CLEANTECH COMMUNITY GATEWAY

Haines Junction Bioenergy Project – Evaluation of Waste Heat Potential Final Report

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Executive Summary

The Dakwakada Development Corporation (DDC), the Champagne and Aishihik First Nations (CAFN), Yukon Energy Corporation, Cold Climate Innovation of the Yukon Research Centre, and the Village of Haines Junction are investigating the potential for a biomass power plant in the Haines Junction community. The plant is expected to provide renewable electricity for the territory and has the potential to produce a viable community heat source and create local economic opportunities. To this end, the proponents are interested in investigating the use of the power plant's thermal energy production to create benefit for the community.

The following report endeavours to evaluate the technical and economic feasibility of utilizing the waste heat from a 500 kW_e bioenergy gasification plant in the Haines Junction area and, when possible, the secondary option of using heat from a 2 MW_e power plant was also considered. The options evaluated in this report include a community District Energy System (DES), increased electrical power production with Organic Rankine Cycle (ORC) technology, and localized food production through Controlled Environment Agriculture (CEA) Greenhouses.

The report evaluates these options against a set of criteria including, technical feasibility, economic feasibility, environmental impacts, socioeconomic considerations, and risk. A previous phase of the work also considered preliminary siting considerations. Based on secondary research, Excel-based modeling, and interviews with numerous experts and suppliers, a set of preliminary recommendations are made to the project proponents.

It is understood that ultimately the community must evaluate the options available to them through the lens of their own priorities and criteria, as well as better define the nature and scale of the proposed biomass power plant. However, given what is currently known about the project, the lowest risk, highest community benefit would appear to stem from the implementation of a very simple heat network that distributes heat from the 500 kW_e power plant to the community school in Haines Junction. In the less likely event that a 2 MW_e system is selected, the option of a DES serving the school, arena complex, convention centre and swimming pool complex is considered the most viable. Both the options of CEA greenhouses and ORC were deemed to have risks in excess of benefits and were not ultimately advocated for.

Nevertheless, further work to confirm project feasibility will be required once the power plant has been selected, siting confirmed, and the quality and quantity of heat available corroborated.

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Disclaimer

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CTCG has based this report on information received or obtained, on the basis that such information is accurate and, where it is represented to CTCG as such, complete.

Acronyms

ATM: Atmosphere

CAC: Criteria Air Contaminants

CAFN: Champagne and Aishihik First Nations

CEA: Controlled Environment Agriculture

CPC: Community Power Corporation

DDC: Dakwakada Development Corporation

DES: District Energy System

FEED: Front-End Engineering and Design

GE: General Electric

GHG: Greenhouse Gas

HID: High Intensity Discharge

HPS: High Pressure Sodium

kW_e: Kilowatt Electric

kW_{th}: Kilowatt Thermal

LED: Light-Emitting Diode

LMP: Lessoway Moir Partners

LPM: Liters Per Minute

MH: Morrison Hershfield

MMBTU: Million British Thermal Units

NPV: Net Present Value

ORC: Organic Rankine Cycle

P&W: Pratt & Whitney

R&D: Research and Development

SAD: Seasonal Affective Disorder

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1 Introduction

The Dakwakada Development Corporation (DDC), the Champagne and Aishihik First Nations (CAFN), Yukon Energy Corporation, Cold Climate Innovation of the Yukon Research Centre, and the Village of Haines Junction are investigating the potential for a biomass power plant in the Haines Junction community. The plant is expected to provide renewable electricity for the territory and has the potential to produce a viable community heat source, and create local economic opportunities. To this end, the community is interested in investigating the use of the power plant's thermal energy production to create benefit for the community.

The Clean Technology Community Gateway (CTCG) is a neutral, not-for-profit organization comprised of public and private sector partners who are collaborating to develop and deploy clean energy solutions within remote and rural communities. Their expertise lies in technical evaluations of various clean technologies, grounded in sound economic and socially beneficial decision-making.

The primary objective of this project is to evaluate the technical and economic feasibility of utilizing the waste heat from a 500 kW_e bioenergy gasification plant in the Haines Junction area. The options being evaluated include a community District Energy System (DES), increased electrical power production with Organic Rankine Cycle (ORC) technology, or localized food production through commercial Controlled Environment Agriculture (CEA) Greenhouses.

The project objectives are to identify potentially viable heat use options, and to evaluate them against a set of criteria including, the viability of the business case, risks, siting requirements, environmental impacts, and socioeconomic considerations. The project will assess previously conducted appraisals, review publically available literature and product specifications, and engage in conversations with industry experts and suppliers. Based on these evaluation criteria, preliminary recommendations have been made as to the viability of the various options presented.

Given that funding for this waste heat evaluation has been obtained from different sources with different funding objectives, the completed report has been divided into sections to better address specific project goals. Section 2 of this report evaluates the viability of a DES to heat community buildings, as well as the use of ORC technology to increase the project's electrical power production. Section 3 addresses the viability of localized food production through CEA greenhouses, and Section 4 makes recommendations in consideration of the results from the previous sections.

Since Stantec is conducting the Front-End Engineering and Design (FEED) study for the power plant concurrently to this waste heat study, it was deemed necessary to provide preliminary siting considerations for potential thermal energy projects in advance of the final report. Therefore siting considerations are presented as a separate report in Appendix E, which was delivered earlier in the project's development.

2 DES & ORC Evaluation

The purpose of this study is to provide an evaluation of the potential uses for the thermal energy produced by a 500 kW or 2 MW electric biomass power plant in Haines Junction. This section will specifically examine two options for each of the power plant capacities:

1. A District Energy System (DES) serving buildings in Haines Junction
2. Additional power generation using Organic Rankine Cycle (ORC) technology

These two options were evaluated individually and in combination based on their technical and economic feasibility, social impacts such as job creation, environmental impacts such as air pollution and noise, and the technical and economic risk associated with each scenario.

2.1 Methodology

Excel spreadsheets were used to perform the economic feasibility assessments based on capital cost, operating cost and revenues over the lifetimes of the proposed systems[1]. Snapshots of these spreadsheets are provided in the appendices and the Excel files are available separately.

2.1.1 Inputs and Assumptions

It has been assumed that the power plant will be connected to the Whitehorse electricity grid, and that it will operate as a base load at maximum load factor. Therefore, it is further assumed that the full thermal output from the system will be available at all times that the biomass power plant is operating.

The cost of electricity, the price paid by the utility company for electricity exported to the grid, and the cost of heating with fuel oil are key inputs into the economic evaluation of the options listed above. The values assumed in the economic analyses are listed in Appendix A.

No inflation or energy price increases have been included in this analysis. It has been assumed that the cost of grid electricity, the selling price of electricity and the cost of fuel oil will all be proportional to the cost of oil and vary at the same rate.

The cost of borrowed capital has been set at 6.2% (Morrison Hershfield 2012) and projects were evaluated over a 15-year lifetime with a 15-year loan period. It should be noted that the DES infrastructure has an expected service lifetime of more than 15 years.

[1] The Excel modeling was further validated using RETScreen analysis. When utilizing similar inputs and assumptions the report's modeled NPV and IRR results were found to vary by less than 5 percent. However, a discrepancy in the results was identified between the model's default heating value and RETScreen's. The model used in this report utilized the heating value stipulated in the Morrison-Hershfield report, which is lower than that given in RETScreen. Ultimately, the report's assumptions are therefore more conservative than RETScreen's.

None of the economic evaluations include the cost of the feedstock as an operating cost. It has been assumed that the cost of feedstock is included in the operating cost of the biomass power plant and that the heat is freely provided to the DES or ORC.

2.1.2 Plant Option 1: 500 kW Electric

The first system under consideration by the project proponents is a bank of Biomax 100 gasifiers to internal combustion units manufactured by the Community Power Corporation (DDC 2012). The system would be capable of producing 500 kW electric, 320 kW_{th} of hot air and 510 kW_{th} of hot water, at an annual availability of 75%. The units must undergo servicing at an interval of 30 days (CPC n.d.).

2.1.3 Plant Option 2: 2 MW Electric

The second system under consideration by the project proponents is a 2 MW electric Nexterra gasification to internal combustion engine system (DDC 2012). The system produces 3 MW of useful heat from the engine jacket and exhaust gas heat exchanger. The engine exhaust gas temperature is 400^{o}C and the waste heat is of high quality, potentially suitable for power generation as well as space heating (Beatty 2012).

2.1.4 District Energy System Costs

This assessment of DES feasibility builds upon the previous DES feasibility studies completed by Morrison Hershfield in 2012, and Lessoway Moir Partners and Quest Engineering Group in 2004, however, it is likely that the capital and operating cost of the DES was overestimated in the more recent MH study.

Low temperature, low pressure district energy systems are a relatively new phenomena in Canada and existing cost data for DES used in the MH study was likely based on insulated steel piping for large, high pressure networks. Steel piping requires more labour to fabricate and assemble, and requires a much higher degree of accuracy in design and fabrication. Low-temperature, low-pressure DES networks, such as the one proposed for Haines Junction, consist of pre-insulated PEX pipe, which is supplied in 300 foot rolls that can be rolled out and cut to length on site, significantly reducing material and labour costs (Gala 2012) (Uponor 2012).

In this study, the capital cost of the DES was estimated based on the cost components shown in Appendix B; it is important to note that before the location of the plant is determined and the pipe network path is defined, the exact number and type of fittings, and the pipe network length are rough estimates only.

Furthermore, the operating cost of the DES in the MH study is likely to be over-estimated, since it includes the cost of a full time operator. The operating cost components included in this study are listed in Appendix B.

2.1.5 ORC Capital Costs

The costs of the two ORC systems consist of the capital cost of the ORC itself (known with relative certainty based on quotes from suppliers (Maggio 2012) (Confrancesco 2012)), the installation cost, (estimated based on man hours required for the installation of the Pratt & Whitney Turboden T10 HR (Confrancesco 2012)), and the cost of auxiliary heat exchange equipment. Quotes were not obtained for the auxiliary equipment, due to the very preliminary nature of this assessment and lack of technical specification at this stage; therefore the costs assigned are the best estimates of the authors, based on prior experience. The capital costs of the ORC system are outlined in Appendix B.

2.1.6 ORC Operating Costs

ORCs require approximately 3 to 5 man hours per week for operation (Confrancesco 2012) and they have low annual maintenance costs relative to steam turbines since the turbine blades are not prone to corrosion from water, given the use of an organic working fluid (Turboden n.d.). The ORC operating costs used in the economic feasibility assessment are listed in Appendix B.

2.2 District Energy System Feasibility

2.2.1 Overall Technical Feasibility of a DES

Without a site visit and survey of the buildings proposed as part of a DES, the technical feasibility of DES can only be assessed at the network level, not the building level. However, installing the supply and return pipelines from the power plant to the DES customers is unlikely to present any insurmountable technical challenges.

2.2.2 Technical Feasibility of a DES with 510 kW_{th}

The thermal energy from the CPC system is limited in its usefulness because of the mixed heat carrying mediums and low temperatures. The 500 kW_e CPC system produces 320 kW_{th} of heat in the form of hot air, and a further 510 kW_{th} of heat in the form of 90^oC-100^oC hot water (Renalli, Community Power Corporation 2012).

The 320 kW_{th} of heat available in the form of hot air must be used by a facility located directly next to the power plant due to energy losses in transferring or transporting heat from hot air. The hot air could theoretically be used for various space heating needs (Renalli, Community Power Corporation 2012), but its most likely use will be to dry the biomass feedstock, given a strict moisture content requirement of 15%.

Most of the thermal energy, 510 kW_{th}, is available as hot water and is sufficient for hot water space heating. Given the limited quantity of heat from this system, it makes sense to heat one large heat load in order to maximize the heat sales per unit length of distribution pipe required. The school is the single largest consumer of thermal energy in the community at 463 MWh/year, and its peak heat demand is 360 kW - slightly less than the peak thermal output of the hot water supplied by the CPC system, providing a margin of excess for oversizing and heat loss during transmission.

It is worth noting the high frequency of servicing required by the CPC units implies that the full heat output of the system will not be available at all times; the system will either supply 75% output 100% of the time (with one unit out of service at a time) or 100% of full output 75% of the time (implying that all units are shut down for servicing at the same time) (Renalli, Community Power Corporation 2012).

2.2.3 Technical Feasibility of a DES with 3 MW_{th}

3 MW thermal is more than sufficient to meet the peak heating requirements of the seven buildings identified as potential DES customers in Scenario 1 of the MH study.

2.2.4 Economic Feasibility of a DES with 510 kW_{th}

In the case of heating the school, it is recommended that the power plant be located as close to the school as possible, in order to minimize the length of the heat supply pipe. A simple “goal seek” analysis in Excel reveals that in order for the school heating option to have an IRR of 15% on an equity investment of $96,000 (over 15 years at 6.2% depreciation and 6.2% interest on borrowed capital) the length of the heat supply pipe between the power plant and the school must be no more than 344 m.

There is potential to connect an additional building to the heat supply from the CHP plant and the most likely candidate would be the building with the lowest capital cost to connect to the system (a function of pipe distance and the complexity of the building energy transfer station), and the highest annual energy consumption. The returns on connecting to the additional building will be limited by how much system capacity is available to heat the additional building. The convention centre is a good candidate, however, a backup/peaking system would be required.

Table 1 summarizes the economic feasibility of the 510 kW_{th} DES options; since the location of the plant is unknown, the impact of total network pipe length on economic feasibility has been explored between two limits: an IRR of 15% and an NPV of 0. The right hand column in Table 1 explores the amount of capital funding or grants that would be required to result in an NPV of 0, if the total pipe network length was increased by 500 m (if, for example, the plant was located farther from the heat loads than ideal).

Table 1: DES Feasibility for the 510 kW_{th} System

Buildings Connected	Heat Supply	Economic Indicators	Max. Pipe Length for IRR = 15%	Max. Pipe Length for NPV = 0	Funding Required for NPV = 0 if 500 m of pipe network is added
School	510 kW @ 75% availability	Max Pipe Length	324 m	385	$477,000
		IRR	**15%**	6%	
		Capital Cost	$367,000	$425,000	
		Equity Requirement (25%)	$92,000	$106,000	
		NPV	$52,700	**$0**	
School	382 kW @ 95% availability	Max Pipe Length	399 m	471 m	$415,000
		IRR	**15%**	6%	
		Capital Cost	$438,000	$506,000	
		Equity Requirement (25%)	$109,000	$126,000	
		NPV	$62,000	**$0**	
School and Convention Centre	510 kW @ 75% availability	Max Pipe Length	423 m*	509 m	$477,000
		IRR	**15%**	6%	
		Capital Cost	$521,000	$602,000	
		Equity Requirement (25%)	$130,000	$151,000	
		NPV	$74,000	**$0**	
School and Convention Centre	382 kW @ 95% availability	Max Pipe Length	322 m*	393	$478,000
		IRR	**15%**	6%	
		Capital Cost	$426,000	$492,500	
		Equity Requirement (25%)	$107,000	$123,000	
		NPV	$60,500	**$0**	

* difficult to achieve in reality, since the distance between the school and the convention centre is approximately 250 m

2.2.5 Economic Feasibility of a DES with 3 MW_{th}

A district energy system serving the six[2] buildings modeled in Scenario 2 appears to be economically viable. However, the high marginal cost of connecting additional buildings to the DES indicates that a smaller network, serving only the four[3] high heat demand buildings identified in Scenario 3 of the MH study, has a lower risk and higher returns. Therefore it is recommended that the DES serve only these four buildings initially, and that the DES be designed for expansion at a later date if desired. The distance between the buildings on the DES is fixed in each scenario, however the distance between the power plant and the heating network is unknown. A distance of 150 m has been arbitrarily assumed for the sake of comparing the two scenarios, and the maximum total pipe length resulting in an NPV of 0 has also been explored.

A summary of the economic feasibility of the 3 MW_{th} DES options is provided in Table 2, below.

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[2] School, Fire Hall, Convention Centre, Arena Complex and the Swimming Pool & Community Hall Complex, YK Government Administration Building

[3] School, Convention Centre, Arena Complex and the Swimming Pool & Community Hall Complex

Table 2: DES Feasibility for the 3 MW_{th} System

Buildings Connected	Heat Supply	Economic Indicators		Max. Pipe Length for NPV = 0	Funding Required for NPV = 0 if 500 m of pipe network is added
School, Fire Hall, Arena, Convention Ctr., Swimming Pool Cmplx, YK Gov't Admin Bldg	3 MW @ 95% availability	Total Network Pipe Length	1250	1706 m	$472,000
		IRR	21%	6%	
		Capital Cost	$1,546,000	$1,977,000	
		Equity Requirement (25%)	$386,000	$494,000	
		NPV	$406,000	**$0**	
School, Arena, Convention Ctr., Swimming Pool Cmplx.	3 MW @ 95% availability	Total Network Pipe Length	400	979	$472,000
		IRR	42%	6%	
		Capital Cost	$722,000	$1,268,000	
		Equity Requirement (25%)	$180,000	$317,000	
		NPV	$514,000	**$0**	

2.3 Power Generation with ORC Feasibility

Additional power generation with an ORC generator was evaluated for technical and economic feasibility. Two ORC models were identified; the General Electric Clean Cycle (General Electric 2011), which requires pressurized hot water (or 80% glycol mixture at 1 atm) at a supply temperature of 147^{o}C and a heating rate of 1000 kW, producing approximately 100 $kW_{e,net}$, and the Pratt & Whitney Turboden T10 HR, which requires hot thermal oil at 290^{o}C at 1 atm, and a heating rate of 5540 kW, producing 865 $kW_{e,net}$ (Turboden 2011). Pratt & Whitney do not sell units with a nominal capacity of less than 1MW_e in North America, therefore the feasibility of operating the T10 at less than full output was investigated.

2.3.1 Technical Feasibility of Power Generation with the 510 kW_{th} System

The potential to utilize the waste heat from the CPC system as the heat supply to an Organic Rankine Cycle (ORC) generator was considered, however, the limited quantity of heat and the low temperature of the heat resource make it unsuitable for ORC. ORC is not a viable option for augmenting the electrical output of the 500 kW_e CPC power plant.

2.3.2 Technical Feasibility of Power Generation with the 3 MW_{th} System

The quantity and quality of heat from the Nexterra engine is theoretically sufficient to meet the heat input requirements of three General Electric Clean Cycle ORC generators. The three units would have a combined net electrical output of about 240 kW_e. Alternatively, a Pratt & Whitney (Turboden) T10 HR ORC generator could be operated at less than full output, this system would produce approximately 375 $kW_{e,net}$.

2.3.3 Economic Feasibility of Power Generation with the 3 MW_{th} System

It is assumed that the electricity generated by the ORC would be sold to the electrical grid at the same rate as the power produced by the Nexterra generator, and would therefore provide significant additional revenue to the power plant. ORC systems have very low operating costs, require less additional infrastructure than a DES, and when operated as a base load, provide predictable electricity sales revenue.

