Alternatives North

Alternatives North is a Territorial social and environmental justice coalition based in Yellowknife. Members include churches, labour unions, environmental organizations, women and family advocates, anti-poverty groups as well as individuals with an interest in our work. We have participated in climate change planning and actions over the past decade, publishing reports on "100% Renewable by 2050" (2016) and "Climate Emergency: Getting the NWT off Diesel" (2020).

In this report we chose to examine one of the technologies identified by our work in 2020, Biomass District Heating, in greater detail; In this case for downtown Yellowknife. Alternatives North's intent in completing this analysis was to conduct the first step in developing a business plan in order to prove the economics and attract a developer for this project.

To ensure our studies accuracy we partnered with the City of Yellowknife and Arctic Energy Alliance in order to benefit from their experience and data on district heating, energy costs, and typical heating loads. We also added to this by engaging multiple key customers in the target area. Together, this study represents the most detailed analysis to date on heating energy use in downtown Yellowknife.

To further ensure accuracy, Alternatives North engaged FVB, an engineering and management consulting company specializing in District Energy to complete the feasibility analysis. FVB has helped design, construct, and operate district energy systems within Canada and around the world and has prior experience in Yellowknife from its previous work analyzing the potential for geothermal district heating conducted by the City of Yellowknife in 2011.

Funding was generously provided through a grant from the Government of Canada's Northern Responsible Energy Approach for Community Heat and Electricity (Northern REACHE) program.

This study examines the financials of a biomass District Heating system that is constructed and operated as either a for-profit or non-profit organization to ensure that any organization with an interest in taking the next steps can use it.

This report confirms Alternatives North's previous findings that biomass district heating can deliver meaningful, cost negative, GHG reductions fast enough to help the NWT meet its emission reduction goals for 2030.

Lachlan MacLean, P.Eng.

Alternatives North Member, Project Manager

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Alternatives North

YELLOWKNIFE BIOMASS DHS FEASIBILITY STUDY

FINAL REPORT

SUBMITTED ON: JANUARY 13, 2023

SUBMITTED BY:

FVB ENERGY INC

CELEBRATING 30 YEARS | 1992 - 2022

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NAPEG ID#: L5216

PERMIT TO PRACTICE
FVB ENERGY INC.
Signature
Date Jan 13, 2023
PERMIT NUMBER: P 381
The Association of Professional Engineers, Geologists and Geophysicists of the NWT / NU

Permit to Practice #P381

EXECUTIVE SUMMARY

FVB was retained by Alternatives North to develop concepts and evaluate the feasibility of a utility-scale biomass-based district heating system that would provide renewable thermal energy to target buildings in Yellowknife's downtown.

Following a review of potential target buildings, the following concepts were developed:

- 'For-Profit' concept:
  - Heating service to 50 buildings representing 244,000 m² of gross floor area.
  - Developed by an external utility/enterprise with a business case focus.
- 'Not-for-Profit' concept:
  - Heating service to 74 buildings representing 294,000 m² of gross floor area.
  - Developed by a local partnership (i.e., Indigenous, civic, territorial, etc.), with a focus on developing more building connections and maximizing greenhouse gas emission reductions.

Figure 1: Study Target Area Source: Google Earth

The biomass energy centre is envisioned to use a wood pellet fuel feedstock to heat hot water that is then distributed to the target buildings through underground insulated pipes. The proposed plant would be located on a vacant lot on the north side of downtown.

The biomass district heating system is estimated to provide ~80% of the connected buildings' annual thermal energy requirements. The remaining thermal energy requirements would be provided by the building's existing heating systems.

The following summarizes the 30-year financial analysis results for the two concepts:

- 'For-Profit' concept:
  - Project capital cost of $72 million (2022 CAD $).
  - Project return of 8%.
  - Average annual greenhouse gas emission reduction of 13,100 tonnes of CO_{2e}, for a total of 393,000 tonnes of CO_{2e} reduced over 30-years.
  - Average annual *profit* per GHG reduction of $126/tonne of CO_{2e}.

- 'Not-for-Profit' concept:
  - Project capital cost of $85 million (2022 CAD $).
  - Project return of 20%.
  - Average annual greenhouse gas emission reduction of 16,100 tonnes of CO_{2e}, for a total of 483,000 tonnes of CO_{2e} reduced over 30-years.
  - Average annual *profit* per GHG reduction of $199/tonne of CO_{2e}.

Both concepts demonstrate strong business case results. The 'For-Profit' concept may have a strong enough business case to attract interest from a utility partner or other for-profit enterprise. The 'Not-for-Profit' concept demonstrates a stronger business case as it is assumed the consortium would have better access to grant funding. The additional profits could be used to expand the district heating system, further discount the thermal energy rates, and/or implement other alternative technologies to further reduce GHG emissions within the community.

Sensitivities were considered for the blended fuel oil market rate, thermal energy rate discount, capital cost, and grant funding. Both concepts survived all the sensitivities analyzed, however, the model demonstrates the highest sensitivity to the blended fuel oil market rate which drives the project revenues from thermal energy sales.

In addition, two scenarios were considered. The impact of climate change results in a slight reduction in the project business case due to reduced heating needs resulting from warmer global temperatures. The impact of removing the carbon tax from fuel oil and electricity costs results in a significant reduction in the business case for both concepts. Neither concept survives the scenario without a carbon tax. This illustrates the impact of a carbon tax to incentivize renewable energy projects.

This study demonstrates that a biomass district heating system can be feasibly implemented and have both a strong business case and greenhouse gas reduction potential. Developing a utility-scale biomass district heating system in Yellowknife could form an important part of the territorial climate change strategy.

CONTENTS

REPORT GLOSSARY

Below are definitions of acronyms and units frequently referenced in this report.

AN	Alternatives North
BAU	Business as Usual (also referred to as status-quo)
CO_{2e}	CO_2 Equivalent
EC	Energy Centre
DHS	District Heating System
DHW	Domestic Hot Water
EFLH	Equivalent Full Load Hours
ETS	Energy Transfer Station
FVB	FVB Energy Inc.
GFA	Gross Floor Area
GHG	Greenhouse Gas
GJ	Gigajoule, is an energy measurement unit
HEX	Heat Exchanger
HHV	Higher Heating Value
kg CO_{2e}	Kilograms of carbon dioxide (CO_2) equivalent GHG emissions
LDC	Load Duration Curve, a curve representing system hourly thermal load over the year
LHV	Lower Heating Value
LTHW	Low Temperature Hot Water, heating water temperatures typically between 80°C and 115°C
MW_t	Megawatt Thermal, is a measure of instantaneous thermal demand or capacity
MWh_t	Megawatt Hour Thermal, is a thermal energy measurement unit
MWh_e	Megawatt Hour Electric, is an electrical energy measurement unit
OAT	Outdoor Air Temperature
O&M	Operation & Maintenance
REIT	Real Estate Investment Trust
ΔT	Temperature Differential (delta T)
t CO_{2e}	Tonnes of carbon dioxide (CO_2) equivalent GHG emissions

1 INTRODUCTION

The majority of the buildings within Yellowknife use fuel-oil for their heating requirements. Over the last several years there have been examples of small-scale, residential / light-commercial biomass heating systems developed within individual buildings or to serve micro-district heating systems. This study reviews the feasibility of developing a utility-scale biomass district heating system with widespread implementation throughout Yellowknife's downtown.

The goal of this study is to define concepts that align with territorial goals of using biomass fuel feedstock to reduce fuel oil consumption and thereby decreasing the greenhouse gas (GHG) emissions in the community. Then, to analyze the concepts and determine the feasibility of the business case.

This study looks at two different approaches to developing the project: 'For-Profit' utility structure, and a 'Not-for-Profit' utility structure. The 'For-Profit' concept would develop a district heating system as a utility, with the intent of providing a business case that would attract external corporate investment. The 'Not-for-Profit' concept is envisioned to be developed through Indigenous and/or local government ownership and structured to provide a non-profit district heating utility with the intent to maximize the number of customers.

The first part of this study defines target building requirements and reviews the load and energy data for the target buildings. This includes reviewing existing fuel consumption data and estimating customer building loads.

The second part of this study provides an overview of the design of the district heating system. This is broken into three major components: the biomass energy centre, the distribution piping system, and the building connections.

The third part of this study provides a 30-year financial analysis of the district heating system for both utility approaches.

Last, the study defines next steps, and provides summary remarks.

1.1 Relative Accuracy

In preparing this report, FVB has relied upon the accuracy and completeness of the information provided by Alternatives North (Client) and has not made particular or special enquiries outside of or in addition to such information.

The analysis provided is general in nature and intended to convey opinions & observations of FVB based on our extensive experience with energy.

The accuracy of the presented results should be considered as indicative only. This is attributed to variability in the historical annual data, metering data inaccuracies, energy reduction potential, climatic variability, and variability in building operation. Regardless of the relative accuracy, the presented information should be considered the best information available for future planning. Improvements in data collection at the building level can help improve future load and energy projections.

1.2 Acknowledgements

FVB would like to thank and acknowledge support from the following parties:

- Alternatives North
- Arctic Energy Alliance
- The City of Yellowknife
- Fink Machine Inc.

1.3 Reference Material

This document is based on the following reference materials:

- Previous assessments of district heating in Yellowknife, completed by FVB and others, provided by the City of Yellowknife.
- Fuel oil usage data for select target buildings, collected by Alternatives North.
- Biomass usage data for select target buildings, collected by Alternatives North.
- Gross floor area data for select target buildings, provided by Alternatives North.
- Historic wood pellet delivery costs from La Crête to Yellowknife, provided by the City of Yellowknife.
- 2012 Wood Pellet Testing Report, prepared by Arctic Energy Alliance.
- Google Earth satellite imagery.

2 TARGET BUILDINGS

This section outlines the methodology used to estimate the building heating requirements of the target buildings. A combination of actual buildings fuel usage collected by potential customers and FVB's in-house database was used to determine the peak heating demand and annual thermal energy of the target buildings.

2.1 TARGET AREA

The following figure shows an overview of the target area considered in this study – shaded in purple.

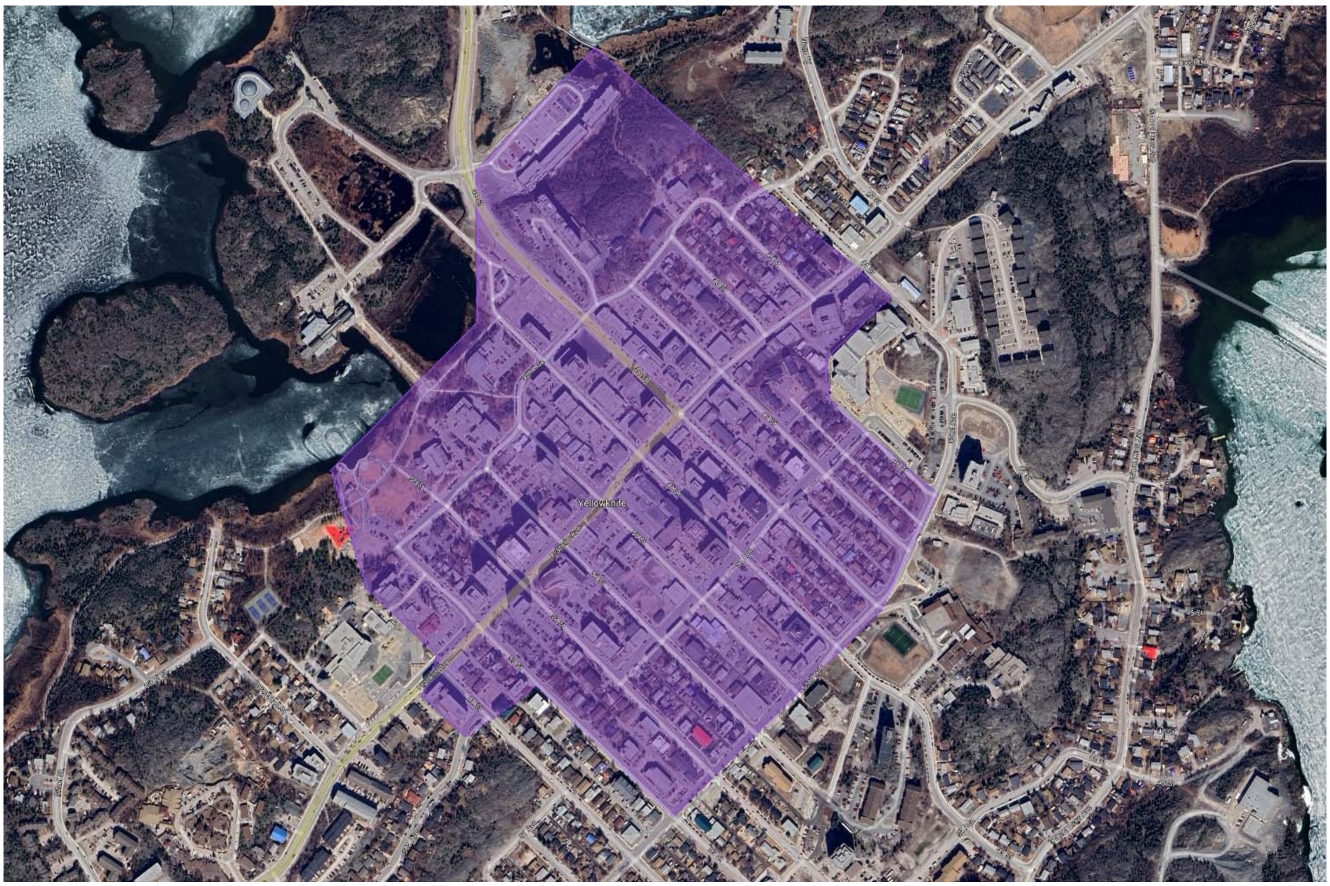

Figure 2: Target Area Source: Google Earth

It should be noted that this study only considers the downtown area, however, there exists potential to develop a system further beyond the shaded area, sharing the benefits of district heating with more of the community. This expansion potential will be explored in a future addendum to this study.

2.2 TARGET CUSTOMER BUILDINGS

The 'For-Profit' concept considers customer buildings that are located within the target area. These target buildings are selected based on direction provided by the client[1], and is based on the criteria outlined by the 'Building Connection Requirements' memo[2] provided in Appendix C. This memo defines the general requirements and considerations used when selecting buildings. These target buildings have the advantage that they are generally owned by the City, other governments, or one of the major REITs; typically simplifying marketing efforts and connection agreements.

The 'Not-for-Profit' concept considers all the 'For-Profit' buildings, as well as additional buildings that were smaller than the minimum target buildings requirements. These buildings are expected to decrease the business case of this concept but is shown to demonstrate the potential of a larger district heating system.

Fuel oil and biomass usage data was collected by the client for a variety of buildings located in the project's target area[3]. This fuel data was generally provided as bulk shipment and/or usage volumes over defined periods and is utilized to estimate the target building's peak heating demand & annual thermal energy requirements.

The following table summarizes the target customer building estimates:

Table 1: Target Customer Building Estimates

Description	For Profit	Not-for-Profit
# of Target Buildings[4]	50 buildings	74 buildings
Gross Floor Area[5]	244,000m²	294,000m²
Peak Heating Demand	21.9 MW_t	26.4 MW_t
Annual Thermal Energy	43,600 MWh_t	53,700 MWh_t

As shown, the 'Not-for-Profit' concept includes for nearly 50% more target buildings than the 'For-Profit' concept, representing ~20% additional gross floor area, peak heating demand, and annual thermal energy requirements.

Refer to Appendix A for additional details on key assumptions.

[1] Buildings that have recently installed new heating equipment are excluded. However, these may be a considered when the equipment is due for replacement. Buildings with existing biomass heating systems are considered on a case-by-case basis.
[2] The target building minimum gross floor area is assumed at 10,000 ft^2, as defined in the "Building Connection Requirements" memo.
[3] The study uses historical metered fuel oil and biomass consumption data (provided by the client) or demand density and annual energy metrics (i.e., W/m², kWh/m²) to estimate the annual thermal energy requirements of the target buildings.
[4] This refers to the number of district heating system connections; multiple buildings may be served from the same connection point.
[5] Where available, gross floor areas were provided by the client. In absence of this, areas were estimated using Google Earth.

3 BIOMASS DISTRICT HEATING SYSTEM CONCEPTS

This section describes the biomass district heating system concepts.

In general, a district heating system delivers thermal energy to multiple buildings from a centralized source. In modern district heating systems, the thermal energy is produced at a central energy centre and is then distributed in the form of hot water through underground pre-insulated pipelines to the customer buildings.

The illustration below shows a central energy centre and connections to three buildings in a district heating network.

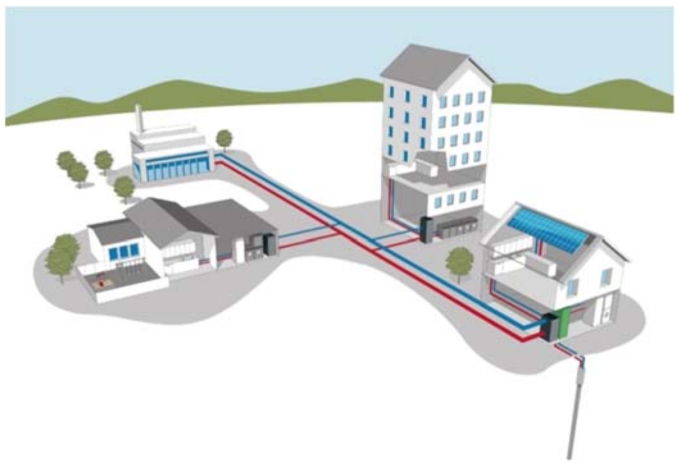

Figure 3: District Heating Network

The district heating concepts shown in this study consider a biomass heating system that delivers renewable heating that offsets building fuel consumption. Further details of the biomass district heating system are provided in the following sections, and in the design basis document provided in Attachment II.

3.1 System Diversification

One of the benefits of aggregating buildings together is the impact to the system peak heating demand. Since the peak heating demands of the connected buildings do not all occur at the same time, the district heating system peak production requirements is less than the sum of the connected building peak demands. These non-coincidental peak demands are referred to as the system diversification[6].

This study assumes a system diversification factor of 85% based on the large number of buildings served, the type and energy standards of buildings, the local climate, and district heating system design.

The following table summarizes the diversified load and energy estimates for the connected buildings:

Table 2: Target Buildings Estimated Diversified Heating Demand & Annual Thermal Energy Requirements

Description	For Profit	Not-for-Profit
Undiversified Peak Heating Demand	21.9 MW_t	26.4 MW_t
System Diversification	85%	85%
Diversified Peak Heating Demand	18.6 MW_t	22.4 MW_t
Annual Thermal Energy Requirements	43,600 MWh_t	53,700 MWh_t

Note that the building's annual thermal energy requirements remain unchanged.

3.2 Load Duration Curves

A load duration curve represents the distribution of the district heating system's diversified heating demand requirements over the course of a year. The load duration curve is a powerful tool used to optimize heating equipment sizing and estimate the thermal energy provided.[7]

A load duration curve is prepared for both the 'For-Profit' and the 'Not-for-Profit' biomass district heating system concept, as shown on the following pages.

[6] System diversification also accounts for the inherent "thermal inertia" or "buffer capacity" of the hot water in the distribution system.
[7] As represented by the shaded area beneath the load duration curve.

3.2.1 'For-Profit' Load Duration Curve

The following load duration curve is provided for the 'For-Profit' district heating system concept:

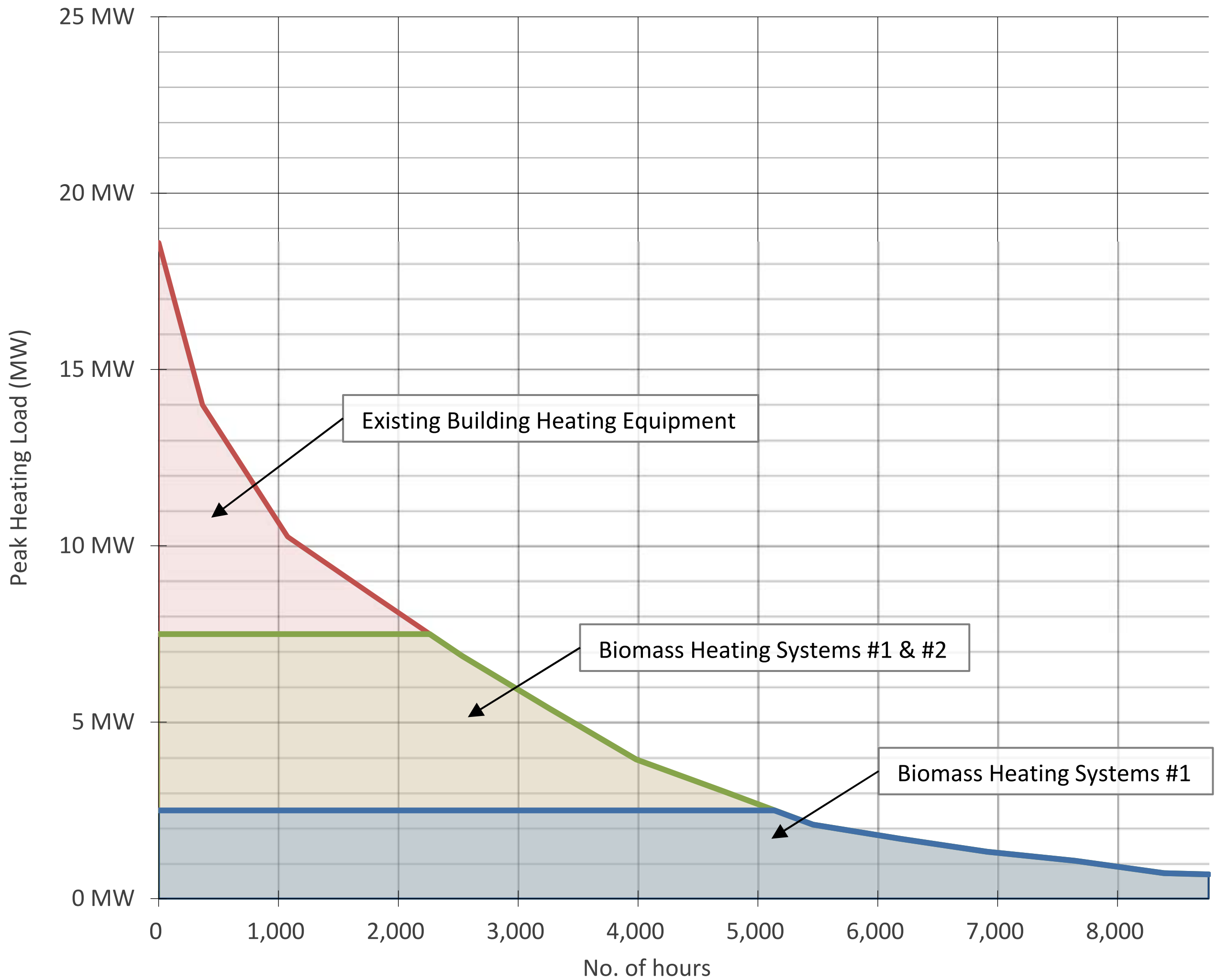

Figure 4: 'For-Profit' Load Duration Curve

A 7.5 MW_t biomass heating system (consisting of one @ 5 MW_t, and one @ 2.5 MW_t biomass heating system) is estimated to provide over 80% of the system thermal energy requirements.[8]

The remaining thermal energy and back-up heating capacity is provided by the target customer's existing heating equipment, as represented by the area shaded in red.

