on taxes on production within the Yukon	0.012	$500
	Effect of annual operating expenditures of forestry and logging industry on GDP within the Yukon	0.700	$5,000
	Effect of annual operating expenditures of forestry and logging industry on labour income within the Yukon	0.335	$2,000
	Effect of annual operating expenditures of forestry and logging industry on taxes on production within the Yukon	0.012	$80
Pellet Mill	Effect of capital cost of non-residential construction industry on GDP within the Yukon	0.735	$2,800,000
	Effect of capital cost of non-residential construction industry on labour income within the Yukon	0.365	$1,400,000
	Effect of capital cost of non-residential construction industry on taxes on production within the Yukon	0.012	$45,000
	Effect of annual operating expenditures of forestry and logging industry on GDP within the Yukon	0.700	$2,400,000
	Effect of annual operating expenditures of forestry and logging industry on labour income within the Yukon	0.335	$1,200,000
	Effect of annual operating expenditures of forestry and logging industry on taxes on production within the Yukon	0.012	$42,000

7.0 SOCIAL CONSIDERATIONS

7.1 RISKS

In some populations in Yukon there is a negative perception surrounding the use of biomass. The negative attitudes are primarily urban and are related to harvesting techniques (clear cutting), concern for the environment and loss of habitat, and air pollution and aesthetics. There is a lack of social license even though Yukoners have been heating with biomass since before European contact and there is concern with larger scale biomass harvesting. Better communication explaining the industry is needed.

7.2 OPPORTUNITIES

Biomass is a locally available renewable resource. All Yukon communities are situated in the boreal forest. The industry can create jobs in Yukon communities. The impact on employment will mostly be in the communities (outside of Whitehorse) where suppliers will need to hire local people to harvest the fibre. Biomass creates an opportunity for local generation and distribution in which communities can have their own plant, use their own resources, and create employment for local residents. Teslin is a good example of this opportunity.

Unlike fossil fuels biomass does not contribute to climate change. The use of biomass will decrease Yukon’s reliance on imported fossil fuels and create energy security. Being locally accessible biomass offers the possibility of stable, cost effective fuel that is clean, creates jobs, decreases Yukon’s carbon footprint, helps maintain healthy forests and decreases the risk of forest fires near communities.

The growth of the biomass industry in Yukon will need to be influenced by a development framework that includes incentives, policies and regulations that encourage investment in biomass energy and protection of the environment. This can lead to social sustainability of the industry.

8.0 TECHNOLOGICAL CONSIDERATIONS

8.1 RISKS

8.1.1 Wood Chip Fuel Quality

The main disadvantage of using chips is that they have variable quality, which can contribute to higher stack emissions (higher than pellets, but lower than cordwood) and maintenance problems that can lead to overall system failures. During reviews of woodchip boiler systems that are currently in operation in the Yukon, it was found that many operational challenges have been encountered related to the quality of chips. The main variables that affect wood chip quality are moisture content, chip size, and contaminants.

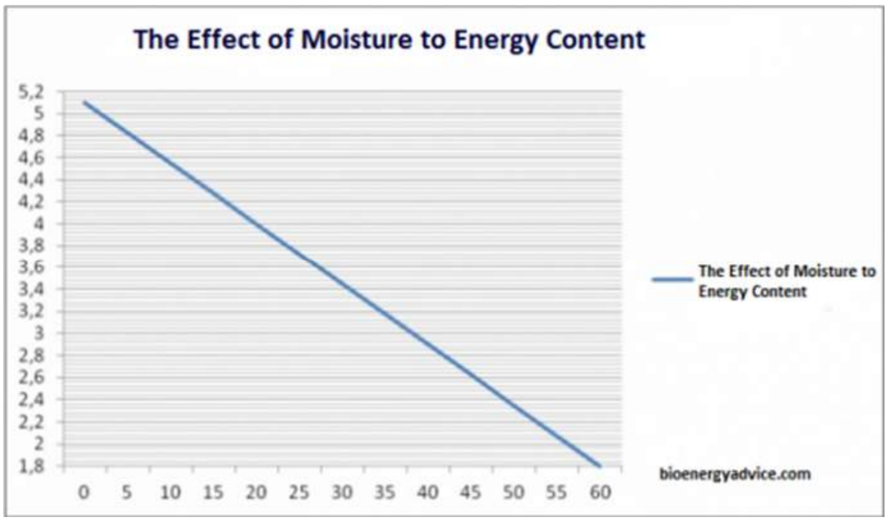


Figure 8-1 - Effect of Moisture on Energy Content

Moisture content is controllable by allowing sufficient time for the fuel to dry before use. Wood chips with high moisture content are detrimental for a number of reasons. Higher moisture content equates to higher density of fuel which introduces new challenges in transporting and delivering higher mass loads and causes more clogging of fuel handling equipment. High moisture content fuel causes incomplete combustions in the burn chamber and results in a reduction in boiler emission quality. The energy output of biomass fuel is also proportional to the moisture content as shown in Figure 8-1 where the vertical axis represents energy content in kWh/kg and the horizontal axis represent percent moisture content.

Wood chip size is generally controllable through the choice of woodchipper. Common types of woodchippers include: drum, disc, and screw chippers. Drum chippers are generally unsuitable for this application due to high variability in chip sizes. Disc chippers produce uniform sized chips but have limited output capacity and cannot accept larger feedstock. Screw chippers are preferred for this application due to their uniform chip size and large throughput capacity. Challenges have been encountered with this type of chipper at the Dawson City District Heating System where dried logs cause the screw blades to quickly become dull, requiring them to be sharpened at the manufacturer's factory in Europe at high cost to the fuel supplier.

Contaminants in the fuel supply can be considered improperly sized biomass, including fines, sticks, off-spec chips, etc., as well as any other materials that may find its way into the feedstock during processing (metals, bolts, tools, and garbage as examples). Contaminants represent a significant maintenance and operational issue if not controlled. Business cases for the any project include routine maintenance as part of their assessment, but force outages, equipment damage, and general wear and tear caused by contaminants pose serious and proven operational risks to the operation.

These risks can be controlled and managed through the fuel supply contract procurement process by carefully defining the minimum standard of fuel quality and diligently enforcing these standards.

8.2 OPPORTUNITIES

8.2.1 Condensing Biomass Boilers

Biomass heating and power generating technology has advanced substantially in recent decades due to a renewed interest in biomass as a clean and renewable energy source. As the growth in demand continues, research and development in the field of biomass energy can be expected to advance as well.

Improvements to energy efficiencies can be expected as combustor technology improves. Many boiler manufacturers offer condensing boilers that pass flue gases through a secondary heat exchanger to improve heat capture and achieve efficiencies of up to 99% under certain circumstances. These boilers are available for use in other parts of the world but have not yet been approved for use in Canada. Introducing these boilers will offer an incremental improvement of 15% to 20% efficiency which will improve cost effectiveness relative to competing energy forms but should not be expected to produce a major disruption to the industry.