Both systems would cost approximately $3 million installed, but the additional power produced by the Pratt & Whitney system would result in a higher return on investment, even when operated at less than full output. However, significant engineering work may be required to convert the Nexterra engine exhaust gas heat exchanger to operate with thermal oil rather than a water/glycol mixture, and the cost of this work, as well as the additional cost of the equipment is entirely unknown. Pursuit of this option would necessitate collaboration with Nexterra's engineering group.

Four ORC scenarios were investigated: two ORC options, with two different rates for electricity sales to Yukon Energy. The results of the economic feasibility assessment are summarized in Table 3.

The economic feasibility assessment indicates that at an electricity purchase price of $200/MWh, the Pratt & Whitney T10 HR appears to be a good investment. However, the 3 General Electric Clean Cycles option does not look economically feasible even at the higher electricity purchase price.

Table 3: ORC Economic Feasibility Assessment

ORC System			Electricity Purcahse Price 150 $/MWh		Electricity Purchase Price 200 $/MWh	
3 x GE Clean Cycle	Capital Cost	$3,259,000	IRR	n/a	IRR	6%
	Equity (25%)	$815,000	NPV	($920,000)	NPV	($21,000)
1 x P&W T10 HR	Capital Cost	$3,450,000	IRR	8%	IRR	29%
	Equity (25%)	$863,000	NPV	$109,000	NPV	$1,517,000

2.3.4 Additional Considerations for ORC

It is worth noting that it is possible to combine a DES with the Pratt & Whitney T10 HR ORC, however in order to produce water at a temperature suitable for the DES, the ORC condenser cooling water outlet temperature must be raised. Raising the cooling temperature results in a decrease in efficiency, and reduced power production (Turboden 2011). Reducing the power production reduces electricity sales, and decreases the economic viability of ORC, however this scenario requires further research before a conclusive statement on viability could be made. It is clear that the capital cost of such a system would be very high.

Finally, the required qualifications of the ORC operator/supervisor are not clear in the Yukon Boiler and Pressure Vessel Code. It appears that the code is not written to address the operation of such devices, and ORC may be exempt (Yukon Territories 2002). However, it is likely that the same individual could fill the positions of the biomass power plant supervisor and the ORC supervisor, and that the qualifications required for supervising a 2 MW_e biomass gasification plant will meet or exceed the required qualifications for supervising an ORC system.

2.4 Siting Considerations

Please see Appendix E for previously completed Preliminary Siting Considerations Report.

2.5 Environmental Impacts

2.5.1 District Energy System Environmental Impacts

All of the buildings in Haines Junction considered for connection to a DES currently have individual heating systems that burn fuel oil (assumed to be light fuel oil or diesel); these boilers and furnaces produce criteria air contaminants (CAC) that are harmful to the environment and human health, in addition to producing greenhouse gas emissions (GHG). The International Agency for Research on Cancer has recently classified diesel exhaust emissions as carcinogenic to humans (2012), and acute exposure to diesel exhaust has been shown to cause a host of undesirable health impacts (US EPA 2002).

Displacing the combustion of diesel in building heating systems with heat from the biomass power plant would reduce this source of noxious air pollution in the community. Furthermore, reducing the volume of diesel fuel stored in tanks throughout the community would reduce the potential for fuel spills and leaks, and reduce the risk of contaminating the community's soil and groundwater.

Combustion of diesel fuel for space heating also generates greenhouse gas emissions; displacing the diesel fuel consumed for space heating in community buildings with heat from the DES would reduce the community's GHG footprint.

The benefits of reduced CAC emissions, soil and groundwater contamination risks, and GHG emissions are proportional to the volume of diesel fuel displaced for space heating in the community, and the extent of the DES. Table 4 provides preliminary estimates of the reduction in diesel fuel consumed, and the reduction in CAC and GHG emissions that could be expected from the various DES scenarios (S&T Consultants 2008), (Environment Canada 2010).

Table 4: Avoided CAC and GHG Emissions under DES Scenarios

DES Scenario	Heating Load Displaced (MWh/yr)	Estimated Volume of Diesel Saved (L/yr)	Estmated Reduction in CAC Emissions (t/yr)						Estimated Reduction in GHG Emissions (t/yr)		
			CO	NOx	SOx	PM	PM_{10}	$PM_{2.5}$	CO_2	CH_4	N_2O
School	463	34274	21	185	663	52	37	27	93	0	0
School & Convention Ctr	587	42267	25	228	817	64	45	33	115	0	0
School, Convention Ctr, Arena & Pool Cmplx.	1102	97093	58	524	1877	147	104	76	265	0	0
School, Fire Hall, Arena, Convention Ctr., Swimming Pool Cmplx, YK Gov't Admin Bldf.	1515	132604	80	716	2563	200	142	103	361	0	0

2.5.2 ORC Environmental Impacts

Electricity in the Yukon is primarily generated by hydroelectric power plants, however, in times of high demand, diesel generators are required very occasionally to meet peak demand (Yukon Energy Corporation 2012). An ORC generator exporting energy to the Yukon grid would only reduce CAC and GHG emissions if the electricity it is producing displaces electricity generated with diesel. It is difficult to quantify the avoided CAC and GHG emissions that would result from an ORC generator operating in Haines Junction, but the impact is likely to be negligible at the regional level due to the minimal volume of diesel consumed for power generation in the territory (Yukon Energy Corporation 2012).

2.5.3 Noise Pollution

Neither the DES nor the ORC are expected to increase noise emissions in the community. It is possible that operation of the DES may be slightly quieter than the individual building heating systems, however without noise measurements of current systems this is only speculation. The ORC turbine does produce a whining noise that could be considered undesirable, however the ORC would be housed in the power plant building, surrounded by concrete walls, and the noise from the ORC should not be noticeable outside the power plant.

2.6 Socioeconomic Impacts

2.6.1 Job Creation

Neither the DES nor the ORC option will create large numbers of permanent, full time jobs in Haines Junction. The daily operating requirements of both the DES and the ORC are minimal. It is estimated that the DES will create one part time position of two hours per day, and the ORC will create a part time position of three to five hours per week. The Yukon is beset by labour shortages and high costs for skilled labour (Serecon Management Consulting Inc. 2007). There may be a challenge in recruiting skilled part-time employees. Some consideration should be given to this challenge in advance.

2.6.2 Community Capacity Building

The creation of local knowledge about the installation and operation of district energy systems could be of substantial value to Haines Junction. If the community becomes one of the first in the region to install and operate such a system they will become a resource for other local communities who may wish to replicate their system. Becoming a local leader in the field of district energy systems would facilitate the spread of knowledge and creation of regional capacity in the field of DES.

2.7 Project Risks

There is a degree of technical risk associated with all of the options described in this report. Both DES and ORC technology are relatively new in the Canadian context, and some technical challenges may need to be overcome in the implementation and operation of both options.

However, district energy systems are not a new concept and they carry relatively low technical risk if they are designed and installed correctly with the right pipe sizing, leak detection, backup and control systems. Conversely, integrating a thermal oil ORC with the engine jacket and exhaust gas heat exchanger of the Nexterra power plant represents a significant innovation and is an engineering task that would require costly development and testing. Therefore the technical risk of the ORC option is much higher than that of the DES option.

There is also a secondary technical risk from the power plant itself; all of the options considered in this report depend on a reliable supply of heat from the power plant. Given that generating electricity from biomass via gasification is still a relatively new technology, there is a risk that the system may not be as reliable as the foregoing economic assessments have assumed.

If the heat supply from the power plant is not reliable, the heat or electricity sales will be lower and the return on investment will fall. Therefore, even if an option appears to have higher returns, there may also be more equity at stake, and more to lose if the power plant does not perform as expected.

An additional secondary risk to the heat supply comes from the security of the biomass resource available for the power plant. Any uncertainty with respect to a long term, affordable source of feedstock translates into uncertainty with respect to the availability of heat.

The environmental risks associated with both options are minimal. The heating fluid in the DES is likely to be water mixed with antifreeze, and depending on the chemical selected, a leak from the system may pose an environmental risk; however non-toxic antifreeze is commercially available. The high temperature thermal oil and the ORC working fluid (silicone oil) pose some health and environmental risks, however both the exhaust gas heat exchanger and the ORC would be operated as closed loops, and disposal of large volumes of these oils is not an ongoing part of plant operation (Solutia 2011) (Solvay North America 2011).

2.7.1 Decision-Making Framework

The decision to invest in any of the options described in this report requires the commitment of significant capital, and possibly the investment of taxpayer dollars in public infrastructure. Therefore decision-making should take into account stakeholder objectives and careful weighing of relative project risks. Table 5 compares the options examined in this study based on the degree to which they meet various objectives, and Table 6 compares the relative risk associated with each option. The list of objectives is by no means exhaustive, and the community may wish to add to the list. The community may also wish to create their own weighting system if certain objectives are more important than others.

Table 5: Fulfillment of Stakeholder Objectives

Options \ Decision Criteria		Return on Investment	Job Creation	Innovation & Capacity Building	Improved Air Quality	Reduced Diesel Spills & Leaks
Community Power Corp. 500 kWe System						
Option 1:	School Only DES	Depends on siting of power plant, however IRR is expected to be good, for a relatively small investment	One, part-time permanent position	Development of local capacity to install, operate and maintain a low temperature, low pressure DES	Small reduction in CAC and GHG emissions	Smallest reduction in total fuel consumed
Option 1: Objectives Score		4	1	1	1	1
Option 2:	School & Convention Ctr. DES	Depends on siting of power plant, however IRR is expected to be lower than option 1 due to the additional pipe network cost	One, part-time permanent position	Development of local capacity to install, operate and maintain a low temperature, low pressure DES	Slightly higher reduction in CAC and GHG emissions than option 1	Slightly larger reduction in total fuel consumed
Option 2: Objectives Score		1	1	1	2	2
Nexterra 2 MWe System						
Option 3:	4 Building DES	Depends on siting of the power plant, however, IRR is expected to be very good for the high heat sales and limited infrastructure cost of this option	One, part-time permanent position	Development of local capacity to install, operate and maintain a low temperature, low pressure DES	Very significant reduction in CAC and GHG emissions relative to status quo	Very significant reduction in total fuel consumed
Option 3: Objectives Score		3	1	1	3	3
Option 4:	6 Building DES	Depends on siting of the power plant, however, IRR is expected to be lower than option 3, due to the small marginal increase in heat sales and high marginal cost of additional infrastructure	One, part-time permanent position	Development of local capacity to install, operate and maintain a low temperature, low pressure DES	Highest reduction in CAC and GHG emissions relative to the other options	Highest reduction in fuel consumption, relative to the other options
Option 4: Objectives Score		2	1	1	4	4
Option 5:	Generate Electricity with ORC	Depends on the selling price of electricity and the non-repeated engineering costs associated with development	No additional jobs anticipated, outside of the power plant	Development of local capacity to operate an ORC, high degree of innovation, potential for generating intellectual property	No CAC and GHG reduction expected until YK electricity demand consistently exceeds the capacity of the hydroelectricity generators	No reduction in fuel consumption expected until YK electricity demand consistently exceeds the capacity of the hydroelectricity generators
Option 5: Objectives Score		1	0	3	0	0
Scoring: 0=no change from status quo, 1=moderate, 2=good, 3=very good, 4=excellent						

Table 6: Relative Risks

Options \ Decision Criteria		Technical Risk	Financial Risk	Environmental Risk
Community Power Corp. 500 kWe System				
Option 1:	School Only DES	Very simple system, low technical risk, existing system can be used as backup	Low total capital cost, low equity requirement	Small risk of antifreeze leak from system
Option 1: Risk Score		-1	-1	-1
Option 2:	School & Convention Ctr. DES	Slightly more complex system than option 1, but technical risk is still low	Higher capital cost than option 1, with diminished returns due to lower heat sales to the second building, and the use of the back up boiler in the second building during peak periods	Small risk of antifreeze leak from system
Option 2: Risk Score		-1	-2	-1
Nexterra 2 MWe System				
Option 3:	4 Building DES	Relatively simple system, a backup boiler would be required	Lower capital cost than options 4 & 5, high return on equity invested due to limited network infrastructure and high heat sales	Small risk of antifreeze leak from system
Option 3: Risk Score		-2	-1	-1
Option 4:	6 Building DES	More complex system than option 3, but not significantly so	Much higher capital cost than option 3, with diminished returns from heat sales to additional buildings. More equity at risk if power plant fails	Small risk of antifreeze leak from system
Option 4:Risk Score		-2	-3	-1
Option 5:	Generate Electricity with ORC	High technical risk due to innovative application of ORC technology and uncertainty about performance	A lot of equity at risk if the power plant or ORC application is unsuccessful	Small risk posed by accidental release of thermal oil and silicone oil
Option 5: Risk Score		-3	-3	-1
Scoring: 0=no change from status quo, -1=low risk, -2=moderate risk, -3=high risk				

2.8 Next Steps

Before a final decision regarding the optimal use of heat from the biomass power plant in Haines Junction is made, the following next steps are recommended:

1. Confirm the size of the power plant that will be providing the supply of heat
2. Select a site for the power plant
3. Determine the DES supply line route and pipe length
4. Re-evaluate DES economic feasibility with current cost estimates and confirmed pipe network path length
5. Confirm accuracy of heating load data for DES customers (the last study was done in 2004)
6. Refine capital cost estimates
7. Re-evaluate DES economic feasibility with refined cost estimates and current heat demand and consumption data.
8. Begin consultation with DES designers/suppliers either directly or through the FEED consultants for the biomass power plant

3 Greenhouse Evaluation

Because of Haines Junction's location north of the 60th parallel, winters are long and dark, with as few as four hours of light each day, and summers are generally warm, with long hours of daylight up to 19 hours. The mean temperature is 11°C in June and -21°C in January. Frost may occur at any time of year, and by the end of October there is ice on many of the lakes (Yukon Community Profiles 2004). Given the climatic realities of Haines Junction and similar northern communities, year-round commercial agricultural production has traditionally been viewed as unfeasible.

There is growing interest—particularly in Canada's North—in the concept of regional food security, meaning when all people, at all times, have access to sufficient, safe, and nutritious food to maintain a healthy and active life (World Health Organisation n.d.). The need for a reliable food supply in the Yukon was highlighted in the spring of 2012 when flooding and road washouts resulted in the closure of the Alaska Highway. Whitehorse and neighbouring areas experienced food shortages particularly of perishable goods such as fruits and vegetables (CBC 2012). Interest has emerged in the Yukon around improving local food production, and developing local supply chains.

In regions of the world considered otherwise inhospitable growing environments, advances in Controlled Environment Agriculture (CEA) have presented themselves as viable options for creating a local food supply. CEA attempts to account for hostile outside growing conditions through integrated techniques and technologies to control all aspects of the internal growing environment: lighting, temperature, nutrients, hydroponics and air control. According to O'Brien, these variables create the potential to develop a commercial agriculture business anywhere that the input cost is less than the output potential (O'Brien 2011). Therefore the technical and economic feasibility of a greenhouse in Haines Junction is a function of the degree to which the temperature, lighting, CO_2 and nutrients can be controlled at a lower cost than that earned in revenue from yields.

The project proponents wish to better understand the viability of a year-round, commercial greenhouse in Haines Junction. While viability is usually measured by financial indicators, it can also be understood to be reflected in "health aspects (improved fresh food availability, quality and nutrition), the environmental footprint (environmental emissions of local production vs. transportation emissions from shipping products in from long distances), and by various social aspects" (Evans 2008). The following sections attempt to address the proponent's interest in local food production, and provide insight into what such a project might entail, and its associated costs and benefits.

3.1 Methodology

As a recent article in the Globe and Mail astutely noted, the concept of food production systems in the Canadian North is not a challenge of technology, as researchers have designed high-tech, winter-resistant vegetative incubators before. The challenge is developing northern greenhouses that are capable of supporting themselves financially.

Developing a year-round greenhouse that employs locals, and sells enough produce to break even without subsidy, has never been accomplished in Canada[4] (Paperny 2012). Consequently determining the viability of such a venture is inherently fraught with speculation.

CTCG has developed a modelling tool to help communities make high-level evaluations around the technical and financial feasibility of local food production using controlled environment agriculture greenhouses. Assumptions were used to develop a conceptual greenhouse to model the project's viability. These inputs and assumptions are described in the following section and in Appendix G.

The detailed design of a greenhouse facility is operations and crop specific; there is significant variation in possible design criteria, and the specific features of the proposed greenhouse are unknown and outside the scope of this report. As such, assumptions and standardized inputs were used to model potential viability. Should the project proceed, further work will be required to determine the ideal production scenarios. This will include detailed planning of the inputs and outputs associated with facility design (see Table 7 (Both 2005)).

Table 7: Greenhouse inputs and outputs important for facility design.

Inputs	Outputs
Seeds, cuttings, plugs, etc.	Finished plant material
Growing media	Plant waste
Energy (heating fuel and electricity)	Heat (loss to air and conduction to subsoil)
Light	Stray light from supplemental lighting
Carbon Dioxide	Oxygen
Water	Runoff
Fertilizer	Leachate
Labour	
Disease and pest management	

3.1.1 Inputs and Assumptions

The modeling conducted in this evaluation relies on the research and expertise of those working to develop and operate cold-climate food production systems, greenhouse suppliers, and government and academic research. The MH Report (Morrison Hershfield 2012) and the LMP study (Lessoway Moir Partners and Quest Engineering Group 2004) were employed for Haines Junction specific inputs, and the *Multi-Year Development Plan for Yukon Agriculture and Agri-Food 2008-2012* was utilised for Yukon agricultural inputs (Serecon Management Consulting Inc. 2007). Most of the greenhouse cost estimates were derived from a report detailing the production, operation and capital costs associated with the Chena Hot Springs Greenhouse in Alaska. The greenhouse uses advanced technologies and production techniques to overcome the climatic

[4] Commercially viable, cold climate greenhouses do exist outside of Canada, see (Avard 2010) for description of international case studies.

limitations of year-round Alaskan food production (O'Brien 2011). See Appendix A of the Preliminary Siting Report for a brief description of the operation.[5]

A complete table of inputs and assumptions is available in Appendix G.

3.1.2 Market Demand

Industry trends indicate that commercial greenhouse vegetables are typically tomatoes, cucumbers, lettuce or sweet peppers with production geared towards the wholesale market for distribution through chain stores (XCG Consultants Ltd. 2008, 5.3). Modeling assumed poly-cultivation of the three vegetables with the highest per capita demand in the Yukon from the crops listed above, namely tomatoes, cucumbers, and lettuce (Serecon Management Consulting Inc. 2007). The smaller scale production expected in Haines Junction, suggests that farm gate sales[6], farmers' markets and potentially direct sales to retail stores are more viable channels than the wholesale market. With this in mind, average retail prices for these vegetable classes were used as revenue inputs (Real Canadian Superstore 2012).

Total market demand was calculated in order to determine the required size of the potential greenhouse.

