NWT Community Wood Pellet District Heating Study

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For:

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Executive Summary

Wood Pellets have been used for space heating in the NWT for many years, primarily 18kg bags for residential use, and mainly in Hay River, Fort Smith and Yellowknife. The success of the pellet boiler system at the North Slave Correctional Facility in Yellowknife, installed in November 2006, has led the way for many other commercial systems installed in Yellowknife, Behchoko and Dettah by the GNWT, The City of Yellowknife, Northern Properties REIT, the Yellowknives Dene First Nation, and others. The GNWT is currently installing commercial wood pellet boiler systems in Hay River and Fort Smith as well.

Wood pellets in bulk format present a substantially cheaper heating source than current fossil fuel sources for both all weather road and winter road resupply communities. Transport costs become more substantial as pellets are moved greater distances, so communities closer to pellet mills can access pellets at a lower cost than communities further away. However, heating oil is also more expensive in more remote communities, so wood pellets are still cheaper in most cases.

District heating systems can present the most favourable case for large-scale pellet use in smaller communities as a single central boiler system can be operated by trained personnel. A district heating system that initially uses imported wood pellets could also lead to a local industry of harvesting local biomass resources as wood chips once a reliable chip supply has been established.

In order to identify a location with a favourable economic potential for a pellet-fired District Heating System, a good combination of the following features should be identified in that community:

- Wood pellets are substantially cheaper than current heating fuels.
- The heating requirements are high
- There is a cluster of buildings close together
- The cost of doing a project in the location is relatively low

Based on our initial pre-feasibility analysis, the following all weather road access communities show the greatest potential for a pellet fired district heating system and warrant further investigation in order identify a potential pilot project: Fort Resolution, Fort Providence, Behchoko, and Wrigley. Several winter road access communities also appear to have economic potential, but present additional logistical challenges associated with providing and storing a years supply of pellets, and so should not be the initial focus of development efforts.

Although economic factors tend to be the initial decision point, a strong local interest in the project is also very important, as is the presence of an entity that could own and operate the system as a utility. Community governments and aboriginal organizations could be eligible for substantial capital subsidies and grants from a number of different Federal and Territorial sources.

In addition to the potential cost savings, substantial Greenhouse Gas reductions are also possible with a pellet-fired district heating system. While these reductions do not currently provide an economic benefit, that may change with the introduction of a carbon tax or cap-and-trade system. Also, when using wood pellets instead of heating oil, there is no risk of oil spills, which are toxic to the environment and can be very expensive to clean up.

1. Introduction

The Arctic Energy Alliance was contracted by the Department of Environment and Natural Resources (ENR) of the Government of Northwest Territories (GNWT) to provide a study identifying which communities are best suited for increased use of wood pellets for space heating. This document will provide part of the background information required for the government's Biomass Strategy.

The first part of the study investigated the possible wood pellet supply locations, transportation methods, and delivered costs of providing Northwest Territories' (NWT) communities with a renewable fuel alternative to heating oil.

The second part of the study (this document) investigates possible scenarios for community scale wood pellet central heating facilities with district heating systems. The goal is to identify one or more communities that represent a good opportunity for a pilot project. A pre-feasibility cost analysis was undertaken for the non tax-based communities that have road access to determine where more attention, such as a community consultation and more detailed feasibility study, is warranted. Larger tax-based communities (Yellowknife, Hay River, Inuvik, Fort Smith, Fort Simpson) were not included in the scope of this analysis, due to their greater complexity.

Arctic Green Energy was sub-contracted to provide technical expertise in the development of this study.

1.0 District Heating Systems

District Heating Systems include a central heating plant and a piping network that distributes heat to buildings and houses. They can include only a few buildings, or a whole community. This approach has been tried with varying degrees of success in the NWT in the past; however currently the vast majority of buildings and houses contain individual heating systems. This independence allows for a great amount of freedom in heating systems, but can cost more overall than a single common heating source. It also means that individual buildings are on their own if their heating system fails. District heating systems are very common in northern European countries due to their reliability and efficiency. Systems range in size from small neighbourhoods and towns, to very large urban centres such as Copenhagen.