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[8] The combined capacity of the biomass heating systems is estimated to operate for ~2,200 full load hours per year, as indicated by the horizontal 'green' line. The smaller biomass heating system (capacity of 2.5 MW_t) is estimated to operate with over 5,000 full load hours per year, as indicated by the horizontal 'blue' line. With an expected turndown of ~30% the installed capacity, the 2.5 MW_t biomass heating system would be able to operate at low system load throughout the year.

3.2.2 'Not-for-Profit' Load Duration Curve

The following load duration curve is provided for the 'Not-for-Profit' district heating system concept:

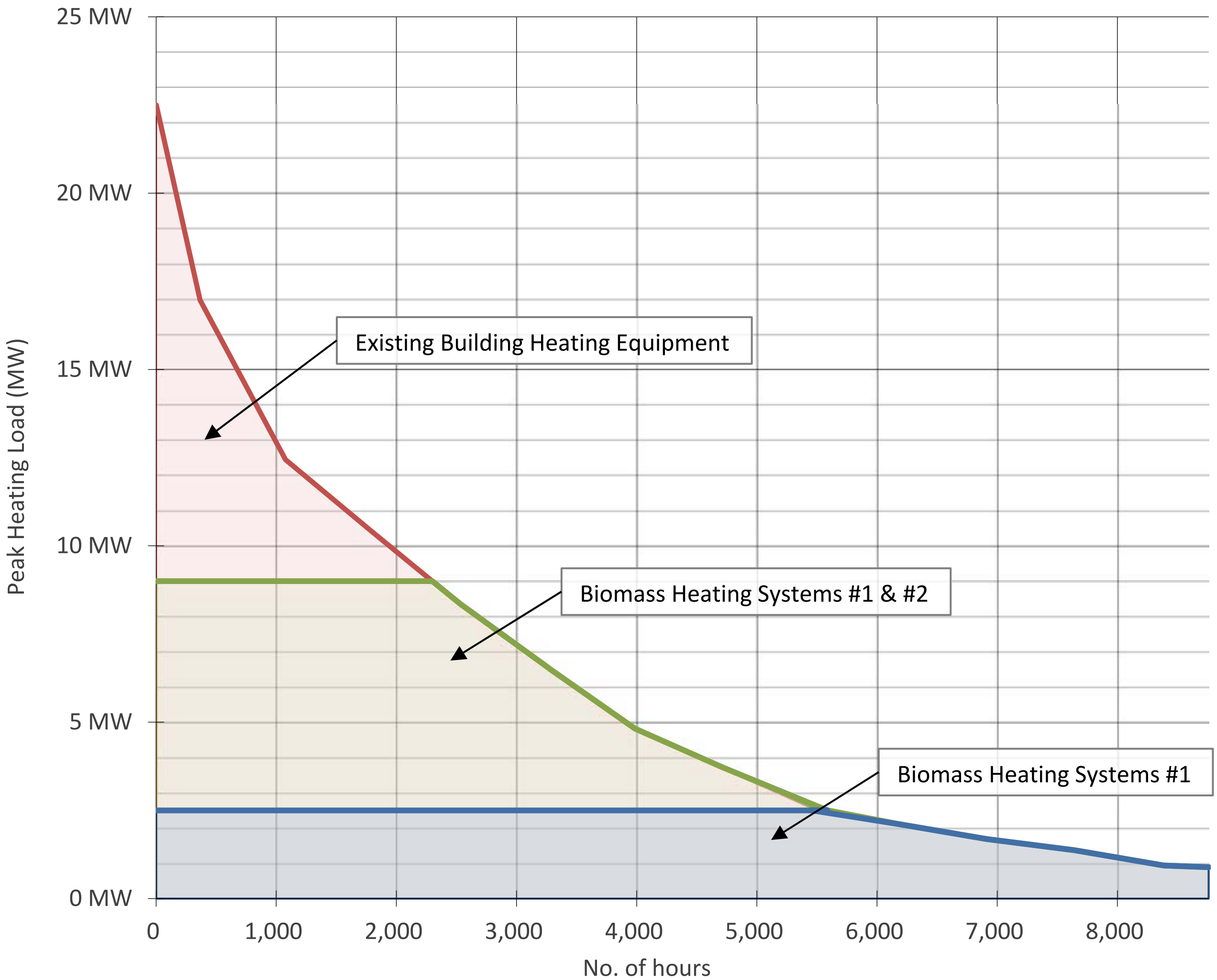

Figure 5: 'Not-for-Profit' Load Duration Curve

A 9.0 MW_t biomass heating system (consisting of one @ 6.5 MW_t, and one @ 2.5 MW_t biomass heating system) is estimated to provide over 80% of the system thermal energy requirements.[9]

The remaining thermal energy and back-up heating capacity is provided by the target customer's existing heating equipment, as represented by the area shaded in red.

[9] The combined capacity of the biomass heating systems is estimated to operate for ~2,300 full load hours per year, as indicated by the horizontal 'green' line. The smaller biomass heating system (capacity of 2.5 MW_t) is estimated to operate with over 5,500 full load hours per year, as indicated by the horizontal 'blue' line. With an expected turndown of ~30% the installed capacity, the 2.5 MW_t biomass heating system would be able to operate at low system load throughout the year.

3.2.3 Biomass District Heating System

The annual thermal energy that can be provided to the target buildings is defined as the thermal energy sales and is used to estimate the biomass district heating system's revenue.

The district heating system would also need to produce additional thermal energy[10] annually to overcome system thermal losses and internal thermal energy usage in the energy centre. The annual thermal energy production is used to estimate the biomass district heating system's fuel expenses.

The following table summarizes the installed biomass heating system capacity, and annual thermal energy estimates for the biomass district heating systems:

Table 3: District Heating System Installed Capacity & Annual Thermal Energy Estimates

Description	For Profit	Not-for-Profit
Installed Biomass Heating System Capacity	7.5 MW_t	9.0 MW_t
Annual Thermal Energy Sales	35,500 MWh_t	43,600 MWh_t
Annual Thermal Energy Production	37,300 MWh_t	45,700 MWh_t

[10] Estimated at 5% of annual thermal energy sales.

3.3 Biomass Energy Centre

The energy centre or 'heating plant' is the central point of thermal energy production for the district heating system. It is the facility where fuel is delivered and stored, where heating equipment capacity and auxiliary equipment is housed, and the key centre for operations & maintenance staff.

The following figures provide an example of a biomass energy centre in Oujé-Bougoumou, Quebec, and an urban energy centre in Prince George, BC:

Figure 6: Oujé-Bougoumou Biomass Heating Plant

Figure 7: Prince George Downtown Energy Centre

The energy centre site is proposed at a vacant lot in the north end of the target area, as shaded 'green' in the following figure.

Figure 8: Assumed Energy Centre Location Source: Google Earth

This location has strong access to major roadways, and adequate space for the building, fuel delivery, on-site wood pellet storage silos, and fuel handling & conveyance systems. As well, it is centrally located, near the proposed target buildings.

The building is envisioned to be fit-for-purpose with steel structural elements, and an insulated concrete block or metal panel exterior. The building would be aesthetically pleasing but have minimal architectural treatments.

Inside the energy centre, the biomass heating systems would be installed, complete with fuel conveyance system, fuel feed bins, fuel feed systems, combustion system, heat recovery boilers, fuel exhaust systems, exhaust clean-up, and ash handling systems.

Figure 9: Typical Biomass Heating System (8 MW$_t$ Capacity Shown) Source: Schmid Energy Solutions

Heat in the form of low-temperature hot water (LTHW) would be produced in the biomass energy centre[11] and circulated to the target customer buildings. The energy centre would also include additional auxiliary systems.

Further details are provided in Attachment II.

[11] The maximum supply temperature is 105°C for the proposed biomass heating system concept. However, the supply temperatures could be increased to 115°C with future added peaking capacity. The supply temperature would be reduced throughout the year to increase system efficiencies.

3.4 DISTRIBUTION PIPING

The distribution piping system (DPS) is a closed-loop network of buried piping that supplies heated water to the target buildings and returns it to the biomass energy centre for reheating.

The study assumes a buried, pre-insulated steel distribution piping system[12]. These European (EN-253) piping systems[13] are characterized by thin-walled steel carrier pipes, factory applied polyurethane foam insulation, and outer casing of high-density polyethylene (HDPE).

The piping is generally assumed to be buried in trenches with sand bedding and native fill.[14]

Figure 10: Buried Distribution Piping Installations

The pipe routing would need to consider above and underground utility right-of-way to prevent conflicts with existing services such as electric cables, fibre optics, sewage mains, and storm systems.

[12] An all-welded steel piping system is the preferred option as it can accommodate higher working pressures and temperatures. All welded steel piping systems are both watertight and have inherent strength. Guarantees of uninterrupted supply can be provided to potential customers with greater confidence than with other materials.

[13] Widely used in North America.

[14] No permafrost or bedrock is assumed in the target area. The presence of bedrock along the piping alignment (i.e., near the hotels to the north, etc.) should be reviewed at later stages of design development.

3.5 Building Connections

Building connections includes both the energy transfer station (ETS) which acts as the thermal energy interface between the district heating system and the target building heating system, and any required interconnecting piping and building modifications to be compatible with the district heating service.

A typical energy transfer station includes heat exchangers, controls and instrumentation, energy meter, isolation valves, and associated equipment and piping.

Figure 11: Typical Large Building Prefabricated Energy Transfer Station

Building connections also include any required interconnecting piping and building modifications that would be required to be compatible with the district heating service.

3.6 District Heating Benefits

A select few advantages of district heating systems are noted as follows:

3.6.1 Greenhouse Gas Emission Reduction

One of the key goals identified by the client is to utilize biomass fuel to offset building fuel oil usage, thereby directly reducing the associated greenhouse gas emissions. By connecting to a district energy system, customer buildings would, by extension, demonstrate environmental and energy leadership.

District heating systems provide the required framework to cost-effectively meet increasingly stringent decarbonization targets, often without additional renovations or modifications in the customer buildings.

3.6.2 Alternative Technologies

The district heating system infrastructure should be considered as a long-term asset that can utilize technologies not feasible at the building-only level. Specific to this study, it would allow for the utilization of industrial-grade biomass heating systems and auxiliary equipment. However, district heating systems serve as an energy platform that is adaptable to alternative technologies that can use a diverse range of energy & fuel sources.

This can effectively reduce the initial capital invested, reduce annual costs, maximize the overall system efficiency, and reduce the risks associated with utility costs.

3.6.3 Future Adaptability

It can be expected that the district heating system would continuously grow, adapt, modernize, and improve these assets to meet the goals, opportunities, and challenges to continuously improve the district heating utility.

3.6.4 System Resiliency

District heating systems allow for the ability to provide thermal services to customer buildings during emergency situations, like unplanned power outages, severe weather events, or fuel curtailments, by utilizing centralized generation, distribution pipelines, and on-site fuel storage.

3.6.5 Full Thermal Energy Service

Additional benefits could be realized with the development of a full thermal energy service that would replace the need for a building to install, operate, and maintain their own heating equipment. This could greatly reduce the amount of heating equipment and redundant capacity installed at each individual building, allowing for an overall capital savings, and cost synergies.

4 ECONOMIC EVALUATION

This section summarizes the 30-year financial analysis that evaluates the economic feasibility of the biomass district heating system concepts. This analysis considers project revenues, project expenses, and greenhouse gas emission reductions. This analysis also considers the impact of additional sensitivities and scenarios.

All values are shown in 2022 Q3 Canadian dollars, unless otherwise indicated.

4.1 Project Revenue

The financial analysis assumes that project revenue is provided solely from thermal energy sales.

The thermal energy rate is based on the estimated average fuel cost for the target buildings[15], and is converted using the fuel assumptions provided in Appendix A.

The following table summarizes the assumed fuel oil utility rate and thermal energy rate:

Table 4: Fuel Oil Utility Rate and Thermal Energy Rate Assumptions

Description	Utility Rate (Input)	Thermal Energy Rate (Output)
Blended Fuel Oil Market Rate	\$1.50 / Litre	\$208 / MWh_t
Commercial Discount Rate (-15%)	-\$0.225 / Litre	-\$ 31 / MWh_t
Thermal Energy Rate Discount (-10%)[16]	N/A	-\$ 18 / MWh_t
Carbon Tax	\$0.138 / Litre	\$ 19 / MWh_t
Total Rate	**\$1.413 / Litre[17]**	**\$178 / MWh_t**

As shown, the thermal energy rate also includes both a 15% discount to reflect typical commercial discounts for bulk fuel oil purchase, and an additional 10% discount over the customer building's current blended fuel oil market rate to incentivize connection to the district heating system. As well, this study assumes that fuel oil purchases would be subject to a carbon tax.

The blended fuel oil market rate is assumed to escalate by 2% per year. The thermal energy rate is estimated annually to reflect the changes in the fuel oil utility rate.

The financial analysis assumes the following implementation schedule[18] to reflect project market penetration and a multi-year construction period:

- Year 2025: 33% of the thermal energy sales.
- Year 2026: 67% of the thermal energy sales.
- Year 2027 and beyond: 100% of the thermal energy sales.

[15] The same thermal energy rate is assumed for all target buildings.
[16] As provided by the client.
[17] Defined in this report as the fuel oil utility rate.
[18] The implementation schedule, market penetration, and system build-out require further review at later stages of design development.

4.2 Project Expenses

The following section defines the project expenses of each concept, including capital costs, utility costs, and operation & maintenance costs.

4.2.1 Project Capital

The annual project capital expenses are based on the overall project capital costs, access to grants, debt/equity assumption, and capital spend schedule.

The following table summarizes the key capital cost assumptions for each concept:

Table 5: Project Capital Assumptions

Description	For Profit	Not-for-Profit
Project Capital Cost[19]	$ 71.7 million	$ 84.5 million
Grant Funding (% of Project Capital)	10%	30%
Project Equity Capital Amount	-	-
Project Debt Financing Principal Amount[20]	$ 64.5 million	$ 59.2 million

As shown above, it is assumed the 'Not-for-Profit' concept would have better access to grant funding. Though the project capital cost is higher than the 'For-Profit' concept, the debt financing principal amount is assumed to be lower.

Refer to Appendix B for a summary of the capital cost estimates, and Attachment III for the cost basis documents.

The financial analysis assumes that project capital costs are incurred over multiple years. The project capital costs are assumed to escalate by 2% per year and are adjusted based on the year the capital is spent.

This financial analysis assumes the following capital spend schedule[21]:

- Year 2024: 50% of the project capital.
- Year 2025: 25% of the project capital.
- Year 2026: 25% of the project capital.

This financial analysis assumes no salvage cost for equipment.

[19] Shown in 2022 Q3 Canadian Dollars.
[20] This financial analysis assumes that the remaining project capital costs after grant funding would be 100% financed. Project debt is assumed to be repaid over a 20-year period, at an interest rate of 3.5%.
[21] The capital spend schedule, market penetration, and system build-out require further review at later stages of design development.

4.2.2 Utility Costs

This section outlines the biomass & electricity utility costs[22] that are associated with the biomass district heating system concepts.

Further details on fuel assumptions are provided in Appendix A.

4.2.2.1 Biomass Feedstock Cost

This study assumes that biomass wood pellets would be supplied from the La Crête sawmill and delivered to site through a direct, bulk contract at a rate of $215 per wet tonne.

The blended biomass feedstock rate is assumed to escalate by 2% per year[23].

4.2.2.2 Electrical Utility Costs

The biomass energy centre would require electricity for biomass heating system auxiliary equipment, distribution pumps, and the balance of plant equipment. This study assumes that all electricity would be provided by the electricity grid serving Yellowknife and assumes a blended electricity rate of $242 per MWh_e.

The electrical utility rate is assumed to escalate by 3% per year.

4.2.3 Operations & Maintenance Costs

Operation & maintenance costs include for the following items[24]:

- Maintenance & Repair Costs[25]
  - Biomass Boiler & Ancillary Equipment Maintenance and Repair
  - Balance of Plant Maintenance and Repair
  - Distribution Piping System Maintenance and Repair
  - Building Connections Maintenance and Repair
  - Water & Treatment Chemicals
- Operating & Administrative Costs
  - Operating Labour & Supervision costs[26]
  - Operating Administrative costs
  - Plant Administrative costs
- Insurance

The operation & maintenance costs are assumed to escalate by 2% per year.

[22] The values assumed in this study are based on FVB's current understanding of the utility rates at the time of the analysis and should be revisited during later stages of design development.
[23] Wood pellet have historically shown ~1% to 1.5% annual cost increases, as per the client.
[24] Note that taxes are excluded from the financial analysis. The treatment of taxes may provide an advantage to the 'Not-for-Profit' concept.
[25] Assumes the use of a sinking fund.
[26] Based on the Yellowknife's current median labor union rates as per the latest Union of Northern Workers (UNW) collective agreements. Further details on the assumed operation requirements and plant classification are provided in Attachment II.

4.3 Analysis Results

The following sections summarize the financial analysis results for the 'For-Profit' and 'Not-for-Profit' concepts.

4.3.1 Net Project Cashflow

The net project cashflow represents the net project revenues and net project expenses over the 30-year project horizon.

The following table summarizes the project cashflow for the two concepts:

Table 6: Project Cashflow

Description	For Profit	Not-for-Profit
Project Revenues		
Thermal Energy Sales	$318.0 million	$390.2 million
Total Project Revenues	*$318.0 million*	*$390.2 million*
Project Expenses		
Project Capital		
Project Capital Equity Amount	-	-
Project Debt Repayment Cost	-$96.5 million	-$90.0 million
Salvage Cost	-	-
Utilities		
Biomass Feedstock Cost	-$79.3 million	-$97.3 million
Fuel Oil Cost	-	-
Electrical Utility Cost	-$21.9 million	-$26.9 million
Operation & Maintenance	-	-
Maintenance & Repair Cost	-$36.3 million	-$44.2 million
Operating & Admin Cost	-$27.9 million	-$28.4 million
Insurance	-$6.3 million	-$7.2 million
Total Project Expenses	*-$268.3 million*	*-$294.0 million*
Net Project Cashflow	**$49.7 million**	**$96.2 million**

From the above table, the concepts result in a positive average annual cashflow (profit) as follows:

- 'For-Profit': $1.7 million
- 'Not-for-Profit': $3.2 million

4.3.2 Accumulated Project Cashflow

The following figure shows the accumulated cashflow for the 'For-Profit' & 'Not-for-Profit' concepts:

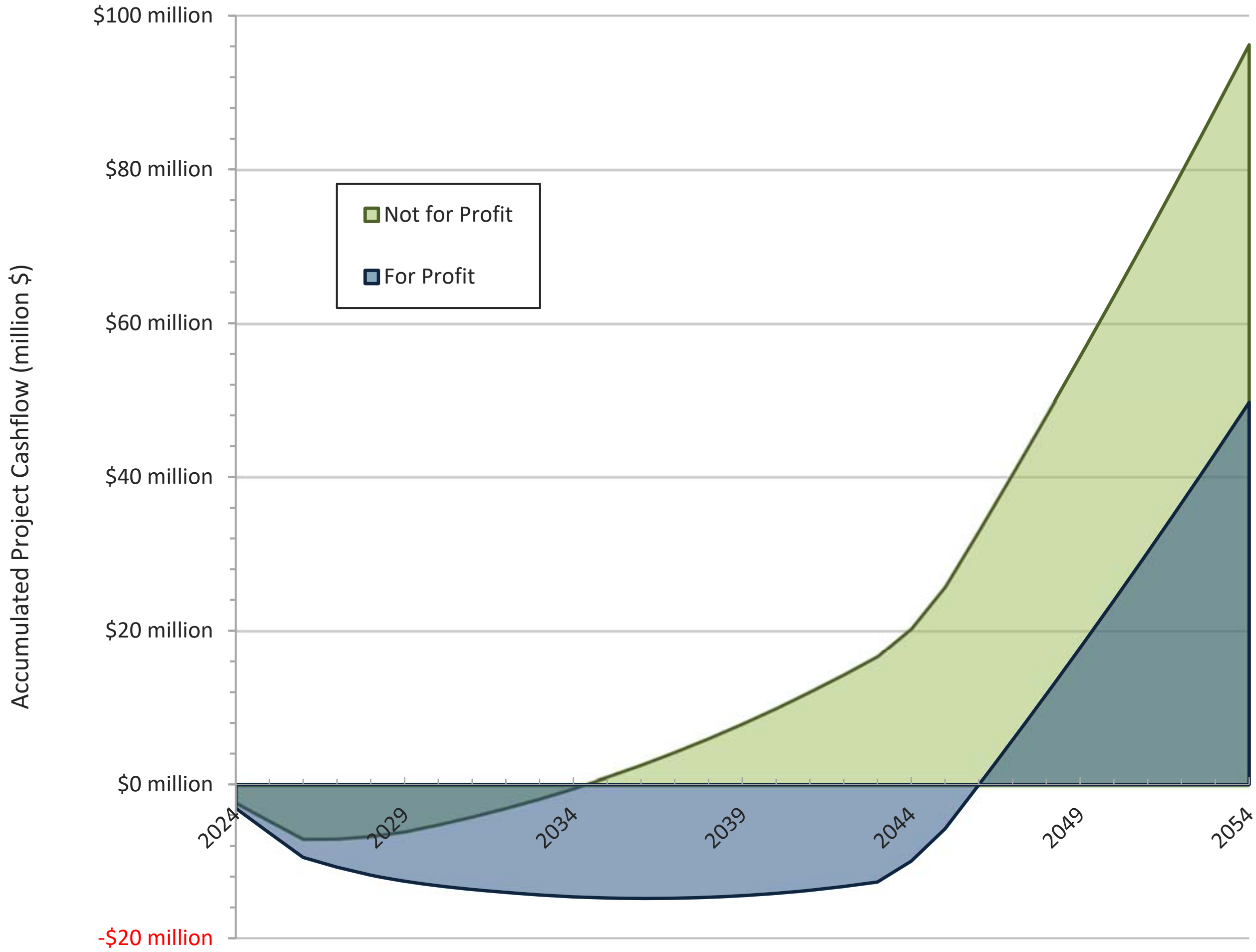

Figure 12: Accumulated Project Cashflow

The shaded areas of the curve represent the accumulated cashflow over the 30-year project horizon.