The following formula was used to calculate market demand for each of the three vegetables:

$$M = D \bullet P \qquad (1)$$

Where:

$M = \text{Market Demand (kg/year)}$
$D = \text{Disappearance Rate (kg/person/year)} - \text{also know as per capita consumption}$
$P = \text{Population}$

3.1.3 Greenhouse Size & Features

Sizing for the greenhouse was established by scaling the production facility to meet the potential local demand. This is the most logical method of determining size, given that sizing a facility where yields exceed demand would compromise economic feasibility. Three market scenarios were examined, one in which the Haines Junction greenhouse is sized to meet 100% of local demand, another where sizing is expected to meet 25% of Whitehorse demand, and finally where sizing is to meet both 100% of local demand and 25% of Whitehorse demand.[7]

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[5] The case study presents a more recent picture of the greenhouse operations than the ones used in the assumptions. The case study outlines operations after an expansion and the integration of new LED lighting technologies.
[6] When consumers visit the farm to make purchases
[7] Yukon per capita yearly disappearance rates and yields per acre for lettuce, cucumbers and tomatoes were derived from the *Multi-Year Development Plan for Yukon Agriculture and Agri-Food 2008-2012* (Serecon Management Consulting Inc. 2007). This report also indicates that 25% is the realistic locally grown market share for each of the three vegetable groups.

Greenhouse yield data from the Yukon[8] (Serecon Management Consulting Inc. 2007) was used in order to determine the size of the required greenhouse, once market demand for all three vegetables was known. It was assumed that the yield numbers were based on total greenhouse area, and taking into account the fact that not all area in a greenhouse is used for growing and a small percentage of production is lost to quality control.

Equation 2 was used to calculate the required greenhouse footprint size in each scenario, given market demand and yield values for each vegetable:

$$F = (M/Y)_{lettuce} + (M/Y)_{cucumbers} + (M/Y)_{tomatoes} \qquad (2)$$

Where:

$F =$ *Required Footprint size* (m^2)
$M =$ *Market Demand* (kg/year)
$Y =$ *Yield* (kg/m^2)

The calculated greenhouse footprint sizes based on this formula are shown in Table 8. Table 8 also indicates how many Chena Hot Springs Greenhouses would be needed to achieve the required footprint area.

Table 8: Predicted Greenhouse Footprint Based on Market Demand

	Haines Junction 100%	Whitehorse 25%	HJ 100% WH 25%
Greenhouse Footprint Area Required (m^2)	486	5338	5824
Chena Units	1.21	13.30	14.51

Given the methodology's reliance on the Chena model for much of the analysis, a number of the facility's design choices were also adopted. While this was practical from a modelling perspective, many of these features are also commonly adopted elements throughout the greenhouse industry due to their efficiency and durability; however, there may also be higher capital costs associated with some of these features. A detailed production plan and greenhouse design will allow for optimisation around these trade-offs. Descriptions of recommended greenhouse elements are given in Appendix F.

3.1.4 Heat Requirements

See Section 2.2.2 Technical Feasibility of a DES with 510 kW_{th} for a complete description of the 500 kW_e CPC system's heating characteristics.

Greenhouse heating systems that give good temperature uniformity, such as circulating hot water heating systems, are generally preferred by growers. While forced hot air

[8] Conversations with the Yukon Agricultural Branch (Ball 2012) have indicated that the yield data provided in the *Multi-Year Development Plan for Yukon Agriculture and Agri-Food 2008-2012 is likely an industry average and may not be specific to the Yukon.*

systems typically have lower initial costs, their decreased heating efficiency and less satisfactory uniformity will generally reduce long-term profitability (Both 2005).

The maximum heating power required in each scenario was estimated using a standard formula to calculate heat loss. This formula is a function of greenhouse surface area, temperature variation between the outside and inside of the greenhouse, and the structure's U-value, a measure of thermal resistance (Canada Plan Service n.d.). The indoor growing temperature used for this model was a conservative 24°C, a high estimate based on the current Chena greenhouse growing temperatures (Werner 2012). The extreme minimum monthly temperatures recorded for Haines Junction provided a low temperature of -53.9°C that was used as the outdoor temperature (Environment Canada n.d.). Lastly, a U-value of 2.27 W/m^2K was assumed for a double polycarbonate structure with energy curtains (Canada Plan Service n.d.) (O'Brien 2011). The calculation also allowed for coefficients to represent losses due to wind speed, air infiltration and heating system design, however based on the assumptions of a well-built greenhouse structure with a radiant heating system and wind speeds below 25 km/hr, all coefficients were equal to one. The heating calculations did not account for passive heating from solar gains, or lighting.

Surface area and heat loss calculations were determined utilising the Chena Greenhouse as a conceptual model (O'Brien 2011). The surface area of one Chena greenhouse was calculated and the total surface area in each scenario was estimated by multiplying this value by the number of Chena units. The formulas for surface area (3) and heat loss (4) are detailed below:

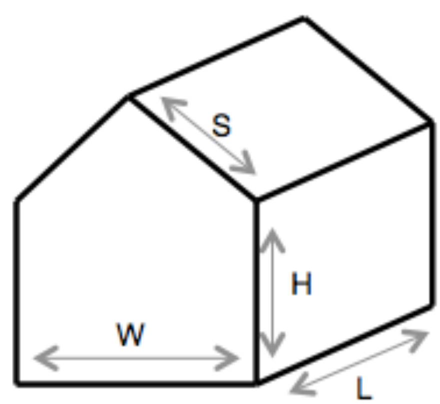
$$A = (2 \bullet H \bullet L + 2 \bullet W \bullet H + W \bullet R \bullet W/2 + 2 \bullet S \bullet L) \bullet C \qquad (3)$$

$$Q = A \bullet \Delta T \bullet U/1000 \qquad (4)$$

Where:

A = Surface area (m^2)
L = Length of greenhouse (m)
W = Width of greenhouse (m)
H = Height of greenhouse (m)
R = Roof pitch (rise/run) -slope of roof
S = Roof side-length (m) = $((W/2)^2 + (RW/2)^2)^{1/2}$
C = Chena units

Q = Heat loss (kW)
ΔT = Difference between indoor and outside temperatures (°C)
U = U-value (W/m^2K)



Surface area of:

Sidewalls = $2 \bullet H \bullet L$
Endwalls = $2 \bullet W \bullet H + W \bullet R \bullet W/2$
Roof = $2 \bullet S \bullet L$

In order to confirm the heating and cost assumptions made in this report a detailed preliminary quote and heating estimate was acquired from Harnois Greenhouse, see Appendix H. The greenhouse quoted relied on the commercially available greenhouse design that most closely represented the expected footprint required for the 100% Haines Junction production scenario: a Harnois Ovaltech III Greenhouse with dimensions of 35 ft x 156 ft (10.7 m x 47.5 m) and a total area of 5,460 ft^2 (507.3 m^2). As part of this quote, greenhouse heating engineers with TrueLeaf Industries also calculated the greenhouse's expected heating system needs (see Appendix H). To do this, they estimated the expected available heat given specifications from a customer case study using a single CPC Biomax 100 unit. The heating details of the case study were as follows (Renalli 2012):

- Outlet temp from Engine = 100^{o}C
- Inlet temp back to Engine = 75^{o}C
- Flow Rate = 90.8 LPM

3.1.5 Economic Feasibility

Estimating the annualized costs and deducting them from predicted annual revenues determined the economic feasibility of the project. This methodology is outlined in further detail below. The yearly costs consisted of the operation and maintenance costs and loan repayment on construction capital. The yearly cash flows for 25 years, including the original 25% capital investment in year 0, and a discount rate of 6.2% was used to calculate the NPV for each scenario.

3.1.5.1 Capital Costs

Capital costs were assumed based on the Chena Model (Mager 2008). A complete list of construction and durables costs, as well as O&M costs is outlined in Appendix G. These figures were used to represent a single Chena unit (18.3 m x 21.9 m greenhouse) from which costs were extrapolated to meet size requirements for each production scenario. This method was also used by O'Brien in a feasibility analysis of Controlled Environment Agriculture Greenhouses in Alaska (O'Brien 2011). It was assumed that 25% of the total capital cost was paid for in equity, and a loan was secured to cover the remaining 75%. The loan repayment was annualized over 25 years at 6.2% annual interest (Morrison Hershfield 2012). Capital cost components that were not addressed include: heating costs, land acquisition, ongoing shipping costs, and transportation costs to market. Taxes were also not applied to capital or operating costs, nor were they accounted for in any financial calculations.

3.1.5.2 Operation and Maintenance (O&M) Costs

The modeled O&M cost estimates include material inputs (hydroponic medium, fertilizer, seeds, etc.), accessories, electricity, labour, and packaging/marketing costs. Although the amount of electricity used was based on the Chena model, the costs were adjusted to represent the Haines Junction electricity rate structure (Yukon Electrical 2012).

An estimated lifetime for each construction and durable material was given based on the Chena model. The costs associated with replacing these materials were assumed to be the same as the original costs, and were included as maintenance costs in the appropriate replacement years. For example, if lighting was given a 5-year lifetime, its replacement cost (equal to its original cost) was included in the operation and maintenance cost for years 5, 10, 15, 20 and 25. Inflation was not considered in any financial calculations.

3.1.6 Methodology Limitations

As previously described, there are no commercially operating greenhouses north of 60; therefore, an obvious limitation of this study is that the assumptions made are based on results recorded outside of the study area. In the case of projected greenhouse yields, the report relies on data provided in the *Multi-Year Development Plan for Yukon Agriculture and Agri-Food 2008-2012* (Serecon Management Consulting Inc. 2007). Correspondence with the Yukon Agriculture Branch indicate that these yield numbers may be lower than could be expected (Ball 2012).

Further, while the research around the Chena Hot Springs Greenhouse in Alaska is instructive, the greenhouse is not operated specifically as a commercial venture. Many of the production decisions are made based on the resort's desire for appealing menu items, achieving research needs, and serving an important role in the community. The climatic and geographic features of Chena are also not identical to Haines Junction. It is unlikely that the practical implementation of a greenhouse in Haines Junction would yield results identical to those of Chena, or exactly the same as data recorded in other studies.

The heat loss estimates included in the modeled greenhouses were based on the required number of Chena units to meet the production scenarios. The actual greenhouse dimensions for the proposed project in Haines Junction are unknown. It is also unknown what materials will be selected for the potential Haines Junction greenhouse. As such, a single U-value was used to represent the entire surface area (twin wall polycarbonate). In reality, different materials might be used for the greenhouse coverings, each having a unique U-value.

Additionally, in greenhouse operation, vegetables have different optimal growing temperatures. In the case of poly-cultures, greenhouse production areas are divided to allow for temperature variation. These differences in indoor temperature affect heat loss. Overall, the model's heat loss estimate correlates well with both Chena's heat requirements and the quote from Harnois Greenhouses. It would therefore appear that the heat loss expectations given are reasonable for a greenhouse sized to meet 100% of Haines Junction's demand for produce (Werner 2012) (McIntosh 2012). These assumptions should be further investigated once more details are known about the greenhouse design and production plan.

The Chena model used to estimate both cost and heat loss inputs is a relatively small greenhouse—comparable in size to that required for the 100% Haines Junction scenario. However, extrapolating this data to the larger greenhouse production scenarios—at more than 13 times the size of Chena—is inherently flawed. Costs and heat loss data for the larger Whitehorse scenarios are likely overestimated given that they do not account for the relative benefits of larger greenhouses. A larger facility with increased production would likely benefit from economies of scale achieving lower per unit input costs, and reduced sidewall heat loss, if expansion was accomplished through gutter-connected greenhouses.

Finally, Jeff Werner has indicated that some of the indicated durables' lifetime periods are likely longer than those modelled, but given the difficultly in predicting, it is recommended that conservative lifetimes are used (Werner 2012).

3.2 Technical Feasibility

Determining the technical viability of the proposed greenhouse project in Haines Junction is largely a question of sufficient waste heat availability from the proposed biomass energy system to support required production.

The management of the greenhouse environment is strongly reliant on temperature manipulation. The response of plants to increasing temperature is reasonably predictable: "There is a temperature range, for most plants, from 10°C to 24°C, over which there is a near linear positive response in terms of increased growth" (Vox 2010). This is complicated by the fact that in a commercial operation the ideal crop temperature is usually a compromise point between the cost of heat energy and the diminishing crop returns from the elevated temperatures (Vox 2010).

While there are optimum temperatures for each crop and for each stage of development, the modeling utilized in this report makes a number of assumptions with regards to heat load calculations. Detailed analysis of heating demands and costs will be required once final selection of crops and greenhouse design has been made.

3.2.1 Waste Heat Supply

Given the 510 kW_{th} associated with the CPC 500 kW_e system, Table 9 outlines the expected size and heating demand for each greenhouse production scenario.[9] It is good practice when determining heating requirements and sizing equipment to ensure at least a 10% buffer above the estimated heating requirements to ensure that enough heat is available for peak loads.

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[9] Note that the expected sizing and heat loss estimates have changed from those outlined in the preliminary siting report. This is as a result of a change in methodology and expected yields. Not only have yields been improved to better reflect those given in the Yukon's Multi-Year Agricultural Development Plan (Serecon Management Consulting Inc. 2007), but the preliminary siting report assumed that the modeled greenhouse dimensions were a single Chena unit width, by whatever length was required to meet necessary yield area. Here heating is determined by multiplying the scenario's Chena units by Chena's heat demand. As outlined in Methodology Limitations, this is useful for modelling, but likely overestimates the costs and heating needs of the larger scenarios.

Table 9: Expected Heating Demand for Three Production Scenarios

Heating Demand	Haines Junction 100%	Whitehorse 25%	HJ 100%, WH 25%
Greenhouse Footprint Area Required (m2)	486	5338	5824
Maximum Heating Power Required (MMBTU/hr)	0.569	6.24	6.81
Maximum Heating Power Required (kW_{th})	167	1829	1995

When assuming 510 kW of extractable heating power is available, there is more than enough heat for the 100% Haines Junction production scenario, while also allowing for a 10% buffer for extreme peak loads and potentially future expansion. However modelling indicates that it would not be technically feasible to heat either of the larger production scenarios without supplemental heating systems.

The modeled results for the Haines Junction scenario can also be compared to those calculated for the Harnois quote, based on the CPC case study specifications given in the Methodology Section. The greenhouse heating engineer's total calculated heat load for the OvalTech greenhouse with a 50^{o}C Δ T, resulted in a requirement of 600,000 BTU per hour (176 kW), whereas the waste heat available produces a 42^{o}C Δ T, or about 500,000 BTU per hour (147 kW) (McIntosh 2012). Hence the Harnois quote includes a supplemental heating system based on the expectation that waste heat alone will not be sufficient.

Assuming that the Haines Junction project will be capable of extracting more heat from the hot water than was achieved in the CPC case study, supplemental heating may not be required (however, back up heating would still be needed). The CPC case study highlights the importance of the quality and availability of the heat from the potential bioenergy plant.

3.2.2 Other Technical Challenges

Other technical challenges from the perspective of the Haines Junction project would be achieving high building material insulative values, acquiring an adequate source of CO_2 enrichment, and identifying a cost effective means of lighting the greenhouse during the low daylight periods of winter. Appendix F highlights the greenhouse features selected to overcome these challenges. These greenhouse features will address the technical limitations of production in Haines Junction; however there is typically a greater capital cost associated with improved greenhouse design features.

3.3 Financial Feasibility

The traditional "southern" greenhouse model is a low-cost, monoculture, large size, product-exporting greenhouse (Evans 2008). Greenhouse production in northern and remote locations is fundamentally different in that most costs—baring perhaps transportation to market—will be greater, scale is inherently smaller, and multiple crops are usually required to meet local demand. Further, all products must be consumed either locally or in other nearby communities, limiting the size of the potential market. While it can be assumed that any technical challenges associated with northern greenhouse production can be overcome, the ultimate viability of a project will hinge on whether ideal growing conditions can be achieved at a cost less than that of potential revenue.

3.3.1 Project Costs & Revenues

Costs used for the greenhouse model were largely adopted from Mager's model based on Chena Hot Springs Resort as discussed in the Methodology Section (Mager 2008). For a detailed list of all default costs used in the model, see Appendix G. O'Brien has suggested that prices from greenhouse suppliers will likely reflect quality, and that prudence in greenhouse vendor selection is generally advised (2011). One project-specific quote (see Harnois Quote Appendix H) and one generic quote (see CropKing Quote Appendix I) were obtained from greenhouse suppliers to better understand the applicability of the modeled capital costs. While overall quoted capital costs were similar to those modeled, individual line items varied substantially. Further research will be required to determine costs once the specific greenhouse design has been confirmed.[10]

While greenhouse projects are typically characterized by high capital costs, the yearly operation and maintenance costs represent a much larger proportion of the project's lifetime costs and a major challenge in achieving economic feasibility. The most significant modeled O&M cost was labour, at over $150,000 yearly for the Haines Junction production scenario. Material inputs, electricity, and packaging/marketing costs were also significant, as each totaled close to $50,000 a year. Because of the high O&M costs identified in the model, these variables were further investigated in the alternative financial scenarios outlined below.

Low project revenues also severely limited the project's modeled viability. Project revenues were limited by the relatively affordable retail price of produce in the Whitehorse area (Ball 2012) (Real Canadian Superstore 2012).

It should be noted that heating costs were not included in our model as the waste heat from the biomass power plant was assumed to be provided free of charge. Heating is often one of the largest operating costs incurred for greenhouse operations, especially in colder climates. As such, this cost should be the subject of future investigation if it is expected that there will be a requirement for supplemental or back up heaters. Preliminary heating cost analysis using the U.S. Department of Agriculture's greenhouse operations software, *Virtual Grower*, estimates costs for a 47.5 m x 10.7 m greenhouse in Gulkana, Alaska (selected for it's relative proximity to Haines Junction), as $20,208 USD annually when using wood chips, and $66,412 when using propane (see Appendix J).

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[10] Both suppliers were exceedingly helpful and indicated that they would be happy to offer further complimentary assistance in greenhouse design and production. Should the project proceed, it is recommended that the proponents engage in conversations with potential suppliers to determine a good fit with regards to location, helpfulness, and expertise.

3.3.2 Enterprise Budget

Vegetable production greenhouses in Canada typically achieve average sales per square meter of $102 (O'Brien 2011, 14). The base case scenario outlined in Table 10 below achieves $123/m^2, but would need to achieve $683/m^2 to break-even. These numbers appear to be high as a result of using a small, non-commercial greenhouse (Chena) as a model. Industrial greenhouse facilities are capably of achieving financial viability through economies of scale and intensive production techniques.