District heating systems can present the most favourable case for large-scale pellet use in smaller communities. With a common system, resources are shared and the system can be operated and maintained to a higher degree by properly trained personnel, while each building can retain its existing heating source as a back-up. A district heating system also allows for the potential of tying in a waste heat recovery system from the diesel power generators, and also the possibility of using a biomass fired cogeneration system to generate electricity as well as heat. It could also lead to a local industry of harvesting local biomass resources for heating, in a wood chip boiler similar to the pellet boilers currently being used. Some boilers can be modified to accept wood chips or wood pellets. This would allow a system to be installed using imported wood pellets initially, and switched to locally harvested wood chips when a reliable supply of chips has been established. This would not only provide cost savings on heating, but would provide local employment and boost the local economy.

A district heating system is composed of several main components, including the boiler plant where the heat is produced, the piping network that carries the heat to the individual buildings being heated, the heat exchangers and supplementary controls required in each building to interface with the building heating system, and the storage units to hold the pellet supply for the boiler.

1.1 Boiler Plant

The central boiler plant is where pellets are burned and heat is produced. Often a single boiler is used, but there can also be two or more boilers that work together to provide the required heat. Most of the pellets boilers installed in Yellowknife have come directly from Europe installed in a 40' shipping container which serves as the final housing for the boiler. This approach saves the cost of building a structure to house the boiler. The container can be insulated, and also sided to match nearby buildings to improve its appearance.

Photo: AEA. Northern Property REIT boiler system enclosed in a siding clad intermodal container at Garden Apartments in Yellowknife.

Pellet boilers range in size from under 100kW (340 MBH) to over 10MW (34,000 MBH). For small systems, several residential sized boilers in the range of 25kW (85 MBH) can be combined. The wood pellet heating systems installed in the NWT have ranged from 300kW (1000 MBH) to 1.5MW (5,100 MBH).

1.2 Piping Network

The piping network is what carries the heat from the boiler plant to the buildings to be heated. It is usually buried below ground in a trench. Two pipes are buried in the same trench, one for hot supply to the buildings and the other for cool return back to the boiler. Pipes can be plastic (eg HDPE or PEX) or steel, and usually come pre-insulated. Plastic pipes are much cheaper than steel pipes, although steel is considered to provide greater durability. Pre-insulated PEX pipes are available in sizes up to 100mm (4”) and are suitable for systems with a heating fluid temperature up to 95°C (203°F). For small systems, dual 50mm (2”) PEX pipes in one insulated outer shell can be used, providing further cost savings over steel pipe. For the size and nature of systems we are considering in this study, pipe sizes and operating temperatures are suitable for the use of less costly PEX piping rather than steel.

Photos: Finnish Forest Research Institute. Left- Lengths of pre-insulated pipe. Right- Trenched Pipe.

1.3 Heat Exchangers & Controls

The heating fluid in a district heating system is rarely used to distribute the heat within the buildings being heated. There is usually a heat exchanger installed in the building that transfers the heat into the building heating system. For buildings with hydronic (hot water) heating, a plate heat exchanger is commonly used, which is relatively small and easy to add into the existing heating piping. The heating system controls are modified to draw heat from the district heat network first and to engage the building boilers, if required, to provide additional heat.
For small buildings and houses that are heated by forced-air furnaces, a fan coil can be added to the furnace to transfer the heat into the furnace air. As with hydronic systems, the furnace controls can be modified to draw heat first from the district heating system, and to engage the furnace burner to provide additional heat if required. Most furnaces are designed to accept a fan-coil to be used for air conditioning, which is rarely used in the NWT.

1.4 Pellet Storage

Wood pellets are relatively easy to transport and store compared to other heating fuels. The primary requirement is dryness as moisture will turn the pellets back into sawdust, which makes them unusable. Because wood pellets are non-toxic, spills are not a concern, aside from being wasteful. If wood pellets were to spill, they can be raked or vacuumed, with no damage to the environment. Wood pellets are generally handled and stored using commonly available grain handling systems.