8.2.2 Particulate Emission Capture

Advancements in emissions capture technology will help address the rise in particulate emissions that will result from increased biomass energy use. Electrostatic Precipitators (ESPs) are widely use in industrial applications to remove pollutants from flue gases. ESPs use an electrostatic field to attract particles to collection plates for removal and safe disposal. Modern ESPs can reach collection efficiencies of up to 99.9% at particle sizes of 1 μm and larger. The currently available ESPs are large and expensive and generally impractical for small and medium sized systems. Approximate unitary cost ranges for large-scale Wet ESP systems are provided in the EPA Air Pollution Control Technology Fact Sheet (EPA) in $/cfm of exhaust product flow as follows:

- Capital Cost: $40 to $200/ cfm
- O&M Costs: $6 to $10/ cfm annually.
- Annualized Cost: $12 to $46/ cfm.
- Cost Effectiveness: $65 to $660/ ton removed.

The effective flow range for this type of ESP is 1,000 cfm to 100,000 cfm. For reference a Viessmann Vitoflex 300-UF, 720kW boiler produces a fuel gas volume flow rate of 1,020 cfm.

Miniaturized ESPs that are suitable for small commercial and residential applications are beginning to enter the market, such as the “OekoTube” but not yet widely available. As this technology advances and pricing becomes more favorable, it may offer an effective method to reduce particulate emissions from wood burning systems.

9.0 ENVIRONMENTAL CONSIDERATIONS

9.1 RISKS

9.1.1 Particulate Emissions

In recent years with a growing concern of the impact of climate change, a new emphasis is being placed on clean and environmental sustainability energy options and biomass heating has reemerged as a strong option. Along with the focus on low GHG energy, air quality and energy system particulate emissions has come under scrutiny. The Air Quality Index (AQI) tracking in Yukon is relatively new, and historical AQI data is currently unavailable however, with the onset of global climate change and the increased risk of forest fires, local AQI conditions are now being recorded and forecasted using satellite image modelling. In 2012, the Yukon Government committed to implement the Canada-wide Air Quality Management System (AQMS) which aims to manage the quality of local air zones. Many jurisdictions including Whitehorse are now requiring all new wood stoves to be EPA certified which evaluates and certifies wood stoves that meet minimum efficiency and particulate emission standards.

Particulate emission rates from biomass combustion can vary widely depending on the species of wood, moisture content, burn temperature, and oxygen present during combustion. Temperature and oxygen are controllable through proper design of the fuel feed and combustion systems. Species and moisture content are generally more variable and controlled through the fuel supply chain. As outlined in an article titled *Particulate Matter Emissions Factors for Biomass Combustion*, $PM_{2.5}$ emission rates from fireplace and wood stove burning ranged from a low of 6.2 g/kg for olive wood to a high of 20.20 g/kg for eucalyptus (Simone Simoes Amaral, 2016). By comparison, $PM_{2.5}$ emissions from compacted wood pellets in a controlled combustor is 0.24 g/ kg (Simone Simoes Amaral, 2016). As discussed in section 8.2.2, advancements in particulate capture will help reduce the health and environmental impacts of increased use of biomass energy.

9.1.2 Environmental Impact of Fuel Switching

Most forest activities produce impacts and increased forest harvesting and fuel management and abatement is no exception. Here are areas of concern:

- **Wildlife impacts.** Changes in forest cover affect various species differently. Since the prescription is to change the forest type - not to deforest any site – the main wildlife impacts will be to change the mix of species. Closed canopy spruce and pine have less species diversity compared with mixed stands. A closed canopy of pine and spruce favor wildlife species that feed on pine and spruce seeds, bark, and buds. Common examples include red squirrels (and their predators), grosbeaks, cross bills, siskens, and chickadees. Open stands are generally more conducive to species such as moose, caribou, and deer. Moose, deer, and elk respond to increases in deciduous browse. Woody biomass left behind after forest harvesting, or FireSmart activities and standing dead trees provide crucial habitat for a wide variety of species. Mitigation options for addressing impacts of increase forest harvesting and fuel abatement include the implementation of green tree and coarse woody debris retention targets and setting maximum forest removal standards.

- **Road Access.** The second most influential cause of impacts that affect wildlife is increased vehicle access over logging trails. Although off-road vehicles are a recreational activity, they impact other recreational uses as well as wildlife. It is generally desirable to decommission road access to treated stands and to devise a vehicle access management plan that provides effective and fair rules for vehicle activities of all kinds.
- **Drying of surface**. The efficacy of fuel abatement is sometimes challenged by claims that opening a stand will dry the surface, actually increasing the fire hazard. Drying can occur in conifer stands that have been limbed and thinned. However, if surface fuels have been removed, it is less likely to support a surface fire. In addition, thinning will reduce the risk of a crown fire particularly if trees are well spaced (eg. canopy limbs no closer than 3 meters). This concern of increased fire hazard from opening a stand has some validity for some local treatments if trees remain too closely spaced. Wood debris is also critical to maintaining soil quality. Increased harvesting that would likely result from widespread adoption of wood biomass could result in depletion of soil quality especially if large volumes of biomass are removed from the same site over multiple harvest times.
- **Impacts on Recreation.** Most areas adjacent to settlement have recreational trails, both formal and ad hoc. FireSmart treatments will certainly change the number and ambiance of trails. FireSmart activities will result in a conversion from coniferous to deciduous or mixed stands in some locations. In time a growing aspen cover will create a different but acceptable aesthetic. Careful discussions and public engagement are needed to minimize these impacts.
- **Visual disruption.** The periphery of most or all neighborhoods merit fuel management, affecting the visual character of Whitehorse's and other community boundary zones. It is important to acknowledge this while emphasizing that fuel management prescriptions do not involve creating permanent clear-cuts. The objectives are a reduction in fire hazard through fuel abatement and stand conversion aspen, mixed wood and open mature pine stands.

With these considerations in mind, the Yukon Government should take a lead in messaging to the public with a focus on the following points:

- Necessity and Effectiveness of FireSmarting (fuel management) activities
- Wildlife impacts
- Road and Access management
- Aesthetics and management of treated areas.
- ESCOs and conversion of public buildings to wood chip heating
- Emergency measures and evacuation plans.

9.2 OPPORTUNITIES

9.2.1 Greenhouse Gas Emission Reduction

As previously discussed in section 5.1.1 above, the rate of greenhouse gas emissions from production of biomass energy is critically important in determining the effectiveness of this energy source reducing greenhouse gas and helping to address the climate change crisis. If the GHG emission rate from biomass is accepted to be essentially zero, as discussed in section 5.1.1, then biomass energy would be effective at offsetting GHG emissions in the Territory and allow a path to reaching the 2030 goal of 30% reduction in GHG emissions relative to the 2010 emissions rates.

The *Our Clean Future* action plan identifies Road Transportation and Building Heating Systems as the two largest emitting sectors which account for 54% and 21% of territorial emissions respectively. The action plan commits to a 40% reduction in home heating energy using a combination of energy efficiency improvements to new and existing buildings and leveraging renewable heating energy, such as biomass heating and electrical heat pumps using hydro, wind, solar, and biomass electrical sources.

In the action plan, the Government of Yukon commits reducing Greenhouse Gas emissions from Buildings by 8 kt by 2030. Based on The Climate Registry emission rate of Light Residential Fuel Oil (2753 $gCO2_{2}$/L), approximately 2.9 million L of heating oil would need to be offset annually (The Climate Registry , 2020). An equivalent energy output to this volume of heating oil would be approximately 7,600 t/ yr of wood pellets, or 11,446 t/ yr of wood chips at 35% moisture content without considering emissions from harvesting, processing, or transportation.