Table 10: Modelled Base Case Financial Feasibility of Three Production Scenarios

	Haines Junction 100%	Whitehorse 25%	HJ 100%, WH 25%
Total Capital/Construction & Durable Goods Cost ($)	($167,625.70)	($1,839,359.82)	($2,006,985.50)
Annualized Capital/Construction & Durable Goods over 25 years[11] ($)	($10,022.28)	($109,974.65)	($119,996.92)
Yearly O&M Costs[12] ($)	($304,947.45)	($3,342,398.24)	($3,646,905.27)
Yearly Revenue ($)	$59,998.26	$658,361.99	$718,360.25
NPV over 25 years [13]($)	**($3,417,482.18)**	**($37,452,482.66)**	**($40,864,439.86)**
Average Current Production Revenue ($/m2)	$123.34	$123.34	$123.34
Required Average Yearly Production Revenue to Break-Even ($/m2)	$683.42	$682.71	$682.69

The base case modeled results indicate that a greenhouse is not economically feasible at any of the three production scenarios, and that the operating costs consistently exceed revenue. The model does not account for greater efficiency or cost reductions that might be associated with increased greenhouse size in the larger production scenarios. However, it is also unreasonable to assume that Haines Junction has the capacity to rapidly achieve industrial standards given their relative production inexperience, higher than normal costs, and lower demand scenarios.

3.3.3 Alternative Financial Scenarios

Similar greenhouse feasibility studies have concluded that reducing heating costs alone does not significantly improve the economic viability of greenhouses in unsatisfactory growing environments. This research has indicated that for the ventures to be successful, other financial variables must also be improved. This can include a

[11] At 6.2%, assuming 75% Debt/25% Equity Ratio
[12] Not including replacement costs
[13] At 6.2% annually

significant increase in greenhouse commodity prices, an increase in transportation costs for southern grown produce (XCG Consultants Ltd. 2008), or reduced fixed and variable operating costs, including electricity and labour (O'Brien 2011). Several variables were integrated into the base case model to create a revenue positive financial scenario.

3.3.3.1 Increased Revenue

Retailers typically add a 50% margin to their wholesale purchase cost when setting their retail price to consumers (i.e. they sell at twice their purchase cost) (Evans 2008). The base case scenario assumes that local greenhouse production in Haines Junction would be sold directly to consumers, rather than via retailers or wholesalers, allowing them to retain this margin. Research in the Yukon has indicated that consumers have shown a strong desire to buy locally. This has also translated into high premiums for a limited amount of Yukon production. This local premium may be as high as two to four times that of imported production (Serecon Management Consulting Inc. 2007).

Given that the base case modeled revenues were assumed to be equal to the current selling price of imported produce, actual revenues could be much higher if marketed properly. In the alternative financial scenario retail prices were doubled to estimate revenue generation potential.

3.3.3.2 Decreased Salary Costs

The average salary in Haines Junction is $42,500, representing an hourly wage of $20.43 (Yukon Community Profiles 2004). This is 32% less than the rate assumed in the base case scenarios. In the alternative financial scenario it is posited that only one full time labourer at the Haines Junction average wage is required per greenhouse unit. Any supplemental labour is provided through volunteers or subsidized positions. Conversations with Jeff Werner have indicated that an even lower hourly wage may be feasible (Werner 2012).

3.3.3.3 Reduced Electricity Use

Electricity rates were held constant for the alternative scenarios, however it was assumed that LED lighting could reduce the wattage requirement by 50% (Werner 2012). Capital costs for lighting were not changed because it was assumed that the additional costs associated with LEDs could be approximately offset by their much longer operating lifetimes (further investigation would be required to confirm). The values for additional kilowatts and kilowatt-hours from other services (e.g. ventilation, pumps, etc.) were also reduced by 50%, thus effectively cutting total electricity costs in half. Given the large expense of electricity, commercial viability will hinge on achieving extreme demand side management and identifying means of reducing this expenditure.

3.3.3.4 Reduced Material Costs

At $112.7/m^2$, the material costs included in the base case scenarios were quite high when compared to the 2009 Canadian greenhouse industry average ($16.2/m^2$)(O'Brien 2011) and a generic quote received from CropKing ($18.9/m^2$)(Cropking n.d.). CropKing quoted growing supplies at $9,899 for a 13.4 m x 39.0 m greenhouse (Cropking n.d.). In the alternative financial scenario, $9,899 was used as the yearly material costs for the 100% Haines Junction scenario, and this cost was standardized to Chena units and applied to the remaining production scenarios. The packaging and marketing costs were also eliminated in the alternative financial scenario. This was done under the assumption that the Haines Junction greenhouse would primarily market their produce through farm gate and farmers' market sales, each requiring minimal packaging costs.

It was found that the NPV became positive only when all of the above changes were applied to the base case scenarios simultaneously. The results of this alternative financial scenario are shown in Table 11 below. All scenarios result in a positive NPV, suggesting that a greenhouse operation in Haines Junction might be economically feasible under certain conditions. This alternative scenario also helps to highlight areas where available subsidies could be best targeted to increase the viability of the project. A more in-depth production plan would be required to further estimate economic feasibility.

Table 11: Budgets for Alternative Financial Scenarios

	Haines Junction 100%	Whitehorse 25%	HJ 100%, WH 25%
Total Capital/Construction & Durable Goods Cost ($)	($167,625.70)	($1,839,359.82)	($2,006,985.50)
Annualized Capital/Construction & Durable Goods over 25 years[14] ($)	($10,022.28)	($109,974.65)	($119,996.92)
Yearly O&M Costs[15] ($)	($79,485.26)	($883,065.32)	($963,446.89)
Yearly Revenue ($)	$119,996.52	$1,316,723.99	$1,436,720.50
NPV over 25 years[16] ($)	**$163,328.08**	**$1,655,822.73**	**$1,807,907.68**
Average Current Production Revenue ($/m2)	$246.69	$246.69	$246.69
Required Average Yearly Production Revenue to Break-Even ($/m2)	$219.92	$221.95	$221.94

While a typical commercial greenhouse will make most production and operational decisions based on increased yields and revenue generation, greenhouses in northern and remote communities can provide numerous non-financial benefits, particularly as a "community greenhouse". These benefits may not be revenue generating, but they do have value, and are outlined in greater detail in the Socioeconomic Impacts Section.

[14] At 6.2% discount rate, assuming 75% Debt/25% Equity Ratio
[15] Not including replacement costs
[16] At 6.2% discount rate annually (see cash flows for details)

3.4 Siting Considerations

Please see Appendix E for previously completed Preliminary Siting Considerations Report.

3.5 Environmental Impacts

Greenhouse cultivation is the most intensive form of crop production, with yield per cultivated area up to 10 times greater than that of field production (Vox 2010). By controlling the growing microclimate and optimizing conditions to specific cultivars, greenhouse production achieves higher yields, better quality and a lengthening of produce market availability. This intensity comes at a cost however; greenhouse production is typically associated with large quantities of energy, water and agrochemicals, and can produce significant amounts of plant waste.

Ideally, a greenhouse in Haines Junction would aspire to be a sustainable operation characterised by being resource conserving, socially supportive, commercially competitive and environmentally sound. Therefore a detailed production plan should rely on cultivation techniques, equipment management and constructive materials aimed to reduce agro-chemicals, energy and water consumption as well as waste generation.

It may also be important to consider the potential effect of noise and light pollution on neighbours depending on the siting of the facility. Further, in order to reduce the amounts of waste to be removed from the greenhouse, on-site composting is recommended (Bergstrand 2010). Of particular importance when evaluating the environmental performance of a proposed greenhouse is the potential energy consumption, GHG emissions, and water use.

3.5.1 GHG Emissions

Conventional greenhouse vegetable production is characterised by a large carbon footprint associated with heating, transportation, CO_2 enrichment and the production of fertilisers (Bergstrand 2010).

The proposed greenhouse in Haines Junction is expected to utilize grid-derived electricity. The Yukon energy grid is typified by very low proportions of diesel generation, and is mostly characterized by hydro derived power (Yukon Energy Corporation 2012). Therefore GHG emissions from electricity use are expected to be relatively low.

Greenhouses are conventionally heated using fossil fuels, however fluctuations in fossil fuel prices over the last 10 years have increased interest among growers in alternative heating systems. Biomass has been recognized as a sustainable renewable fuel alternative that can also reduce GHG emissions. Biomass combustion is understood to release, at most, the same amount of CO_2 that was absorbed via photosynthesis in the plant's life cycle. Therefore when harvested sustainably, the fuel source is considered carbon neutral (Basu 2010).

Should the proposed project in Haines Junction proceed utilizing the heat generated from the biomass CHP system, the carbon footprint associated with heating would be negligible. However, given that fossil fuel back-up systems are expected to be required for both heat and electricity, and with the further understanding that the 510 kW_{th} produced by the proposed system may be insufficient for commercial-scale production, further investigation would be required to determine the precise carbon footprint of such a system.

Another GHG emission consideration is the practice of enriching the greenhouse atmosphere with supplemental CO_2, a prevalent production technique used by commercial greenhouse growers to increase the yield of their plants. While the technique is not well understood in terms of its contribution to fugitive greenhouse gas emissions, Edwards has suggested that during a typical production season, a tomato greenhouse can generate 125.5 kg/m^2 (heating and dosing) of CO_2, of which only 17.4 kg/m^2 is utilized by the crop (2008).

There are several potential means to mitigate this source of emissions in the Haines Junction project. Preliminary research from McGill University has indicated that biomass, following gasification, could provide more CO_2 for greenhouse enrichment than propane or natural gas per unit of energy. Biomass gasification coupled with syngas combustion could be a promising renewable alternative to propane and natural gas for CO_2 enrichment in greenhouses (Dion 2011). Finally, Jeff Werner at the Chena Hot Springs Greenhouse in Alaska has indicated great success in the use of fungiculture, specifically growing edible oyster mushrooms, as a means of CO_2 enrichment. Mushrooms respirate, exchanging oxygen for CO_2 production, and could also represent an incremental revenue stream for the greenhouse.

Finally, the project's proximity to the retail market, either locally in Haines Junction, or in nearby Whitehorse, will sharply reduce transportation fuel consumption and associated emissions, while also improving product quality.

3.5.2 Energy

The typical annual energy usage of a greenhouse is 75% for heating, 15% for electricity and 10% for vehicles (Bartok, Jr. 2005). While heating makes up the largest expected energy use for a greenhouse, addressing electricity demand is also vital in terms of the environmental performance of the greenhouse as well as the economic viability of the facility.

Energy efficiency measures for greenhouses include obvious measures such as efficient design and material choices (see Appendix F), site selection (see Appendix E), and management practices. Given that electricity demand for the Haines Junction project would be in excess of that required from a typical greenhouse due to supplemental lighting in winter, addressing lighting technology selection is a critical energy and cost saving measure.

LED grow lights are increasingly understood to offer dramatic benefits over traditional high intensity discharge (HIDs) growing lights, including using 25% to 90% less power; lifespans that are 10 to 50 times longer than a typical HID grow light bulb; and payback periods of 6 months with heavy use (Mahr, et al. 2010).

As LEDs are a relatively new addition to the greenhouse industry, research is still required to understand their optimum role in production lighting schedules and design. Upon switching from high pressure sodium bulbs to LEDs, the Chena Greenhouse—which experiences similarly long, dark winters to Haines Junction—observed a reduction in lighting electrical demand of nearly 50%. They have also observed a relatively small 2% replacement rate for bulbs since switching (Werner 2012).

3.5.3 Water

In addition to higher yields and better quality production, the choice of adopting a hydroponic system has a number of observed environmental benefits since "the implementation of closed hydroponics can drastically reduce the use of water and fertilizers and the environmental pollution associated with over-irrigation, which is quite common in protected horticulture" (Vox 2010, 69).

3.5.4 Economic Benefit of Improved Environmental Performance

Innovative greenhouse designs that address the environmental impacts of intensive food production while simultaneously improving the quantity and quality of yields are an area of growing international interest. An instructive example of this is the Dutch greenhouse growers, who when faced with increasingly strict environmental regulations around the release of chemicals, developed a closed-loop production system. Many of these greenhouses now grow in water and rock wool, not in soil, lowering the risk of infestation, reducing the need for fertilizers and pesticides, and reducing and reusing water supplies. The tightly monitored closed-loop system also improved performance and yields, as variability in growing conditions were minimized. Thus, by addressing environmental and efficiency concerns, the Dutch dramatically lowered their environmental footprint but also lowered their costs, improved product quality, and enhanced their global competitiveness (Porter and van der Linde 1995). A logical conclusion to draw is that greenhouse technologies designed to function effectively and offer the durability required for northern Canadian production, could easily be exported to markets abroad. The Haines Junction project could provide a showcase of these optimised systems.

3.6 Socioeconomic Impacts

A greenhouse in Haines Junction is unlikely to be a financially lucrative undertaking as indicated in the financial analysis provided above. However, in determining the viability of such a facility, the community may also wish to consider the intrinsic value that such an operation could provide to Haines Junction and the surrounding area. A commercial greenhouse may serve a sense of community pride, increase health and overall community wellness, as well become an identifying mark that could boost tourism appeal (O'Brien 2011). CAFN Chief James Allen in describing the project, suggests that, "a large greenhouse project utilizing waste heat could supply our regional need for vegetables and decrease our reliance on the Alaska Highway for food transport. The production of renewable energy plus the added benefits will create numerous jobs for our people and help our region become more self-sufficient" (Yukon College 2012).

Indeed, research has shown a number of other community benefits to northern communities, ranging from cultural integration, to providing psychological value and light therapy for the management of Seasonal Affective Disorder (SAD)(Evans 2008).

3.6.1 Economic Development

The most obvious economic development opportunity associated with the proposed greenhouse would be the need for one to two full-time hires. There would also be a requirement for part-time staff particularly for harvesting and packaging. Depending on crops selected and production practices there may also be a need for value-added processing staff, for example creating local artisan salsa or pickled products.

Peripheral economic development might include the need to employ local trades for greenhouse construction and maintenance. From a community perspective, these jobs will add to the direct supply of income circulating within the community, and any effect to increase the circulation of capital in small economies will generate a significant multiplying effect (O'Brien 2011, 51).

3.6.2 Community Capacity Building

Community capacity building, is about developing the capacity of communities to respond to their own challenges and opportunities (Avard 2010). Local challenges around food security and unemployment could be addressed by the community, thus shaping the direction of their own social development. The Carmacks Greenhouse in the Yukon is an instructive example of this. Not only has the greenhouse become the largest tourist attraction in Carmacks after the Tage Cho Hudan Interpretive Centre, "it has also raised the town's community spirit" (Vision's North 2009). Initially centered on addressing food security concerns in the small northern community, the seasonal greenhouse, received initial funding from the Yukon government's Community Development Fund and Agriculture Canada, and has now been permanently adopted by the Little Salmon Carmacks First Nation. "All produce gets shared—part goes to community members in the Carmacks diabetes program, part goes to the First Nation for local events and part is sold farm gate style to tourists and locals. The greenhouse has also given extra vegetables to the local school lunch program" (Vision's North 2009).

A greenhouse operation would also provide beneficial community opportunities for skills development and education. Agriculture is an often-used teaching tool, and means to promote education and social reintegration. The greenhouse project at Yukon College in Whitehorse provides a local example of a platform for learning construction and greenhousing techniques as part of a skills for employment program. The project also showcases innovative solutions to northern greenhousing (Yukon College 2012).

3.6.3 Community Health

While the overall price and quality of produce available in Whitehorse is considered to be satisfactory (Ball 2012), food that is grown locally, ripened on the vine, and picked just hours before reaching market, is deemed to be more nutritious and appetizing. Presently there is no commercial food production occurring in Haines Junction (Riseborough 2012) and residents must travel up to two hours to Whitehorse to purchase perishables (Ball

2012). Improving community access to fresh and nutritious vegetable options is also likely to improve community health and wellbeing.

3.7 Project Risks

The most obvious project risk highlighted in the previous feasibility analysis is the projected high costs and low returns associated with operation. While the alternative financial scenario highlights potential areas to reduce costs, commercial viability is contingent on lowering costs, higher yields and produce sold at a premium.

Similar feasibility studies have concluded that cold-climate greenhouses require more investment than it is possible to recoup selling produce (XCG Consultants Ltd. 2008) (O'Brien 2011) (Paperny 2012). Pena, referring to the riskiness of greenhouse ventures has noted “rising fuel costs present a major problem to growers. The lack of marketing experience and the high degree of skill necessary to successfully grow above the break-even point under intensified greenhouse conditions are other problems. Due to these and other factors, many new greenhouse vegetable growers are not successful” (Pena 2005).

The *2008-2012 Multi-Year Development Plan for Yukon Agriculture and Agri-Food*, suggests that agriculture in the Yukon appears marginal from a financial perspective, with the overall operating expenses of $4.26 million being greater than the total farm receipts of $4.08 million (Serecon Management Consulting Inc. 2007). A number of studies have supported the notion that high costs and/or low productivity continue to be major challenges facing the industry. In particular, labour costs are viewed as significant constraints in the current market (Serecon Management Consulting Inc. 2007). As confirmed by the economic analysis offered in this report, the small scale of production and high costs are likely two of the more significant causes of marginal financial conditions. Some of the potential risks of the Haines Junction project are examined in greater detail below.

3.7.1 Financing

Greenhouses are considered notoriously risky ventures by lending institutions and often struggle to secure financing. If a loan is available, most lending institutions are reluctant to provide more than 50%-80% of the capital requirement. As a result, the use of equity or venture capital is the most common means of financing greenhouse operations (Pena 2005).

Operating greenhouses are scattered across Canada’s Far North—in Kuujjuaq, Inuvik, Iqaluit and Carmacks. They provide fresh food and experience these communities wouldn’t otherwise have. They also depend almost entirely on financial support from government, aboriginal leadership, or academic institutions (Paperny 2012). Correspondence with representatives from the Federal and Territorial governments have indicated a strong interest in supporting local food production in the North, and that an innovative greenhouse in Haines Junction would likely qualify for subsidy (Ball 2012) (Lenton 2012). This would help to mitigate the financial risk of the project, however no firm commitments have yet been made. The nature and amount of available funding will also depend on the project proponents. It has yet to be determined if the greenhouse would be privately, municipally, First Nations, or college owned and operated. Ownership models would need to be determined prior to investigating financing options.

3.7.2 Successful Crop Production

Not only have northern greenhouses been deemed financially risky ventures, they also require tremendous expertise and extensive training not yet abundantly available in the North. Data suggests that the primary contributor to greenhouse failure is a lack of effective management (O'Brien 2011). The greenhouse management team must be willing to devote the time to establish marketing channels and manage the many facets of the business, as well as understand the scientific and technical aspects of operation.

Mitigating this risk will involve building the capacity of those involved in the project. Greenhouse vegetable production methods are best learned by working with an experienced greenhouse operator to develop skills in managing nutrient levels, preventing insects and diseases, and controlling the greenhouse environment (Dey 2001).

3.7.3 Energy Costs

The feasibility analysis contained in this report has made a number of assumptions regarding energy amounts and costs. One assumption is that the ongoing cost of heating the facility will be negligible given that waste heat from a bioenergy power plant is employed. However, as the technical feasibility portion of this report has indicated, there may be insufficient heat from a 500 kW_e system to heat all but the smallest production scenario. Any increased production or greenhouse expansion would require an additional heating system, likely to be powered by fossil fuel, unless sufficient additional biomass is available. Further, the required back-up system will also likely be powered with fossil fuel. Whether the supplemental and back-up power is generated using fossil fuel or biomass, it will be subject to fuel price fluctuations and availability. The future price of electricity is another consideration that must be made if there is an expectation that utility rates will increase significantly over the life of the project.