Grain silos, which are very common in every farming community, are often used to store pellets and come in sizes from 10’s of tonnes to 1000’s of tonnes, depending on diameter and height. Grain silos can be constructed out of corrugated steel sheets bolted together such as the Twister silo, or solid welded steel plates such as the Wheatland silo, both shown below. A silo would be shipped in parts by flatbed truck and would require assembly on site, possibly involving a small crane to erect the silo vertically.

Grain silos have an advantage over intermodal containers for pellet storage. Grain silos are vertical storage units, so gravity feeds the pellets out through the cone bottom, whereas horizontal storage requires a sloped interior that reduces the useable space.

For a community on an all-weather road, the storage unit just has to be large enough to handle one truckload of wood pellets (about 40 tonnes) at a time, and have a small reserve, because truckloads of pellets can be brought as needed directly from the pellet mill. Therefore a 50 tonne silo is all that would be required. In order to meet the needs of a large distributed heat system in a winter road resupply community, either one large silo or a series of smaller silos would be required, such as is currently the case with petroleum products stored in large tanks.

Left Photo: AEA. Welded steel plate silo. This 40t silo is 8.2m tall, diameter of 3.7m
Right Photo: AEA. Bolted corrugated steel sheet silo.This 55t silo is 8.2 m tall, diameter of 4.3 m

An intermodal container, as the name suggests, is a container that can be transferred amongst different transportation modes, such as ships, trains and trucks. In the North it is not uncommon to see them also used as storage sheds since they are vermin and weather proof. In Yellowknife containers have been modified internally to be used as pellet storage tanks. The pellet storage can then be stacked on top of the container housing the boiler.

Photo: AEA. NPREIT Pellet boiler system at Bison Apartments using a stacked intermodal container as storage.

2.0 Factors that affect DHS system economic potential

The following factors were determined to be of primary importance in the possibility of a pellet-fired district heating system showing a potential for economic viability or not. In the end, it is the best combination of the factors that is most important and why each community is different and has a different potential.

2.1 Fuel Cost Differential

The difference between the cost of wood pellets and other heating fuels on the basis of heat energy provided is perhaps the single most important factor in determining whether a project to switch heating sources will be economically viable. Wood pellets become more costly as the transportation distance from the pellet mill increase; the same is also true for heating oil to a lesser extent. These values were determined by AEA for all communities in the NWT in a previous study, and were used in this analysis. These values can also be found in **Appendix A.**

The greater the difference between the cost of wood pellets and heating oil, the better will be the economic performance of a pellet DHS.

2.2 Climate

The amount of heating required in a community is proportional to the Heating Degree Days (HDD) for that location, which is a measure of how much cold weather the community experiences. For example, the annual HDD for Fort Smith is 7439, while for Inuvik it is 9767. This means that a similarly constructed building can be expected to require 31% more heating per year in Inuvik than in Fort Smith. The more heating required in a year, the greater the annual savings will be for a system that burns wood pellets instead of heating oil.

The greater the HDD in a community, the better will be the economic performance of a pellet DHS.

2.3 Energy Density

Because the cost of installing piping to distribute the heat is a significant part of the overall cost of the system, the further apart the buildings are, the more costly the system will be as more pipe is required to connect them to the system. What is desirable then is a high heating demand in a small geographic area, such as a cluster of buildings that are close together and have high heating requirements.

The greater the Energy Density in a community, the better will be the economic performance of a pellet DHS.

2.4 Capital Cost Factor

In general, the more remote a community is, the more everything will cost. This is due to increased transportation costs, as well as the increased local costs of doing business due to higher utility and operational costs. The availability of skilled labour is also an important factor, as bringing trades-people into a community and putting them up in hotels increases costs substantially. Community Cost Factors measure the relative cost of a similar project in different communities and range from 1.0 in Yellowknife to 2.25 in Colville Lake. As an example, Enterprise and Jean Marie River are of similar size and climate, both with all weather road access, but have cost factors of 1.2 and 1.52 respectively. This means that a similar project can be expected to cost 27% more in Jean Marie River than in Enterprise.

The greater the Capital Cost Factor in a community, the worse will be the economic performance of a pellet DHS.