9.2.2 Availability of Waste Wood

As discussed in section 2.5, several streams of waste wood are potential sources of biomass fuel material, including:

- Waste wood from FireSmarting operations;
- Waste wood from highway development and clearing, and industrial activities such as mining and aggregate resource development; and
- Waste wood from insect infested and fire kill stands.

These sources of fuel present several opportunities that will benefit the local fuel suppliers and support growth of the local industry. Waste wood harvested during fire clearing, FireSmart activities and highway clearing and construction activities is typically collected at the roadside and made available to residents as a free source of cordwood for home heating. These sources could be integrated into the commercial biomass fuel supply chain as a low-cost source of raw material. Providing ownership rights over the harvested materials to the harvesting contractor for processing and sale as wood chip fuel is an option. However, discussions with local harvesting service providers suggest that this model on its own will not be fully self-sustaining due to the high cost of log removal, transport, and processing that is required to capitalize on the additional revenue stream.

10.0 LEGISLATIVE CONSIDERATIONS

Key legislation affecting Forest management include: *Territorial Lands (Yukon) Act*, Yukon Timber Regulations, *Timber Harvest Planning and Operating Guidebook* (INAC), and *Species at Risk Act*.

Forest management planning on public lands is guided by strategic FRMPs, TSAs, timber harvest plans, and site plans. The FRMP is developed at a landscape level and provides a guide to forest planners and managers in how they will develop future resource development and planning. The FRMP provides an integrated forest planning framework to guide forest management activities at the broad scale. A TSA is completed as part of this process. The TSA requires inputs as forest inventory, growth and yield data and management assumptions identifies broad areas available for forest development. Timber harvest plans are operational plans guided by the SFMP and TSA. The timber harvest plans identify and describe forest resources, ecosystems and health, timber volumes and outlines harvesting schedule and methods. Site plans are localized plans that identify stand level management activities, methods of timber harvesting, environmental protection, and silviculture obligations.

10.1 FOREST RESOURCES ACT

Forest harvesting in the Yukon is governed by the *Forest Resources Act (FRA)*, exceptions being cutting wood for personal use (e.g., for cooking or heating) or removing timber by the extractive industry under the *Quartz Mining Act*, *Placer Mining Act*. The purpose of the FRA is to promote sustainable uses of forest resources in Yukon. Cutting is also allowed under *Territorial Lands (Yukon) Act*.

Yukon's *FRA* contains requirements for completing Regional Forest Management Plans that reflect local social, economic, and environmental values, setting sustainable Annual Allowable Cut (AAC) levels, and establishing secure timber harvest tenures.

Forest tenures under FRA include:

- Timber Resource License

  Timber Resource Licenses are issued for harvesting of timber for commercial purposes and have a term up to 10 years, renewed for one additional term, subject to approval by the Yukon Government.

- Fuel Wood License

  Fuel Wood Licenses are required to harvest fuel wood for commercial purposes. Licenses allow a maximum volume of 20,000 m^3 to be harvested. The maximum term is five years renewed for one additional term, subject to approval by the Yukon Government.

- Woodlot License

  A woodlot license is issued for a maximum 10 years with an option to renew and allows the right to harvest in areas less than 3,000 ha.

- Forest Resource Permit

Forest Resource Permits are issued to harvest timber or fuel wood for personal use or harvesting of non-timber resources for commercial purposes. They can be issued for a maximum of three years and are not renewable or assignable.

- Cutting Permit

Cutting Permits may be issued to a commercial license holder with an approved timber harvest plan and site plan. They have a maximum term of three years.

10.2 PROTECTED AREAS LEGISLATION

In the Yukon, land can be protected by any one of several pieces of legislation including the *Parks and Land Certainty Act*, *Environment Act*, *Wildlife Act (Statutes of Yukon 2002c)*, *Inuvialuit Final Agreement*, and Yukon First Nation Agreements. Federal legislation that applies in Yukon includes the *Canada Wildlife Act*, *Species at Risk Act*, and *Canada National Parks Act*. This Protected Areas legislation affects the land that can be devoted to the harvest of trees for biomass.

11.0 RECOMMENDATIONS

The following recommendations have been identified and highlighted based on the outcomes of research and analysis in preparing this report. These recommendations are compiled from multiple sources including stakeholder interviews, research of relevant publications, and the results of our economic analysis of biomass development options.

1. Prioritize the installation of biomass heating systems in new and existing Yukon Government facilities.

   To achieve the Yukon Government's 2030 GHG target of emissions 30% below 2010 rates, all new building projects should at the outset include a feasibility review of applying biomass as the primary energy source with an appropriate backup heating system utilizing conventional fuels. Additionally, retrofitting existing buildings with biomass burning systems will help reduce the existing carbon emissions rates. Prioritizing larger scale retrofits using district and large stand-alone systems in the range of 800 kW and up are presenting a more cost-effective route to achieving targets. Larger scale projects are also expected to present a more time-efficient route with larger retrofit projects being similar in duration but more impactful than smaller capacity projects. Initial installations should utilize imported woodchips to achieve a suitable level of fuel security as needed with a view to transition to locally produced fuel to take advantage of the cost savings, GHG emissions savings and economic benefits available from local fuel production.

   Government leadership in developing the demand market for biomass fuel will encourage growth in the local fuel supply capacity through private sector investment and entrepreneurship. This will also serve to develop the supporting services market, including equipment suppliers and service technicians and help to reduce the perception of risk to private building developers.

2. Provide incentives for development of local woodchip producers.

   Through the stakeholder interview process it was learned that while significant biomass fibre can be made available as a byproduct of FireSmarting, there remain significant challenges to rapid growth in the fuel supply market:

   - Lack of significant primary wood industry in Yukon increases cost structure relative to southern suppliers,
   - Wood supply is often difficult to access and often not available in locations required for processing and drying,
   - Current supply contracts and harvesting permits are short term,
   - Storage requirements for 1-year wood drying time before delivery to customer.

   When considered in combination, these factors will out-weigh the opportunity of 'free' wood fiber that would be available to local fuel producers. It is expected that additional incentives will be needed during the initial growth phase. These may take the form of:

- Supply contracts with benefits or weighted awards based on shipping distances to incentivize local suppliers and shorter shipping distances,
- Supply contracts based on GJ delivered rather than volume or mass to incentivize proper fuel drying and therefore a more efficient fuel with lower particulate emissions,
- FireSmart harvesting contracts with additional incentives for participation in the biomass fuel supply chain,
- Direct financial investment in the form of grants or tax write-offs for the purchase of fuel production systems during the initial establishment phase.

3. <u>Prioritize advanced study of wood pellet manufacturing infrastructure when pellet demand exceeds 30,000 t/ yr.</u>

   A wood pellet mill in Yukon will provide a local source of wood pellets that offer benefits to the local economy, increased local fuel security, and reduced costs and GHG emissions from shipping distances. The economic model presented in section 6.0 of this report indicates favorable return on investment for the installation of a 30,000 t/ yr pellet production mill. The anticipated annual pellet sales required for net positive cash flow is between 30,000 t/ yr and 50,000 t/ yr. The current estimated annual demand for pellets in Yukon is 2,000 to 3,000 t/ yr. A pellet mill in Yukon would also be well placed to serve the growing demand for wood pellets on the Dempster highway in the Northwest Territories, specifically Inuvik which currently has an estimated annual demand of approximately 3,000 t/ yr from commercial scale biomass plants without accounting for residential demand. It is recommended that a detailed feasibility study be completed to assess the updated economic conditions in 2030 at which point the annual biomass fuel demand is expected to have grown to between 25,000 and 30,000 t/ yr.