Mitigating this risk will involve reducing energy costs through energy efficient designs and technologies, relying on renewable and reused heat, and optimising production to decrease heating and electricity requirements.

3.7.4 Marketing

There are a number of marketing risks associated with a potential greenhouse in Haines Junction. At the predicted scale of operation it is likely that farm gate sales, farmers' markets and other direct-to-consumer channels will be the most logistically feasible and economically lucrative paths to market. This will require a strong marketing strategy to ensure that consumers are inclined to seek out Haines Junction produce and pay a premium for it. Pena (2005) has determined that in the case of greenhouse tomatoes, the unique value proposition to consumers of local produce versus that of field grown imports relies on:

1. Freshness, since they are grown close to retail centers and picked ripe; and
2. Higher quality since they are grown in a highly controlled environment.

From a microeconomic perspective while these two advantages allow for demand at a higher price, it also encourages a high degree of vulnerability to product substitution. Meaning, the real key to marketing success is the availability, visual appearance and quality of competing substitutes. “Up to a point, the retail price of tomatoes produced in a greenhouse is not as critical on their demand as the price, visual appearance and quality of available field grown tomatoes” (Pena 2005). Haines Junction produce would need to be of very high quality in order to sell at the price required for commercial success.

Mitigating the market risks will involve communicating the benefits of locally grown produce, and a committed effort to access and secure local markets. There are farmers’ markets located at several centers including Whitehorse, Dawson City, and Carmacks and there is also an active restaurant and catering industry in the Yukon (Serecon Management Consulting Inc. 2007).

3.7.5 Risk Mitigation

There are a number of potential avenues worth pursuing to mitigate the potential risks of the Haines Junction Greenhouse Project. Detailed market and production planning would likely be the first step in better understanding the true financial risks of the project. Adopting a modular approach to the project would also help to minimize the project’s risk. This might entail beginning the project with a single greenhouse, perhaps with seasonal operation to start, allowing those involved to gradually gain experience with operations and production techniques.

Conversations with Dawn Charlie of the Carmack’s greenhouse identified another means to mitigate risk. Dawn suggests the idea of creating a local food production cooperative, composed of two to three community greenhouses in the area (of which Carmacks could be one) (Charlie 2012). Such a collaboration would allow for knowledge sharing and best practices, reduce costs through bulk purchasing, encourage shared staff and resources, and allow for potentially more cost effective mono-culture production.

Finally, given the expected levels of community and First Nations involvement in the project, it may be necessary to interpret the value of the project beyond strict economic feasibility. While a greenhouse operator traditionally thinks only of the costs of operation, a community can think of many of those costs as a source of revenue, money retention and multiplication, investment and increased quality of life and health (O'Brien 2011).

This raises the possibility of establishing the project as a social enterprise, rather than as a purely financial undertaking. Broadly defined, a social enterprise is a business directly involved in the production or selling of goods and services for the dual purpose of generating earned income and contributing to social and environmental aims (Enterprising Non Profits 2010).

3.8 Next Steps

Should the project proponents see value in moving forward with the proposed greenhouse project in Haines Junction, the following actions will be required:

- **Finalise Power Plant Project Details.** There is limited further work that can be done until the type, size, performance and siting of the power plant project has been confirmed. The greenhouse feasibility analysis outlined in this report has made a number of assumptions regarding these details, and should be confirmed before further work is conducted.
- **Engage a Greenhouse Manager.** This may only be a part-time role initially, but expertise is required to conduct the market analysis, business planning, and greenhouse design. Determining the availability of a skilled and interested manager from within the community or surrounding area prior to undertaking the build is critical to ensuring long-term success, and will also be an indicator of what future human resources would be available to the project.
- **Build a Consortium.** The funding sources available and the outside expertise required will depend strongly on who is involved in the project. Formalising project roles, building consensus, and establishing engagement with stakeholders is an important early step in the project.
- **Draft Business and Operations Plan.** The proposed greenhouse manager should manage this process, though enlisting outside expertise may be required depending on their skillset. This business plan will require a more precise examination of the Haines Junction and Whitehorse markets, disappearance rates (demand) for the area, financial viability of various crops and production plans, technical logistics, financing and other available funding sources. It will also be necessary to outline the ownership and role delegation for the project.
- **Site Visits and Workshops.** Both the Chena Greenhouse in Alaska, and the Carmacks Greenhouse in the Yukon have suggested that they would be happy to offer the Haines Junction project proponents a tour and introduction to their operations. In addition to site visits, having the greenhouse manager attend workshops and training will improve their understanding of greenhouse production and operations. Barry McIntosh of Harnois Greenhouses suggested the potential to utilize local education institutions to develop an intensive greenhouse grower's training program to develop the expertise of multiple members of the community and increase capacity around CEA agriculture (McIntosh 2012).
- **Pilot Program.** Nearly all of the experts spoken to recommend the development of a smaller pilot program before full-scale, commercial operations are attempted. The idea being that finding labour, learning production techniques, and developing markets, is a difficult undertaking for novices. It is possible to minimize some risk by starting small and escalating production as the community's confidence grows. This could start as simply as extended season lean-to or poly-tunnel greenhouse designs. A more advanced program might be to develop a smaller greenhouse for local use in Haines Junction, before

attempting to access the Whitehorse market. Such a greenhouse could utilize the waste heat from the power plant as the primary initial heating stage, but might also require a small boiler system as the second stage. Simple unit heaters could be relied upon for back-up heat. This configuration correlates with the Harnois quote outlined in Appendix H. “This initial local house could be used as a way to learn production techniques and then, if conditions allow, move forward with the larger phase. This larger phase could use traditional heat sources or look at the various biofuel systems available” should the community expand to a 2 MW_e system (McIntosh 2012).

4 Recommendations

There are risks and rewards associated with each of the heat-use options examined in this report. Although the community's decision will ultimately depend on the size and nature of the power plant selected, the authors of this report are able to make preliminary recommendations to the project proponents.

4.1.1 Recommended use of heat available from a 500 kW_e Power Plant

Given the strong likelihood of proceeding with the 500 kW_e power plant, a very simple heat network that distributes the heat from the power plant to the community school is the best investment for the community since it has the lowest capital cost and provides relatively good returns from the sale of heat. It would also reduce the CAC and GHG emissions from the school heating system. However, this recommendation is based on the assumptions made in the report regarding siting and proximity to the power plant. These assumptions would need to be confirmed once power plant siting has been finalized.

ORC technology for increased power production is deemed unviable in conjunction with the 500 kW_e power plant.

While this amount of heat is theoretically capable of heating all or most of a small community greenhouse, the base case scenarios are heavily revenue negative; achieving the alternative financial scenario for positive revenue will be difficult, particularly for novice growers. Financial viability would likely only be achievable with massive subsidization. Such a project would also involve a great deal of commitment to the science and business of greenhouse operations. If this option is pursued, an emphasis should be placed on the intrinsic value of the project with regards to food security, community pride, innovation and capacity building. This emphasis could also help the project to secure funding from government, academic groups, or other funding agencies.

4.1.2 Recommended use of heat available from a 2 MW_e Power Plant

If a 2 MW_e power plant is pursued, the reports author's preliminary recommendation is to consider the development of a DES serving the school, arena complex, convention centre and swimming pool complex. Given the typical risk aversion required of community energy projects, it would be wise to innovate incrementally and not take on excessive technical risk. While the ORC option does theoretically offer greater financial returns over the life of the project, a biomass gasification power plant is, in itself, an innovative technology. Integrating an ORC with this system would add to the overall complexity and uncertainty of the project, while risking an additional $3 million in capital and providing no local or regional environmental benefits, or additional employment. The ORC may provide good returns on investment, however it is a high-risk investment and it is recommended that the community does not pursue this option.

Furthermore, a DES serving the school, arena complex, convention centre and swimming pool complex would require a much lower capital investment than the ORC, provide very good returns, result in significant reductions in CAC and GHG emissions in the community, and create one part time job. It is recommended that the community invest in the four-building DES rather than the six-building DES since the heat sales from the two additional buildings are not high enough to offset the additional cost of the network infrastructure. However, if the community values CAC and GHG emissions reductions more than a high return on investment, this option is still viable, though not as lucrative as the smaller network.

The focus of the greenhouse feasibility analysis was the 500 kW_e power plant. However, while the 2 MW_e option does present the potential to keep the costs of heating multiple greenhouses low or nil, the same risks and challenges exist as presented at the smaller scale option. The high operational costs and the prospect of potentially low yields and revenues make the greenhouse option both risky and complex, more so when large-scale production is posited. This option is therefore not advisable.

5 Conclusion

Ultimately the community must evaluate the options available to them through the lens of their own priorities and criteria. It is impossible to eliminate project risk, but minimizing and mitigating risk involves a detailed understanding of the options and their implications. Given what is currently known about the project, the lowest risk, highest community benefit would appear to stem from the implementation of a very simple heat network that distributes heat from the 500 kW_e power plant to the community school in Haines Junction. Should this option be pursued it will also be important to plan for the potential expansion of the heating network in tandem with the power plant's proposed scaling.

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Appendix A Key Energy Pricing Assumptions

Table 12: Key Energy Pricing Assumptions

Commodity	Rate	Note/Reference
Electricity sold to the grid at Haines Junction	150 to 200 $/MWh	(DDC 2012)
Electricity purchased from the grid at Haines Junction	Demand charge of $12.31/kW 138.1 $/MWh for the first 2MWh 150 $/MWh for the next 5.4MWh 200 $/MWh for consumption above 7.4 MWh per month	(Yukon Electrical 2012)
Marginal cost of space heating with fuel oil	187 $/MWh	(Stantec Consulting Ltd. 2010) This correlates well with the cost of fuel oil at an annual fuel utilization efficiency of 65% and a heating value of 38.2 MJ/L

Appendix B DES & ORC Cost Estimates

Table 13: DES Capital Cost Components

Capital Cost Component	Estimated Cost	Comment
Distribution Line	$944/m	Based on twin (supply & return) pre-insulated 2.5" PEX pipe, with a remote multiplier of 1.7 (Stanners 2012), and an installed cost of $495/m (Gala 2012).
Fittings	$1000/building	Depending on size and type, fittings cost between $50 and $200 each.
Building Energy Transfer Station	$10,000/building	For in-building valves, flow meters, controls, etc.
DES Mechanical & Electrical Control Room	$50,000 for a single-building system $100,000 for a multiple building system	System wide heat exchangers, valves, controls, etc. Estimate only (Gala 2012).
Backup Boiler	$200,000	For multiple building DES, not required for single building (Morrison Hershfield 2012), (Gala 2012).

Table 14: DES Operating Cost Components

Operating Cost Component	Estimated Cost	Comment
Feedstock	$0/yr	Biomass costs are the responsibility of the power plant. Heat assumed to be supplied for free from the biomass power plant.
Labour	$29,200	Two hours of labour per day at $40/hour (Gala 2012)
Spare Parts	$10,000/yr	(Gala 2012)
Maintenance	$7500/yr	1 week of skilled labour
Electricity for Pumps	$18,565/yr	22kW operating 24/7 at Haines Junction general service rates (Gala 2012) (Yukon Electrical 2012).

Backup Boiler Fuel Consumption	Variable	Depends on network size and heat supply availability (Morrison Hershfield 2012)

Table 15: ORC Capital Cost Components

Capital Cost Component	Estimated Cost	Comment
ORC	GE Clean Cycle: $956,000 each P&W T10 HR: $3,060,000 each	Capital costs multiplied by a factor of 1.7 for remote location (Stanners 2012).
ORC Installation	GE Clean Cycle: $100,000 each P&W T10 HR: $190,000	
Auxiliary Heat Exchange Equipment	GE Clean Cycle: $30,000 each P&W T10 HR: $200,000	

Table 16: ORC Operating Cost Components

Operating Cost Component	Estimated Cost	Comment
Supervision/operation labour	$7000/unit per year	Based on ½ hour of operator time per day, seven days a week, except during annual maintenance, at $40/hour
Annual Servicing	GE Clean Cycle: $13,000 per unit, per year P&W T10 HR: $89,000 per year	Based on phone conversation with GE representative and standard service offering from P&W

Appendix C Calculations - District Energy System Evaluation

Building	Annual Heat Consumption (MWh/yr)	Peak Heat Demand (kW)	Heated Area (m2)	Energy Density	Note
School	463	360	3148	147	
Convention Centre	230	184	1241	185	
Arena (Counts as 1 Building)					
Arena Lower Floor	99	31	464	213	
Zamboni Room	39	8.1	nd	nd	
Arena Chiller Plant	31	6.6	nd	nd	
Fire Hall	106	43.8	435	244	
Main Pump House 2	14.5	10.7	129	112	
Public Works Maintenance Shop	81	84.7	459	176	
Swimming Pool	101	25.6	920	110	
Community Hall	98	122	nd	nd	
Curling Rink	40.4	31.1	nd	nd	
Sewage Lift Station	45.6	5.3	46.8	974	
Pump House 1	51	7.6	48	1063	
Cultural Centre	200	154	2936	68	New Building & Heating System
Health Centre	64	390	390	164	New Building & Heating System
Visitor Centre	nd	nd	nd	nd	
Gov't Admin Building	306	236	1275	240	New Building & Heating System

Scenario	Annual Consumption (MWh/yr)	Peak Heat Demand (MW)	Transmission Line (m)	Distribution Line (m)	Total Line (m)	Comments
Scenario 1 (MH Study) (7 Buildings)	1706	1.2	1170	578	1748	This scenario is unlikely because it includes buildings with new heating systems that will be unlikely to change
Scenario 2 (MH Study) (6 Buildings)	1515	1.1	800	300	1100	
Scenario 3 (MH Study) (4 Buildings)	1102	0.8	0	250	250	
Scenario 4 & 5 (GET Study) (School Only)	463	360	See CPC sheet	See CPC sheet	See CPC sheet	
Scenario 6 & 7 (GET Study) (School + Convention Ctr)	693	544	See CPC sheet	See CPC sheet	See CPC sheet	The full heating load of both buildings would not be met by the heat from the CPC system during peak heating periods, use of a backup/peaking system will be necessary

Morrison Hershfield Study Scenarios	Scenario 1: 1.2 MW 7 Buildings	Scenario 2: 1.1 MW 6 Buildings	Scenario 3: 0.8 MW 4 Buildings	Notes
Loads and Energy				
CHP System Availability	95%	95%	95%	**This is an assumption, should be confirmed with Nexterra**
Available Heat (kW)	3000	3000	3000	Confirmed with Phil Beaty, P.Eng - Nexterra
Displaced Heating Energy (kWh)	1714482	1514613	1102043	Same as M&H
Contract Load (kW)	1202	1048	769	Same as M&H
Diversified Load (kW)	1188	1023	743	Same as M&H
Distribution Piping				
Supply Line (Trench Meters)	150	150	150	**The distance between the power plant and the distribution network**
Distribution Line (Trench Meters)	1748	1100	250	**Based on MH study, added 150 m for transmission from plant, MH study only includes distances between buildings**
Distribution Line ($/m, installed)	944	944	944	40$/ft x 2 (supply & return for materials) X 1.7 for remote location + 150$/ft for installation: based on discussion with Eugene Gala of E-Mission Free and their system costs. Installation cost has been increased by 375% for remote location. Assumed all lines are the same cost - same as MH study
Fitings	7000	6000	4000	
Distribution Line Total Cost	1798332	1185750	381520	
DPS Subtotal	$1,798,332	$1,185,750	$381,520	
Energy Transfer Stations				
# Buildings Connected	7	6	4	Same as M&H
Average ETS Cost	10,000	10,000	10,000	$60,000 per building is way too high for the small buildings this study is looking at
ETS Subtotal	$70,000	$60,000	$40,000	
Plant				
Mechanical Room	$60,000	$60,000	$60,000	Based on discussion with Eugene Gala of E-Mission Free
Electrical	$40,000	$40,000	$40,000	Based on discussion with Eugene Gala of E-Mission Free
Backup Boiler	$200,000	$200,000	$200,000	Same as M&H
Plant Subtotal	$300,000	$300,000	$300,000	
Total Capital Cost	**$2,168,332**	**$1,545,750**	**$721,520**	
Lifetime	15	15	15	
Interest Rate	6.20%	6.20%	6.20%	
Annualized Capital Cost	($226,184)	($161,241)	($75,264)	This assumes the whole thing is financed, no equity or funding included
Operating Cost				
Feedstock	0	0	0	Paid for by the power plant operation
Labour	29200	29200	29200	2 hours per day at $40/hr
Spares	10,000	10,000	10,000	Based on discussion with Eugene Gala of E-Mission Free, their maximum spares & repair budget is $10,000
Maintenance	7500	7500	7500	Estimate - 1 Week of Labour
Electricity	18,565	18,565	18,565	22 kW of pumps operating 24/7 at Haines Junction general service rates
Backup boiler fuel cost (5% of the annual consumption)	9913	8757	6372	Same as M&H
Total Annual Operating Cost	($75,178)	($74,022)	($71,637)	
Heat Rate ($/MWh)	185			Same as M&H - See calculation on 0.5MW page for comparison
Annual Revenue from Heat Sales	$317,179	$280,203	$203,878	Same as M&H
Annual Cash Flow	$15,817	$44,940	$56,977	

Annual Cash Flow Year	Scenario 1: 1.2 MW 7 Buildings	Scenario 2: 1.1 MW 6 Buildings	Scenario 3: 0.8 MW 4 Buildings
0	-$542,083	-$386,438	-$180,380
1	$72,363	$85,251	$75,793
2	$72,363	$85,251	$75,793
3	$72,363	$85,251	$75,793
4	$72,363	$85,251	$75,793
5	$72,363	$85,251	$75,793
6	$72,363	$85,251	$75,793
7	$72,363	$85,251	$75,793
8	$72,363	$85,251	$75,793
9	$72,363	$85,251	$75,793
10	$72,363	$85,251	$75,793
11	$72,363	$85,251	$75,793
12	$72,363	$85,251	$75,793
13	$72,363	$85,251	$75,793
14	$72,363	$85,251	$75,793
15	$72,363	$85,251	$75,793
IRR	**10%**	**21%**	**42%**
NPV	**$142,779**	**$405,673**	**$514,330**

	Scenario 1: 1.2 MW 7 Buildings	Scenario 2: 1.1 MW 6 Buildings	Scenario 3: 0.8 MW 4 Buildings
Equity	25%	25%	25%
Funding	0	0	0
Investment	$542,083	$386,438	$180,380
Loan	$1,626,249	$1,159,313	$541,140
Loan Period	15	15	15
Rate	6%	6%	6%
Payments	($169,638)	($120,931)	($56,448)