From the above figure, the concepts result in a positive accumulated cashflow period as follows:

- 'For-Profit': 23 years, or by the year 2047.
- 'Not-for-Profit': 11 years, or by the year 2035.

At the time of positive cashflow, a decision may be made to share the profits with utility customers, to expand the district energy system to other sectors, or to implement additional alternative energy technologies.

4.3.3 Total & Annual GHG Emissions Reduction

The following summarizes the financial analysis results for the total project greenhouse gas emission reductions over the 30-year project horizon[27]:

- 'For-Profit' Concept: 393,000 tonnes of CO_{2e}.
- 'Not-for-Profit' Concept: 483,000 tonnes of CO_{2e}.

The following figure shows the average annual GHG emissions reduction and average annual project profit:

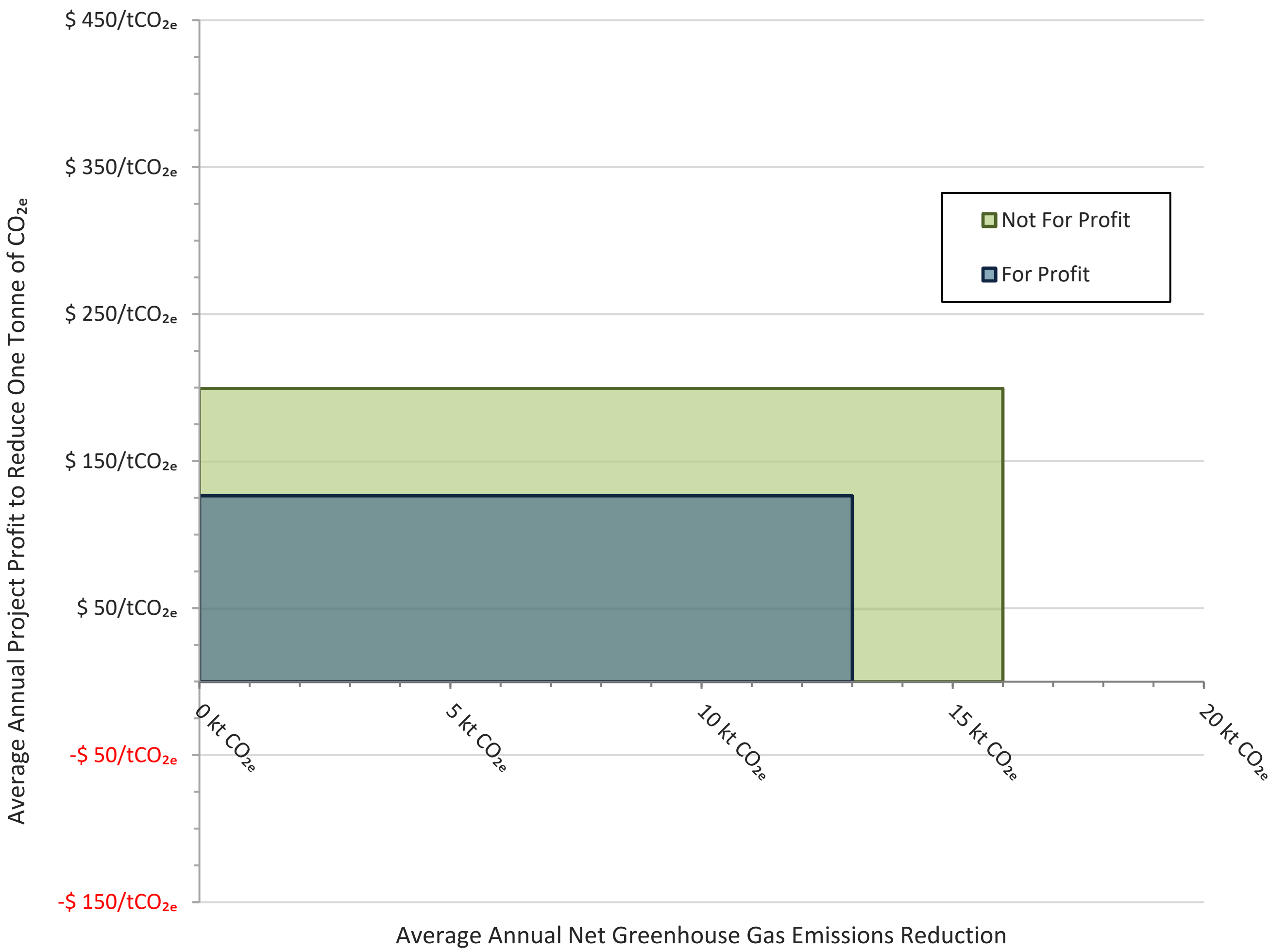

Figure 13: Average Annual Profit per Unit of GHG Emissions Reduction

The shaded area above represents the average annual results over the 30-year project horizon.

[27] Based on the assumptions noted in this study. Further details are provided in Appendix A.

4.3.4 Key Financial Metrics

The following table summarizes the key financial metrics for the financial analysis:

Table 7: Financial Analysis Results

Description	For Profit	Not-for-Profit
Project Return (%)	8.2%	20.4%
Net Present Value	$16.5 million	$45.5 million
Levelized Cost of Energy	$ 16.0 / MWh	$ 36.1 / MWh
Levelized Cost of GHG Reduction	$ 42.0/tCO_{2e}	$ 94.4/tCO_{2e}

The net present value and levelized costs assume a project discount rate of 3.0%.

These values are different than the previous costs previously shown in the report. These levelized cost metrics evaluate the total project costs over the project horizon with consideration to the assumed project discount rate.

Note: the levelized costs shown above are positive, indicating a profit.

4.4 Sensitivities

This study considers four sensitivities, that include variability in blended fuel oil market rates, thermal energy sales rate discounts, capital costs, and project grant funding.

4.4.1 Blended Fuel Oil Market Rate

The following summarizes the blended fuel oil market rate sensitivity assumed for the two concepts:

- Low: -20%
- Base Case: 0%
- High: 30%

The following chart illustrates the sensitivity analysis results:

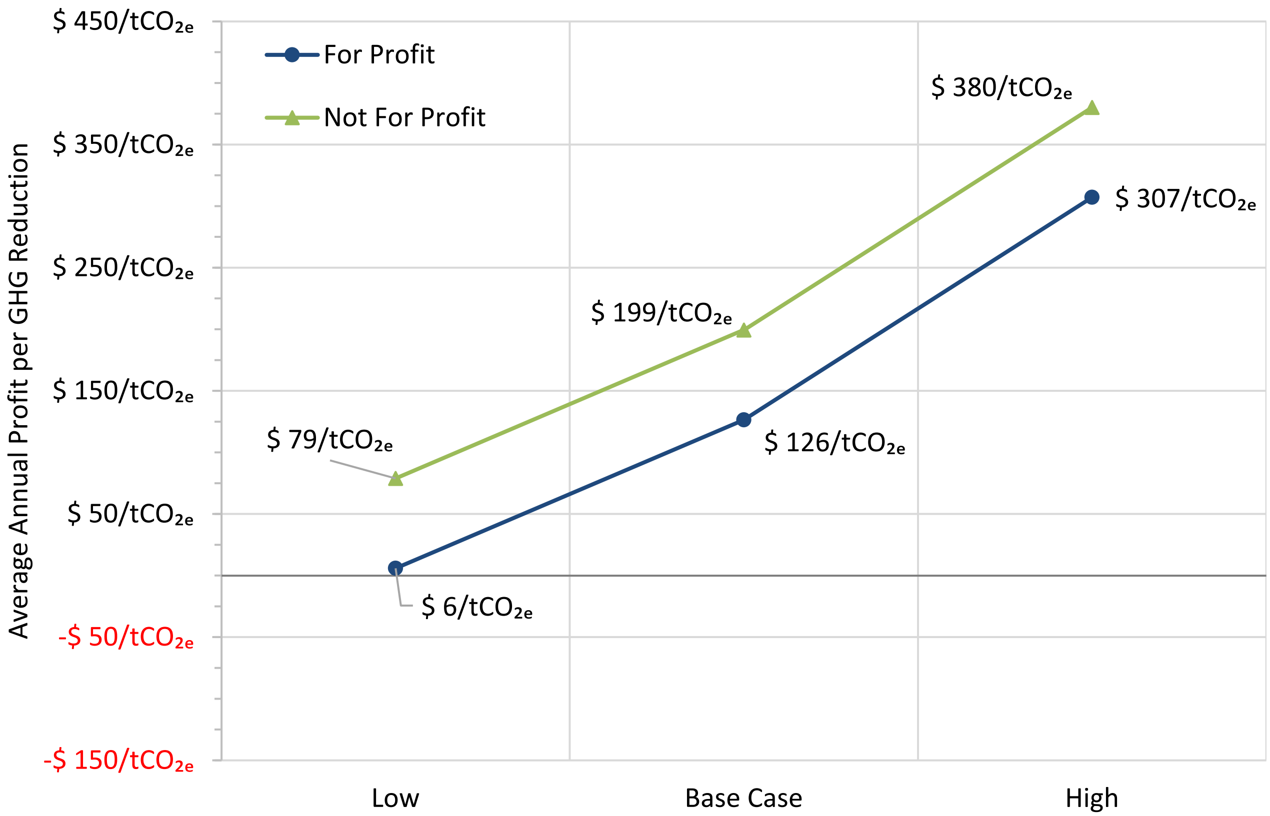

Figure 14: Blended Fuel Oil Market Rate Sensitivity Results

Since the blended fuel oil market rate is directly related to the only project revenue stream, the above charts indicate a strong correlation between the project business case and the blended fuel oil market rate.

As shown, both concepts survive the blended fuel oil market rate sensitivity.

4.4.2 Thermal Energy Rate Discount

The following summarizes the thermal energy rate discount sensitivity assumed for the two concepts:

- Base Case: -10%
- No Discount: 0%
- Premium Rate: 5%

The following chart illustrates the sensitivity analysis results:

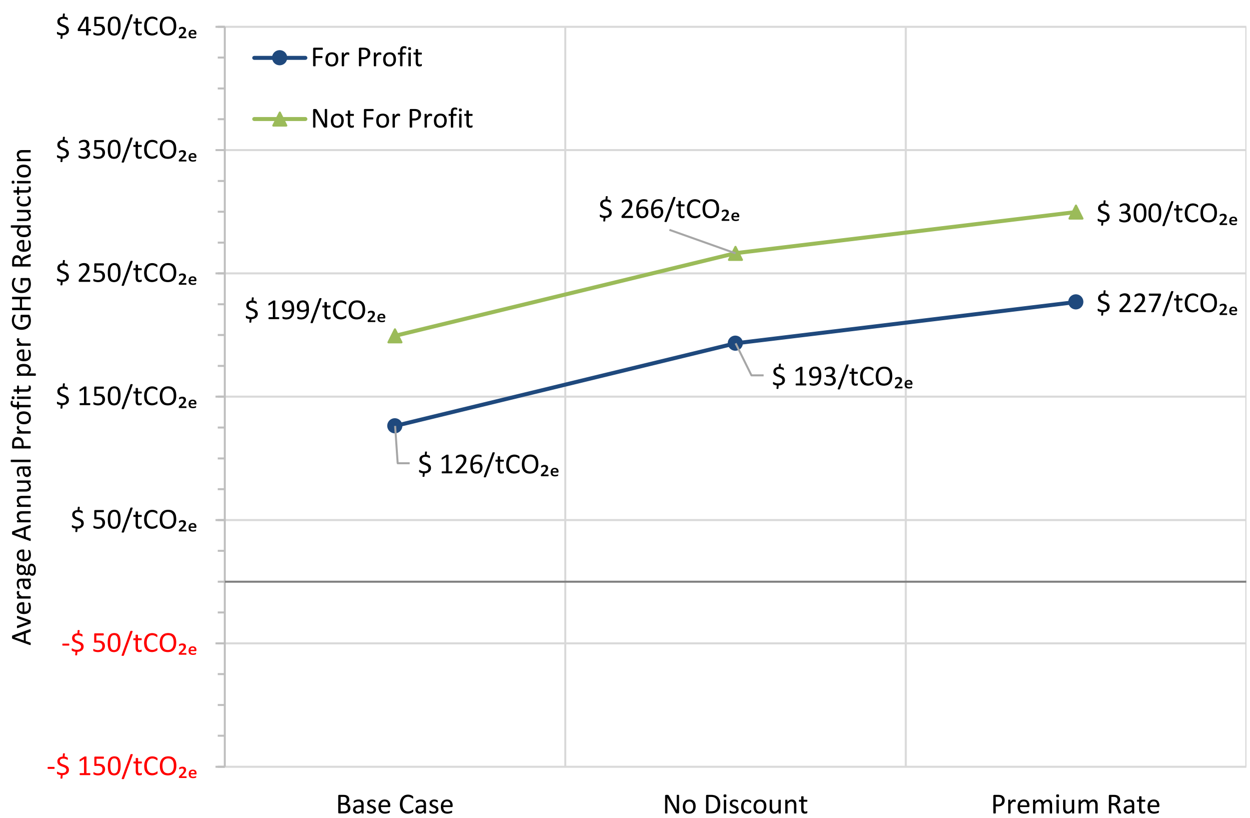

Figure 15: Thermal Energy Rate Discount Sensitivity

As shown, both concepts survive the thermal energy rate discount sensitivity.

4.4.3 Capital Cost

The following summarizes the capital cost sensitivity[28] assumed for the two concepts:

- Low: -10%
- Base Case: 0%
- High: 35%

The following chart illustrates the sensitivity analysis results:

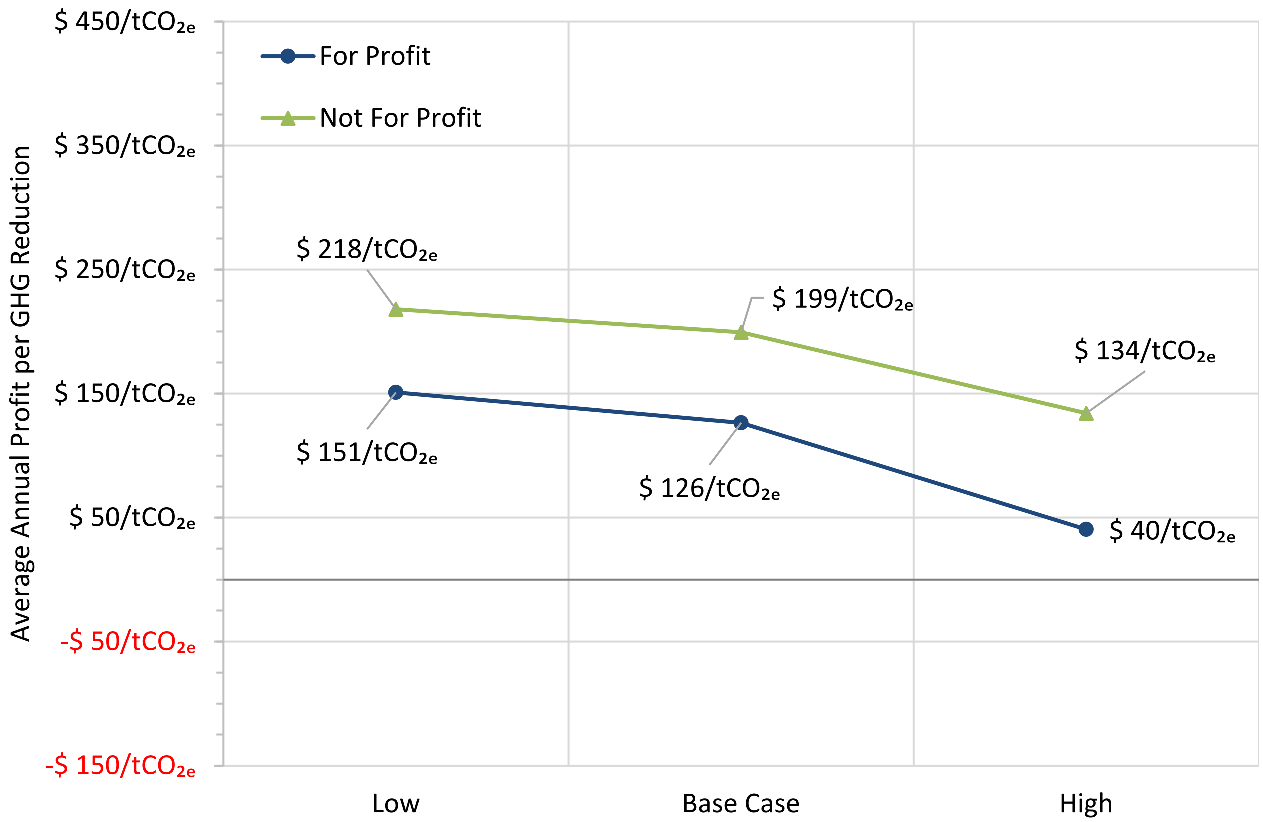

Figure 16: Capital Cost Sensitivity

As shown, both concepts survive the capital cost sensitivity.

[28] The values are based on the accuracy bounds of the provided capital cost estimate.

4.4.4 Grant Funding

The following summarizes the grant funding sensitivity assumed for the two concepts:

- Low: 15% (Not-for-Profit); 0% (For-Profit)
- Base Case: 30% (Not-for-Profit); 10% (For-Profit)
- High: 50% (Not-for-Profit); 25% (For-Profit)

The following chart illustrates the sensitivity analysis results:

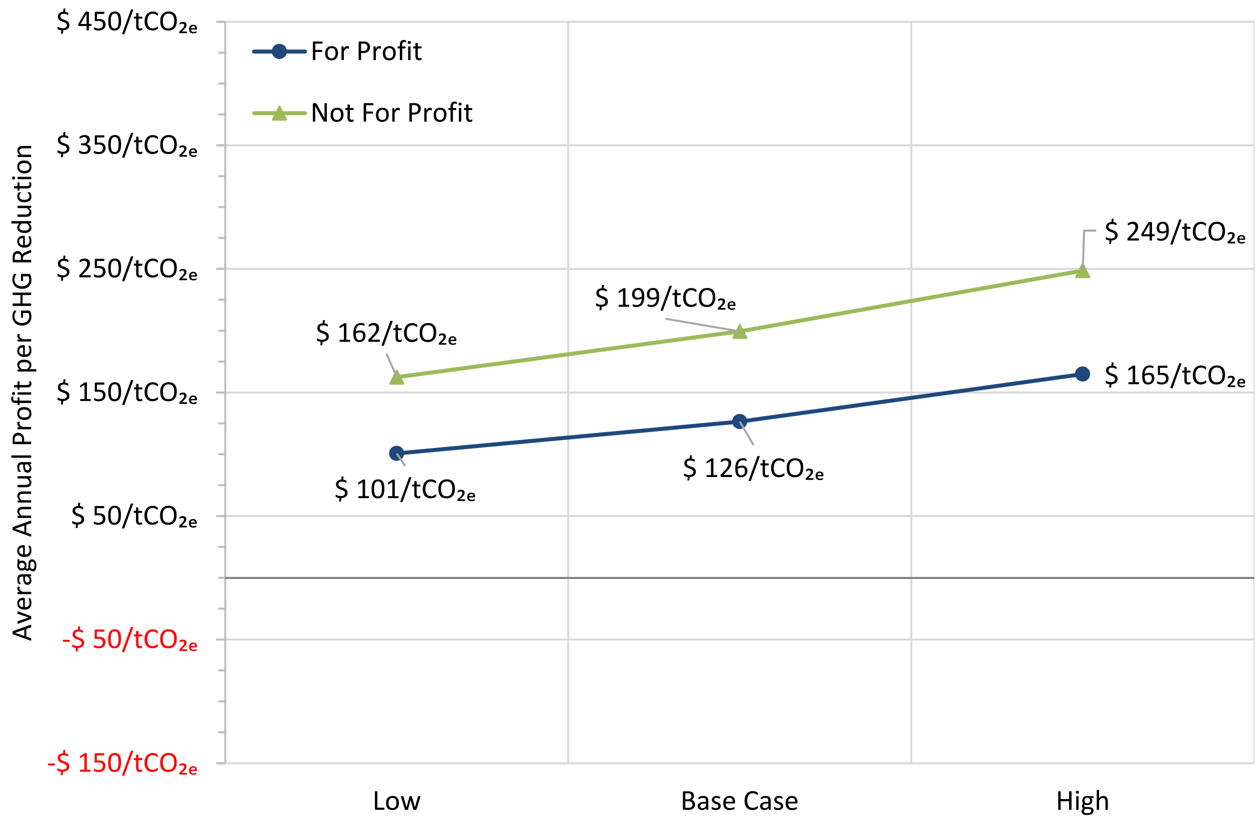

Figure 17: Grant Funding Sensitivity

As shown, both concepts survive the grant funding sensitivity.