4. <u>Provide programs for training of heating plant operators and fuel processing technicians.</u>

   Investments in the education and training of operators and service technicians for both heating plants and fuel processing equipment is critical for the success of the overall industry. Biomass plants, especially wood chip fired plants are more complex than traditional oil and gas heating plants and require more maintenance and repair. The economic viability of these systems depends on avoiding extended periods of downtime. As discussed in section 2.3.3 of this report, this industry in Yukon has experienced several false starts with early biomass installations during the 1980s, largely attributed to equipment failures, failures due to low fuel quality, and general fuel shortages. This has resulted in a lingering negative sentiment in the community. To maintain a public support for this initiative, it will be important to demonstrate these systems as effective, efficient, and reliable for which high quality fuel and proper equipment maintenance is key.

   Basic heating plant operator training is typically provided by the equipment vendors during the system commissioning, however additional training is often available through the vendor and should be arranged regularly to allow continuing education on current operating methods.

5. <u>Communicate the benefits of biomass energy to the public.</u>

   The Yukon Government has made a commitment to reducing GHG emission by 263 kt/ yr using a series of initiatives detailed in the *Our Clean Future* report published in September 2020. Among these, the YG committed to continue public education events and campaigns to raise awareness of the benefits of electric vehicles. Similarly, to help achieve public support for an extensive investment in biomass energy, public education events and information sessions should be arranged. During these events, discussions should focus on the need for energy security, the opportunities for local employment, sustainable forest management practices, greenhouse gas emissions, reliability of modern biomass heating technology, and heating cost effectiveness of modern systems. These events could also provide education on operation and maintenance of residential wood heating systems to help improve fuel efficiency and reduce particulate emissions.

12.0 CONCLUSION

This report provides an analysis of the biomass industry in Yukon, its benefits, the potential for growth and a critical investigation into the biomass industry as it currently operates in Yukon and provide projections of future growth. The approach utilized in this report was to identify internal and external influences and risks to the industry from Political, Economic, Social, Technological, Legal and Environmental (P.E.S.T.L.E.) utilizes.

The findings of this study show numerous benefits that can be gained from a strong and growing biomass industry. This report investigates the benefits as well as the risk and barriers to growth. The primary driving factor is the environmental benefits that biomass offers as an alternative to fossil fuel energy. The low carbon emissions of biomass fuel offers one of few viable avenues to achieve the 2030 GHG reduction commitments in the *Our Clean Future* strategy. The economic analysis conducted on biomass heating plants of various size and configuration has generally shown that financial return on investment is unlikely to be favorable in comparison to fossil fuel and electricity-based alternatives, large heating plants over 800kW fueled using locally produced wood chips begin to show positive net present value. Based on this, financial returns should not be considered as the main driving factor while advancing this industry. A locally established wood pellet mill presents favorable economic returns once the minimum expected threshold of 30,000 t/yr of demand has been reached which is expected to occur when the *Our Clean Future* carbon reduction targets are met, assuming they are met primarily through fuel switching to biomass.

A sustainable supply of biomass fuel is readily available in Yukon. The annual allowable cut is approximately 146,000 t/yr across the territory of which only 10% is utilized. This in addition to residual wood sources from FireSmart activities, tree clearing for development of highways, mines and construction projects, and the standing dead from forest fires and insect kill far exceed the demand projections over the timeframe of this study. The forestry industry is currently underdeveloped and exists primarily for the purpose of supplying cordwood for residential wood stoves. Yukon lacks the benefit of a mature lumber industry that can offer support to a biomass fuel industry by supplying equipment, expertise, and inexpensive residual wood byproducts. There are opportunities to link the growth of the biomass fuel industry to the FireSmart activities to share resources and expertise.

The case study review of similar jurisdictions investigated the biomass industries in Northwest Territories, British Columbia, Quebec and PEI and the driving economic conditions that led to either advancement or stagnation of their biomass industries. Quebec and BC share a similar energy profile with low GHG hydroelectricity making up the vast majority of their electrical needs and inexpensive natural gas acting as the primary heating fuel. The incremental benefit of moving to biomass fuel in these regions is small in comparison to the cost and so Biomass has not been prioritized. NWT and PEI are more dependent on fossil fuels imported by truck and have been able to benefit from switching to low GHG biomass systems that are more cost competitive with conventional oil-fired systems. PEI also sought to utilize the residual byproducts of their existing forestry industry. The driving factors behind the successful conversion in these case studies are; a desire to move from heavy fossil fuels to a lower GHG alterative, high cost or limited availability of alternative low carbon energy sources, improved regional fuel security and economic benefits of locally produced fuel.

The stakeholder engagement process identified a number of risks and opportunities that should be considered. These include;

- There is believed to be social acceptance for renewable energy but lingering distrust for commercial scale biomass heating systems due to several failed projects in the past.
- There is a strong cordwood industry but otherwise no primary wood or lumber industries in Yukon as is seen in BC and Alberta.
- There are abundant forest resources available in Yukon, but social license may be rescinded if there is seen to be excessive damage to the forests.
- There is currently inadequate demand for biomass fuel to support growth of the supply industry.

A PESTLE analysis was completed to identify internal and external risks and opportunities to the growth of the industry. The following are highlighted discussions from the PESTLE analysis.

A Yukon Government policy to evaluate biomass heating systems for all new Government owned buildings and additional retrofits of large existing buildings will drive demand for cost effective fuel supplies. Further, if supply contracts were prioritized for local producers based on shipping distances, there would be stronger incentive for growth in the supply industry.

The carbon emission rates of biomass heating fuels are challenging to properly quantify and are variable depending on numerous site specific factors. The Yukon Government is working to quantify the emission rates of biomass fuel. For the purposes of calculations in this report, an emissions factor value of 0.065 kg CO_2/kg is carried (adapted from Pembina, 2013). However, if in the future the YG were to adopt a more conservative net-zero GHG emission rate for biomass, it could have a large and immediate effect on the industry and the technologies that are accepted for use in reducing GHG emissions.

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APPENDIX A

Stakeholder Interview Guide

Stantec

Meeting Notes

Stakeholder Interview

Yukon Biomass Lifecycle Analysis / 144902971

How to use this guide:

1. Create a copy of the master guide (this file).
2. Fill out the copy during your stakeholder interview.
3. Save the file for your record as meeting notes and future reference purposes.

Date/ Time: ____________________

Place: ____________________

Organization: ____________________

Name of representative: ____________________

Role: ____________________

Stantec attendees: ____________________

Background

"In this strategy, we will focus on increasing the use of wood and other forms of biomass energy in large commercial and government buildings with significant heating demand. Sustainably harvested biomass is a low-carbon and renewable energy source. It can help reduce our greenhouse gas emissions while supporting jobs in our local biomass industry and decreasing the risk of forest fires around Yukon communities."