CLEANTECH COMMUNITY GATEWAY

Morrison Hershfield Study Scenarios	Scenario 4: 360 kW School Only (Backup Boiler used 25% of the time)	Scenario 5: 360 kW School Only (Backup boiler not in use, heat source 3/4 ths at 95% availability)	Scenario 6: 544 kW School + Convention Ctr (Backup Boiler used 25% of the time)	Scenario 7: 544 kW School + Convention Ctr (Backup boiler not in use, heat source 3/4ths at 95% availabiltiy)	Notes
Loads and Energy					
CHP System Availability	75%	95%	75%	95%	Depends on whether units can be serviced in rotation or if the whole system must be shut down for 20% of the time
Available Heat	510	408	510	408	
Losses (%)	10%	10%	10%	10%	Losses are assumed to be low because the extent of the network is limited
Displaced Heating Energy (kWh)	463000	463000	605500	478000	Same as MH study for the school, when the CHP system isn't available the backup boiler supplies heat. It is assumed that the operating cost and revenue associated with this are taken over by the operator of the DES/CHP system
Contract Load (kW)					I don't know what this means
Diversified Load (kW)	396	396	598	598	Same as MH study for the school and convention centre plus 10% losses
Distribution Piping					
Distribution Line (Trench Meters)	324	399	423	322	**USED GOAL SEEK TO DETERMINE IRR = 15% for SCENARIOS 4&5**
Distribution Line ($/m, installed)	944	944	944	943.8	40$/ft x 2 (supply & return for materials) X 1.7 for remote location + 150$/ft for installation: based on discussion with Eugene Gala of E-Mission Free and their system costs. Installation cost has been increased by 375% for remote location. Assumed all lines are the same cost - same as MH study
Fittings	1000	1000	2000	2000	
Distribution Line Total Cost	306791	377576	401227	305904	
DPS Subtotal	$306,791	$377,576	$401,227	$305,904	
Energy Transfer Stations					
# Buildings Connected	1	1	2	2	Just the school
Average ETS Cost	10,000	10,000	10,000	10,000	$60,000 per building is way too high for the small buildings this study is looking at
ETS Subtotal	$10,000	$10,000	$20,000	$20,000	
Plant					
Mechanical Room	$30,000	$30,000	$60,000	$60,000	Based on discussion with Eugene Gala of E-Mission Free - halved for very simple system, full system for two buildings, this could be an overestimate
Electrical	$20,000	$20,000	$40,000	$40,000	Based on discussion with Eugene Gala of E-Mission Free - halved for very simple system, full system for two buildings, this could be an overestimate
Backup Boiler	$0	$0	$0	$0	Rely on exising boilers; they would have to recirculate water in the heat supply pipe to keep it from freezing when the CHP system is down, but it doesn't have to be a big heat load
Plant Subtotal	$50,000	$50,000	$100,000	$100,000	
Total Capital Cost	**$366,791**	**$437,576**	**$521,227**	**$425,904**	Sum of plant costs and pipe costs
Lifetime	15	15	15	15	Likely more than this, but this is conservative
Interest Rate	6.20%	6.20%	6.20%	6.20%	Arbitrary
Annualized Capital Cost	($38,261)	($45,645)	($54,371)	($44,427)	
Operating Cost					
Feedstock	0	0	1	2	Covered by the power plant
Labour	14600	14600	14600	14600	1 hours per day at $40/hr
Spares	2,000	2,000	2,001	2,002	Based on discussion with Eugene Gala of E-Mission Free, their maximum spares & repair budget is $10,000
Maintenance	3750	3750	3750	3750	Estimate - 1/2 Week of Labour
Electricity	9,283	9,283	12,377	12,377	11 kW of pumps operating 24/7 at Haines Junction general service rates
Backup boiler fuel costs	11243.4	2667	15783.6	3758	scaled from M&H Study
Total Annual Operating Cost	($40,876)	($32,300)	($48,512)	($36,489)	
Heat Rate ($/MWh)	185	185	186	187	Same as M&H - See calculation below for marginal cost of heating with oil in Haines Junciton
Annual Revenue from Heat Sales	$85,655	$85,655	$112,018	$88,430	
Annual Cash Flow	**$6,518**	**$7,711**	**$9,135**	**$7,514**	Sum of annual capital cost, operating cost and revenue

1200 $/m for DPS is very high. Pre-insulated PEX pipe can be installed for far less because it can be rolled out and cut on site.
$60,000 per building is very high, the whole mechanical plant for a DHN is $60,000 for a 2MWth system - Eugene Gala.
The Green Heat Initiative Report for Kwadacha estimates $5000 per building ETS for commercial buildings

Cost of heating with oil in Haines Junction		Note
Fuel cost ($/L)	1.314	http://www.energy.gov.yk.ca/fuel.html
AFUE (%)	65%	From MH
Discount for wholesale (%)	2%	from Whitehorse study
Heating value of oil (MJ/L)	38.2	http://www.cmhc-schl.gc.ca/en/co/renoho/refash/refash_018.cfm
Conversion from MJ to MWh	0.0002777	MWh/MJ
Marginal cost of heating with fuel oil in H	187	$/MWh heat delivered

Annual Cash Flow Year	Scenario 4: 360 kW School Only (Backup Boiler used 25% of the time)	Scenario 5: 360 kW School Only (Backup boiler not in use, heat source 4/5ths at 100%)	Scenario 6: 544 kW School + Convention Ctr (Backup Boiler used 25% of the time)	Scenario 7: 544 kW School + Convention Ctr (Backup boiler not in use, heat source 4/5ths at 95% availabiltiy)
0	-$91,698	-$109,394	-$130,307	-$106,476
1	$16,083	$19,122	$22,727	$18,621
3	$16,083	$19,122	$22,727	$18,621
4	$16,083	$19,122	$22,727	$18,621
5	$16,083	$19,122	$22,727	$18,621
6	$16,083	$19,122	$22,727	$18,621
7	$16,083	$19,122	$22,727	$18,621
8	$16,083	$19,122	$22,727	$18,621
9	$16,083	$19,122	$22,727	$18,621
10	$16,083	$19,122	$22,727	$18,621
11	$16,083	$19,122	$22,727	$18,621
12	$16,083	$19,122	$22,727	$18,621
13	$16,083	$19,122	$22,727	$18,621
14	$16,083	$19,122	$22,727	$18,621
15	$16,083	$19,122	$22,727	$18,621
IRR	**15%**	**15%**	**15%**	**15%**
NPV	**$52,696**	**$62,301**	**$73,777**	**$60,718**

	Scenario 4: 360 kW School Only (Backup Boiler used 25% of the time)	Scenario 5: 360 kW School Only (Backup boiler not in use, heat source 3/4ths at 100%)	Scenario 6: 544 kW School + Convention Ctr (Backup Boiler used 25% of the time)	Scenario 7: 544 kW School + Convention Ctr (Backup boiler not in use, heat source 3/4ths at 95% availabiltiy)
Equity	25%	25%	25%	25%
Capital Funding	0	0	0	0
Investment	$91,698	$109,394	$130,307	$106,476
Loan	$275,093	$328,182	$390,921	$319,428
Loan Period	15.00	15.00	15.00	15.00
Rate	6%	6%	6%	6%
Payments	($28,696)	($34,233)	($40,778)	($33,320)

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Appendix D Organic Rankine Cycle Evaluation

Key Assumptions			Notes
Yukon Energy EPA price for electricity produced (SOP Price)	200	$/MWh	From conference call with Stantec - November 7, 2012 **This is the single most significant determinant of ORC viability - should be confirmed with Yukon Electric/Yukon Energy**
Interest on borrowed capital	6%		Arbitrary
Discount rate	6%		Arbitrary
Loan Period	15	yrs	Arbitrary
Equity	25%		Arbitrary
Feedstock cost	0	$/t	all costs are to the main power plant
Plant lifetime	15	years	Adam Maggio, General Electric
Availability	95%		**Based on 3 week shutdown for maintenance, full time operation otherwise. SHOULD BE CONFIRMED WITH NEXTERRA**
Remote Location Cost Multiplier	1.7		Based on BCBN #

System	Inlet Temp (oC)	Outlet Temp (oC)	Heat Delivery Fluid	Flow (L/S)	Required Glycol % at 1atm	Cp of Fluid	Cp ratio	Qin, th (kW)	Qout, e, gross (kW)	Qout, e, net (kW)	net electric efficiency	Capital Cost	Installation Cost	Total Installed Cost	Maintenance Cost/Unit	Operating Cost	Heat Recovery/Transfer Efficiency
GE Clean Cycle	143	127	Glycol & Water	15	80%	3.39	1.23	1003	125	100	10.0%	$956,250	$130,000	$1,086,250	$13,263	$6,935	80%
P&W T10 HR	290	145	Thermal Oil	21	n/a	1.81	n/a	5540	898	865	15.6%	$3,060,000	$390,000	$3,450,000	$88,852	$6,935	80%

IMPORTANT NOTES

GE System cost is based on a budgetary estimate of 4500 $/kW from a turnkey supplier - Adam Maggio, General Electric
GE Opex is based on an estimate of 0.75 cents/kwh - Adam Maggio, General Electric
GE Installation cost is an estimate of the additional heat exchange equipment required to recover heat from the gasification power system

P&W System cost is based on a discussion with P&W and a quote from February 2012 - Kirsten Cofrancesco, Pratt & Whitney
P&W Operating cost is based on service offerings from Pratt & Whitney, Standard offering, averaged for lifetime
P&W Installation cost is $190,000 for installation + $200,000 for additional thermal oil heat recovery system from the gasification power system

The biggest technical challenge, and biggest unknown at this point is how the heat will be recovered from the gasification power plant and what temperature it can be recovered at?
It is not at all clear how much heat will actually be available at the required temperature for these systems
The engine water jacket temperature is only about 80oC, therefore additional heat will be needed from the gas cooling & cleaning stage
A thermal oil system that recovers heat from the gasification plant at the required temperature is a technical challenge and could requrie significant engineering. The feasibilty is not known at this point.

Available Heat		3000 kW	
ORC System Quantity	Description	Heat Input Required for Full Ouput (kW)	Expected Power Output (kW)
3	General Electric Clean Cycle	3009.6	239
1	Pratt & Whitney T10HR	5540	375

3 x GE Pure Cycle					
Electricity Price	200	$/MWh			
Capex	$3,258,750	$ (US, 2011)			
Discount rate	6%				
Equity	$814,688				
Loan	$2,444,063				
Payments on Loan	($254,946)				
Year	Sales (MW)	Operating Cost	Loan Payments	Revenue	Cash Flow
0	0	0	0	0	-$814,688
1	1991	60595	($254,946)	398182	82641
2	1991	60595	($254,946)	398182	82641
3	1991	60595	($254,946)	398182	82641
4	1991	60595	($254,946)	398182	82641
5	1991	60595	($254,946)	398182	82641
6	1991	60595	($254,946)	398182	82641
7	1991	60595	($254,946)	398182	82641
8	1991	60595	($254,946)	398182	82641
9	1991	60595	($254,946)	398182	82641
10	1991	60595	($254,946)	398182	82641
11	1991	60595	($254,946)	398182	82641
12	1991	60595	($254,946)	398182	82641
13	1991	60595	($254,946)	398182	82641
14	1991	60595	($254,946)	398182	82641
15	1991	60595	($254,946)	398182	82641
IRR	6%				
NPV	($21,133)				

1 x PW T10HR					
Electricity Price	200	$/MWh			
Capex	$3,450,000	$ (US, 2011)			
Discount rate	6%				
Equity	$862,500				
Loan	$2,587,500				
Payments on Loan	($269,909)				
Year	**Sales (MW)**	**Operating Cost**	**Loan Payments**	**Revenue**	**Cash Flow**
0	0	0	0	0	-$862,500
1	3118	$95,787	($269,909)	623699	258004
2	3118	$95,787	($269,909)	623699	258004
3	3118	$95,787	($269,909)	623699	258004
4	3118	$95,787	($269,909)	623699	258004
5	3118	$95,787	($269,909)	623699	258004
6	3118	$95,787	($269,909)	623699	258004
7	3118	$95,787	($269,909)	623699	258004
8	3118	$95,787	($269,909)	623699	258004
9	3118	$95,787	($269,909)	623699	258004
10	3118	$95,787	($269,909)	623699	258004
11	3118	$95,787	($269,909)	623699	258004
12	3118	$95,787	($269,909)	623699	258004
13	3118	$95,787	($269,909)	623699	258004
14	3118	$95,787	($269,909)	623699	258004
15	3118	$95,787	($269,909)	623699	258004
IRR	29%				
NPV	$1,516,829				

Appendix E Siting Considerations Report

Please see following pages.

CLEANTECH COMMUNITY GATEWAY

Haines Junction Bioenergy Project – Evaluation of Waste Heat Potential: Preliminary Siting Considerations

Release Date: November 17, 2012

Submitted By:
Clean Technology Community Gateway
4250 Wesbrook Mall
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Submitted To:
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409 Black St., Whitehorse,
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Executive Summary

The following report outlines the preliminary siting considerations that are required for utilising the thermal energy production from a potential bioenergy plant in Haines Junction, Yukon Territories. Potential uses considered include a community District Energy System (DES), increased electrical power production with Organic Rankine Cycle (ORC) technology, or localized food production through Controlled Environment Agriculture (CEA) Greenhouses.

Siting considerations for the DES are given based on both proposed scenarios of a 500 kW, and a 2 MW power plant; while based on feasibility, the ORC portion considers only the 2 MW option. In both cases siting considerations are few, and are based primarily on proximity to heat source, avoiding disruption to the community, and in the case of DES, proximity to the heat customer(s).

Many of the siting considerations for food production will be broadly applicable, regardless of project scale, however where estimates are made, they assume a 500 kW bioenergy plant. Siting considerations outlined include:

- Site Selection
- Natural Slope and Drainage of the Land
- Greenhouse Orientation
- Soil Quality
- Greenhouse Size and Shape
- Utility Availability
- Water Quality and Availability
- Greenhouse Accessibility
- Labour Availability
- Land Costs
- Zoning Regulations

This report constitutes the first deliverable of a more comprehensive report examining the preliminary feasibility of developing a beneficial heat-use project in tandem with the proposed bioenergy plant.

Acronyms

CAFN: Champagne and Aishihik First Nations

CEA: Controlled Environment Agriculture

CPC: Community Power Corporation

DDC: Dakwakada Development Corporation

DES: District Energy System

EC: Electrical Conductivity

FEED: Front-End Engineering and Design

GE: General Electric

MMBTU: Million British Thermal Units

NPV: Net Present Value

ORC: Organic Rankine Cycle

P&W: Pratt & Whitney

SAR: Sodium Absorption Ratio

Disclaimer

This document is an independent report prepared for the Dakwakada Development Corporation. The views and opinions expressed in this report are those of the author(s). The information, statements, statistics and commentary (together the ‘information’) contained in this report have been prepared by the Clean Technology Community Gateway (CTCG) from publicly available material. CTCG does not express an opinion as to the accuracy or completeness of the information provided, the assumptions made by the parties that provided the information, or any conclusions reached by those parties.

CTCG has based this report on information received or obtained, on the basis that such information is accurate and, where it is represented to CTCG as such, complete.

CLEANTECH COMMUNITY GATEWAY

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1 Introduction

The Dakwakada Development Corporation (DDC), the Champagne and Aishihik First Nations (CAFN), Yukon Energy Corporation, Cold Climate Innovation of the Yukon Research Centre, and the Village of Haines Junction are investigating the potential for a biomass power plant in the Haines Junction community. The plant is expected to provide renewable electricity for the territory and has the potential to produce a viable community heat source, and create local economic opportunities. To this end, the community is interested in investigating the use of the power plant's thermal energy production to create benefit for the community.

The Clean Technology Community Gateway (CTCG) is a neutral, not-for-profit organization comprised of public and private sector partners who are collaborating to develop and deploy clean energy solutions within remote and rural communities. Their expertise lies in technical evaluations of various clean technologies, grounded in sound economic and socially beneficial decision-making.

The primary objective of this project is to evaluate the technical and economic feasibility of utilizing the waste heat from a 500 kW_e bioenergy gasification plant in the Haines Junction area. The options being evaluated include a community District Energy System (DES), increased electrical power production with Organic Rankine Cycle (ORC) technology, or localized food production through Controlled Environment Agriculture (CEA) Greenhouses.

The complete project will assess previously conducted appraisals (e.g. the Morrison Hershfield desktop district energy assessment, and the QUEST Engineering geothermal district energy study), review publically available literature and product specifications, and engage in conversations with industry experts and suppliers. Each of the potentially viable heat use options will be evaluated against a set of criteria including, the viability of the business case, risks, siting requirements, environmental impacts, and socioeconomic effects. Based on these evaluation criteria, preliminary recommendations will be made as to the viability of the various options presented.

2 Siting Considerations

Given that the Front-End Engineering and Design (FEED) study for the power plant is being conducted by Stantec concurrently to this waste heat study, it was deemed necessary to provide preliminary siting considerations for potential thermal energy projects in advance of the final report. The following report outlines the preliminary siting considerations for a District Energy System (DES), increased electrical power production with Organic Rankine Cycle (ORC) technology, and localized food production through Controlled Environment Agriculture (CEA) Greenhouses.

The list of considerations herein is based on the results of preliminary calculations carried out in order to assess the technical and economic feasibility of different uses of the thermal energy from the power plant. It is important to note that these calculations and assumptions are still in their preliminary form and are based on the power plant specifications provided by DDC in relation to the FEED study. At this time the power plant technology option being given primary consideration is a 500 kW_e system (a set of five 100 kW_e units) from Community Power Corporation. Secondary to this consideration, is an examination of a 2 MW_e system from

Nexterra. The choice of power system necessarily defines the range of possible uses for the thermal energy. In the case of ORC and DES both system options are given consideration. However, for the food production assessment, only the 500 kW_e plant is considered.

2.1 Biomass Power Plant Siting Considerations

The siting requirements for the power plant are beyond the scope of this report and are being addressed by the Front-End Engineering and Design Study, however it is important to note that any of the siting considerations for a potential heat project would need to be resolved with the intrinsic requirements of power production. Some general siting considerations for the power plant are outlined in the list below, but are dependent on which power plant is selected. Stantec will provide final confirmation of the power plant's specific siting requirements, but they are likely to include the following:

- Sufficient space for the power plant footprint
- Sufficient space for short-term feedstock storage (one-week minimum on-site supply is recommended)
- Access for feedstock delivery
- Increased traffic for feedstock delivery
- Noise considerations
- Air emissions requirements
- Water supply for plant cooling
- Municipal zoning
- Land lease or purchase costs

2.2 Heat Use Siting Considerations for a 500 kW_e System

The 500 kW_e CPC system produces 320 kW_{th} of heat in the form of hot air, and a further 500 kW_{th} of heat in the form of 90^{o}C hot water (Renalli 2012). Given that the CPC power system has a strict 15% moisture content requirement of its feedstock, it is expected that the hot air generated by the gasification system will be required to dry the wood waste being used as fuel, therefore primary consideration was given to the utilisation of the 500kW thermal output in the form of 90^{o}C hot water from the engine exhaust and water jacket.

2.2.1 Additional Power Generation with an Organic Rankine Cycle Turbine

The low quality and quantity of heat produced by this system is not sufficient to supply an ORC generator. Additional power generation is therefore not technically feasible with a 500 kW_e system.