4.5 Scenarios

This study considers two additional scenarios to review the impact of external factors; climate change and carbon tax that is included with utility rates.

4.5.1 Climate Change

The base scenario assumes there is no change to the local climate from historical climate conditions.

To review the potential impact of climate change, a scenario is provided that considers a decrease in thermal energy sales in response to increases to the average annual temperature in the city of Yellowknife. This scenario assumes that annual thermal energy sales are reduced by 5%.

The following figures summarize the scenarios for both the 'For-Profit' and 'Not-for-Profit' concepts:

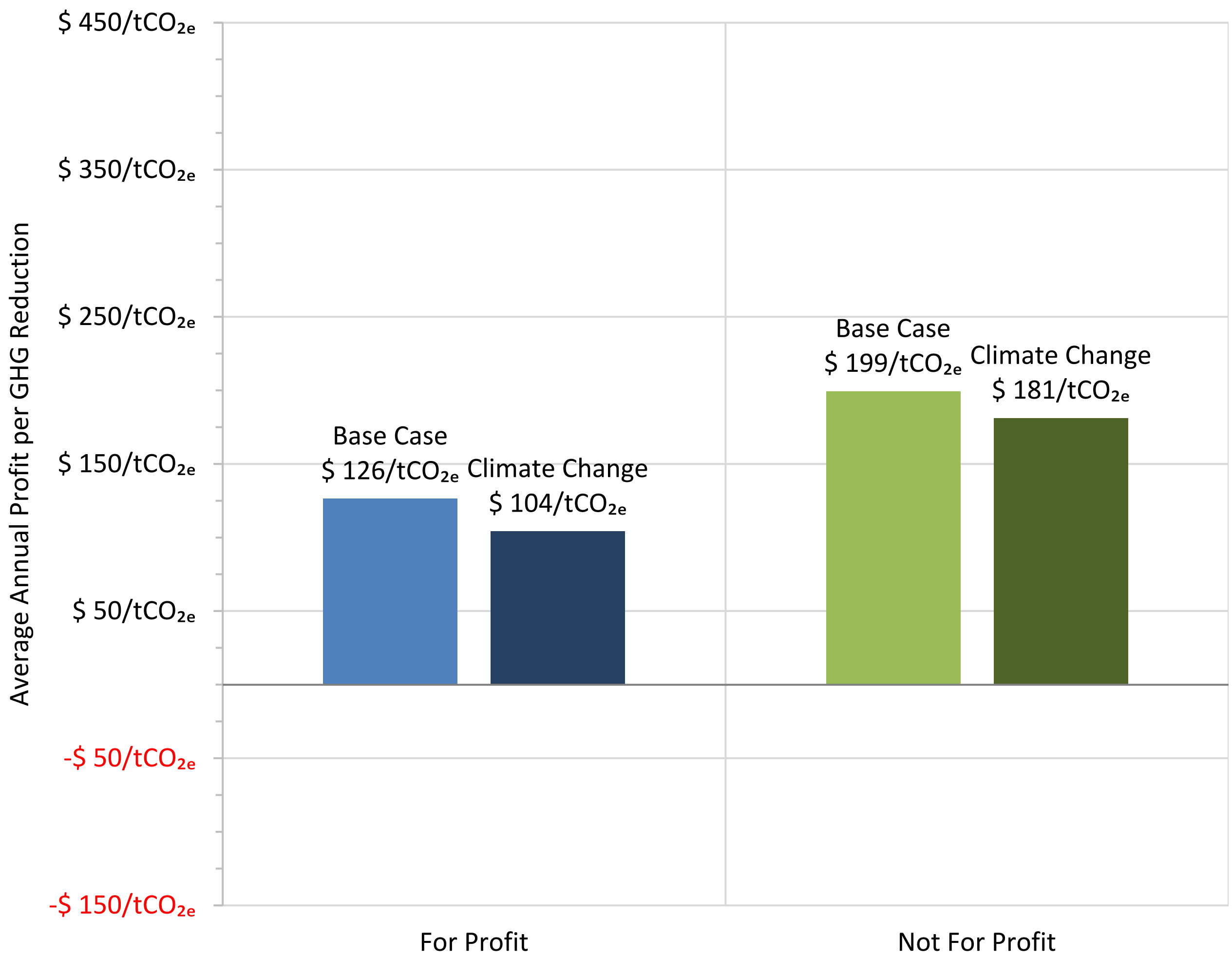

Figure 18: Climate Change Scenarios

As shown, the results survive the 'climate change' scenario.

4.5.2 Carbon Tax

The base scenario assumes that a carbon tax is included and applied to fuel oil and electricity utility costs.[29]

This scenario is provided to consider a scenario where carbon tax is excluded from utility costs.

The following figures summarize the scenarios for both the 'For-Profit' and 'Not-for-Profit' concepts:

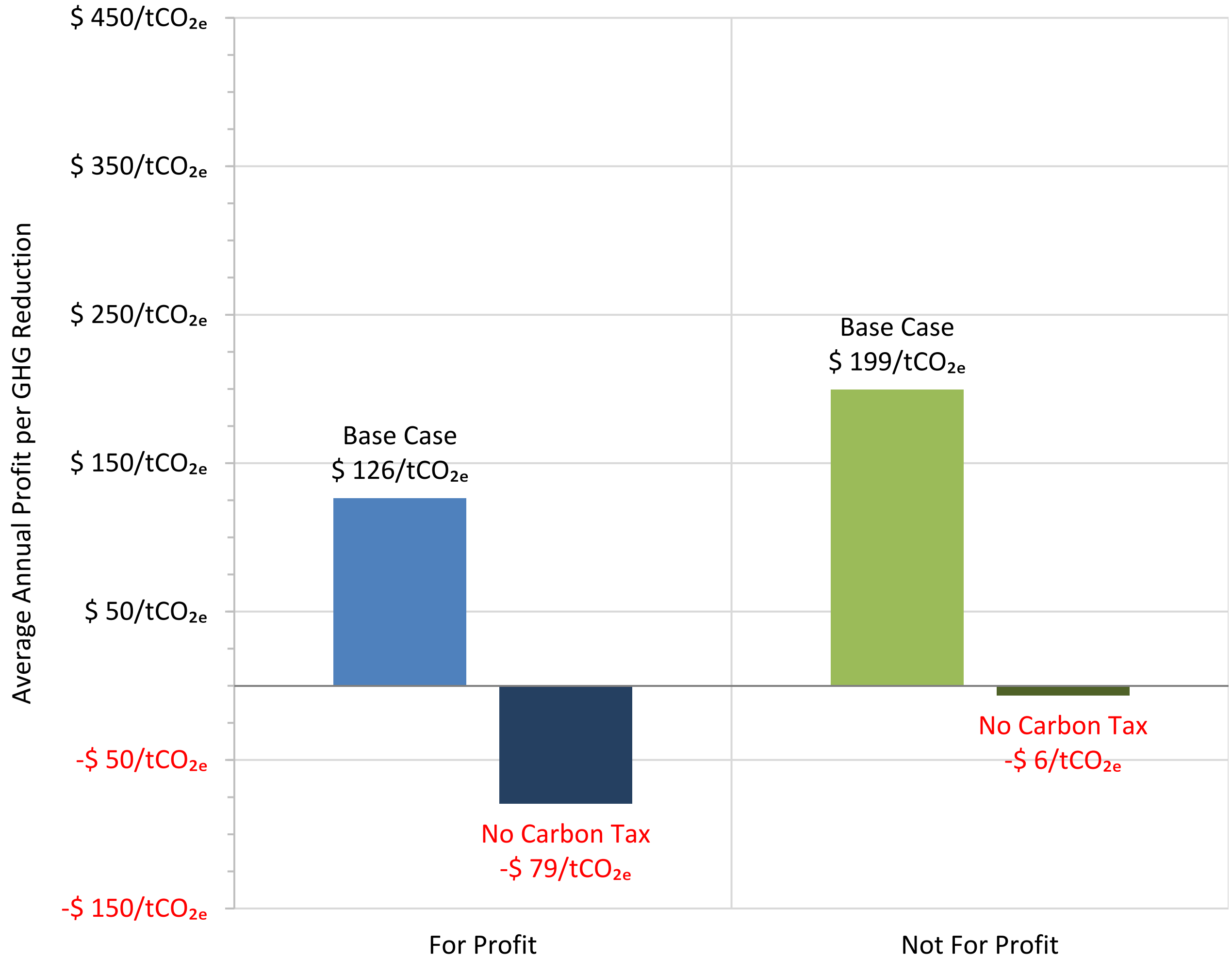

Figure 19: Carbon Tax Scenarios

As shown, ***neither concept survives*** the 'no carbon tax' scenario, indicating a strong correlation between carbon tax and overall financial analysis results.

[29] Based on a decision to implement the federal carbon tax structure in the NWT made by the Government of Northwest Territories, announced on October 31, 2022. Available: https://www.gov.nt.ca/en/newsroom/nwt-carbon-pricing-approach-changing-align-new-federal-requirements.

5 NEXT STEPS

Following this work, the next step would be to identify and engage with potential developer(s)/champion(s) for both the 'For-Profit' and the 'Not-for-Profit' concepts. As well, it is recommended to engage with any stakeholders that may be interested in providing additional project support.

The potential developer(s) would assess the viability of developing a district heating system based on their own definitions of project success, financial assumptions, level of acceptable risk, and concept preferences.

If there is interest, the potential developer(s) may initiate discussions with prospective customers with the goal of developing preliminary agreements or customer term sheets for connection to the system.

The potential developer(s) would continue with preliminary engineering and financial analysis to further refine the concepts, key assumptions, and financial results.

This could include for the following:

- Visits to key customer building connections to confirm interconnection concepts and district heating system compatibility,
- Refinement of peak heating demand and energy estimates,
- Consideration for expansion of the system beyond the assumed target area,
- Consideration for downtown development plans,
- Initiate discussions with biomass fuel feedstock supplier(s) to refine assumptions on price and availability,
- Consideration for other alternative energy technologies, or
- Consideration to provide full thermal energy service that would entirely displace fuel oil consumption in customer buildings.

The timing and project execution steps is dependent on the potential developer(s)' internal processes, and would likely be influenced by customer interest, labour markets, capital/financing availability, and grant funding.

Additional project considerations are provided in Appendix C.

6 SUMMARY REMARKS

The widespread implementation of a utility-scale biomass district heating system in Yellowknife enables significant greenhouse gas emission reductions and reduced costs to the building owners, while resulting in a profitable utility.

Based on the results of the financial analysis, it is FVB's opinion that both the 'For-Profit' and 'Not-for-Profit' models provide favourable business cases.

The 'For-Profit' concept provides an attractive opportunity for a utility or external investor to own and operate the system as a thermal energy utility.

The 'Not-for-Profit' concept offers increased access to grant funding and allows for the development of a larger district heating system. This project provides an opportunity to use profits earned to expand the district heating system and achieve deeper decarbonizing impacts, and/or to reduce the cost of the thermal energy service provided to connected customers.

With the adaptable nature of a district heating system, there is the future opportunity to integrate electric boilers and/or other alternative technologies into the energy centre without requiring changes to the distribution or customer building connections. This modular nature increases the resiliency of the system and allows for future innovations to be implemented.

For both concepts, there is an opportunity for system growth beyond the target area identified in this study. This growth could include servicing additional areas and building connections across the community.

In addition, there is the future opportunity to providing full thermal energy service to customer buildings; whereby no fuel consumption or heating equipment capacity would be required at the buildings.

The financial analysis results are summarized as follows:

1) The sensitivity analysis identified that increased fuel oil costs, charging a premium on thermal energy rates, increased grant funding, and lower project capital costs all results in a more attractive business case.
2) The scenario that considers climate change impact resulted in a slightly less attractive business case.
3) The scenario where utility costs do not include for a carbon tax resulted in no business case for the project. This illustrates the impact of a carbon tax to incentivize renewable energy projects.

A district heating system presents an exciting opportunity to help the community of Yellowknife decarbonize their heating need by offsetting fuel-oil consumption, while also presenting a favourable business case for both the potential developer(s) and the connected customers.

Developing a biomass district heating system in Yellowknife could form an important part of the territorial climate change strategy.

*** End of Main Document ***

APPENDICES

APPENDIX A FUEL FEEDSTOCK ASSUMPTIONS

A.1 Fuel Oil

This study assumed the following characteristics for the fuel oil feedstock:

Table 8: Assumed Fuel Oil Characteristics

Description	Value
Higher Heating Value, HHV	11.1 kWh / L
GHG Intensity[30]	2.76 kg CO_{2e} / L

A fuel oil system seasonal fuel utilization efficiency is assumed as follows:

- Target building existing fuel oil heating system: 65% (HHV)[31]
- Biomass Energy Centre: N/A

This study assumes a commercial blended fuel oil market rate of ***$1.50 per litre***[32], excluding carbon taxes.

Fuel oil purchased commercially in Yellowknife was observed to be provided at varying commercial discount rates based on the volume of fuel oil ordered. This discount is assumed to be ***-15.0%***[33] , and is represents the average commercial discount rate for a typical building connection.

This study assumes that fuel oil purchases would be subject to a carbon tax.

[30] Based on the 2022 National Inventory Report: Greenhouse Gas Sources and Sinks in Canada.

[31] Reflects the typical building's fuel-oil heating system seasonal fuel utilization efficiency. Buildings with known heating system upgrades were considered on a case-by-case basis, based on conversations with the client.

[32] The blended fuel oil market rate based on consensus with the client and uses the average fuel oil cost from the last 12-months (minus the federal carbon tax). Average fuel oil cost is based on Statistics Canada historic monthly household heating fuel retail prices for Yellowknife, available: Statistics Canada. Table 18-10-0001-01 Monthly average retail prices for gasoline and fuel oil, by geography

[33] Based on comparison between historic retail rates and billing data for a representative sample of the proposed target buildings, as provided by the client.

A.2 Biomass

This study assumes the following characteristics for the biomass feedstock:

Table 9: Assumed Biomass Fuel Characteristics[34]

Description	Value
Lower Heating Value, LHV	20.3 GJ / Bone Dry Tonne
Moisture Content	6.00%
Higher Heating Value, HHV	19.08 GJ / Wet Tonne
Ash Content	0.50%
GHG Intensity[35]	0 kg CO_{2e} / Wet Tonne

A biomass system seasonal fuel utilization efficiency was assumed as follows:

- Target building existing biomass heating system: 70% (HHV)
- Biomass Energy Centre: 80% (HHV)

This study assumes the biomass wood pellets would be supplied from La Crête sawmill and delivered to site through a direct, bulk contract. The following table summarizes the key assumptions:

Table 10: Blended Biomass Utility Rate Assumptions[36]

Description	Value
Delivered Cost[37]	$ 215 / wet tonne
Assumed Markup	0%
Pneumatic Blower & Local Delivery Premium[38]	$ 0 / wet tonne
Blended Biomass Utility Rate	***$ 215 / wet tonne***

[34] Based on a 2012 wood pellet testing study prepared by the Arctic Energy Alliance for wood pellets supplied from La Crête sawmill.

[35] This study assumes that the biomass fuel feedstock is sustainably sourced and considered net-carbon neutral. This study does not consider scope 3 emissions associated with any fuel or energy source; therefore, no carbon tax was considered in the blended biomass utility rate.

[36] This analysis neither took credit for the value of the biomass bottom ash as a fertilizer product, nor did it allocate a cost for disposal of the ash stream. Neither option was expected to have an appreciable impact to the overall project economics.

[37] The biomass utility rate is based on historic wood pellet delivery rate information from the La Crête sawmill to the SWF Baling facility in Yellowknife, as provided by the client.

[38] As per the client, the existing biomass heating systems in Yellowknife may be charged a ~$40 per tonne premium for delivery with a pneumatic blower.

A.3 Electricity

This study assumes that all electricity would be provided by the electricity grid serving Yellowknife. The average blended electricity rate is assumed at **$242 per MWh_e**[39] for all purchases from the electrical utility grid. This rate is assumed to include monthly demand charges, fixed costs, and rate riders.

This study assumes that electricity purchases would be subject to the carbon tax.

The grid electricity GHG intensity is based on intensity projections[40] for all the Northwest Territories. This could be considered a conservative assumption, as most of the Yellowknife's electricity is generated by hydroelectric sites, and not diesel generators as are typical elsewhere in the Territory.

A.4 Carbon Tax

This study assumes that a carbon tax is applied to fuel costs[41], and assumes the following carbon tax schedule:

- Year 2022: $50 per tonne of CO_{2e}.
- Between 2022 and 2030[42]: Annual increase by $15 per tonne of CO_{2e} per year, to a value of $170 per tonne of CO_{2e} in the year 2030.
- Beyond 2030, the rate was assumed to escalate by 2% annually.

The carbon tax is applied to fuel costs in accordance with their associated greenhouse gas emissions.

[39] Blended grid electricity rate based on Northland Utilities (Yellowknife) Limited's General Service (Commercial) Rate Schedule and Riders.
[40] Based on 'Canada's Greenhouse Gas and Air Pollutant Emissions Projections 2021' prepared by Environment and Climate Change Canada.
[41] As per NWT decision to implement carbon pricing that aligns with the federal carbon tax.
[42] As per Environment and Climate Change Canada (ECCC) schedule.

APPENDIX B PROJECT CAPITAL COST SUMMARY

Capital cost estimate were prepared for both concepts for the three major components of the district heating system: the Biomass Energy Centre, the Distribution Piping System, and the Building Connections.

The following table summarizes the capital cost estimates in 2022 Q3 Canadian dollars:

Table 11: Project Capital Cost Estimates

Cost Component	'For Profit'	'Not-for-Profit'
Construction Costs		
Biomass Energy Centre	$ 19.7 million	$ 22.4 million
Distribution Piping System	$ 17.5 million	$ 18.9 million
Building Connections	$ 11.5 million	$ 16.2 million
Subtotal Construction Costs	*$ 48.7 million*	*$ 57.5 million*
Owner's Costs		
Owner's Contingencies	$ 12.1 million	$ 14.3 million
Owner's Soft Costs	$ 6.9 million	$ 8.5 million
Owner's Project Development Costs	$ 1.0 million	$ 1.2 million
Land Cost[43]	$ 3.0 million	$ 3.0 million
Subtotal Owner's Costs	*$ 23.0 million*	*$ 27.0 million*
TOTAL Project Costs	**$ 71.7 million**	**$ 84.5 million**

The cost estimates provided are Class 4 (as per AACE International No.17R- 97 Rev August 7, 2020) and were considered preliminary with an expected level of accuracy of +35% and -10%. These accuracy bounds were carried as a sensitivity in the financial model.

It should be noted that the above capital line items have been rounded to the nearest $100,000. This rounding may lead to slight discrepancies between section totals and the subtotals/totals shown.

Refer to Attachment III for further details on the capital cost estimates.

[43] As per the Coldwell Banker's current advertised commercial listing for the project site.

APPENDIX C PROJECT CONSIDERATIONS

This section provides additional considerations for developing a biomass district heating system in Yellowknife and is based on FVB's experience with other biomass-based district heating systems across Canada.

This study considers using a feedstock of wood pellets from a well-established biomass supplier. To maintain a reliable biomass heating system, it is imperative to identify a supply that can produce the necessary quantity of fuel with consistent quality. Wood pellets were chosen in this study as an existing supplier was identified, and due to their overall consistency, high bulk density, and ease of storage and material handling.

Alternative biomass feedstocks can include other direct forms of non-merchantable biomass, such as harvest residues, sawmill residues, wood sourced from pine beetle or forest fire devasted areas, short rotation crops, or construction, renovation & demolition (CRD) waste streams diverted from a local landfill. To utilize these sources in a system, it is important to evaluate the available quantity, the quality of the feedstock, consider fuel preparation requirements, consider additional upgrades to biomass fuel handling, storage, and conveyance systems, and to consult the boiler manufacturer on fuel compatibility.

Biomass combustion is often considered net-carbon neutral because of the avoided emissions associated with the decomposition of the waste biomass, and the carbon sequestered during new growth. Ultimately, this neutrality is dependent on the biomass feedstock source and sustainable harvesting practices and/or waste diversion opportunities.

Scope 3 emissions associated with the harvesting, fuel preparation, and transporting of the biomass feedstock is excluded from the scope of this study. This is consistent with all fuel and energy sources.

However, biomass combustion still produces a local source of emissions, with a flue gas comprised of carbon dioxide, water vapour, and additional components typical of solid fuel combustion. To reduce the impact of the system on air quality, this study provided the biomass system with multi-cyclone filters for additional emissions clean-up and to reduce emission particulate matter. Depending on variation of emission with biomass feedstock and local environmental requirements, the exhaust clean-up technologies implemented should be further evaluated at later stages of design development.

Depending on the biomass feedstock, the bottom ash from the biomass system may be recovered and used/sold as fertilizer, or it may be considered a waste stream that requires disposal. The fly ash from the exhaust stream has less application and is expected to require disposal. Ash production is estimated at <1% of the biomass feedstock volume and would be collected in ash containers.

*** End of Appendices ***

ATTACHMENTS

ATTACHMENT I BUILDING CONNECTIONS MEMO

MEMORANDUM

Attention:	Lachlan MacLean	FVB Project:	222220
Owner:	Alternatives North	Project Name:	Yellowknife Biomass District Heating System Feasibility Study
Sender:	Gary Saskiw - FVB Energy	Date:	May 10, 2022
Distribution:	Lachlan MacLean - Alternatives North Aïda Nciri - Alternatives North Bard Skagestad - FVB Energy FVB - file.	Pages:	1

RE: Criteria for Initial Target Building Selection for Possible District Energy Connection

Minimum Requirements:

1. Is the building located approximately within the core study areas defined as follows:
   a. Downtown: (north of 52^{nd} Avenue & between 44^{th} and 53^{rd} Street)
   b. South: (north of Rycon Drive & between 49^{th} and 52^{nd} Street)
   c. West: (along Franklin Avenue west to the city-owned recreational facilities).
2. Does the building meet the minimum load criteria?[1]
   a. Is the building fuel oil consumption more than 40,000 litres per year (> 300 MWh annual thermal energy requirements), or
   b. Does the building have a gross floor area greater than 10,000 ft^2 (930 m^2)?
3. Do the existing buildings currently utilize a hydronic heating system?