-Our Clean Future: A Yukon strategy for climate change, energy, and a green economy

Purpose of this project

"Undertake an analysis that will provide an overview and critical analysis of the [biomass] industry, its benefits, and potential for growth."

-Project RFP

Purpose of these interviews

- To identify:
  - ways to help energy users switch to biomass
  - regulatory improvements to support the growth of the biomass industry
  - forest management practices to guide sustainable and low-carbon biomass harvesting
  - environmental benefits of the biomass supply chain in Yukon
  - economic benefits of the biomass supply chain in Yukon

Section A: Introductions

A1. About the Interviewee

Stakeholder category:

- ☐ Supplier of biomass - current
- ☐ Supplier of biomass - potential
- ☐ User of biomass - current
- ☐ User of biomass – potential

See user question below

Government
- ☐ Municipal
- ☐ First Nation
- ☐ Territorial

- ☐ Building owner
- ☐ Utility
- ☐ Independent Power Producer
- ☐ Private/ commercial

- ☐ Other:

A2. Connection to biomass industry

Q. How do you choose energy sources?

- ☐ Cost
- ☐ Sustainability
- ☐ Environmental impact
- ☐ Other:
- ☐ Local experience
- ☐ Existing infrastructure
- ☐ Reliability

Notes:

Q. Biomass users: How do you use biomass currently or would want to use it in the future?

- ☐ Traditional cordwood
- ☐ Sawmill residue
- ☐ Imported pellets
- ☐ Other:

Notes:

Q. How would you categorize your interest in the biomass industry?

- ☐ Economic
- ☐ Environmental
- ☐ Social
- ☐ Other:

Notes:

Q. Do you have experience with biomass <u>in</u> Yukon?

☐ Yes ☐ No ☐ Unsure ☐ N/A

Notes:

Q. Do you have experience with biomass <u>outside</u> of Yukon?

☐ Yes ☐ No ☐ Unsure ☐ N/A

Notes:

Q. Does Biomass fit into your short or long-term renewable portfolio?

☐ Yes ☐ No ☐ Unsure ☐ N/A

Notes:

Q Do you have plans to use, increase use, supply, or increase supply of biomass in the future?

☐ Yes ☐ No ☐ Unsure ☐ N/A
See question below

Notes:

If yes,

Q What would you need to be successful in that plan?
(e.g. economic incentives, regulatory change, tax relief, increase in supply)

Notes:

Section B: SWOT Analysis

Topics to consider:

- *resources and infrastructure*
- *local and export markets*
- *current biomass community (both successes and challenges)*
- *promotion and understanding of the market*
- *public/ government policy*
- *combustion technology*
- *boiler technical capability*
- *greenhouse gas reduction*
- *meeting international goals*
- *environmental consequence (both positive and negative)*
- *utilization of a previously unused resource (eg Fire-killed trees)*
- *local employment*
- *cost savings*
- *economic activities for isolated communities*
- *production capacity*
- *local skills and capacity*
- *availability and quality of feedstock*
- *government and private incentives and opportunities*

Q. What do you think are the STRENGTHS of the biomass industry in Yukon?

Q. What do you feel are the WEAKNESSES of the biomass industry in Yukon?

Q. Where do you see OPPORTUNITIES for the wood energy industry in Yukon?
Consider opportunities for: users, suppliers, Yukon government, First Nation governments, municipal governments.

Q. How do you feel about exploring alternatives to harvesting standing timber?
(e.g. biomass residues (e.g. treetops and branches) left near the roadside in harvested blocks, volume from standing dead trees, insect infestation areas, linear disturbances, silvicultural activities, land clearing activities, and disaster mitigation cutting activities)

Q. Where do you see potential THREATS OR BARRIERS to developing a wood energy industry in Yukon?
Consider barriers in regulation, policies, incentives, and also public perception.

Q. Do you have recommendations about how these barriers could be removed or overcome?

The meeting adjourned at ______ am/pm

The foregoing is considered to be a true and accurate record of all items discussed. If any discrepancies or inconsistencies are noted, please contact the writer immediately.

Stantec Consulting Ltd.

NAME credentials

Design with community in mind

APPENDIX B

Operating Expenditures – Imported Chips/ Pellets

Appendix B-1: Operating Expenditures - Imported Chips (3MW)

	Yr 1: 2021/22	Yr 2: 2022/23	Yr 3: 2023/24	Yr 4: 2024/25	Yr 5: 2025/26
Revenue					
carbon tax variance	166,217	207,732	211,887	216,124	220,447
Revenue from sale of thermal energy (heat)	2,010,420	2,050,628	2,091,641	2,133,474	2,176,143
Total Revenue	**$ 2,176,637**	**$ 2,258,360**	**$ 2,303,528**	**$ 2,349,598**	**$ 2,396,590**
Expenses					
operating costs		-	-	-	-
Feedstock - includes stumpage fee where appropriate	589,368	601,155	613,178	625,442	637,950
Transportation costs (imported)	589,368	601,155	613,178	625,442	637,950
Auxilliary load (energy costs)	72,270	73,715	75,190	76,694	78,227
Labour costs	250,000	255,000	260,100	265,302	270,608
Cost of chemicals + water	5,000	5,100	5,202	5,306	5,412
Ash disposal	7,500	7,650	7,803	7,959	8,118
maintenance	-	-	-	-	-
spare parts, material for regular and preventative system maintenance and labour	132,000	134,640	137,333	140,079	142,881
insurance	34,000	34,680	35,374	36,081	36,803
Total Expenses	**$ 1,679,505**	**$ 1,713,095**	**$ 1,747,357**	**$ 1,782,304**	**$ 1,817,951**
Net Income before Adjustment	**$ 497,131**	**$ 545,265**	**$ 556,170**	**$ 567,294**	**$ 578,639**
Adjustments:					
Debt Payment	193,819	193,819	193,819	193,819	193,819
Capital Renewal Reserved Fund- building, bunker storage, soft costs, distribution piping	93,750	95,625	97,538	99,488	101,478
Capital Renewal Reserved Fund- boiler, installation	150,000	153,000	156,060	159,181	162,365
NET CASH FLOW	**$ 59,562**	**$ 102,821**	**$ 108,754**	**$ 114,805**	**$ 120,978**

Appendix B-2: Operating Expenditures - Imported Chips (1MW)