2.5 Summary of Economic Factors

In summary, in order to identify a location with a favourable economic potential for a pellet-fired District Heating System, a good combination of the following features should be identified in that community:

- Wood pellets are substantially cheaper than other heating fuels.
- The heating requirements are high
- There is a cluster of buildings close together
- The cost of doing a project in the location is relatively low

3.0 District Heat System Component Cost Estimates

This pre-feasibility analysis was intended to provide a 'Class D' level estimate at best, and was intended to allow a comparison of communities in order to indentify which ones most warranted a more detailed analysis for a potential pilot project. The cost estimate values that were used were based on an installed system in Yellowknife and were adjusted in each community based on a 'community capital cost factor' that represents the relative cost on doing a project in that community compared to Yellowknife, based on a combination of such factors as transportation costs, cost of labour, accommodations during construction, etc. A list of community cost factors used can be found in **Appendix B**.

3.1 Boiler Plant

The base value used in this analysis for a containerized 1 MW (3400 MBH) wood pellet boiler was $500,000 installed. For a 2MW (6800 MBH) boiler the base value was increased to $750k, and for a 500kW (1700 MBH) boiler it was reduced to $350k, while for a 150kW (500 MBH) boiler a base value of $200k was used. These values include a fully operational pellet boiler and all related control systems in a single 40' shipping container. The boiler cost used for each community system in the analysis was determined based on the estimated total heating demand for each community's proposed heating network, and was adjusted based on the community cost factor described above.

3.2 Piping Network

For the size and operating conditions of systems considered in this study, it was felt that expensive steel pipe was not required, and that much cheaper PEX piping was a suitable choice. The base value that was used for trenched pre-insulated PEX pipes was $350 per meter. The cost of installing the piping for the City of Yellowknife Pool/Arena system was around $330 per meter[1]. For comparison, in Finland three district heating systems with piping networks of 1,900m, 2,800m, and 3,000m and had installed piping costs (in Canadian dollars) of $162, $153, and $144, per meter respectively[2]. A developer of a recent district heating system in central BC reported that a PEX pipe distribution network was installed for about $250 per metre[3].

3.3 Connections

The base value used for connecting each house to the system was $10,000, while for commercial/institutional buildings the value was doubled. This is intended to include the cost of installing the heat exchanger and related controls required to interface with existing heating system.

[1] Arctic Green Energy, conversation
[2] CANBIO Conference Presentation, Finnish Forest Research Institute
[3] Del-Tech Manufacturing, private communication

3.4 Pellet Storage

The base value used for a 50 tonne pellet silo was $50,000 installed, and was used for all weather road communities. For winter road resupply communities, a base cost of $100,000 for a 200t silo was used, and multiplied by the number of silos required to store enough pellets to last a year. A supply only quote was received of $41,500 for a 200 tonne silo[4].

[4] Skyway Grain Systems Inc.

4.0 Community DHS Analysis

4.1 Methodology

In order to compare communities' suitability for a district heating system, aerial photos were used to identify groups of buildings and houses that appeared close enough together to provide an economic balance between increased heating load and increased piping length. For each community a preliminary analysis of heating costs and capital costs was used to determine how much piping could be economically used to connect the 'last building on the system', not including the cost of the central plant. Using this value as a guide a piping layout was developed, from which the total length of pipe was estimated, and the number of houses and buildings recorded.

The heating load was estimated based on floor area observed from the aerial photo, with base values of 109 GJ annually per house and 1.24 GJ per m2 of commercial/institutional buildings, which was then adjusted for each community using heating degree days with Yellowknife as a reference. A pellet boiler plant was sized based on 50% of the design peak heating demand, and was assumed to provide about 90% of the annual heating requirements. More detailed information about the system as modeled can be found in **Appendix C**.

Annual savings estimates were calculated for both May 2008 and May 2009 fuel prices. The reason for this is that May 2008 represented a historical high fuel price, with crude oil approaching $150 per barrel, while May 2009 represented relatively low fuel price due to the worldwide economic crisis and the price of oil having dropped to $30 per barrel. The price of crude oil is currently at about $80 per barrel. It is reasonable to assume that prices are likely to remain between these two values for the near future.