Additional Beneficial Criteria for District Energy to proceed:

1. Is the building owned by the City, Government, or one of the major REITs?
2. Is the mechanical room in the basement or ground floor?
3. Is there an interest from building owners to provide a heat alternative to replacing Owner supplied heating equipment?

[1] Typical high thermal energy density buildings include office buildings, schools, pools, hospitals, hotels, or multi-unit residences. Typically, this excludes townhouses, curling rinks, light-commercial businesses, motels, or halls.

ATTACHMENT II DESIGN BASIS DOCUMENT

Alternatives North

YELLOWKNIFE BIOMASS DHS FEASIBILITY STUDY

DESIGN BASIS DOCUMENT

SUBMITTED ON: JANUARY 13, 2023

SUBMITTED BY:

FVB ENERGY INC

CELEBRATING 30 YEARS | 1992 - 2022

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Issue	Reviewed By	Date
Draft Issue for Client Review	B. Skagestad	July 18, 2022
Final Issue	B. Skagestad	November 24, 2022
Revised Final Issue	B. Skagestad	January 13, 2023

Review By:

B. Skagestad

Prepared By:

G. Saskiw

REGISTERED PROFESSIONAL ENGINEER
G.J. SASKIW
LICENSEE
Jan 13, 2023
NT/NU

NAPEG ID#: L5216

PERMIT TO PRACTICE
FVB ENERGY INC.
Signature
Date Jan 13, 2023
PERMIT NUMBER: P 381
The Association of Professional Engineers, Geologists and Geophysicists of the NWT / NU

Permit to Practice #P381

CONTENTS

BIOMASS DISTRICT HEATING SYSTEM

Based on the initial review of the building load information and building operating temperatures, preliminary design requirements for the proposed biomass district heating system was established. The following requirements are based on information provided by Alternatives North (AN).

The biomass district heating system is comprised of the biomass energy centre, the low-temperature distribution piping, and the building connections.

The biomass energy centre is supplied with wood pellets, which it then combusts in biomass heating systems to create a thermal energy heating product.

This low-temperature hot water product provides baseload heating to targets customers in the downtown central core via a buried, distribution piping system.

The hot water is used to pre-heat the customer buildings internal circulating heating fluid before it enters the boiler or furnace system of the building. If the buildings heating fluid stream meets the required temperature that is needed to heat the building the fluid will circulate through the boiler or furnace without having any additional heat added.

The preliminary biomass district heating system pressure and temperature requirements are based on an initial review of the proposed system targeted distribution area, temperature requirements of existing buildings, and considerations to geodetic elevation variances as well as pipe sizing design parameters (e.g., pressure gradient Pa/m).

An overall concept schematic is provided in Appendix A.

1 BIOMASS ENERGY CENTRE

A baseload biomass fueled hot water heating plant is proposed to be installed that would provide baseload heating to the existing targeted customer buildings in Yellowknife, NWT.

Heat in the form of low-temperature hot water (LTHW) will be generated in the plant and circulated to these buildings.

As this is a baseload source of heat, each buildings internal boilers or furnaces will remain in operation to provide peaking and backup to this baseload plant.

Please refer to Appendix B for reference drawings.

1.1 DESIGN CONDITIONS

The following table describes the process conditions of the proposed, new biomass energy centres for the 'For-Profit' and 'Not-for-Profit' concepts.

Table 1: Biomass Energy Centre Design Conditions

Description	For-Profit	Not-for-Profit
Biomass Energy Centre Installed Capacity	7.5 MW_t	9.0 MW_t
Minimum System Demand (Turndown)	0.75 MW_t	
Equipment Redundancy Philosophy	No Redundancy[1]	
Maximum System Export Capacity	7.5 MW_t	9.0 MW_t
Biomass Energy Centre Thermal System Design Capacity[2]	22.5 MW_t	24.0 MW_t
Winter District Heating System Supply Temperature	105°C[3]	
Winter District Heating System Return Temperature	80°C	
Biomass Energy Centre System Mechanical Design Rating	1,100 kPag[4] @ 121°C	

The biomass energy centre is expected to be defined as a '2nd-class plant' (low-pressure plant above 5,000 kW_t).

The hot water system is expected to be capable of operating with a 25°C delta T during periods of peak demand. The supply water temperature is expected to be reset to below 80°C during the summer months.

[1] There is no allowance for redundant equipment in the plant concept. If one of the biomass heating systems or auxiliary equipment supporting it fails, that capacity is lost, until the failure is corrected.
[2] An allowance in the piping headers design and the overall plant layout has been made for the addition of a future 5 MW_t biomass heating system, and a future 10 MW_t hot water boiler with fuel source to be determined.
[3] With biomass heating system only. Supply temperatures could be increased to 115°C with future added peaking capacity.
[4] Maximum conditions to avoid design registration and to stay within the "Low-Pressure Plant" classification per the Regulations.

1.2 Load Duration Curve

Based on the terms of reference and discussions with the Client, both biomass district heating system concepts were sized based on ~50% of buildings peak thermal capacities, with a target of supplying >80% of the annual thermal energy. The "baseload" thermal energy requirements as well as redundancy would be provided by the target customer building's on-site heating equipment.

1.2.1 'For-Profit' Load Duration Curve

The following load duration curve (LDC) was generated for the downtown 'Central Core' target buildings in the 'For-Profit' concept:

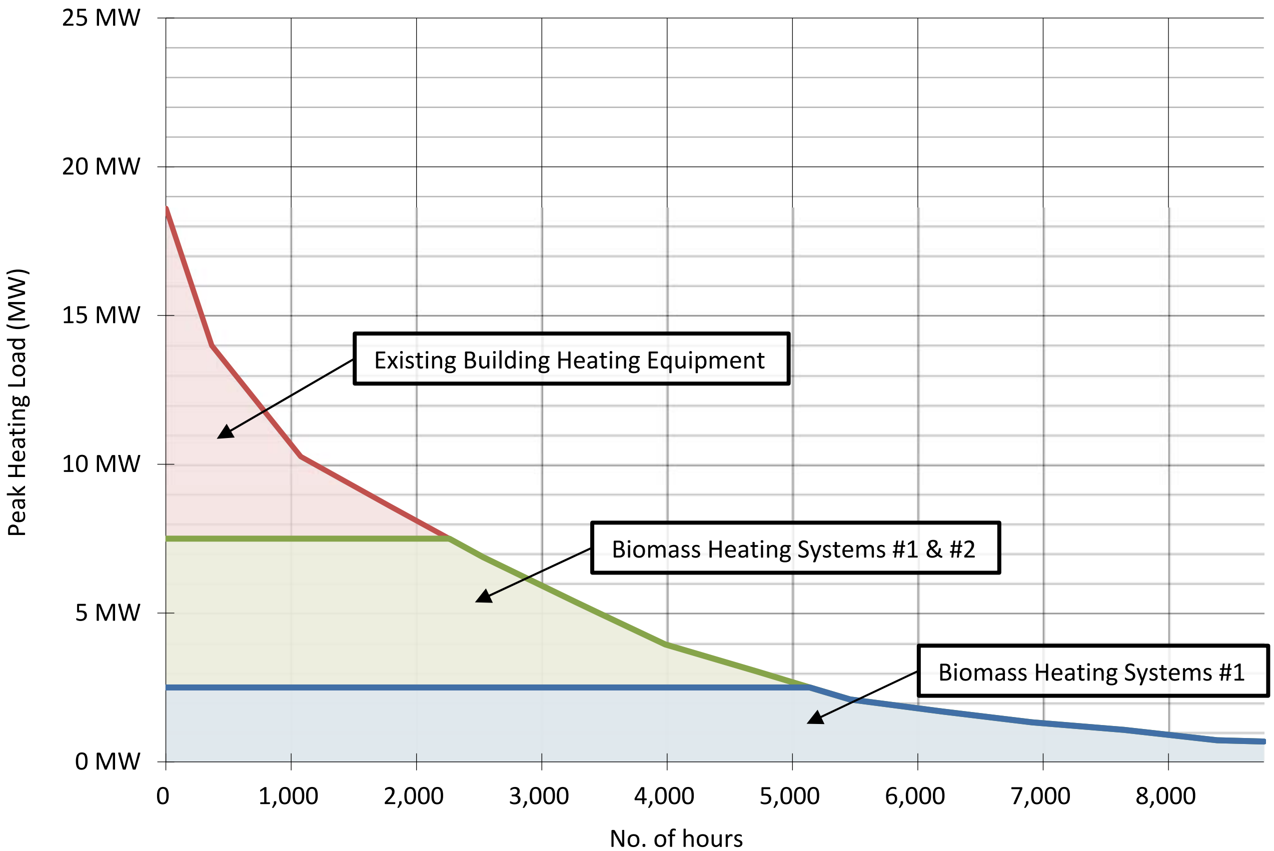


Figure 1: 'For Profit' Central Core Target Buildings Load Duration Curve (Full Build-out)

To improve equipment full load hours and turndown, it is envisioned that the biomass energy centre would consist of two biomass heating systems: one @ 2.5 MW_t and one @ 5 MW_t capacity.

From the load duration curve above, both biomass heating systems (total capacity of 7.5 MW_t) is estimated to operate for ~2,200 full load hours.

The smaller biomass heating system (capacity of 2.5 MW_t) is estimated to operate with over 5,000 full load hours. With an expected turndown of ~30% the installed capacity, the 2.5 MW_t biomass heating system would be able to operate at low system load throughout the year.

1.2.2 'Not-for-Profit' Load Duration Curve

The following load duration curve (LDC) was generated for the downtown 'Central Core' target buildings in the 'Not-for-Profit' concept:

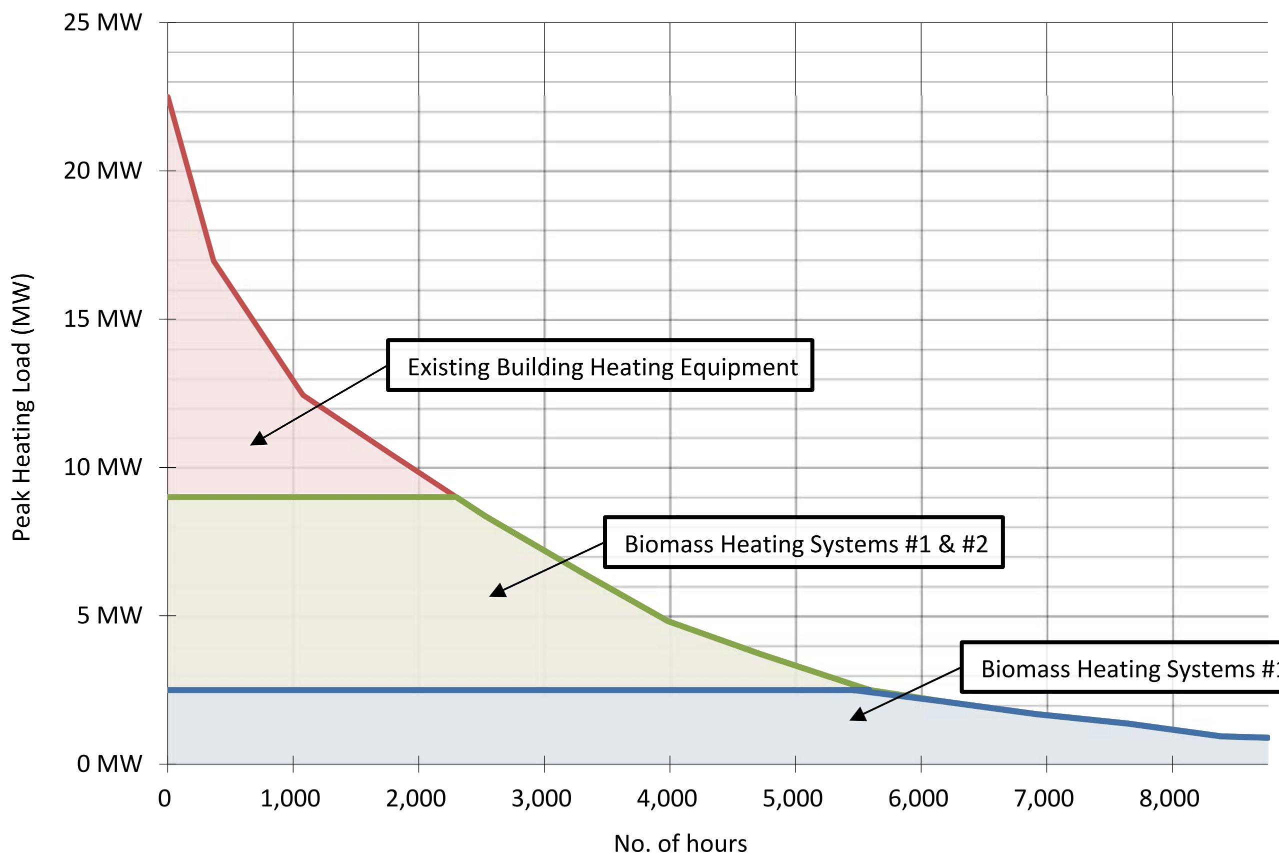


Figure 2: 'Not for Profit' Concept Central Core Target Buildings Load Duration Curve (Full Build-out)

To improve equipment full load hours and turndown, it is envisioned that the biomass energy centre would consist of two biomass heating systems: one @ 2.5 MW_t and one @ 6.5 MW_t capacity.

From the load duration curve above, both biomass heating systems (total capacity of 9.0 MW_t) is estimated to operate for ~2,300 full load hours.

The smaller biomass heating system (capacity of 2.5 MW_t) is estimated to operate with over 5,500 full load hours. With an expected turndown of ~30% the installed capacity, the 2.5 MW_t biomass heating system would be able to operate at low system load throughout the year.

1.3 Process Description

The fuel will be supplied as wood pellets and will be brought to the plant site by 'B-train' (truck-trailer). The wood pellets will be unloaded from the truck bottom hatch into a covered unloading pit where it is transferred up a bucket elevator to the silos for storage. The silos are located outside of the plant.

A conveying system will transfer the fuel pellets from the silos into the plant, and to the boiler combustion chamber. Biomass fuel is fed into the combustor where it is converted to thermal energy and used to heat the water passing through the hot water generator.

Each 'Biomass Heating System' consists of the biomass combustor, hot water generator (boilers), accumulator, interface heat exchanger, and dedicated constant flow circulation pumps. The biomass combustor consists of the fuel handing system, flue recirculation system, economizer section, multi-cyclone filters, dedicated flue gas stack, ash handling systems, and compressed air systems.

The following table describes the preliminary design requirements for the proposed 'Biomass Heating System':

Table 2: Biomass Heating System Design Conditions

Description	For-Profit	Not-for-Profit
Biomass Heating System Installed Capacity	One @ 5.0 MW_t One @ 2.5 MW_t	One @ 6.5 MW_t One @ 2.5 MW_t
Design Pressure	414 kPag[5] (60-psig)	
Maximum Operating Temperatures	108°C supply / 83°C return	

After the pellets have been consumed, the remaining ash is collected by an ash conveyor and deposited in a holding container. The ash holding container will need to be emptied on a periodic basis. The exhaust gas leaving the boiler is passed through a multi-cyclone filter to reduce particulate emissions. An automatic water spray system is used to put out any fuel fires that move backwards beyond the biomass combustion chamber into the fuel hopper.

A pneumatic system is used to periodically clean the boiler tubes.

The circulation pump for each biomass hot water generator maintains constant closed loop flow to the biomass heating system and back. The accumulator is used to manage any sudden temperature swings during start or stop of the biomass heating system or district system. Three-way control valves ensure a minimum biomass heating system inlet temperature.

Expansion tanks are used to absorb the change in volume of the closed loop biomass heating system due to changes in temperature. Similarly, expansion tanks are also required for the closed loop district heating system.

[5] The biomass heating system is to be isolated from district heating system via plate heat exchangers.

Each isolating heat exchanger in the plant is supplied heat from their associated biomass heating system. The isolating exchanger is required to isolate the lower pressure rated biomass heating system from the higher pressure rated hot water distribution piping. The higher-pressure rating of the distribution piping allows for the use of a wide range of pump sizes to maximize how far the hot water can be transmitted to the customer buildings.

Figure 3: Typical Biomass Heating System (8 MW_t Capacity Shown) Source: Schmid Energy Solutions

The maximum temperature of the hot water returning from the buildings to the plant is estimated to be approximately 80°C in winter. The return water would enter the plant and be pumped through two parallel isolating heat exchangers. The heat exchangers will raise the temperature of the distributed water to 105°C.

Two 50% capacity variable flow distribution pumps are used to pump the hot water out of the plant to the buildings and back again in a closed loop. Because the distribution pump flow is variable in nature, a decoupling pipe is used to balance the variable flow distribution system with the constant flow heat exchanger pumps.

The piping system used to convey the hot water in the plant would be of welded construction and insulated for heat conservation. The hot water piping within the plant would be designed and constructed in accordance with ASME B31.1 code requirements and is not expected to require registration with the Territorial Boiler Safety Authority.

The proposed configuration of the plant and the building interface has been employed on several other hot water based supplementary heating system designs in northern climate zones and has proven to be straight forward to operate, reliable, flexible, and robust in FVB's experience.

1.4 WATER TREATMENT

The water treatment equipment includes for commercial-grade chemical pot feeders, cathodic protection coupon rack, and side-stream filtration systems. The system is envisioned to treat the make-up water to the district heating system, typically with the introduction of corrosion inhibitors and pH balancing chemicals. The water treatment requirements need to be established at later stages of design development with input from the Owner's preferred water treatment specialist.

1.5 Thermal Energy Metering

The thermal energy being exported to the buildings would be metered. The metering system would be custody transfer grade and would comply with the requirements of CSA C900 and the regulator, Measurement Canada.

1.6 Electrical System

Feeder circuit breakers and transformers are provided as required, depending on the utility distribution voltage to the plant main feeds. A new 600-V, 3-phase electrical service, up to 1.0 MVA in size, is envisioned to serve the new plant.

The electrical system serving the new plant would be based on distributing 600-V, 3-phase power to all motor consumers larger than 1-hp. Consideration may be provided for higher-voltage supply to larger plant motors, such as the distribution pumps.

A packaged standby diesel generator would be provided to allow for continued operation of at least one distribution pump at the new hot water plant during a power outage. This would be to maintain distribution piping system circulation for freeze protection.

1.7 Control System and Field Devices

A new standalone PLC based plant control system is envisioned for the new biomass energy centre. The control system would include PLC controller with I/O rack, network communication, PC-based operator HMI, historian, power supply, UPS, and engineering workstation. The operator interface would be located within the plant control room.

Each biomass heating system package, and distribution pump package would be provided with its own stand-alone controller to manage its operation. The plant control system would operate in a supervisory control, monitoring, and data gathering role. Should the plant control system fail, each equipment sub-system would be able to continue operating from its stand-alone controller.

All process instrumentation utilized in the new plant would be industrial grade. Actuated control elements would utilize electric powered actuators. No control air would be provided.

1.8 Building

The plant building is envisioned to be fit-for-purpose with steel structural elements and insulated concrete block or metal panel exterior. The exterior finish of the plant walls and wood pellet storage silos would be painted for aesthetics. There would be a minimum of architectural treatments applied to the building.

The equipment bays are spaced to include for the installation of future major equipment. Access platforms and ladders would be strategically provided on major equipment for operation & maintenance access.

The main floor interior space allows for an electrical room, operator control room and washroom. Additional space is available on a second floor to allow for finished rooms, such as a lunchroom, meeting room, IT / communications room or additional maintenance and storage space.

1.9 Building Systems

Building systems would include basic HVAC as needed to maintain minimal environmental conditions in the space. This would include hot water hydronic space heating, and mechanical ventilation only for cooling.

The building would be sprinkler (wet pipe) protected.

Domestic water would be provided only as needed for utility purposes.

1.10 Plant Staffing

Based on FVB's interpretation of the NWT Boiler & Pressure Vessels Acts & Regulations, operation of the plant is expected to be classified for 'General Supervision'. The plant is assumed to be normally unoccupied, with operators entering the process space for normal walk-through checks, fuel offloading, and general maintenance duties. The plant would be provided with a call-out system for after-hours response.

It is FVB's interpretation that the plant will require a '2nd-class chief operating engineer', with additional support would be provided from '3rd-class shift engineer(s)'. It is recommended to review plant staffing requirements with the Territorial Safety Authority (TSA) at later stages of design development.

1.11 Plant Environmental

The flue gas is mostly comprised of carbon dioxide and water vapour; however, the flue gas has additional components typical of solid fuel combustion. The biomass heating system is provided with multi-cyclone filters for additional emissions clean-up and to reduce particulate emissions.

Depending on the biomass feedstock, the bottom ash from the biomass system may be recovered and used as fertilizer, or it may be considered a waste stream that requires disposal. The fly ash from the exhaust stream has less application and is expected to require disposal. Ash production is estimated at <1% of the biomass feedstock volume and would be collected in ash containers.

The major source of noise in a biomass facility is with the pneumatic system that cleans the boiler tubes. Noise attenuation treatment is not expected to be required.

It is recommended to review emission and noise requirements at later stages of design development.

2 DISTRIBUTION PIPING

The heat distribution across the target downtown area and future expansion requires a modernized network of low-temperature hot water (LTHW) piping to service each building with hot water. A map of the proposed distribution piping network is included in Appendix C.

The distribution piping will comprise of a closed-loop, direct-buried, pre-insulated steel piping system, consisting of supply and return pipes.

It is envisioned that variable-flow capacity control and temperature reset control will be implemented on the distribution system. These control measures will improve the overall energy efficiency of the distribution and transmission systems, thereby optimizing the environmental and economic performance of the proposed system.

The network of distribution piping will originate at the proposed biomass energy centre location (see attached map). New distribution pumps will circulate hot water between the connected buildings and the new biomass energy centre.

More scrutiny of the streets is required before determining final route plans. This would have to be done in close cooperation with the local authorities and utilities. Since there are multiple buried utilities in the community[6], the expectation is that there may be obstacles in the ground that will need to be taken into consideration and avoided.