	Yr 1: 2021/22	Yr 2: 2022/23	Yr 3: 2023/24	Yr 4: 2024/25	Yr 5: 2025/26
Revenue					
carbon tax variance	55,406	69,244	70,629	72,041	73,482
Revenue from sale of thermal energy (heat)	670,140	683,543	697,214	711,158	725,381
Total Revenue	**$ 725,546**	**$ 752,787**	**$ 767,843**	**$ 783,199**	**$ 798,863**
Expenses					
operating costs		-	-	-	-
Feedstock - includes stumpage fee where appropriate	196,456	200,385	204,393	208,481	212,650
Transportation costs (imported)	196,456	200,385	204,393	208,481	212,650
Auxillary load (energy costs)	24,090	24,572	25,063	25,565	26,076
Labour costs	125,000	127,500	130,050	132,651	135,304
Cost of chemicals + water	5,000	5,100	5,202	5,306	5,412
Ash disposal	2,500	2,550	2,601	2,653	2,706
maintenance	-	-	-	-	-
spare parts, material for regular and preventative system maintenance and labour	44,000	44,880	45,778	46,693	47,627
insurance	9,000	9,180	9,364	9,551	9,742
Total Expenses	**$ 602,502**	**$ 614,552**	**$ 626,843**	**$ 639,380**	**$ 652,167**
Net Income before Adjustment	**$ 123,044**	**$ 138,235**	**$ 141,000**	**$ 143,820**	**$ 146,696**
Adjustments:					
Debt Payment	53,149	53,149	53,149	53,149	53,149
Capital Renewal Reserved Fund- building, bunker storage, soft costs, distribution piping	24,600	25,092	25,594	26,106	26,628
Capital Renewal Reserved Fund- boiler, installation	43,350	44,217	45,101	46,003	46,923
NET CASH FLOW	**$ 1,944**	**$ 15,776**	**$ 17,155**	**$ 18,561**	**$ 19,995**

Appendix B-3: Operating Expenditures - Imported Chips (0.8MW)

	Yr 1: 2021/22	Yr 2: 2022/23	Yr 3: 2023/24	Yr 4: 2024/25	Yr 5: 2025/26
Revenue					
carbon tax variance	44,324	55,395	56,503	57,633	58,786
Revenue from sale of thermal energy (heat)	536,112	546,834	557,771	568,926	580,305
Total Revenue	**$ 580,436**	**$ 602,229**	**$ 614,274**	**$ 626,559**	**$ 639,091**
Expenses					
operating costs		-	-	-	-
Feedstock - includes stumpage fee where appropriate	157,165	160,308	163,514	166,784	170,120
Transportation costs (imported)	157,165	160,308	163,514	166,784	170,120
Auxillary load (energy costs)	19,272	19,657	20,051	20,452	20,861
Labour costs	62,500	63,750	65,025	66,326	67,652
Ash disposal	2,000	2,040	2,081	2,122	2,165
maintenance	-	-	-	-	-
spare parts, material for regular and preventative system maintenance and labour	36,000	36,720	37,454	38,203	38,968
insurance	4,000	4,080	4,162	4,245	4,330
Total Expenses	**$ 438,101**	**$ 446,863**	**$ 455,801**	**$ 464,917**	**$ 474,215**
Net Income before Adjustment	**$ 142,335**	**$ 155,366**	**$ 158,473**	**$ 161,643**	**$ 164,876**
Adjustments:					
Debt Payment	22,971	22,971	22,971	22,971	22,971
Capital Renewal Reserved Fund- building, silo storage, soft costs	10,750	10,965	11,184	11,408	11,636
Capital Renewal Reserved Fund- boiler, installation	18,500	18,870	19,247	19,632	20,025
NET CASH FLOW	**$ 90,114**	**$ 102,560**	**$ 105,070**	**$ 107,631**	**$ 110,243**

Appendix B-4: Operating Expenditures - Imported Pellets (0.8MW)

	Yr 1: 2021/22	Yr 2: 2022/23	Yr 3: 2023/24	Yr 4: 2024/25	Yr 5: 2025/26
Revenue					
carbon tax variance	44,324	55,395	56,503	57,633	58,786
Revenue from sale of thermal energy (heat)	1,930	1,968	2,008	2,048	2,089
Total Revenue	**$ 46,254**	**$ 57,364**	**$ 58,511**	**$ 59,681**	**$ 60,875**
Expenses					
operating costs		-	-	-	-
Feedstock - includes stumpage fee where appropriate	147,615	150,568	153,579	156,651	159,784
Transportation costs (imported)	147,615	150,568	153,579	156,651	159,784
Auxillary load (energy costs)	19,272	19,657	20,051	20,452	20,861
Labour costs	62,500	63,750	65,025	66,326	67,652
Ash disposal	1,447	1,476	1,505	1,535	1,566
maintenance	-	-	-	-	-
spare parts, material for regular and preventative system maintenance and labour	36,000	36,720	37,454	38,203	38,968
insurance	4,000	4,080	4,162	4,245	4,330
Total Expenses	**$ 418,449**	**$ 426,818**	**$ 435,355**	**$ 444,062**	**$ 452,943**
Net Income before Adjustment	**$ (372,195)**	**$ (369,455)**	**$ (376,844)**	**$ (384,381)**	**$ (392,068)**
Adjustments:					
Debt Payment	22,971	22,971	22,971	22,971	22,971
Capital Renewal Reserved Fund- building, silo storage, soft costs	10,750	10,965	11,184	11,408	11,636
Capital Renewal Reserved Fund- boiler, installation	18,500	18,870	19,247	19,632	20,025
NET CASH FLOW	**$ (424,416)**	**$ (422,261)**	**$ (430,247)**	**$ (438,392)**	**$ (446,701)**

Appendix B-5: Operating Expenditures - Imported Pellets (0.4MW)

	Yr 1: 2021/22	Yr 2: 2022/23	Yr 3: 2023/24	Yr 4: 2024/25	Yr 5: 2025/26
Revenue					
carbon tax variance	22,162	27,698	28,252	28,817	29,393
Revenue from sale of thermal energy (heat)	965	984	1,004	1,024	1,044
Total Revenue	**$ 23,127**	**$ 28,682**	**$ 29,255**	**$ 29,841**	**$ 30,437**
Expenses					
operating costs		-	-	-	-
Feedstock - includes stumpage fee where appropriate	73,808	75,284	76,789	78,325	79,892
Transportation costs (imported)	73,808	75,284	76,789	78,325	79,892
Auxillary load (energy costs)	9,636	9,829	10,025	10,226	10,430
Labour costs	62,500	63,750	65,025	66,326	67,652
Ash disposal	723	738	753	768	783
maintenance	-	-	-	-	-
spare parts, material for regular and preventative system maintenance and labour	18,000	18,360	18,727	19,102	19,484
insurance	3,000	3,060	3,121	3,184	3,247
Total Expenses	**$ 241,475**	**$ 246,304**	**$ 251,230**	**$ 256,255**	**$ 261,380**
Net Income before Adjustment	**$ (218,348)**	**$ (217,622)**	**$ (221,975)**	**$ (226,414)**	**$ (230,943)**
Adjustments:					
Debt Payment	17,860	17,860	17,860	17,860	17,860
Capital Renewal Reserved Fund- building, silo storage, soft costs	9,200	9,384	9,572	9,763	9,958
Capital Renewal Reserved Fund- boiler, installation	12,700	12,954	13,213	13,477	13,747
NET CASH FLOW	**$ (258,108)**	**$ (257,820)**	**$ (262,620)**	**$ (267,515)**	**$ (272,508)**

Appendix B-6: Operating Expenditures - Imported Pellets (0.025MW)