4.2 Analysis Results

The following table show the estimated cost and annual savings for the system modelled in each community. Simple paybacks of less than 10 years were considered to warrant further investigation, and are marked with green dots. Although shorter payback periods are often used to signify economic viability of a project (such as 5 years), it was felt that for a larger community infrastructure project a longer payback can be considered worth pursuing. For systems with a payback over 20 years a red dot was used, while between 10 and 20 years a yellow dot was used.

Please note that as the margin of error for these pre-feasibility estimates is expected to be high, these values are only intended to be an indicator of the relative value of further investigation, not a definitive indication of the merit of a potential district heating system in the community.

Pellet Fired District Heating System Cost and Savings Estimates for NWT Road Access Communities								
Community	Estimated District Heating System Cost	# of Connections	Total Heated Area (m2)	Estimated Annual Net Cost Savings (May 2009 Fuel	Estimated System Simple Payback (May 2009 Fuel Prices)	Estimated Annual Net Cost Savings (May 2008 Fuel	Estimated System Simple Payback (May 2008 Fuel
All Weather Road							
Enterprise	$1,200,000	31	6,100	$86,000	14	$160,000	8
Kakisa	$580,000	11	1,500	$19,000	31	$38,000	15
Fort Providence	$2,300,000	69	16,000	$260,000	9	$440,000	5
Fort Resolution	$2,000,000	73	14,000	$210,000	10	$380,000	5
Jean Marie River	$1,000,000	24	3,400	$50,000	20	$76,000	13
Behchoko (Rae)	$3,700,000	156	28,000	$370,000	10	$690,000	5
Dettah	$900,000	24	4,600	$62,000	15	$120,000	8
Fort Liard	$1,400,000	29	8,400	$110,000	13	No Data	NA
Wrigley	$460,000	6	1,900	$48,000	10	$66,000	7
Fort McPherson	$1,800,000	49	13,000	$140,000	13	$210,000	9
Tsiigehtchic	$1,500,000	34	5,200	$67,000	22	$91,000	16
		0					
Ice Road		0					
Trout Lake	$640,000	9	1,700	$33,000	19	$51,000	13
What'i	$1,700,000	26	7,800	$140,000	12	$250,000	7
Nahanni Butte	$770,000	13	1,900	$32,000	24	$54,000	14
Gameti	$500,000	4	2,400	$74,000	7	$81,000	6
Wekweeti	$1,500,000	26	4,400	$140,000	11	$150,000	10
Tulita	$1,200,000	15	6,900	$170,000	7	$110,000	11
Deline	$1,800,000	48	10,000	$140,000	13	$260,000	7
Norman Wells	$4,300,000	146	25,000	$170,000	25	$570,000	8
Fort Good Hope	$960,000	11	5,600	$120,000	8	$130,000	7
Colville Lake	$670,000	3	820	$16,000	42	$25,000	27
Aklavik	$2,900,000	84	14,000	$21,000	138	$330,000	9
Tuktoyaktuk	$2,800,000	69	14,000	$360,000	8	$330,000	8

5.0 Greenhouse Gas Reductions

Greenhouse gases such as carbon dioxide are widely believed to be responsible for causing an unnatural increase in worldwide temperatures, which is causing climate change to occur. Wood pellets are considered to be 'carbon-neutral' in that the carbon released by burning them is absorbed by new trees grown to replace the ones cut down in an infinitely sustainable cycle, and no net increase in atmospheric carbon occurs.

International awareness that we need to collectively reduce greenhouse gas emissions is increasing. Although mandatory reductions are not currently in place in most places, many forward-thinking and conscientious individuals and organizations are working to reduce their own emissions. There currently exist voluntary trading programs allowing individuals who reduce their emissions to sell the value of those reductions to others to offset their own emissions.

Carbon Neutral North is one voluntary program that provides an opportunity to offset emissions, and uses 'Gold Standard' credits. The current cost of carbon offsets through this program is $35 per tonne.