The soil conditions are not fully known but is generally considered to be sand that is in the discontinuous permafrost zone, but little to no permafrost in the target area served. Although not expected, the presence of potential permafrost areas needs to be carefully evaluated at the design stage. There is the possibility of encountering bedrock, especially in the area to the north of downtown.

The installation of the distribution system is assumed to be by excavated trench methods. The distribution system will be situated along the edges of roads, in sidewalks, and in ditches as much as possible. Generally, we have assumed a depth of burial to the top of the pipes of 900-1,200 mm (maximum) cover. This may vary depending on Community regulations concerning burial depth requirements as well as the location of other utility services. Pipe stress is (generally) handled through expansion loops.

Existing underground utilities are water and sewers, whereas electrical and telecom are mostly overhead.

The distribution piping would be routed to allow for a minimum separation from other underground utilities. In general, industry accepted practices allow for a vertical clearance of 300 mm, and horizontal clearance ranging from 300 mm to 1,000 mm[7] between the utility piping and buried distribution piping. It is recommended to discuss acceptable clearances with the utility companies at later stages of design development.

[6] According to information provided by the Client.
[7] Depending on utility type and depth of bury.

2.1 Design Conditions

The pipe sizing for the selected route has been governed by the following key factors:

- System ΔT (delta temperature).
- Dynamic pressure gradient.
- Maximum allowable velocity.
- Distribution network pressure at the design load conditions.
- Differential pressure requirements to service the most remote customer.

The following table describes the process conditions of the proposed 'Distribution Piping':

Table 3: Distribution Piping Design Conditions

Description	Value
Maximum Operating Temperature	120°C supply
Design Pressure	1,100 kPag (160-psig)
Design ΔT	25°C
Dynamic Pressure Gradient	Max. 175 Pa/m (Mains) & 250 Pa/m (Branches)
Maximum Flow Velocity	2.5 metres per second (~8 ft/s).

2.2 Buried Distribution Piping

From the technical point of view, considering the potential size and capacity of the Yellowknife District Heating distribution system, an all-welded steel piping system is the preferred option as it can accommodate higher working pressures and temperatures. From the operational point of view, all welded steel piping systems are both watertight and have inherent strength. Guarantees of uninterrupted supply can be provided to potential customers with greater confidence than with other materials.

European piping systems designed strictly for this type of hot water system application are the preferred choice for installation in the distribution piping system. These European pipe systems are characterized by thin-walled steel construction, factory applied polyurethane foam insulation bonded to the pipe wall, bonded HDPE outer jacket, and a built-in leak detection system.

Once the project moves forward to the execution stage, project specification documents should be developed such that more than one manufacturer's piping system may be considered.

3 BUILDING CONNECTION

Building connections includes for both the Energy Transfer Station (ETS), or the interfaces between the District Heating System (DHS) and the building heating system and includes any required interconnecting piping and building modifications to be compatible with the district heating service.

The ETS will be designed so that the building can be "indirectly" connected to the main distribution system, in series with the existing boilers. This means that the building's internal heating and domestic hot water systems (secondary side) are isolated from the DHS distribution system (primary side) by means of heat exchangers. If the ETS heat exchanger can supply the heat required for the building, the boilers will not have to operate. If the heat supplied by the heat exchanger is insufficient than the boilers will raise the supply temperature to meet the design requirement, providing peaking and back-up heating as required.

The hot water delivered to each building will typically be interfaced to a building's existing heating system generally as indicated in the drawings provided in Appendix D.

3.1 Design Conditions

The temperatures summarized below are derived from collected operating data and review of available design information.

Table 4: Primary/Secondary Side Design/Operating Temperatures

System / Loop	Supply Temperature	Return Temperature
Primary District Heating System	105°C	75-80°C
Secondary Building Hot Water/Glycol Loop	80-85°C	70-75°C
Secondary Domestic Hot Water Loop	60°C	20°C

The DHS will supply up to 105°C to the building ETS and return in the range of 75 to 80°C during peak periods at an operating pressure of less than 1,100 kPag (160 psig).

The building's internal heating system would draw heat from the ETS and supply water to its internal heating systems at a maximum temperature of 80 to 85°C and return at a maximum of 70 to 75°C during peak operating conditions.

The above should be regarded as average ranges, and some of the buildings may have either higher or lower operating temperatures. The individual buildings' design parameters will be determined at later stages of design development.

3.2 Energy Transfer Station

An ETS consists of heat exchangers, controls and instrumentation, energy meter, isolation valves, and associated equipment and piping. Modulating temperature controls will be used to control the heat transfer to the buildings' heating systems. In addition, boiler interlocks will be provided to control the firing of the existing boilers. Additional temperature control function will be implemented to prevent reverse heat transfer from the buildings to the district heating system in the event the DHS temperature is lower than the building return temperatures.

Only energy meters that meet current CSA C900 heat metering standard and international standards such as EN-1434 will be used. The thermal energy meters will also require Measurement Canada approval.

3.3 Building Modifications

No building surveys were performed, so the description below is based on information provided by the Client, details provided by potential customers, and previous studies of district heating in Yellowknife.

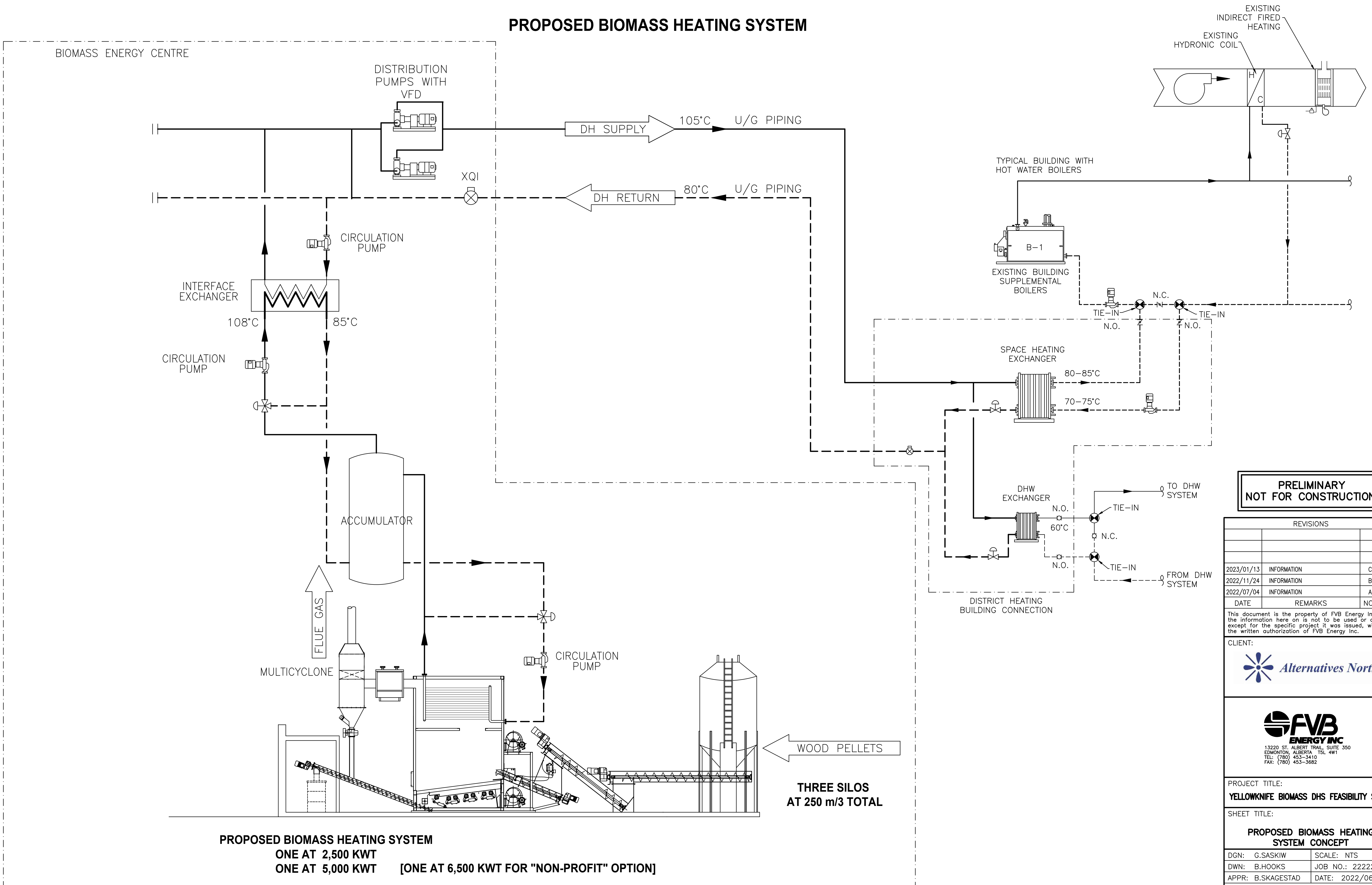
Based on this information, most buildings are hydronic and thus require only minor modifications to the existing system in order for the building to successfully accept the heat delivered by the proposed DHS. To optimize the potential system temperature differentials, existing 3-way valves and units with no control valves (such as unit heaters) should be modified.

For the purposes of the study, an allowance for these estimated building modification costs is included as part of the project capital cost. The required retrofits in each building would be investigated in more detail at later stages of design development.

*** End of Main Document ***

Appendix A Biomass District Heating System Drawings

PROPOSED BIOMASS HEATING SYSTEM



PRELIMINARY NOT FOR CONSTRUCTION

REVISIONS		
DATE	REMARKS	NO.
2023/01/13	INFORMATION	C
2022/11/24	INFORMATION	B
2022/07/04	INFORMATION	A

CLIENT: Alternatives North

FVB ENERGY INC
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EDMONTON, ALBERTA T5L 4W1
TEL: (780) 453-3410
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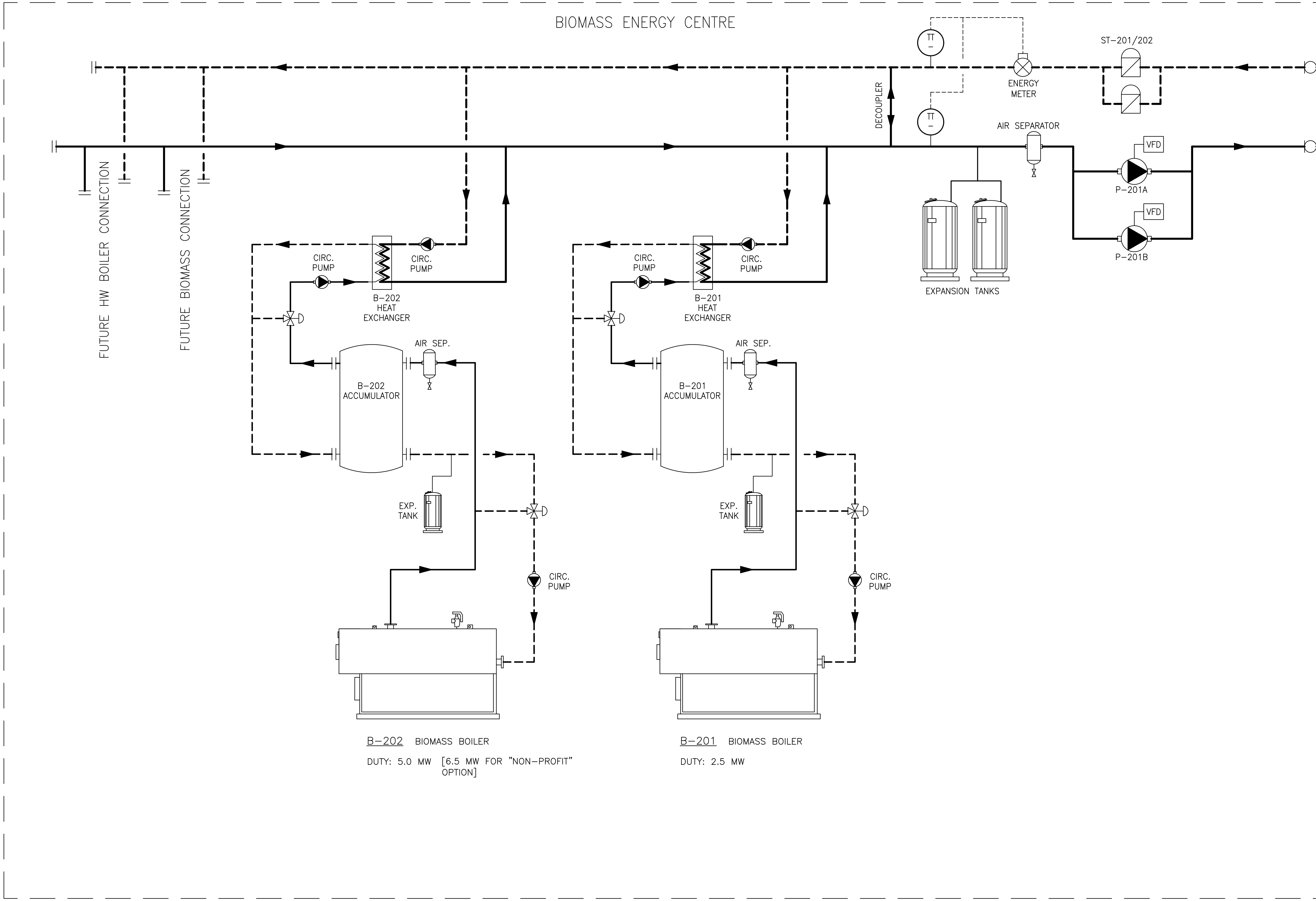
PROJECT TITLE: YELLOWKNIFE BIOMASS DHS FEASIBILITY STUDY

SHEET TITLE: PROPOSED BIOMASS HEATING SYSTEM CONCEPT

DGN: G.SASKIW	SCALE: NTS
DWN: B.HOOKS	JOB NO.: 222220
APPR: B.SKAGESTAD	DATE: 2022/06/29
DWG NO.: SK-2220-01	

Appendix B Biomass Energy Centre Drawings



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REVISIONS		
DATE	REMARKS	NO.
2023/01/13	INFORMATION	C
2022/11/24	INFORMATION	B
2022/07/04	INFORMATION	A

CLIENT:
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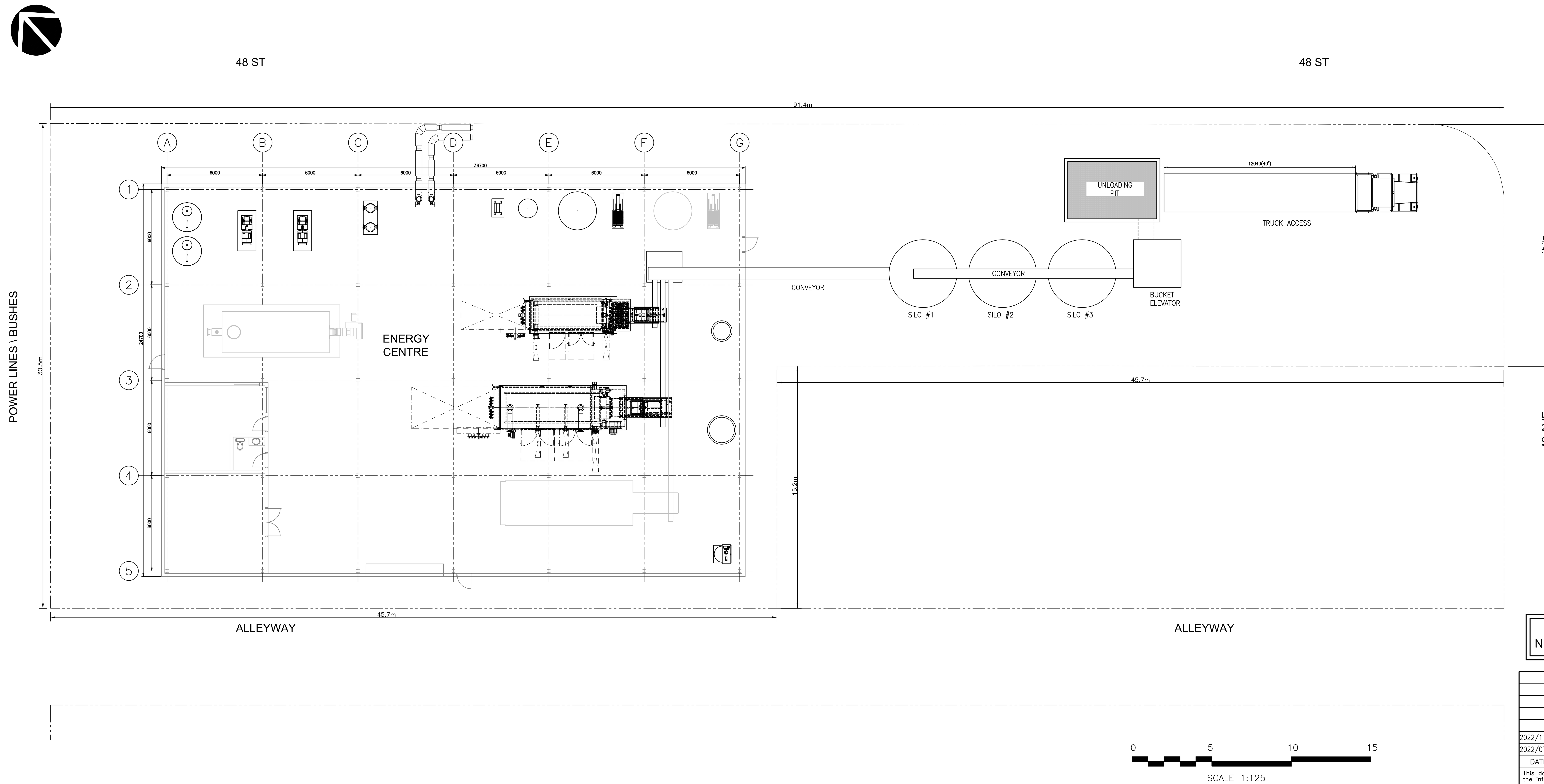
PROJECT TITLE:
YELLOWKNIFE BIOMASS DHS FEASIBILITY STUDY

SHEET TITLE:
BIOMASS ENERGY CENTRE SCHEMATIC

DGN: G.SASKIW	SCALE: NTS
DWN: B.HOOKS	JOB NO.: 222220
APPR: B.SKAGESTAD	DATE: 2022/06/30
DWG NO.: M-2220-01	



PRELIMINARY
NOT FOR CONSTRUCTION

REVISIONS		
2022/11/24	INFORMATION	B
2022/07/04	INFORMATION	A
DATE	REMARKS	NO.

Alternatives North

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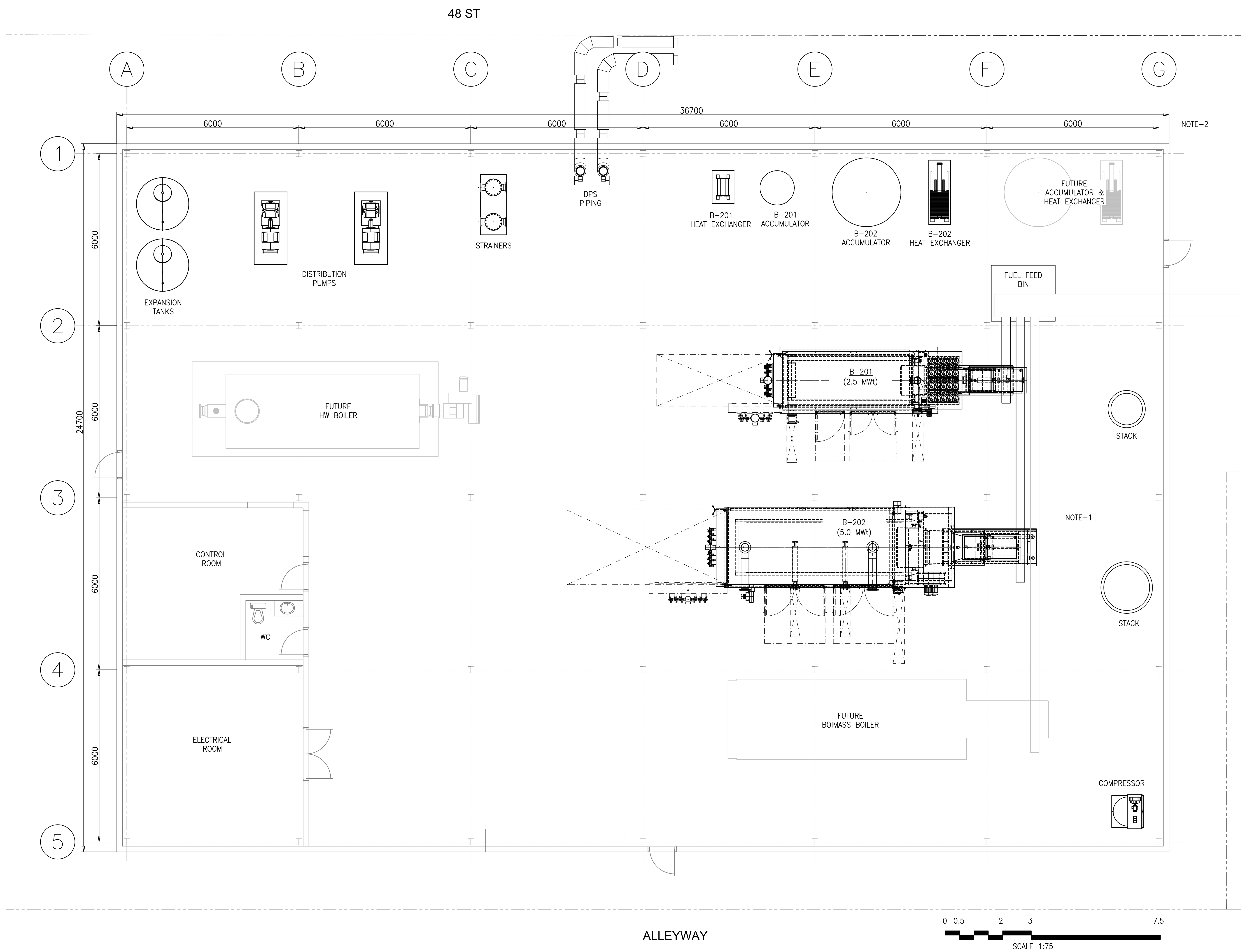
PROJECT TITLE:
YELLOWKNIFE BIOMASS DHS
FEASIBILITY STUDY

SHEET TITLE:
ENERGY CENTRE
SITE PLAN

DGN: G.SAKIW	SCALE: 1:125
DWN: B.HOOKS	JOB NO.: 222220
APPR: B.SKAGESTAD	DATE: 2022/06/24
DWG NO.: M-2220-11	



NOTES:

1. FOR THE "NON–PROFIT" OPTION BOILER B–202 CAPACITY IS 6.5 mWt.

2. BUILDING FOOTPRINT FOR THE "NON–PROFIT" OPTION IS APPROX. 20% LARGER THAN INDICATED ON THE DRAWING.

PRELIMINARY
NOT FOR CONSTRUCTION

REVISIONS		
2022/11/24	INFORMATION	B
2022/07/04	INFORMATION	A
DATE	REMARKS	NO.