	Yr 1: 2021/22	Yr 2: 2022/23	Yr 3: 2023/24	Yr 4: 2024/25	Yr 5: 2025/26
Revenue					
carbon tax variance	1,385	1,731	1,766	1,801	1,837
Total Revenue	**$ 1,385**	**$ 1,731**	**$ 1,766**	**$ 1,801**	**$ 1,837**
Expenses					
operating costs		-	-	-	-
Feedstock - includes stumpage fee where appropriate	4,613	4,705	4,799	4,895	4,993
Transportation costs (imported)	4,613	4,705	4,799	4,895	4,993
Auxillary load (energy costs)	602	614	627	639	652
Ash disposal	45	46	47	48	49
maintenance	-	-	-	-	-
spare parts, material for regular and preventative system maintenance and labour	1,000	1,020	1,040	1,061	1,082
insurance	200	204	208	212	216
Total Expenses	**$ 11,073**	**$ 11,295**	**$ 11,521**	**$ 11,751**	**$ 11,986**
Net Income before Adjustment	**$ (9,688)**	**$ (9,564)**	**$ (9,755)**	**$ (9,950)**	**$ (10,149)**
Adjustments:					
Debt Payment	1,149	1,149	1,149	1,149	1,149
Capital Renewal Reserved Fund- storage, soft costs	250	255	260	265	271
Capital Renewal Reserved Fund- boiler, installation	1,500	1,530	1,561	1,592	1,624
NET CASH FLOW	**$ (12,587)**	**$ (12,497)**	**$ (12,724)**	**$ (12,956)**	**$ (13,192)**

APPENDIX C

Operating Expenditures – Locally Produced Chips/ Pellets

Appendix C-1: Operating Expenditures - Locally Produced Chips (3MW)

	Yr 1: 2021/22	Yr 2: 2022/23	Yr 3: 2023/24	Yr 4: 2024/25	Yr 5: 2025/26
Revenue					
carbon tax variance	166,217	207,732	211,887	216,124	220,447
Revenue from sale of thermal energy (heat)	2,010,420	2,050,628	2,091,641	2,133,474	2,176,143
Total Revenue	**$ 2,176,637**	**$ 2,258,360**	**$ 2,303,528**	**$ 2,349,598**	**$ 2,396,590**
Expenses					
operating costs		-	-	-	-
Feedstock - includes stumpage fee where appropriate	589,368	601,155	613,178	625,442	637,950
Transportation costs (produced locally)	11,594	11,826	12,063	12,304	12,550
Auxilliary load (energy costs)	72,270	73,715	75,190	76,694	78,227
Labour costs	250,000	255,000	260,100	265,302	270,608
Cost of chemicals + water	5,000	5,100	5,202	5,306	5,412
Ash disposal	7,500	7,650	7,803	7,959	8,118
maintenance	-	-	-	-	-
spare parts, material for regular and preventative system maintenance and labour	132,000	134,640	137,333	140,079	142,881
insurance	34,000	34,680	35,374	36,081	36,803
Total Expenses	**$ 1,101,732**	**$ 1,123,766**	**$ 1,146,242**	**$ 1,169,167**	**$ 1,192,550**
Net Income before Adjustment	**$ 1,074,905**	**$ 1,134,594**	**$ 1,157,286**	**$ 1,180,431**	**$ 1,204,040**
Adjustments:					
Debt Payment	193,819	193,819	193,819	193,819	193,819
Capital Renewal Reserved Fund- building, bunker storage, soft costs, distribution piping	93,750	95,625	97,538	99,488	101,478
Capital Renewal Reserved Fund- boiler, installation	150,000	153,000	156,060	159,181	162,365
NET CASH FLOW	**$ 637,336**	**$ 692,150**	**$ 709,869**	**$ 727,943**	**$ 746,378**

Appendix C-2: Operating Expenditures - Locally Produced Chips (1MW)

	Yr 1: 2021/22	Yr 2: 2022/23	Yr 3: 2023/24	Yr 4: 2024/25	Yr 5: 2025/26
Revenue					
carbon tax variance	55,406	69,244	70,629	72,041	73,482
Revenue from sale of thermal energy (heat)	670,140	683,543	697,214	711,158	725,381
Total Revenue	**$ 725,546**	**$ 752,787**	**$ 767,843**	**$ 783,199**	**$ 798,863**
Expenses					
operating costs		-	-	-	-
Feedstock - includes stumpage fee where appropriate	196,456	200,385	204,393	208,481	212,650
Transportation costs (produced locally)	3,865	3,942	4,021	4,101	4,183
Auxillary load (energy costs)	24,090	24,572	25,063	25,565	26,076
Labour costs	125,000	127,500	130,050	132,651	135,304
Cost of chemicals + water	5,000	5,100	5,202	5,306	5,412
Ash disposal	2,500	2,550	2,601	2,653	2,706
maintenance	-	-	-	-	-
spare parts, material for regular and preventative system maintenance and labour	44,000	44,880	45,778	46,693	47,627
insurance	9,000	9,180	9,364	9,551	9,742
Total Expenses	**$ 409,911**	**$ 418,109**	**$ 426,471**	**$ 435,000**	**$ 443,700**
Net Income before Adjustment	**$ 315,635**	**$ 334,678**	**$ 341,372**	**$ 348,199**	**$ 355,163**
Adjustments:					
Debt Payment	53,149	53,149	53,149	53,149	53,149
Capital Renewal Reserved Fund- building, bunker storage, soft costs, distribution piping	24,600	25,092	25,594	26,106	26,628
Capital Renewal Reserved Fund- boiler, installation	43,350	44,217	45,101	46,003	46,923
NET CASH FLOW	**$ 194,535**	**$ 212,219**	**$ 217,527**	**$ 222,940**	**$ 228,462**

Appendix C-3: Operating Expenditures - Locally Produced Chips (0.8MW)

	Yr 1: 2021/22	Yr 2: 2022/23	Yr 3: 2023/24	Yr 4: 2024/25	Yr 5: 2025/26
Revenue					
carbon tax variance	44,324	55,395	56,503	57,633	58,786
Revenue from sale of thermal energy (heat)	536,112	546,834	557,771	568,926	580,305
Total Revenue	**$ 580,436**	**$ 602,229**	**$ 614,274**	**$ 626,559**	**$ 639,091**
Expenses					
operating costs		-	-	-	-
Feedstock - includes stumpage fee where appropriate	157,165	160,308	163,514	166,784	170,120
Transportation costs (produced locally)	3,092	3,154	3,217	3,281	3,347
Auxillary load (energy costs)	19,272	19,657	20,051	20,452	20,861
Labour costs	62,500	63,750	65,025	66,326	67,652
Ash disposal	2,000	2,040	2,081	2,122	2,165
maintenance	-	-	-	-	-
spare parts, material for regular and preventative system maintenance and labour	36,000	36,720	37,454	38,203	38,968
insurance	4,000	4,080	4,162	4,245	4,330
Total Expenses	**$ 284,028**	**$ 289,709**	**$ 295,503**	**$ 301,413**	**$ 307,442**
Net Income before Adjustment	**$ 296,408**	**$ 312,520**	**$ 318,771**	**$ 325,146**	**$ 331,649**
Adjustments:					
Debt Payment	22,971	22,971	22,971	22,971	22,971
Capital Renewal Reserved Fund- building, silo storage, soft costs	10,750	10,965	11,184	11,408	11,636
Capital Renewal Reserved Fund- boiler, installation	18,500	18,870	19,247	19,632	20,025
NET CASH FLOW	**$ 244,187**	**$ 259,714**	**$ 265,368**	**$ 271,135**	**$ 277,017**

Appendix C-4: Operating Expenditures - Locally Produced Pellets (0.8MW)