The following table shows the value of the estimated reductions in carbon emissions as a result of the biomass district heating system in the communities analysed in this study, both annually and over a 20 year project life. This is not to imply that these reductions could be sold as credits for this amount, as that would require independent monitoring and verification. This is merely intended to give an economic value to the reduction of environmental impact. The values shown are the costs that would be paid (at current prices) to purchase carbon offset credits for the emissions that will occur without the installation of the pellet fired district heating systems modeled in this study.

GREENHOUSE GAS REDUCTION VALUES			
Community	**Annual GHG reduction (tonnes)**	**Annual Offset Value**	**Lifetime (20yr) Offset Value**
All Weather Road			
Enterprise	430	$15,000	$300,000
Kakisa	99	$3,500	$70,000
Fort Providence	1100	$39,000	$780,000
Fort Resolution	980	$35,000	$700,000
Jean Marie River	230	$8,100	$162,000
Behchoko (Rae)	2100	$75,000	$1,500,000
Dettah	370	$13,000	$260,000
Fort Liard	610	$22,000	$440,000
Wrigley	160	$5,800	$116,000
Fort McPherson	1200	$41,000	$820,000
Tsiigehtchic	430	$15,000	$300,000
Ice Road			
Trout Lake	120	$4,400	$88,000
What'i	670	$24,000	$480,000
Nahanni Butte	130	$4,500	$90,000
Gameti	210	$7,500	$150,000
Wekweeti	350	$12,000	$240,000
Tulita	600	$21,000	$420,000
Deline	850	$30,000	$600,000
Norman Wells	1900	$69,000	$1,380,000
Fort Good Hope	490	$17,000	$340,000
Colville Lake	74	$2,600	$52,000
Aklavik	1300	$45,000	$900,000
Tuktoyaktuk	1400	$48,000	$960,000

6.0 What We Learned

Based on our analysis, the following communities have favourable economic potential for a biomass district heating system and warrant further investigation:

All Weather Road Communities:

- Fort Resolution
- Fort Providence
- Behchoko
- Wrigley

Winter Road Resupply Communities:

- Whati
- Gameti
- Tulita
- Fort Good Hope
- Tuktoyaktuk

There is both Territorial and Federal Government funding available, both infrastructure funding and climate change funding, that could be accessed to assist communities to develop biomass fired heating systems. A community-owned central utility may prove to be a favourable model for developing these systems.

7.0 Recommendations

- Increase efforts to publicize cost savings and greenhouse gas reductions of existing wood pellet boiler systems, in particular those installed by the GNWT, to build awareness and confidence in commercial wood pellet heating.

- Identify at least one all-weather road community that has the best combination of strong local interest in a potential project, favourable economics, and close proximity to existing commercial biomass systems for availability of trained operation and maintenance personnel. A feasibility study should then be undertaken for a pilot project of a community biomass district heating system, working toward a planned completion by the start of the 2011/2012 heating season.

Appendix A: Fuel Costs

For more detailed information on the cost of transporting wood pellets to all communities in the NWT, compared to the cost of heating fuel, see the pellet cost study previously released by AEA.