Alternatives North

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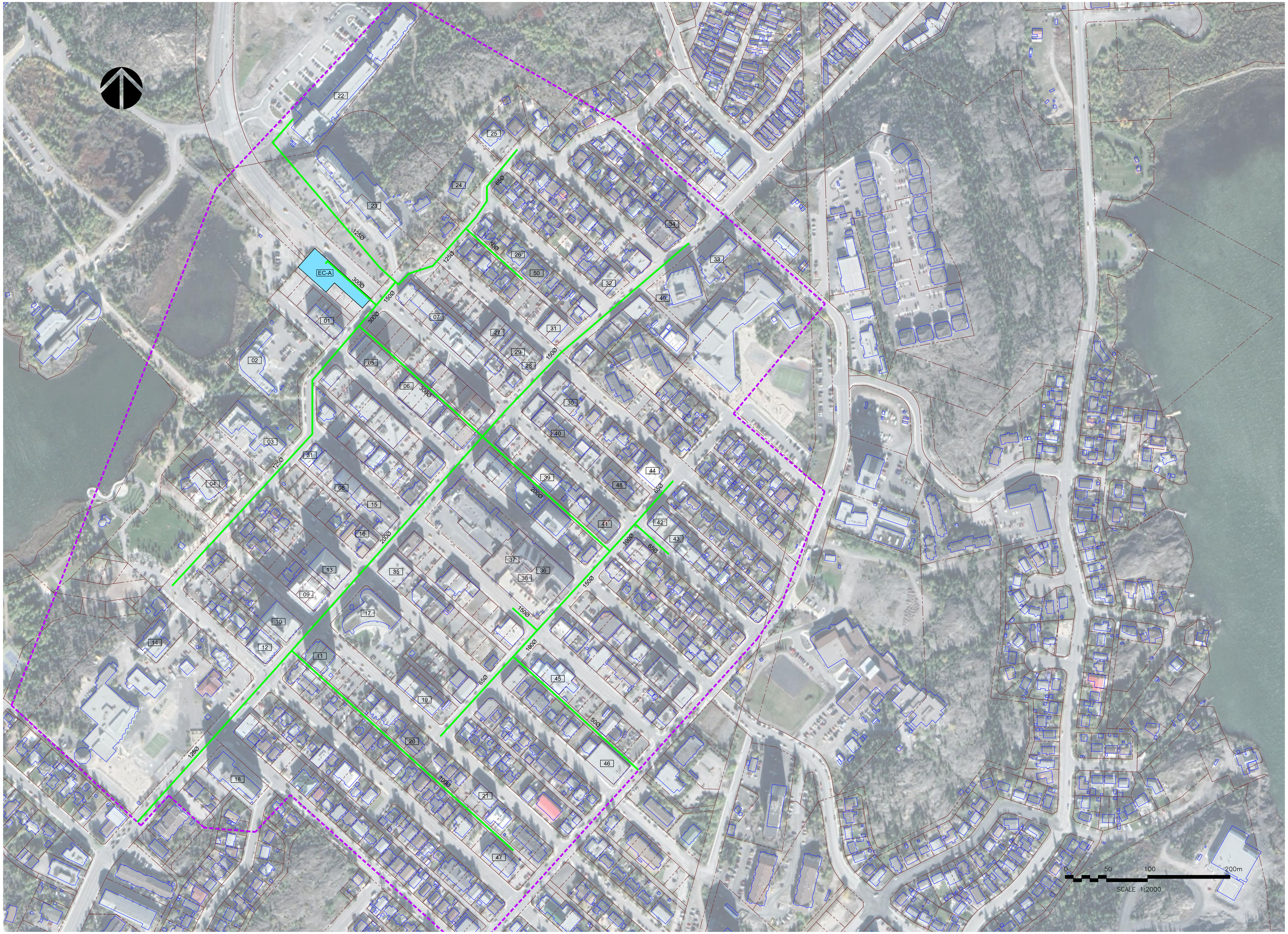
PROJECT TITLE:
YELLOWKNIFE BIOMASS DHS
FEASIBILITY STUDY

SHEET TITLE:
ENERGY CENTRE
PLAN

DGN: G.SAKIW	SCALE: 1:75
DWN: B.HOOKS	JOB NO.: 222220
APPR: B.SKAGESTAD	DATE: 2022/06/24
DWG NO.: M–2220–12	

Appendix C Distribution Piping Drawings



LEGEND:

- AREA BOUNDARY
- DPS PIPING
- # CONNECTION NUMBER
- EC-# ENERGY CENTRE LOCATION
- 250Ø PIPING LINE SIZE

PRELIMINARY
NOT FOR CONSTRUCTION

REVISIONS

DATE	REMARKS	NO.
2022/11/24	INFORMATION	C
2022/07/18	INFORMATION	B
2022/06/03	INFORMATION	A

Alternatives North

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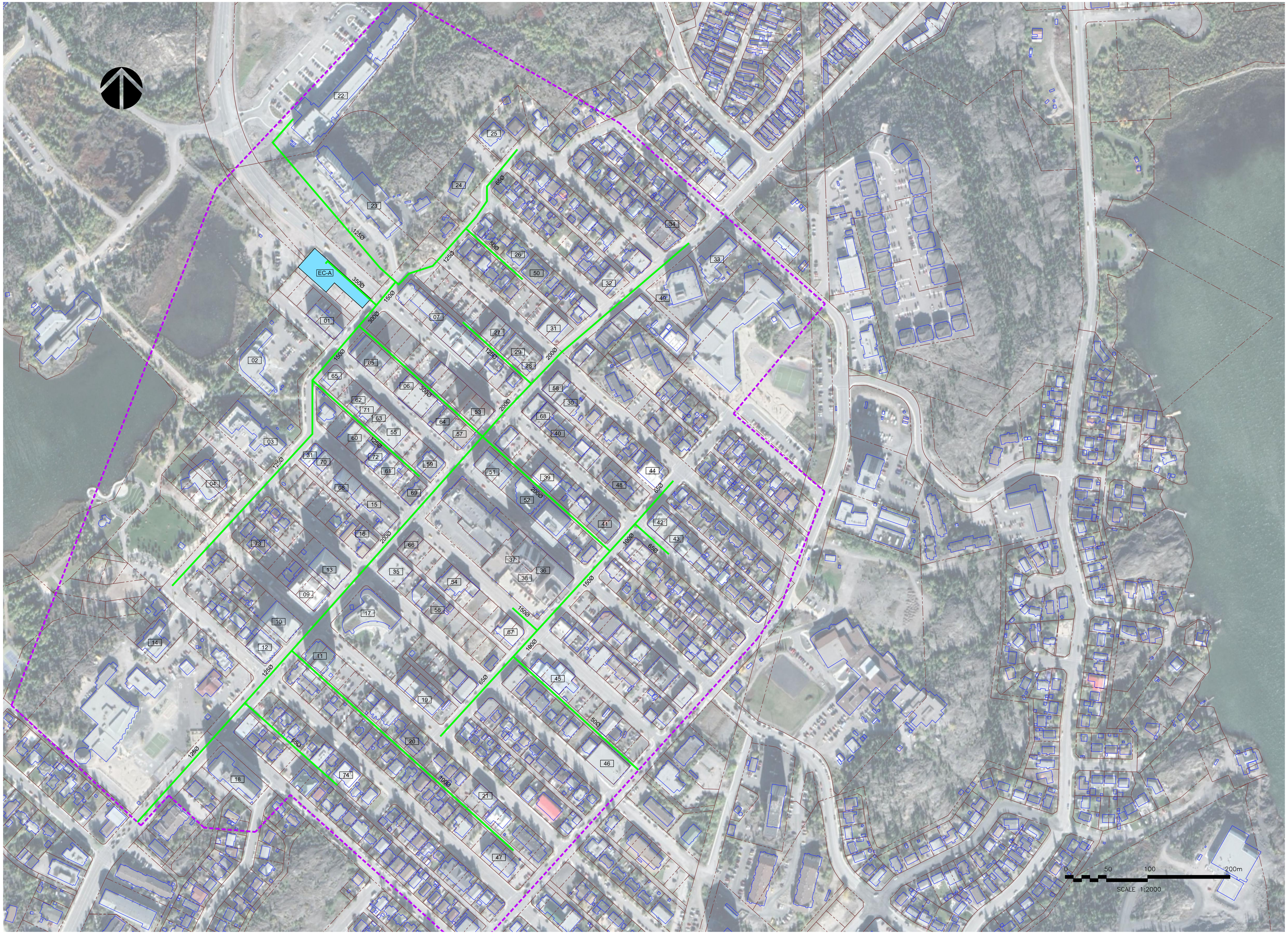
PROJECT TITLE:
YELLOWKNIFE BIOMASS DHS
FEASIBILITY STUDY

SHEET TITLE:
CENTRAL CORE
AREA PLAN
'FOR-PROFIT'

DGN: B.SKAGESTAD	SCALE: 1:2000
DWN: B.HOOKS	JOB NO.: 222220
APPR: B.SKAGESTAD	DATE: 2022/05/13
DWG NO.: D-2220-01	



LEGEND:

	AREA BOUNDARY
	DPS PIPING
#	CONNECTION NUMBER
EC-#	ENERGY CENTRE LOCATION
250Ø	PIPING LINE SIZE

PRELIMINARY
NOT FOR CONSTRUCTION

REVISIONS

DATE	REMARKS	NO.
2022/11/24	INFORMATION	C
2022/07/18	INFORMATION	B
2022/06/03	INFORMATION	A

Alternatives North

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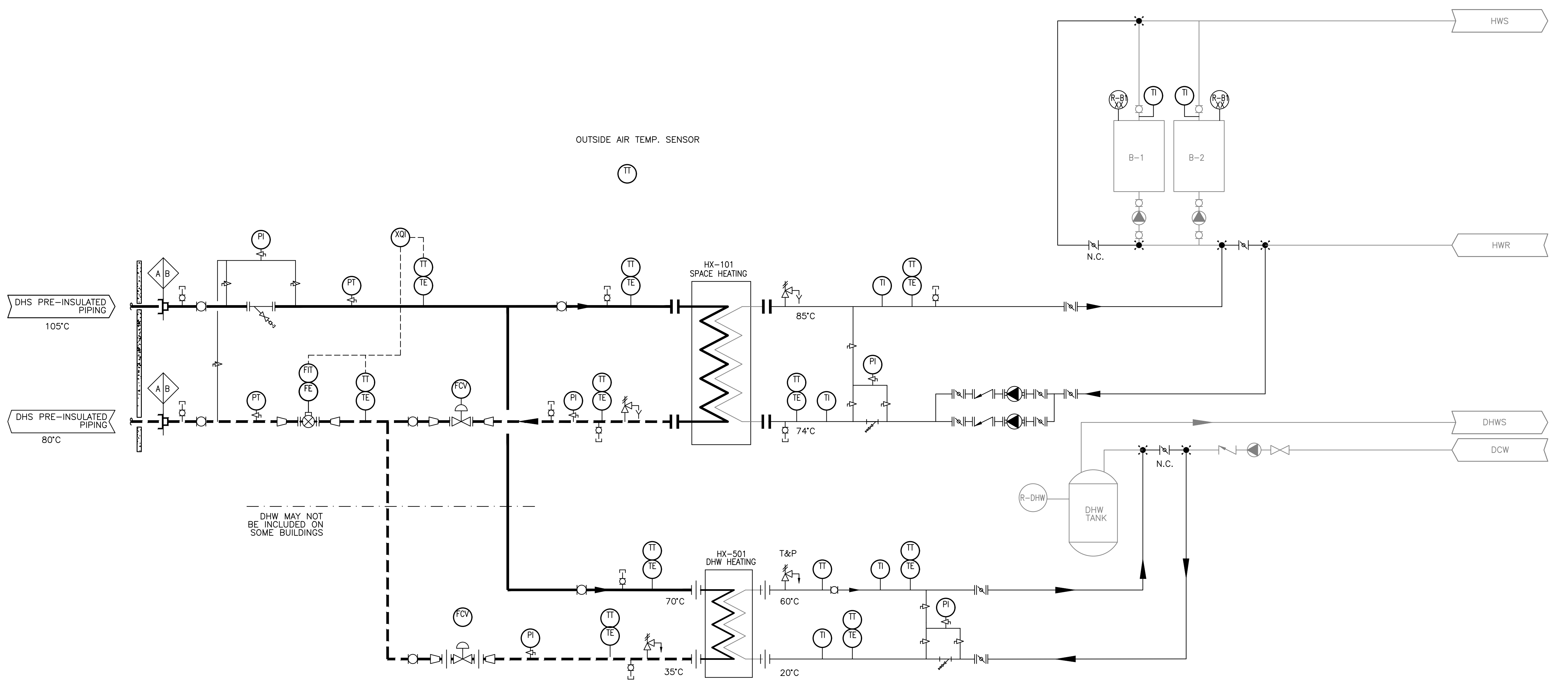
PROJECT TITLE: YELLOWKNIFE BIOMASS DHS FEASIBILITY STUDY

SHEET TITLE: CENTRAL CORE AREA PLAN 'NOT-FOR-PROFIT'

DGN: B.SKAGESTAD	SCALE: 1:2000
DWN: B.HOOKS	JOB NO.: 222220
APPR: B.SKAGESTAD	DATE: 2022/05/13
DWG NO.: D-2220-02	

Appendix D Building Connection Drawings



- (T) THERMOSTATIC SENSOR
- (PT) PRESSURE TRANSMITTER
- (PI) PRESSURE INDICATOR
- (TT) TEMPERATURE TRANSMITTER
- (TC) TEMPERATURE CONTROLLER
- (TI) TEMPERATURE INDICATOR
- (PDC) PRESSURE DIFFERENTIAL CONTROLLER
- (DP) DIFFERENTIAL PRESSURE SENSOR
- (PS) DIFFERENTIAL PRESSURE SWITCH
- DHS RESIDUAL HEATING SUPPLY
- DHR RESIDUAL HEATING RETURN
- CHS CUSTOMER HEATING SUPPLY
- CHR CUSTOMER HEATING RETURN
- SOLENOID VALVE
- GLOBE VALVE
- CATHODIC ISOLATION FLANGES
- BALL VALVE
- FLOW METER
- BFLY VALVE
- PUMP
- GATE VALVE
- INST. TAG
- CHECK VALVE
- CONTROL VALVE
- EXPANSION JOINT
- CAP
- STRAINER
- REDUCER
- TRAP
- FLOW ARROW
- THREE WAY VALVE
- TIE IN POINT
- DRAIN
- PIPE BREAK
- NEEDLE VALVE
- PSV
- PIPE SPEC BREAK — A – PRE-INSULATED EN253; B – STD STEEL W/ INSULATION

PRELIMINARY NOT FOR CONSTRUCTION

- RESIDUAL HEAT PRIMARY PIPING
- RESIDUAL HEAT SECONDARY PIPING
- EXISTING PIPING

REVISIONS

DATE	REMARKS	NO.
2022/11/24	INFORMATION	B
2022/07/18	INFORMATION	A

CLIENT: Alternatives North

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FAX: (780) 453-3682

PROJECT TITLE: **YELLOWKNIFE BIOMASS DHS FEASIBILITY STUDY**

SHEET TITLE: **ENERGY TRANSFER STATION BUILDING INTERFACE TYPICAL SCHEMATIC**

DGN: G.SASKIW	SCALE: NTS
DWN: B.HOOKS	JOB NO.: 222220
APPR: B.SKAGESTAD	DATE: 2022/06/30

DWG NO.: M-2220-02

*** End of Appendices ***

ATTACHMENT III COST BASIS DOCUMENTS

A.1 Biomass Energy Centre Cost Basis Document

Alternatives North

YELLOWKNIFE BIOMASS DHS FEASIBILITY STUDY

BIOMASS ENERGY CENTRE COST BASIS DOCUMENT

SUBMITTED ON: JANUARY 10, 2023

SUBMITTED BY:

FVB ENERGY INC
CELEBRATING 30 YEARS | 1992 - 2022

Disclaimer

FVB Energy Inc. ("FVB") has prepared this Capital Cost Basis Document for Alternatives North (Client).

This report has been prepared by FVB Energy Inc. for the benefit of the Client, to whom it is addressed. The information and data contained herein represent FVB's best professional judgment considering the knowledge and information available to FVB Energy Inc. at the time of preparation. FVB denies any liability whatsoever to other parties, who may obtain access to this report for any injury, loss or damage suffered by such parties arising from their use of, or reliance upon, this report or any of its contents without the express written consent of FVB and the Client.

The cost estimates and any estimates of rates of productivity provided as part of the study are subject to change and are contingent upon factors over which FVB Energy Inc. has no control. FVB Energy Inc. does not guarantee the accuracy of such estimates and cannot be held liable for any differences between such estimate and ultimate results.

Issue	Reviewed By	Date
Draft for Review	Bård Skagestad, P.Eng.	August 23, 2022
Final	Bård Skagestad, P.Eng.	November 24, 2022
Revised Final	Bård Skagestad, P.Eng.	January 10, 2023

Prepared By: ______________________
(Signature)

Name: **Gary Saskiw, P.Eng.**

CONTENTS

1 INTRODUCTION

1.1 Document Purpose

The purpose of this document is to provide a realistic allocation of construction costs for the biomass energy centre component of the biomass district heating system.

1.2 Methodology

Based on information and documents received, quantities of major elements were determined or measured and priced at rates considered competitive for a project of this type under a stipulated price contract in Yellowknife, NWT. The estimate is a combination of FVB factored unit costs adjusted for location, and R.S. Means assembly, square foot, and unit costs.

Additional vendor quotes for major plant equipment are included in Appendix A.

1.3 Cost Summary

Table 1: Cost Estimate Summary

Cost Component	For-Profit	Not-for-Profit
Construction Costs		
Site Works	$400,000	$500,000
Architectural/Civil/Structural	$6,200,000	$7,400,000
Electrical	$1,900,000	$2,100,000
Mechanical	$3,000,000	$3,200,000
Major Equipment	$4,700,000	$5,200,000
Construction Soft Costs	$3,500,000	$4,000,000
Subtotal Construction Costs	*$19,700,000*	*$22,400,000*
Owner's Costs		
Owner's Contingencies	$4,900,000	$5,600,000
Owner's Soft Costs	$2,900,000	$3,400,000
Subtotal Owner's Costs	*$7,800,000*	*$9,000,000*
TOTAL Project Costs	**$27,500,000**	**$31,400,000**

Note: the element totals have been rounded to the nearest hundred thousand.

1.4 Class of Estimate

The cost estimates provided are Class 4 (as per AACE International No.17R- 97 Rev August 7, 2020) are considered preliminary with an expected level of accuracy of +35% and -10%.

1.5 Exclusions

The following have been specifically excluded from this capital cost estimate:

- Owner's project management or on-site inspection and supervision during installation.
- Owner’s project development, administrative, marketing of service, and accounting costs.
- Cost of land acquisition, easements and right of ways.
- Costs for environmental investigation and remediation.
- All legal fees and expenses.
- Erratic market conditions, such as lack of bidders.
- COVID-19 pandemic considerations for potential lower productivity factors, shutdowns, and delays.
- Construction coordination with other works.
- Escalation for deferred, phased or future works.
- Preventative maintenance, operation, and major repair contracts.
- Security coordination.
- Third party QA/QC inspection & commissioning.
- Post-disaster construction allowance.
- LEED Accreditation/certifications for the plant building.
- Rock blasting and explosives.
- Demolition of any existing structures above or below grade.
- Utility (electricity, natural gas, sewer, water) interconnection charges.
- Building furnishings, appliances, office supplies and equipment, janitorial supplies and equipment, CCTV and electronic access control security systems, corporate IT equipment, spare parts, tools, material handling equipment, stored consumables.
- Duties.
- Sales taxes.

1.6 Cost Allocations

The following have been specifically allowed for in the cost estimate:

- $100,000 allowance for the remediation of onsite hazardous materials.
- $150,000 for fuel offload pit and truck weather protective enclosure over pit.
- $250,000 for exterior foundations to support fuel handling and storage equipment.
- $50,000 for access platforms and ladders.

2 DOCUMENTATION

These opinions of probable costs have been prepared based on the "Yellowknife Biomass DHS Feasibility Study – Design Basis Document" prepared and issued by FVB Energy, dated November 24, 2022. The concepts shown are to be considered preliminary.

Design changes and/or additions made subsequent to this issuance of the documentation have not been incorporated in this report unless noted below.

3 COST CONSIDERATIONS

3.1 Currency

Costs are listed in Canadian Dollars and have been estimated for the 3rd quarter of 2022.

3.2 Cost Base

Costs are estimated on the basis that a competitive bidding process will be employed to establish construction cost. A minimum of three (3) contractor bids have been assumed. The costs assume bids were received under a single stipulated price contract arrangement.