	Yr 1: 2021/22	Yr 2: 2022/23	Yr 3: 2023/24	Yr 4: 2024/25	Yr 5: 2025/26
Revenue					
carbon tax variance	44,324	55,395	56,503	57,633	58,786
Revenue from sale of thermal energy (heat)	1,930	1,968	2,008	2,048	2,089
Total Revenue	**$ 46,254**	**$ 57,364**	**$ 58,511**	**$ 59,681**	**$ 60,875**
Expenses					
operating costs		-	-	-	-
Feedstock - includes stumpage fee where appropriate	147,615	150,568	153,579	156,651	159,784
Transportation costs (produced locally)	2,237	2,281	2,327	2,373	2,421
Auxillary load (energy costs)	19,272	19,657	20,051	20,452	20,861
Labour costs	62,500	63,750	65,025	66,326	67,652
Ash disposal	1,447	1,476	1,505	1,535	1,566
maintenance	-	-	-	-	-
spare parts, material for regular and preventative system maintenance and labour	36,000	36,720	37,454	38,203	38,968
insurance	4,000	4,080	4,162	4,245	4,330
Total Expenses	**$ 273,071**	**$ 278,532**	**$ 284,103**	**$ 289,785**	**$ 295,581**
Net Income before Adjustment	**$ (226,816)**	**$ (221,169)**	**$ (225,592)**	**$ (230,104)**	**$ (234,706)**
Adjustments:					
Debt Payment	22,971	22,971	22,971	22,971	22,971
Capital Renewal Reserved Fund- building, silo storage, soft costs	10,750	10,965	11,184	11,408	11,636
Capital Renewal Reserved Fund- boiler, installation	18,500	18,870	19,247	19,632	20,025
NET CASH FLOW	**$ (279,038)**	**$ (273,975)**	**$ (278,995)**	**$ (284,115)**	**$ (289,338)**

Appendix C-5: Operating Expenditures - Locally Produced Pellets (0.4MW)

	Yr 1: 2021/22	Yr 2: 2022/23	Yr 3: 2023/24	Yr 4: 2024/25	Yr 5: 2025/26
Revenue					
carbon tax variance	22,162	27,698	28,252	28,817	29,393
Revenue from sale of thermal energy (heat)	965	984	1,004	1,024	1,044
Total Revenue	**$ 23,127**	**$ 28,682**	**$ 29,255**	**$ 29,841**	**$ 30,437**
Expenses					
operating costs		-	-	-	-
Feedstock - includes stumpage fee where appropriate	73,808	75,284	76,789	78,325	79,892
Transportation costs (produced locally)	1,118	1,141	1,163	1,187	1,210
Auxillary load (energy costs)	9,636	9,829	10,025	10,226	10,430
Labour costs	62,500	63,750	65,025	66,326	67,652
Ash disposal	723	738	753	768	783
maintenance	-	-	-	-	-
spare parts, material for regular and preventative system maintenance and labour	18,000	18,360	18,727	19,102	19,484
insurance	3,000	3,060	3,121	3,184	3,247
Total Expenses	**$ 168,785**	**$ 172,161**	**$ 175,604**	**$ 179,116**	**$ 182,699**
Net Income before Adjustment	**$ (145,658)**	**$ (143,479)**	**$ (146,349)**	**$ (149,276)**	**$ (152,261)**
Adjustments:					
Debt Payment	17,860	17,860	17,860	17,860	17,860
Capital Renewal Reserved Fund- building, silo storage, soft costs	9,200	9,384	9,572	9,763	9,958
Capital Renewal Reserved Fund- boiler, installation	12,700	12,954	13,213	13,477	13,747
NET CASH FLOW	**$ (185,418)**	**$ (183,677)**	**$ (186,994)**	**$ (190,376)**	**$ (193,827)**

Appendix C-6: Operating Expenditures - Locally Produced Pellets (0.025MW)

	Yr 1: 2021/22	Yr 2: 2022/23	Yr 3: 2023/24	Yr 4: 2024/25	Yr 5: 2025/26
Revenue					
carbon tax variance	1,385	1,731	1,766	1,801	1,837
Total Revenue	**$ 1,385**	**$ 1,731**	**$ 1,766**	**$ 1,801**	**$ 1,837**
Expenses					
operating costs		-	-	-	-
Feedstock - includes stumpage fee where appropriate	4,613	4,705	4,799	4,895	4,993
Transportation costs (produced locally)	70	71	73	74	76
Auxillary load (energy costs)	602	614	627	639	652
Ash disposal	45	46	47	48	49
maintenance	-	-	-	-	-
spare parts, material for regular and preventative system maintenance and labour	1,000	1,020	1,040	1,061	1,082
insurance	200	204	208	212	216
Total Expenses	**$ 6,530**	**$ 6,661**	**$ 6,794**	**$ 6,930**	**$ 7,069**
Net Income before Adjustment	**$ (5,145)**	**$ (4,930)**	**$ (5,028)**	**$ (5,129)**	**$ (5,232)**
Adjustments:					
Debt Payment	1,149	1,149	1,149	1,149	1,149
Capital Renewal Reserved Fund- storage, soft costs	250	255	260	265	271
Capital Renewal Reserved Fund- boiler, installation	1,500	1,530	1,561	1,592	1,624
NET CASH FLOW	**$ (8,044)**	**$ (7,863)**	**$ (7,998)**	**$ (8,135)**	**$ (8,274)**

APPENDIX D

Operating Expenditures – Pellet Mill

Appendix D: Operating Expenditures - Pellet Mill

	Yr 1: 2021/22	Yr 2: 2022/23	Yr 3: 2023/24	Yr 4: 2024/25	Yr 5: 2025/26
Revenue					
Revenue from sale of pellets	4,950,000	5,049,000	5,149,980	5,252,980	5,358,039
Total Revenue	**$ 4,950,000**	**$ 5,049,000**	**$ 5,149,980**	**$ 5,252,980**	**$ 5,358,039**
Expenses					
operating costs	-	-	-	-	-
feedstock cost, stumpage cost, transportation costs, labour cost	1,800,000	1,836,000	1,872,720	1,910,174	1,948,378
energy costs	1,208,611	1,232,783	1,257,439	1,282,588	1,308,240
maintenance	-	-	-	-	-
spare parts, material for regular and preventative system maintenance, labour	450,000	459,000	468,180	477,544	487,094
insurance	37,500	38,250	39,015	39,795	40,591
Total Expenses	**$ 3,496,111**	**$ 3,566,033**	**$ 3,637,354**	**$ 3,710,101**	**$ 3,784,303**
Net Income before Adjustment	**$ 1,453,889**	**$ 1,482,967**	**$ 1,512,626**	**$ 1,542,879**	**$ 1,573,736**
Adjustments:					
Debt Payment	107,677	107,677	107,677	107,677	107,677
Capital Renewal Reserved Fund- building, storage	25,000	25,500	26,010	26,530	27,061
Capital Renewal Reserved Fund- pellet mill, hammer mill, dryers, screeners	137,500	140,250	143,055	145,916	148,834
NET CASH FLOW	**$ 1,183,712**	**$ 1,209,539**	**$ 1,235,884**	**$ 1,262,755**	**$ 1,290,164**