2.2.2 District Energy System

The quantity of heat from the 500 kW_e system is not sufficient to supply a multiple-building district energy system (DES). However preliminary calculations show that it could meet the full heating requirements of one large heat load. The plant should be located as close as possible to the largest potential heat customer, likely the school.

Based on the peak heat demand and annual thermal energy consumption of the school (Morrison Hershfield 2012) (Lessoway Moir Partners and Quest Engineering Group 2004), it is technically and economically feasible that hot water piped from the power plant to the school could displace the school's full heating load for the entire year.[1]

With respect to use of the thermal energy from the 500 kW_e power plant, optimal siting should take into consideration:

- Close proximity to the school - no more than 350 m
- Minimal disruption of traffic, or interference with existing infrastructure during heat pipe installation

2.3 Heat Use Siting Considerations for the 2 MW_e System

The thermal energy produced by the Nexterra 2 MW_e system is expected to be 3 MW_{th} (Stantec Consulting Ltd., 2012).

2.3.1 Additional Power Generation with an Organic Rankine Cycle Turbine

The heat available is theoretically suitable for powering an ORC turbine instead of supplying a DES or a greenhouse, and this option appears economically viable, although detailed analysis of the technical feasibility of this option remains to be carried out.

Two options for ORC were considered; a set of three General Electric (GE) Clean Cycle units producing approximately 240 kW_e net, and one Pratt & Whitney (P&W) Turboden T10HR, operating at below its specified heat rate, producing approximately 375 kW_e net. The primary technical challenge of implementing either of these options is providing the supply of heat to the ORC via a fluid at atmospheric pressure, using either glycol (in the case of the GE system) or thermal oil (in the case of the P&W system).

There are few siting considerations that must be accounted for, the primary being space for the ORC unit inside the main power plant. Required space estimates for the unit are approximate until more is known about the ancillary heat exchange equipment, pumps and other related materials, but would likely require a space of about 12 m x 22 m inside the structure housing the Nexterra plant.

2.3.2 District Energy System

The heat produced by the Nexterra system is sufficient for heating the seven DES candidate buildings identified in the 2012 Morrison Hershfield DES study for Haines Junction. Preliminary financial analysis based on the estimated capital and operating costs of such systems (Gala 2012), and the estimated revenue from heat sales to the DES customers indicates that a DES is potentially technically and economically feasible. Optimal siting for a DES should take into consideration:

- Close proximity to the largest heat customers on the DES. The DES has the lowest capital risk and highest Net Present Value (NPV) if it includes only the school, convention centre, arena complex and the pool complex. The site should be selected

[1] It is recommended that the heating requirements of the school be reviewed before any final decision is made, to confirm that heating loads have not substantively changed.

to minimize the total distribution pipe length, and the pipe network should be no more than 850 m total for the customers listed above.
- Minimal disruption of traffic, or interference with existing infrastructure during heat DES installation.

2.4 Heat Use Siting Considerations for Year-Round Food Production

Because of Haines Junction's location north of the 60th parallel, winters are long and dark, with as few as four hours of light each day, and summers are generally warm, with long hours of daylight up to 19 hours. The mean temperature is 11°C in June and -21°C in January. Frost may occur at any time of year, and by the end of October there is ice on many of the lakes (Yukon Community Profiles, 2004). Given these climatic realities, year-round agricultural production, or even seasonally, will be a challenge at a commercial scale.

There is astonishing variation in the types and levels of technical complexity among greenhouse designs. In regions of the world considered otherwise inhospitable growing environments, advances in Controlled Environment Agriculture (CEA) have presented themselves as viable options for creating a local food supply. CEA attempts to account for hostile outside growing conditions through integrated techniques and technologies to control all aspects of the internal growing environment: lighting, temperature, nutrients, hydroponics and air control. According to Obrien, these variables create the potential to develop a commercial agriculture business anywhere that the input cost is less than the output potential (OBrien, 2011). Therefore the technical and economic feasibility of a greenhouse in Haines Junction is a function of the degree to which the temperature, lighting, CO_2 and nutrients can be controlled at a lower cost than that earned in revenue from yields.

Unlike thermal energy use for ORC and DES, greenhouses present almost limitless variables that must be considered and accounted for with regards to ideal location and design of a greenhouse. Siting considerations will be further impacted by design features of the structure, including the building materials selected, the technology employed, crop selection, and target markets. Prior to developing a greenhouse project, a detailed business and production management plan will be required to address these variables. The following broadly outlines the initial features that must be considered in selecting a site for a potential greenhouse in Haines Junction.

2.4.1 Site Selection

A site survey that includes a topographical map is an important task during preliminary siting evaluations. It will help to clarify local runoff patterns, quantities of required back fill, road access, and potential zoning regulations. The elevations shown on the map should have a minimum of 1-foot contour intervals (Both, 2005). The site plan should accurately show the property and indicate current buildings, roads, and locations of all utilities. Locations of streams, and ponds may be required as part of the permitting process.

2.4.2 Natural Slope and Drainage of the Land

Grading land can be very expensive and greenhouse structures are typically located on a slope of five percent or less. It is also important to be aware of local land features; avoid siting on flood plains, frost pockets, or on hilltops where heating demand will be higher due to increased wind factors.

2.4.3 Soil Quality

Greenhouse vegetables can be grown in soil or hydroponically. Hydroponic production refers to the use of growing media other than soil. Typically it is not economical to produce greenhouse vegetables in soil due to the build up of soil borne diseases and insects that require the soil to be replaced or pasteurized (Dey, 2001). Given that greenhouse vegetables are primarily grown in soilless grow systems, the quality of the topsoil will not likely be an important siting consideration. However should soil be considered as a growth media (it is less costly, and pest management may not be as great a concern in a northern climate) then local soil quality may merit consideration.

2.4.4 Greenhouse Orientation

A greenhouse should be aligned to maximize the amount of direct sunlight without excessive shading. An east-west alignment allows for the greatest surface area with southern exposure. However, a gutter connected greenhouse structure aligned in an east-west orientation would bear a sidewall with a southern exposure, but shadows produced by the gutters would be stationary as the sun moved across the horizon. Consequently a gutter-connected structure as might be considered in Haines Junction for the larger production scenarios outlined below, would be orientated in a north-south alignment to allow the shadows to move throughout the day (XCG Consultants Ltd., 2008). Given the lack of available sunlight in winter, it is critical to avoid areas where nearby structures or trees will cast shadows on the greenhouse (Kessler, 2006).

2.4.5 Greenhouse Size and Shape

Typically, the size and shape of a property will depend on what size operation the proponents expect to run. The Alabama Cooperative Extension System recommends a minimum of three acres to be economically viable (Kessler, 2006). Correspondence with northern greenhouse experts indicates sizes between one to five acres for economic viability.[2]

The size of greenhouse is also impacted by the type of build, crops to be grown, the growing system used, the level of automation, the amount and location of equipment used, and the overall physical arrangement possible on the site. These variables will determine bay width and length, gutter height, type of glazing, type of ventilation, etc. Use of supplemental lighting, shade/energy curtains, and production of hanging baskets can also impact gutter height. In addition, irrigation booms may require additional vertical clearances (Both, 2005). Given these unknown variables in the potential Haines Junction project, assumptions were made based on the growing systems, and technologies used in the Chena Greenhouse in Alaska. The greenhouse uses advanced technologies and production techniques to overcome the climatic

[2] Correspondence with Barry McIntosh, of Harnois Greenhouses on November 13, 2012 indicated a five acre minimum for northern greenhouses, and during an Agriculture and Agri-Food Canada workshop on November 14, 2012 entitled, “Understanding Sustainable Northern Greenhouse Technologies,” one acre was used as the base case for feasibility.

limitations of year-round Alaskan food production (OBrien, 2011). See Appendix A for a brief description of the operation.[3]

In the economic and technical assessment being conducted for this report, potential size is being determined given regional market demand for greenhouse produce (specifically, lettuce, cucumbers, and tomatoes), in other words, scaling the production facility to meet the potential local demand. This is the most logical method of determining size, given that sizing a facility where yields exceed demand would compromise economic feasibility. Three market scenarios are examined, one in which the Haines Junction greenhouse is sized to meet 100% of local demand, another where sizing is expected to meet 25% of Whitehorse demand, and finally where sizing is to meet both 100% of local demand and 25% of Whitehorse demand.[4] Total square footage required given these calculations is presented in Table 1. Note, that in even the highest production scenario the required acreage is small by commercial greenhouse standards, at just less than 1.5 acres.

Table 1 Greenhouse Square Feet Required Based on Estimated Market Demand

	Haines Junction Market (100%)	Whitehorse Market (25%)	Combined
Lettuce	3,424.60	37,578.18	41,002.78
Cucumbers	1,023.95	8,249.24	9,273.18
Tomatoes	1,059.58	11,626.76	12,686.33
All 3 Vegetables	5,508.12	57,454.18	**62,962.30**

As these sizing requirements are based on modeled projections, it is difficult to determine precise greenhouse dimensions, however adopting the Chena Greenhouse as a model, a single greenhouse unit has dimensions of 60 feet by 72 feet. Table 2 gives an indication of how many Chena Greenhouse units would be required for each production scenario.

[3] The case study presents a more recent picture of the greenhouse operations than the ones used in the assumptions. The case study outlines operations after an expansion and the integration of new LED lighting technologies.

[4] Yukon per capita yearly disappearance rates and yields per acre for lettuce, cucumbers and tomatoes were derived from the Multi-Year Development Plan for Yukon Agriculture and Agri-Food 2008-2012 (Serecon Management Consulting Inc. 2007). This report also indicates that 25% is the realistic locally grown market share for each of the three vegetable groups.

Table 2 Number of 60’ x 70’ Greenhouse Units Required Based on Estimated Market Demand

	Haines Junction Market (100%)	Whitehorse Market (25%)	Combined
Lettuce	0.79	8.70	9.49
Cucumbers	0.24	1.91	2.15
Tomatoes	0.25	2.69	2.94
All 3 Vegetables	1.28	13.30	**14.57**

While the focus of this initial report is to address preliminary siting considerations, Table 3 and Table 4 indicate the results of ongoing modeling for heating demand based on heat loss calculations and the Haines Junction area’s yearly climate. While Table 3 considers the average temperature lows in Haines Junction over a year, Table 4 calculates the heating power required assuming the recorded extreme lows for the area (Appendix B presents Haines Junction climate normals and extremes, or in the absence of such data, Whitehorse data was used). It is worth considering that the heating system must be scaled to regulate the internal greenhouse temperature in even extreme temperatures outside the daily mean.

Table 3 Yearly Greenhouse Thermal Requirements Based on Minimum Daily Temperature

	Haines Junction Market (100%)	Whitehorse Market (25%)	Combined
Maximum Thermal Power			
MMBTU/h	0.35	2.95	3.30
kW	102.24	865.86	968.10
Average Yearly Thermal Energy			
MMBTU	1,521	12,881	14,403
kWh	455,451.44	3,857,147.51	46,420,428.76

Table 4 Maximum Thermal Power Based on Extreme Minimum Monthly Temperature

	Haines Junction Market (100%)	Whitehorse Market (25%)	Combined
MMBTU/h	0.54	4.61	5.15
kW	159.54	1,351.10	1,510.60

The thermal energy expected from the CPC system is well in excess of the heating requirements of a greenhouse servicing just the Haines Junction market, however it appears to be less that what would be required to serve either the Whitehorse market or a combination of the two markets. Further technical and economic analysis is required to determine the feasibility of these scenarios.

These projections account for only yield-producing acreage and do not consider land for office areas, storage, processing, additional cropland for seasonal crops, or other ancillary land requirements. Given that the project proponents are considering a modular power plant with the intent to expand, an important siting consideration will be ensuring that there is enough land to grow the agricultural component of the plan in tandem with increased power production.

Finally, permanent greenhouse facilities are often constructed with a solid concrete foundation, and structural foundation footers and/or walls must extend below the frost line. Main interior concrete walkways should be at least 4 inches thick and 10 feet wide to accommodate vehicular traffic (Both, 2005). These construction considerations may ultimately impact the decision for where to site the facility.

2.4.6 Availability of Utilities

In addition to the heat being supplied from the bioenergy power plant, the greenhouse will require electricity, water, and possibly sewer/septic tank services connected. It is important to site the greenhouse where the fewest infrastructure upgrades well be required.

Each critical component (heat and electricity) will also need provision for a connection to an emergency generation system, preferably to be installed when the greenhouse is constructed. The emergency system should have enough capacity to operate all potential control systems, boilers and circulators in the heating system, and at least the first stage of fan ventilation systems (Both, 2005).

2.4.7 Water Quality and Availability

In siting a greenhouse, consideration must be given to the availability of water and its quality. Depending on how much water is needed, obtaining permits may be required. Factors such as the crops being produced, area to be watered, light intensity, growing medium and time of year will all influence the water requirements of a greenhouse operation. A typical greenhouse operation requires 800 cubic meters of water per 100 square meters of growing space per year (Dey, 2001). Given this approximation, the potential water demands for each scenario are given in Table 5.

Table 5 Estimated Greenhouse Water Availability Required Yearly

	Haines Junction Market (100%)	Whitehorse Market (25%)	Combined
Approximate Volume Required	4,094 m^3	42,701 m^3	**46,795 m^3**

Regardless of the water source, a water quality test will be required. This is a relatively inexpensive procedure, or the required information may be available from the Yukon Water Board. When present in excess amounts, some salts are toxic to plants, so water with high levels of soluble salts is considered to be of poor quality for greenhouse vegetable crops. Electrical Conductivity (EC) and the Sodium Absorption Ratio (SAR) are used to measure the quality of water. Water with an SAR of four or less and an EC of 0.8 is considered to be good quality water. If the SAR is greater than four and the EC is greater than 0.8, special management practices are required (Dey, 2001).

2.4.8 Greenhouse Accessibility

There are obvious logistical concerns with regards to siting: the farther and less accessible the greenhouse is from suppliers and infrastructure, the higher that operating costs will likely be. Road construction and maintenance is time consuming and costly. The greenhouse should be close enough to major roads for delivery and transport trucks to have easy access, and it is worth considering if there are any weight limits or restrictions on large trucks.

Greenhouse operators may access several channels to market their produce. In the case of a Haines Junction greenhouse, retail facilities managed by the greenhouse operators, either attached to the greenhouse or located offsite will be an important channel for sales. If located on-site, siting should consider the need to locate the greenhouse so customers can see it from at least 200 feet and can access the business easily and safely (Kessler, 2006).

Presently there is no commercial food production occurring in Haines Junction and only limited produce available within the community (Ball 2012). This could indicate demand for an on-site retail facility, as the majority of consumers within the village currently commute up to two hours to Whitehorse for the bulk of their food purchases (Ball, 2012). Siting should consider how best to access this market.

According to the Chief Administrative Officer for the Village of Haines Junction, Michael Riseborough, The Kluane National Park Operations Centre was originally established as an experimental farm in the late 1940’s, and is currently for sale, with Yukon College having expressed an interest in a potential purchase (Riseborough, 2012). Their interest in the property stems from its potential for food development and storage from a research perspective. Chief Allen of the Champagne and Aishihik First Nations has voiced his opinion that the property might be a good location for a community greenhouse (Riseborough, 2012).

Given that the Yukon’s population growth rate for 2011 was the highest in Canada and that most of this growth took place in Whitehorse, Haines Junction’s proximity to this market is a powerful siting consideration. When looking at the greater Whitehorse area Haines Junction is proximal to almost 80 percent of the Yukon population (Yukon Bureau of Statistics, 2011).

2.4.9 Labour Availability

Related to access, is the need for labour availability when considering the siting of the Haines Junction Greenhouse. Operating a greenhouse business is labour intensive and obtaining experienced, dependable labour can be a challenge. Based on published data for a greenhouse production area of approximately 6,654 square meters in Saskatchewan, vegetable production greenhouses require one person-year for every 160 to 232 square meters (1730 to 2500 square feet) (XCG Consultants Ltd., 2008). The Chena Greenhouse in Alaska (4320 square feet) reports that the greenhouse needs to be staffed with a minimum of two full-time, salaried employees. One would be the Greenhouse Production Manager; the second would be the Marketing Manager (Mager, 2008). Required staff based on both of these estimates for the three production scenarios is outlined in Table 6.

Table 6 Estimated Greenhouse Labour Requirements

	Haines Junction Market (100%)	Whitehorse Market (25%)	Combined
Approximate Saskatchewan Estimate	3	33	**36.5**
Approximate Chena Estimate	2.5	26.5	**29**

Kessler suggests that when siting a greenhouse, readily available labour and support facilities should be within a 20-minute drive of the greenhouse (Kessler, 2006). Consideration should also be given as to whether there is a good source of skilled labour in the area, such as a high school program with horticulture students, a university, college, or technical school. Proximity to the Yukon College, Haines Junction Campus is a distinct advantage, particularly given the expected levels of collaboration.

Additional unskilled labour will likely be needed during peak business times. Siting should consider sources of extra, part-time labour potentially from high school students, community residents, or older, retired adults (Kessler, 2006).

Labour availability is an important production consideration, given that the choice of seasonal production will likely require yearly layoffs outside of the growing season. In the case of seasonal operations, planners must consider whether qualified labour can be attracted on a part-time basis. As work in Haines Junction is less likely to be full-time and full year than the Yukon average, this may not be a concern (Yukon Community Profiles, 2004).

2.4.10 Land Costs

The potentially large capital cost of purchasing or leasing land is an important siting consideration (OBrien, 2011). Zapisocky and Lewis in their 2010 report, "Strengthening Local Yukon Food: A Research Report" found that while people in the Yukon may express an interest in farming, "land prices are discouragingly high" and land that is available, is remote and undeveloped (Zapisocky & Lewis, 2010). Given the high costs of land in the Whitehorse surrounding region, land cost must be adequately addressed during initial siting considerations. The Anokiiwin Group estimated that the land and site preparation costs associated with the construction of a 3 MW biomass gasification power plant in Haines Junction could cost as much as $565,000 (Anokiiwin Group, 2011).

Further investigation is required to determine what a realistic price would be to acquire greenhouse land as a purchase or lease. It may also be worth considering future resale price, as an investment of this magnitude merits a full economic picture of the property's value (Kessler, 2006). Some consideration should also be given to applicable land taxes for various sites.

2.4.11 Zoning Regulations

Finally, it is important to ensure that any potential zoning regulations are known in advance. It is worth ensuring that the land is zoned for agriculture and business, particularly if farm-gate sales are being considered. Planning for future expansion is also important.

3 Final Report

This concludes the preliminary siting considerations for ORC, DES and CEA greenhouses as part of the Haines Junction Bioenergy Project – Evaluation of Waste Heat Potential. The final project report, with expected delivery on December 10, 2012, will contain portions of this report in addition to completed modelling and analysis of the preliminary feasibility of the heat use options for the project. Based on evaluation criteria, preliminary recommendations will be made as to the viability of the various options presented. Finally an outline will be provided of required next-steps for most viable options and estimates provided of potential costs for further progress on those options.