3.3 Construction Soft Cost Allowances

Allowances have been made for the following items:

Table 2: Construction Soft Cost Allowances

Item	Allowance
Construction Management and Supervision	7.5%
Contractor Testing and Commissioning	0.5%
Temporary Conditions	7.5%
Bonding, Permitting & Insurance	1.5%
General Contractor Fee	5%
Construction Changes	0%
Taxes (GST)	NIC

3.4 Owner's Contingencies

Allowances have been made for the following items:

Table 3: Owner's Contingencies

Item	Allowance
Design Allowance / Contingency	15%
Escalation Allowance / Contingency	0%
Construction Allowance / Contingency	10%

3.5 Owner's Soft Costs

Allowances have been made for the following items:

Table 4: Owner's Soft Costs

Item	Allowance
Project Management	Not Included
3rd Party Commissioning Authority	Not Included
Engineering	12%

3.6 Statement of Probable Replacement Costs

This opinion of probable costs is made based on experience, qualifications, and best judgement of FVB Energy. FVB Energy has no control over the cost of materials, labour, equipment, nor the contractor's method of determining prices. FVB Energy cannot and does not guarantee that proposals, bids, or actual replacement costs will not vary from this or subsequent estimates.

Current volatile market conditions, caused by the ongoing COVID-19 pandemic and global supply chain issues are difficult to predict and account for. As the project costs are estimated based on preliminary concepts the specific costing, and availability impacts from these phenomena, beyond the present, are not allowed for.

3.7 On-Going Cost Control

FVB Energy recommends that the Owner review this document, including categories, line-item descriptions, exclusions, inclusions, assumptions, contingencies, escalations, and markups. If the project is over budget, or if there are unresolved budgeting issues, alternative systems/schemes should be evaluated before proceeding to the next design phase.

Requests for modifications of any apparent errors or omissions to this document must be made to FVB Energy within ten (10) days of receipt of this estimate. Otherwise, it will be understood that the contents have been concurred with and accepted.

*** End of Main Document ***

Appendix A Vendor Budget Quotes

FINK MACHINE INC.
124 Old Vernon Rd, Enderby, BC V0E 1V0
Tel: 250-838-0077
Web: www.finkmachine.com

State of the Art Bio Energy Heating Systems
Revolutionary Wood Heating Technology
Highly Economical for Commercial, Industrial Buildings

Project Name:	Yellowknife DE System
Project Client:	Yellowknife
Project Location:	Yellowknife
Project Address:	
Quote Provided to:	
Quote Provided by:	David Dubois
Date:	2022-08-15

Fuel Type Chips
Chips Should be below 50% Moisture

Schmid UTSR

Boiler Size	2400 kW
Rating	60 PSI

			QTY	Budget Price
Boiler and Equipment Supplied by Schmid				
Boiler - Includes				
9100.0000	UTSR -2400 Moving Grate Boiler		1	
9100.0000	Water Cooled Fuel Inlet		1	
1000.4334	MZA 2400 Multi-Cyclone		1	
1000.4247	BK -UTSR 2400 Combustion Chamber		1	
1000.3836	HYD-FU-URE Hydraulic Moving Grate		1	
1500.1751	ZUE_UL Natural Gas Ignition System		1	
1500.1417	AGV-EKS-9 Flue Gas Fan		1	
1000.3819	ARFPS-AGV 2400 Flue gas Recirculation		1	
1000.2649	PNM-KOM Pneumatic Connection Material		1	
1000.3853	ZDAR-1 Intermediate Ceiling Cleaning		1	
1000.3827	ZDL-2400 Central Pressure line for Vault Cleaning		1	
Deashing - Includes				
1000.3863	AMC 800 Deashing System		1	
1500.0632	AC-800 Ash container		1	
Control System - Includes				
9100.0000	PersonalTouch visio UTSR Control Cabinet		1	
1000.3206	STEU-ZUND-BRENN-GAS Gas Auto igniter controller		1	

1000.3628	ALRM-WADR-Pmin Pressure limiter	1	
1000.3629	ALRM-WADR-Pmax Pressure limiter	1	
1000.1068	ALRM-WAMA Low Water Control	1	
1000.0715	STEU-KEPU Control unit for Boiler pump	1	
1000.0723	REG-RLH Control for return Temperature	1	
1000.4693	KOSS-MODB-RTU-BR Communications Interface	1	
1000.4786	Portal-Access Remote Access PT Visio	1	
Boiler Fuel Transport and Stoking System			
9200.0000	SAM Collecting Screw - 4 m x 220 mm	1	
1000.0501	BSS-250-PN Pneumatic Fire Protection	1	
1000.0458	FAL-220 Downpipe fitting	1	
1000.4019	STO-500-2.5 Stoker Screw	1	
Other			
3000.0501	DOK-WWBoiler Documentation	1	
	Misc.	1	
UL	Upgrade all motors to UL motors	1	
Additional Equipment			
	Boiler pump	1	
	three way valve	1	
	Misc. Components	1	
	Boiler Assembly on site (does not include plumbing or electrical)	1	
	Combustion chamber, fuel handling equipment, freight to site	1	
	Pressure Vessel Freight to Site	1	
	Accessories		
	Training and Commissioning	1	
	Total		$1,800,000

	Fuel Handling System		$300,000
	Fuel Handling System Assembly	1	
	Auger system from Silo to Boiler	1	
	Pellet Storage Bins	3	

Quote is for budget Purposes ONLY

Pricing does not include Plumbing and Electrical Connections unless otherwise noted

Standard Payment Terms:

35% deposit at contract award

25% when equipment is shipped from Austria

30% on arrival at site

10% payable 14 days after commissioning or 30 days after delivery (which ever comes first)

Price FOB site

Standard delivery time: 22 weeks

Price is valid for 30 days

Applicable taxes are extra

Thank You

Fink Machine Inc.

FINK MACHINE INC.
State of the Art Bio Energy Heating Systems
Revolutionary Wood Heating Technology
Highly Economical for Commercial, Industrial Buildings
124 Old Vernon Rd, Enderby, BC V0E 1V0
Tel: 250-838-0077
Web: www.finkmachine.com

Project Name:	Yellowknife DE System
Project Client:	Yellowknife
Project Location:	Yellowknife
Project Address:	
Quote Provided to:	
Quote Provided by:	David Dubois
Date:	2022-08-15

Fuel Type Chips
Chips Should be below 50% Moisture

Schmid UTSR

Boiler Size	5000 kW
Rating	60 PSI

			QTY	Budget Price
Boiler and Equipment Supplied by Schmid				
Boiler - Includes				
9100.0000	UTSR - 5000 kW		1	
9100.0000	75 kW Insulated gas Ventilator		1	
9100.0000	Water Cooled Fuel Inlet		1	
1000.4339	MZA 5000 Multi-Cyclone		1	
1000.4417	BK-UTSR-5000 Combustion Chamber DENOX		1	
1000.3837	HYD-FU-URE Hydraulic Moving Grate		1	
1500.1751	ZUE_UL Natural Gas Ignition System		1	
1000.3821	ARFPS-AGV 5000 Flue gas Recirculation		1	
1000.2649	PNM-KOM Pneumatic Connection Material		1	
1000.3854	ZDAR-2 Intermediate Ceiling Cleaning		1	
1000.3829	ZDL-5000 Central Pressure line for Vault Cleaning		1	
Deashing - Includes				
1000.3863	AMC 800 Deashing System		1	
1500.0632	AC-800 Ash container		1	
Control System - Includes				
9100.0000	PersonalTouch visio UTSR Control Cabinet		1	
1000.3206	STEU-ZUND-BRENN-GAS Gas Auto igniter controller		1	

1000.3628	ALRM-WADR-Pmin Pressure limiter	1	
1000.3629	ALRM-WADR-Pmax Pressure limiter	1	
1000.1068	ALRM-WAMA Low Water Control	1	
1000.0715	STEU-KEPU Control unit for Boiler pump	1	
1000.0723	REG-RLH Control for return Temperature	1	
1000.4693	KOSS-MODB-RTU-BR Communications Interface	1	
1000.4786	Portal-Access Remote Access PT Visio	1	
Boiler Fuel Transport and Stoking System			
9200.0000	SAM Collecting Screw - 4 m x 290 mm	1	
1000.0502	BSS-375-PN Pneumatic Fire Protection	1	
1000.2429	FAL-290 Downpipe fitting	1	
1000.4019	STO-500-2.5 Stoker Screw	1	
Other			
3000.0501	DOK-WWBoiler Documentation	1	
	Misc.	1	
UL	Upgrade all motors to UL motors	1	
Additional Equipment			
	Boiler pump	1	
	three way valve	1	
	Misc. Components	1	
	Boiler Assembly on site (does not include plumbing or electrical)	1	
	Combustion chamber, fuel handling equipment, freight to site	1	
	Pressure Vessel Freight to Site	1	
	Accessories		
	Training and Commissioning	1	
	Total		$2,200,000

	Fuel Handling System		$300,000
	Fuel Handling System Assembly	1	
	Auger system from Silo to Boiler	1	
	Pellet Storage bins	3	

Quote is for budget Purposes ONLY

Pricing does not include Plumbing and Electrical Connections unless otherwise noted
Standard Payment Terms:
35% deposit at contract award
25% when equipment is shipped from Austria
30% on arrival at site
10% payable 14 days after commissioning or 30 days after delivery (which ever comes first)

Price FOB site
Standard delivery time: 22 weeks
Price is valid for 30 days
Applicable taxes are extra

Thank You

Fink Machine Inc.

*** End of Appendices ***

A.2 DISTRIBUTION PIPING COST BASIS DOCUMENT

YELLOWKNIFE BIOMASS DHS FEASIBILITY STUDY

DISTRIBUTION PIPING COST BASIS DOCUMENT

SUBMITTED ON: JANUARY 10, 2023

SUBMITTED BY:

CELEBRATING 30 YEARS | 1992 - 2022

Disclaimer

FVB Energy Inc. ("FVB") has prepared this Capital Cost Basis Document for Alternatives North (Client).

This report has been prepared by FVB Energy Inc. for the benefit of the Client, to whom it is addressed. The information and data contained herein represent FVB's best professional judgment considering the knowledge and information available to FVB Energy Inc. at the time of preparation. FVB denies any liability whatsoever to other parties, who may obtain access to this report for any injury, loss or damage suffered by such parties arising from their use of, or reliance upon, this report or any of its contents without the express written consent of FVB and the Client.

The cost estimates and any estimates of rates of productivity provided as part of the study are subject to change and are contingent upon factors over which FVB Energy Inc. has no control. FVB Energy Inc. does not guarantee the accuracy of such estimates and cannot be held liable for any differences between such estimate and ultimate results.

Issue	Reviewed By	Date
Draft for Review	Bård Skagestad, P.Eng.	August 23, 2022
Final	Bård Skagestad, P.Eng.	November 24, 2022
Revised Final	Bård Skagestad, P.Eng.	January 10, 2023

Prepared By: ______________________
(Signature)

Name: **Gary Saskiw, P.Eng.**

CONTENTS

1 INTRODUCTION

1.1 Document Purpose

The purpose of this document is to provide a realistic allocation of construction costs for the distribution piping system (DPS) component of the biomass district heating system.

1.2 Methodology

Based on information and documents received, quantities of major elements were determined or estimated and priced at rates considered competitive for a project of this type under a stipulated price contract in Yellowknife, NWT. The estimate is a combination of FVB factored unit costs adjusted for location, and R.S. Means assembly & unit costs.

Note that profile drawings were not available to provide utility elevation information.

1.3 Cost Estimate Summary

Table 1: Cost Estimate Summary

Cost Component	For-Profit	Not-for-Profit
Construction Costs		
Mechanical	$6,500,000	$6,900,000
Electrical & Communications	$900,000	$1,000,000
Civil	$5,900,000	$6,500,000
Construction Soft Costs	$4,200,000	$4,500,000
Subtotal Construction Costs	*$17,500,000*	*$18,900,000*
Owner's Costs		
Owner's Contingencies	$4,400,000	$4,700,000
Owner's Soft Costs	$1,700,000	$1,900,000
Subtotal Owner's Costs	*$6,100,000*	*$6,600,000*
TOTAL Project Costs	**$23,600,000**	**$25,500,000**

Note: the element totals have been rounded to the nearest hundred thousand.

1.4 Class of Estimate

The cost estimates provided are Class 4 (as per AACE International No.17R- 97 Rev August 7, 2020) are considered preliminary with an expected level of accuracy of +35% and -10%.

1.5 Exclusions

The following have been specifically excluded from this estimate:

- Owner's project management or on-site inspection and supervision during installation.
- Owner's project development, administrative, marketing of service, and accounting costs.
- Cost of land acquisition, easements and right of ways.
- Costs for environmental investigation and remediation.
- All legal fees and expenses.
- Erratic market conditions, such as lack of bidders.
- COVID-19 pandemic considerations for potential lower productivity factors, shutdowns, and delays.
- Construction coordination with other works.
- Escalation for deferred, phased or future works.
- Preventative maintenance, operation, and major repair contracts.
- Security coordination.
- Third party QA/QC inspection & commissioning.
- Designated substances removal or abatement.
- Rock blasting and explosives.
- Major landscaping or tree removal and replacement.
- Costs associated with disruption to working area, such as parking.
- Sales Taxes

2 DOCUMENTATION

These opinions of probable costs have been prepared based on the "Yellowknife Biomass DHS Feasibility Study – Design Basis Document" prepared and issued by FVB Energy, dated November 24, 2022. The concepts shown are to be considered preliminary.

Design changes and/or additions made subsequent to this issuance of the documentation have not been incorporated in this report unless noted below.

3 COST CONSIDERATIONS

3.1 CURRENCY

Costs are listed in Canadian Dollars and have been estimated for the 3rd quarter of 2022.

3.2 COST BASE

Costs are estimated on the basis of competitive bids. A minimum of three (3) civil & mechanical contractor bids have been assumed. The costs assume bids were received under a stipulated price contract arrangement.

The civil contract is assumed to be awarded to an out-of-town contractor, under a local mechanical general contractor.

3.3 CONSTRUCTION SOFT COST ALLOWANCES

Allowances have been made for the following items:

Table 2: Construction Soft Cost Allowances

Item	Allowance
Construction Management and Supervision	5%
Contractor Testing and Commissioning	2%
Temporary Conditions	15%
Bonding, Permitting & Insurance	2%
General Contractor Fee	7.5%
Construction Changes	0%
Taxes (GST)	NIC

3.4 Owner's Contingencies

Allowances have been made for the following items:

Table 3: Owner's Contingencies

Item	Allowance
Design Allowance / Contingency	15%
Escalation Allowance / Contingency	0%
Construction Allowance / Contingency	10%

3.5 Owner's Soft Costs

Allowances have been made for the following items:

Table 4: Owner's Soft Costs

Item	Allowance
Project Management	Not Included
3rd Party Commissioning Authority	Not Included
Engineering	8%

3.6 Statement of Probable Costs

This opinion of probable costs of construction is made on the basis of experience, qualifications and best judgement of FVB Energy. FVB Energy has no control over the cost of materials, labour, equipment, nor the contractor's method of determining prices. FVB Energy cannot and does not guarantee that proposals, bids, or actual construction costs will not vary from this or subsequent estimates.

Current volatile market conditions, caused by the ongoing COVID-19 pandemic and global supply chain issues are difficult to predict and account for. As the project costs are estimated based on preliminary concepts the specific costing, and availability impacts from these phenomena, beyond the present, are not allowed for.

3.7 On-Going Cost Control

FVB Energy recommends that the Owner review this document, including categories, line-item descriptions, exclusions, inclusions, assumptions, contingencies, escalations, and markups. If the project is over budget, or if there are unresolved budgeting issues, alternative systems/schemes should be evaluated before proceeding to the next design phase.

Requests for modifications of any apparent errors or omissions to this document must be made to FVB Energy within ten (10) days of receipt of this estimate. Otherwise, it will be understood that the contents have been concurred with and accepted.

*** End of Main Document ***

A.3 BUILDING CONNECTION COST BASIS DOCUMENT

Alternatives North

YELLOWKNIFE BIOMASS DHS FEASIBILITY STUDY

BUILDING CONNECTIONS COST BASIS DOCUMENT

SUBMITTED ON: JANUARY 10, 2023

SUBMITTED BY:

FVB ENERGY INC

CELEBRATING 30 YEARS | 1992 - 2022

Disclaimer

FVB Energy Inc. ("FVB") has prepared this Capital Cost Basis Document for Alternatives North (Client).

This report has been prepared by FVB Energy Inc. for the benefit of the Client, to whom it is addressed. The information and data contained herein represent FVB's best professional judgment considering the knowledge and information available to FVB Energy Inc. at the time of preparation. FVB denies any liability whatsoever to other parties, who may obtain access to this report for any injury, loss or damage suffered by such parties arising from their use of, or reliance upon, this report or any of its contents without the express written consent of FVB and the Client.

The cost estimates and any estimates of rates of productivity provided as part of the study are subject to change and are contingent upon factors over which FVB Energy Inc. has no control. FVB Energy Inc. does not guarantee the accuracy of such estimates and cannot be held liable for any differences between such estimate and ultimate results.

Issue	Reviewed By	Date
Draft for Review	Bård Skagestad, P.Eng.	August 23, 2022
Final	Bård Skagestad, P.Eng.	November 24, 2022
Revised Final	Bård Skagestad, P.Eng.	January 10, 2023

Prepared By: ______________________
(Signature)

Name: **Gary Saskiw, P.Eng.**

CONTENTS

1 INTRODUCTION

1.1 Document Purpose

The purpose of this document is to provide a realistic allocation of construction costs for the building connection component of the biomass district heating system.

1.2 Methodology

Based on this information provided by Alternatives North and from previous studies, a typical building interface schematic was prepared as a representative for a typical building's heating system. An average unit cost was established for some typical building sizes (i.e., large and small) and building type (i.e., residential and commercial) to derive at an average cost curve ($\$/kW_t$).

Based on information and documents received, quantities of major elements were determined or measured and priced at rates considered competitive for a project of this type under a stipulated price contract in Yellowknife, NWT. The estimate is a combination of FVB factored unit costs adjusted for location, and R.S. Means assembly & unit costs.

1.3 Cost Estimate Summary

Table 1: Cost Estimate Summary

Cost Component	For-Profit	Not-For-Profit
Construction Costs		
Major Equipment	$2,100,000	$2,900,000
Contractor Supplied (Material & Labour)	$5,300,000	$7,400,000
Building Modifications (Secondary Piping & Modifications)	$3,600,000	$5,100,000
Construction Soft Costs	$500,000	$800,000
Subtotal Construction Costs	*$11,500,000*	*$16,200,000*
Owner's Costs		
Owner's Contingencies	$2,800,000	$4,000,000
Owner's Soft Costs	$2,300,000	$3,200,000
Subtotal Owner's Costs	*$5,100,000*	*$7,200,000*
TOTAL Project Costs	**$16,600,000**	**$23,400,000**

Note: the element totals have been rounded to the nearest hundred thousand.

1.4 Class of Estimate

The cost estimates provided are Class 4 (as per AACE International No.17R- 97 Rev August 7, 2020) are considered preliminary with an expected level of accuracy of +35% and -10%.

1.5 Exclusions

The following have been specifically excluded from this estimate:

- Owner's project management or on-site inspection and supervision during installation.
- Owner’s project development, administrative, marketing of service, and accounting costs.
- Employee relocation/productivity costs associated with disruption to working spaces.
- All legal fees and expenses.
- Erratic market conditions, such as lack of bidders.
- COVID-19 pandemic considerations for potential lower productivity factors, shutdowns, and delays.
- Escalation for deferred, phased or future works.
- Preventative maintenance, operation, and major repair contracts.
- Security coordination.
- Third party QA/QC inspection & commissioning.
- Post-disaster construction allowance.
- LEED Accreditation/certifications.
- Designated substances removal or abatement.
- Pre-existing structural deficiency rectifications.
- Steam to hot water conversion.
- Sales taxes.

2 DOCUMENTATION

These opinions of probable costs have been prepared based on the "Yellowknife Biomass DHS Feasibility Study – Design Basis Document" prepared and issued by FVB Energy, dated November 24, 2022. The concepts shown are to be considered preliminary.

Design changes and/or additions made subsequent to this issuance of the documentation have not been incorporated in this report unless noted below.

3 COST CONSIDERATIONS

3.1 CURRENCY

Costs are listed in Canadian Dollars and have been estimated for the 3rd quarter of 2022.

3.2 COST BASE

Costs are estimated on the basis that a competitive bidding process will be employed to establish construction cost. A minimum of three (3) contractor bids have been assumed. The costs assume bids were received under a single stipulated price contract arrangement. Each contract is assumed to cover a minimum of five ETS's and building conversions.

3.3 CONSTRUCTION SOFT COST ALLOWANCES

Allowances have been made for the following items:

Table 2: Construction Soft Cost Allowances

Item	Allowance
Construction Management and Supervision	5%
Contractor Testing and Commissioning	Included
Temporary Conditions	Included
Bonding, Permitting & Insurance	Included
General Contractor Fee	Included
Construction Changes	0%
Taxes (GST)	NIC

Items indicated as "included" are directly included in the mechanical & electrical estimates.

3.4 Owner's Contingencies

Allowances have been made for the following items:

Table 3: Owner's Contingencies

Item	Allowance
Design Allowance / Contingency	10%
Escalation Allowance / Contingency	0%
Construction Allowance / Contingency	15%

3.5 Owner's Soft Costs

Allowances have been made for the following items:

Table 4: Owner's Soft Costs

Item	Allowance
Project Management	Not Included
3rd Party Commissioning Authority	Not Included
Engineering	16%

3.6 Statement of Probable Costs

This opinion of probable costs of construction is made on the basis of experience, qualifications and best judgement of FVB Energy. FVB Energy has no control over the cost of materials, labour, equipment, nor the contractor's method of determining prices. FVB Energy cannot and does not guarantee that proposals, bids, or actual construction costs will not vary from this or subsequent estimates.

Current volatile market conditions, caused by the ongoing COVID-19 pandemic and global supply chain issues are difficult to predict and account for. As the project costs are estimated based on preliminary concepts the specific costing, and availability impacts from these phenomena, beyond the present, are not allowed for.

3.7 On-Going Cost Control

FVB Energy recommends that the Owner review this document, including categories, line-item descriptions, exclusions, inclusions, assumptions, contingencies, escalations, and markups. If the project is over budget, or if there are unresolved budgeting issues, alternative systems/schemes should be evaluated before proceeding to the next design phase.

Requests for modifications of any apparent errors or omissions to this document must be made to FVB Energy within ten (10) days of receipt of this estimate. Otherwise, it will be understood that the contents have been concurred with and accepted.

*** End of Main Document ***