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Appendix A – Chena, Alaska Greenhouse Case Study

(Center for Energy and Power 2010)

Case Study: Chena Hot Springs

At the end of Chena Hot Springs Road, sixty miles northeast of Fairbanks, stands a greenhouse that may represent a model for communities across Alaska as they consider local food production. Chena Fresh, a 6,000-square foot, hydroponic greenhouse, makes use of renewable energy and provides Chena Hot Springs Resort with a year-round supply of fresh produce.

What sets the Chena Fresh greenhouse apart from others in the state, if not the world, is its energy efficient design. Power and heating needs for the greenhouse are met by the hot springs themselves. A geothermal power plant supplies the 62 kilowatts needed to operate the lights (48 High-Intensity Discharge lights) and other electrical equipment for up to 16 hours per day. The geothermal resource also supplies the 500,000 BTUs per hour required to keep the structure warm throughout the winter. This saves about 75 gallons of fuel oil every day.

While not every community in Alaska has a geothermal resource, the Chena Fresh greenhouse shows how efficient use of local resources can help a community take steps toward self-sufficiency. A wood-fired heating system or the use of recovered heat from a village power plant may enable a community to supply its own fresh produce economically.

For more information, please see: www.chenafresh.com

Greenhouse at Chena Hot Springs. Photos courtesy of Gwen Holdmann.

For more information about energy efficiency and community greenhouses, please contact:
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UAF University of Alaska Fairbanks | ACEP Alaska Center for Energy and Power | Cooperative Extension Service University of Alaska Fairbanks

Appendix B – Haines Junction Area Climate

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Extreme Maximum (°C)	12.2	15	15.6	20.6	29.5	32.8	31.1	31	25.6	20	13.3	10.6	21.4
Daily Maximum (°C)	-15.8	-8	-1.3	6	12.6	17.9	20	18.6	13.1	4.9	-7.1	-15.5	3.8
Daily (°C)	-21.5	-15.3	-9.1	-0.4	5.4	10.3	12.6	10.8	6.2	-0.4	-12.5	-21.1	-2.9
Daily Minimum (°C)	-27	-22.2	-17	-6.9	-1.8	2.5	5.1	3	-0.9	-6.1	-18.1	-26.8	-9.7
Extreme Minimum (°C)	-53.9	-53.9	-43.9	-30.6	-12.2	-6.7	-3.3	-11.1	-21.5	-36	-47.2	-53.9	-31.2
Extreme Daily Rainfall (mm)	12.7	10.2	3.8	12.7	20.6	33	28.4	25	32.5	63	51.6	58.4	
Rainfall (mm)	1.1	0.6	0.3	0.8	11.8	28.3	35.2	28.3	33.7	13.3	0.8	0.1	
Snowfall (cm)	32.7	19.4	9.9	8.8	4	0	0	0.1	0.4	23.2	31.3	29.8	
Extreme Daily Snowfall (cm)	33.3	29.2	14.2	27	10	3.6	0	3	7.6	67.3	35	23.9	
Snow Depth at Month-end (cm)	41	39	24	1	0	0	0	0	0	7	18	31	
Bright Sunshine (hours)	19	76.5	159.8	226.7	288.2	N	281.9	N	138.4	86.8	25.4	0.9	

Haines Junction Climate Normals 1961-1990, Environment Canada, National Climate Data and Information Archive, Accessed November 11, 2012, available: http://climate.weatheroffice.gc.ca/climate_normals/results_1961_1990_e.html?stnID=1512&StationName=&SearchType=&lang=e&prov=YT&province=YT&month1=0&month2=12

Wind												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Mean hourly wind speed (km/h)	13	13	13	13	13	11	10	11	13	15	14	14
Record hourly speed km/h	72	68	64	60	64	56	63	52	72	63	68	72
Maximum gust speed km/h	100	106	93	89	85	90	91	84	101	97	106	97

Days with Wind												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Above 5 km/h	23	20	23	22	23	24	26	24	21	20	20	22
Above 10 km/h	26	25	29	29	31	30	30	30	28	30	27	27
Above 20 km/h	18	18	19	19	21	18	17	17	19	22	20	21
Above 30 km/h	11	9	7	6	6	4	2	4	7	10	10	12
Above 40 km/h	4	2	1	1	0	0	0	1	1	2	2	4

30-Year Average Wind, Whitehorse Weather Station, The Weather Network, Accessed November 11, 2012, Available: http://www.theweathernetwork.com/statistics/wind/cl2101300/cayt0019

Pressure and Humidity												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean hourly station pressure (kPa)	93	93	93	93	93	93	93	93	93	92	92	93
Mean relative humidity, 6 am (%)	71	71	70	71	70	70	76	80	80	78	76	74
Mean relative humidity, 3 pm (%)	69	63	52	44	38	40	46	48	54	63	74	73

30-Year Average Pressure and Humidity, Whitehorse Weather Station, The Weather Network, Accessed November 11, 2012, Available: http://www.theweathernetwork.com/statistics/wind/cl2101300/cayt0019

Appendix F Description of Greenhouse Features

Table 17: Description of Proposed Greenhouse Features

Greenhouse Feature	Description
Computerized Environmental Controls	Jeff Werner, the Greenhouse Manager at Chena Hot Springs Greenhouse in Alaska has indicated that a northern greenhouse is only as good as its control system. Advanced computerized controls not only help to regulate and optimize growing conditions, vital given Haines Junctions relative inexperience with commercial greenhouse operations, but the controls also provide an early warning system to monitor for failures in any of the vital components (Werner 2012). Control systems are the brain of the greenhouse and regulate all of the environmental equipment in the greenhouse such as fans, heaters, vent door, wet wall, lights and CO_2. Due to the quickly changing environment of the greenhouse, specialized greenhouse controllers are critical to maintaining the correct plant environment. By maintaining tight tolerances on the environment both night and day, significant energy savings can be achieved over simpler thermostat control (Cropking n.d.). Further, computerized control systems have the advantage of recording data for subsequent use in evaluating plant performance or identifying problems with the mechanical aspects of the growing system (Both 2005).
Cooling Systems	In addition to heating systems, most greenhouses are equipped with a pad and fan cooling system. The cooling system is essential if temperatures are to be lowered during the summer months (Chaudhary 2011). Fan and pad evaporative cooling combines forced air ventilation with the ability of evaporating water to remove heat from the greenhouse. Water absorbs a relative large amount of heat when moving from a liquid state to a gaseous state. The most widely used evaporative cooling system in greenhouses consists of exhaust fans along one wall and cross-fluted cellulose pads along the other wall. Warm air from outside is drawn through the pads by the exhaust fans. The pads are kept constantly wet, and through the process of evaporation, heat is removed from the air passing through the pads into the greenhouse (Kessler, Jr. n.d.).
Gutter Connected Greenhouses	“Gutter connect greenhouses are composed of a number of ‘bays’ or compartments running side by side along the length of the greenhouse. The interior working space can be compartmentalized to adapt sectional interior environments, or expanded to one large growing environment. It may be required that varying products and plants at various stages of growth will require different environmental factors, thus requiring the compartments to serve different functions. The roof above each bay is pitched” (O'Brien 2011). Given that a greenhouse in Haines Junction would likely need to diversify the crops being grown in order to meet demand, gutter connected greenhouses will allow for compartmentalized production environments.
Hydroponics	Greenhouse vegetables can either be grown in soil or hydroponically. Hydroponic production refers to the use of growing media other than soil. Generally, it is not considered economical to produce greenhouse vegetables in soil. “Soilless media are well-drained, uniform, disease free and have good moisture-air holding capacities. They provide for more efficient use of water and fertilizer. Media that are used in hydroponic systems include rockwool and

	sawdust. Nearly all commercial vegetable growers use a hydroponic system" (Dey 2001).
Light-Emitting Diode (LED) Lights	"Light-emitting diode (LED) lights are efficient, low heat, long-lasting lights that are being used in greenhouses with increasing frequency. The high initial expense of the lights is offset by their long lifespan (up to 10 years) and low operating costs (up to 30% less energy consumption than other lights)" (Alaska Center for Energy and Power 2010). While the technology is still considered in its nascent stages of development for greenhouses, environments like Haines Junction that will require upwards of 16 hours of supplemental lighting a day in the winter, will need to address the long-term electricity costs of their lighting demand. LEDs may be an effective means to reduce costs. LEDs are also in use in the Yukon College greenhouse in Whitehorse. Costing analysis contained in this report did not include LED prices, as capital costs and energy savings achievable were unknown.
Thermal Screens or Curtain Systems	A thermal screen that doubles as a shade screen is described as one of the best investments a grower can make (Both 2005). Thermal screens allow growers to obtain climate control all year. Winter heating requirements can be reduced by as much as 50 percent when screens are closed at night. Thermal screening systems (shade, heat retention, or blackout curtains) reduce heat loss by reducing the air volume needed to be heated, creating an attic in the greenhouse for an insulative air barrier, and reducing the stratification of heat energy up to the roof. During the summer months screens can be deployed over the crop, returning temperatures back to an optimum growing range (Gintec Shading Technologies n.d.).
Twin-Wall Polycarbonate Covering	Polycarbonate is a recyclable, environmentally friendly material, making it preferable to other types of plastic such as PVC. It is clear, impact resistant and also very easy to cut and install. Polycarbonate coverings typically come with a 10-year warranty (Growers Supply, n.d.). The twin-wall design offers heat retention and efficiency, while also providing durability and strength. Polycarbonate was selected as a covering material for the project's modelling; primarily as this is the same covering used in the Chena greenhouse data. It may also be advisable to compare the cost of polycarbonate covering to greenhouse grade polyethylene plastic. The selection of this covering allows for air to be pumped between the two layers of plastic with inflation fans. The covers are fastened to the greenhouse using an aluminum extrusion. The pillow of air between the two layers of greenhouse plastic provides insulation, rigidity and also has an anti-condensation feature. The greenhouse plastic film has a coating for light diffraction that spreads the incoming light to eliminate shadows, and the inner layer has an IR blocking ability that helps to keep heating costs lower. Correspondence with Barry McIntosh of Harnois Greenhouses has indicated that the choice of polyethylene can save $20,000 over the life of a project, however the covering itself has an estimated lifespan of only four years (McIntosh 2012).

Appendix G Greenhouse Methodology Inputs & Assumptions

Table 18: Greenhouse Methodology Inputs & Assumptions

Greenhouse Dimensions			
Data Used	**Value**	**Source**	**Comments**
Width	18.288 m	(Mager 2008)	Used to calculate Heating Requirements per Chena unit
Length	21.9456 m	(Mager 2008)	Used to calculate Heating Requirements per Chena unit
Height	3.048 m	(Mager 2008)	Used to calculate Heating Requirements per Chena unit
Roof Pitch (rise/run)	0.5	(O'Brien 2011)	Used to calculate Heating Requirements per Chena unit
Vegetable Pricing			
Lettuce Market Price	*4.39 $/kg	(Real Canadian Superstore 2012)	Romaine Lettuce
Cucumber Market Price	*4.2 $/kg	(Real Canadian Superstore 2012)	Prices were given as unit price and then converted to $/kg. Cucumbers were assumed to weigh 0.45 kg.
Tomato Market Price	*4.2 $/kg	(Real Canadian Superstore 2012)	
* All Canadian Prices were converted to US dollars using the exchange rate on November 30, 2012 from Bank of Canada. 1.00 Canadian Dollar(s) = 1.01 U.S. dollar(s), at an exchange rate of 1.0068 (Bank of Canada 2012) Where produce prices were supplied in a range, the high price, was modeled.			
Vegetable Demand			
Haines Junction Population	593	(Yukon Bureau of Statistics 2011)	
Whitehorse Population	26028	(Yukon Bureau of Statistics 2011)	
Lettuce Disappearance Rate	11.05 kg/person/year	(Serecon Management Consulting Inc. 2007)	No disappearance rate info available for micro greens, lettuce used instead.
Cucumber Disappearance Rate	4.24 kg/person/year	(Serecon Management Consulting Inc. 2007)	
Tomatoes Disappearance Rate	8.3 kg/person/year	(Serecon Management Consulting Inc. 2007)	
Greenhouse Vegetable Yield			
Lettuce Yield	83348 kg/acre/year	(Serecon Management Consulting Inc. 2007)	
Cucumber Yield	145687 kg/acre/year	(Serecon Management Consulting Inc. 2007)	

Tomato Yield	202343 kg/acre/year	(Serecon Management Consulting Inc. 2007)	
Note: Assuming these yield numbers take into account production losses and area not used for growing (walkways etc.). They are used to determine total footprint area required.			

Heating Calculation Inputs												
Indoor Greenhouse Temperature	24°C			(Werner 2012)			High estimate to be conservative, based on Jeff Werner's 21-24°C range at Chena Hot Springs					
Structure U-Value	0.4 BTU/(h °F ft²) / 2.27 W/m²K			(O'Brien 2011)			Assuming double polycarbonate walls with energy curtains used					
Haines Junction Temperature Data (below)	Average and Extreme minimum monthly temperatures			(Environment Canada 2012)								
	Jan	**Feb**	**March**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Average Temperature (°C)	-21.4	-15.1	-9.15	-0.45	5.4	10.2	12.55	10.8	6.1	-0.6	-12.6	-21.15
Extreme Minimum Temperature (°C)	-53.9	-53.9	-43.9	-30.6	-12.2	-6.7	-3.3	-11.1	-21.5	-36	-47.2	-53.9
Wind or Exposure Factor	1			(Canada Plan Service 2010)			Assumed less than 25 km/hr winds					
Construction Type/Quality Factor	1			(Canada Plan Service 2010)			Construction quality unknown, assumed "good quality"					
System Factor	1			(Canada Plan Service 2010)			Assumed radiation or convection heating near ground level					
Note: Passive solar gains from sunshine are not taken into account – may reduce heating requirements												

Enterprise Budget Inputs	Default Cost (multiplied by number of Chena Units to obtain total cost)	Default Life	Source	Comment
Capital Costs (Construction & Durables)				
Property Cost	$0.00	100	(Mager 2008)	
License Cost	$0.00	100	(Mager 2008)	
Greenhouse Frame Cost	$20,188.00	20	(Mager 2008)	
Warehouse & Packing Plant on site	$16,600.00	10	(Mager 2008)	
Floor (insulation, concrete slab, paint)	$9,035.00	10	(Mager 2008)	
Floor Heating System	$1,302.00	10	(Mager 2008)	Back up heating system not included in cost estimates
Irrigation/Fertigation (hydroponic structure & equipment)	$24,555.00	14	(Mager 2008)	

Electrical Installation	$6,005.00	10	(Mager 2008)	
Controller	$5,500.00	10	(Mager 2008)	
Water Tank	$1,248.00	7	(Mager 2008)	
Labour (Construction & Equipment Installation)	$13,000.00	10	(Mager 2008)	
Miscellaneous Supplies	$7,952.00	5	(Mager 2008)	
Roof & Walls	$799.00	3	(Mager 2008)	
Plumbing Hot Water	$2,835.00	5	(Mager 2008)	
Plumbing Fresh Water	$356.00	5	(Mager 2008)	
Plumbing MISC	$2,130.00	5	(Mager 2008)	
Extra Cooling Fans & Environmental Control	$147.00	5	(Mager 2008)	
Lights	$16,800.00	5	(Mager 2008)	
Other Durable Goods	$850.00	5	(Mager 2008)	
Utility hook-ups (electrical, heat)	$5,000.00	5	(Mager 2008)	
Cost of fresh water well & hook up	$4,000.00	20	(Mager 2008)	
Yearly Operating and Maintenance Costs	**Default Costs/Cost Units**		**Source**	**Comment**
Material Inputs	$45,243.00	n/a	(Mager 2008)	
Accessories	$1,978.00	n/a	(Mager 2008)	
Heat	$0.00	n/a	n/a	assuming waste heat is provided free of charge
Number of lights	0.120155279 lights/m2	n/a	(Mager 2008)	48x1000 Watt lights
Wattage	1000 W	n/a	(Mager 2008)	Hydro 2160 – Non-Gov Monthly Rate Plan: (a) Demand Charge of $7.39/kW (b) 10 ¢/kWh for the first 2,000 kWh (c) 12.88 ¢/kWh between 2,001 - 15,000 kWh (d) 15.68 ¢/kWh between 15,001 - 20,000 kWh (e) 12.86 ¢/kWh in excess of 20,000 kWh (Yukon Electrical 2012)
Hours used/Day	16 hours	n/a	(Mager 2008)	
*Days used/year	180 days	n/a	(Mager 2008)	
*Additional electrical kW requirement year-round (not including lighting)	14 kW	n/a	(Mager 2008)	
*Additional yearly kWh required (not including lighting)	163117.02 kWh	n/a	(Mager 2008)	
Number of Full Time Workers	2 workers	n/a	(Mager 2008)	
Hourly Wage	30 $/hour	n/a	(Mager 2008)	
Packaging and Marketing	$37,000.00	n/a	(Mager 2008)	

*Note: Lighting electricity costs calculated for 6 months/year (180 days), additional kW/kWh costs calculated over 12 months/year

Additional Enterprise Budget Calculation Assumptions			
Data Used	**Value**	**Source**	**Comment**
Revenue Calculations			
Debt/Equity Ratio on capital cost	75%/25%	n/a	
Interest on capital loan	6.2% annually	(Morrison Hershfield 2012)	
NPV calculation			
Payment period	25 years, paid annually	(Morrison Hershfield 2012)	
Discount Rate	6.2% annually	(Morrison Hershfield 2012)	
Cash Flows	varied with replacement costs at specified lifetimes	n/a	

Alternate Scenario Data			
Data Changed	**Alternate Value**	**Source**	**Comment**
Yearly Labour Cost	1 worker, $42500 salary	(Yukon Community Profiles 2004)	Average salary in Haines Junction. These values were used for the 100% Haines Junction case and number of workers was scaled proportionally to size for additional scenarios
Packaging/ Marketing Cost	$0	None	farm gate and farmers market sales, therefore no packaging required
Materials (growing materials)	$9,899	(Cropking n.d.)	NFT growing supplies for 44' x 128' greenhouse, quote from CropKing. This value was used for the 100% Haines Junction case and scaled proportionally to size for additional scenarios
Vegetable Pricing			
Lettuce Market Price	8.78 $/kg		2x base market price (Serecon Management Consulting Inc. 2007)
Cucumber Market Price	8.4 $/kg		2x base market price (Serecon Management Consulting Inc. 2007)
Tomato Market Price	8.4 $/kg		2x base market price (Serecon Management Consulting Inc. 2007)
Electricity			
Wattage	500 W	(Werner 2012)	assuming LED lights reduce wattage required by 50%

Additional electrical kW requirement year-round (not including lighting)	7 kW	n/a	assuming additional electricity cost can also be reduced by 50%, either by increased efficiency or lower electricity rates
Additional yearly kWh required (not including lighting)	81,558.5 kWh	n/a	assuming additional electricity cost can also be reduced by 50%, either by increased efficiency or lower electricity rates