Community	Landed Cost of Bulk Pellets ($/tonne)	Pellet Source	Bulk Pellet Cost per GJ	Cost of Heating Oil May 2008 ($/GJ)	Cost of Heating Oil May 2009 ($/GJ)	Cost of Heating Oil May 2008 ($/L)	Cost of Heating Oil May 2009 ($/L)
All Weather Road							
Enterprise	$147	AB	$7.45	$33.33	$21.61	$1.28	$0.83
Kakisa	$151	AB	$7.64	$35.16	$21.61	$1.35	$0.83
Fort Providence	$154	AB	$7.80	$36.20	$24.48	$1.39	$0.94
Fort Resolution	$158	AB	$8.01	$35.16	$23.44	$1.35	$0.90
Fort Smith	$168	AB	$8.52	$31.51	$21.09	$1.21	$0.81
Jean Marie River	$175	AB	$8.90	$32.29	$24.48	$1.24	$0.94
Behchoko	$175	AB	$8.90	$32.29	$21.61	$1.24	$0.83
Fort Liard	$172	BC	$8.74	NA	$22.45	no data	$0.86
Wrigley	$201	AB	$10.22	$38.80	$31.25	$1.49	$1.20
Fort McPherson	$259	BC	$13.12	$33.07	$28.65	$1.27	$1.10
Tsiigehtchic	$262	BC	$13.32	$35.42	$31.51	$1.36	$1.21
Winter Road Resupply							
Trout Lake	$200	AB	$10.13	$39.06	$28.39	$1.50	$1.09
What'i	$201	AB	$10.22	$36.72	$25.52	$1.41	$0.98
Nahanni Butte	$189	BC	$9.61	$40.10	$27.60	$1.54	$1.06
Gameti	$224	AB	$11.40	$38.02	$28.91	$1.46	$1.11
Wekweeti	$249	AB	$12.66	$41.93	$30.99	$1.61	$1.19
Tulita	$263	BC	$13.33	$25.78	$32.55	$0.99	$1.25
Deline	$281	BC	$14.26	$35.42	$25.78	$1.36	$0.99
Norman Wells	$282	BC	$14.31	$34.64	$21.83	$1.33	$0.84
Fort Good Hope	$315	BC	$16.01	$33.85	$32.29	$1.30	$1.24
Colville Lake	$350	BC	$17.75	$40.63	$31.77	$1.56	$1.22
Aklavik	$297	BC	$15.10	$40.89	$23.44	$1.57	$0.90
Tuktoyaktuk	$315	BC	$16.00	$39.84	$41.67	$1.53	$1.60

Appendix B: Cost Factors

Note that the following values are intended to be pre-feasibility 'Class D' estimates at best, to allow a relative comparison of communities.

Community	Community Cost Factor (Pipe, Connections)	Equipment Cost Factor (Boiler, Silo)	Boiler Cost Factor (1MW)	Piping Cost Factor (per m)	Connection Cost Factor (Double for ICI bldgs)	Silo Cost Factor
All Weather Road						50 t
Enterprise	110%	105%	$525,000	$385	$11,000	$52,500
Kakisa	124%	112%	$560,000	$434	$12,400	$56,000
Fort Providence	125%	113%	$562,500	$438	$12,500	$56,250
Fort Resolution	111%	106%	$527,500	$389	$11,100	$52,750
Jean Marie River	152%	126%	$630,000	$532	$15,200	$63,000
Behchoko (Rae)	110%	105%	$525,000	$385	$11,000	$52,500
Dettah	105%	103%	$512,500	$368	$10,500	$51,250
Fort Liard	137%	119%	$592,500	$480	$13,700	$59,250
Wrigley	140%	120%	$600,000	$490	$14,000	$60,000
Fort McPherson	135%	118%	$587,500	$473	$13,500	$58,750
Tsiigehtchic	158%	129%	$645,000	$553	$15,800	$64,500
Ice Road						200 t
Trout Lake	133%	117%	$582,500	$466	$13,300	$116,500
What'i	154%	127%	$635,000	$539	$15,400	$127,000
Nahanni Butte	152%	126%	$630,000	$532	$15,200	$126,000
Gameti	135%	118%	$587,500	$473	$13,500	$117,500
Wekweeti	155%	128%	$637,500	$543	$15,500	$127,500
Tulita	138%	119%	$595,000	$483	$13,800	$119,000
Deline	140%	120%	$600,000	$490	$14,000	$120,000
Norman Wells	130%	115%	$575,000	$455	$13,000	$115,000
Fort Good Hope	138%	119%	$595,000	$483	$13,800	$119,000
Colville Lake	225%	163%	$812,500	$788	$22,500	$162,500
Aklavik	137%	119%	$592,500	$480	$13,700	$118,500
Tuktoyaktuk	140%	120%	$600,000	$490	$14,000	$120,000

Appendix C: District Heating System Details

Note that the following values are intended to be pre-feasibility ‘Class D’ estimates at best, to allow a relative comparison of communities.

Pellet Fired District Heating System Details																
Community	Number of Houses Connected	Number of ICI Buildings Connected	ICI Buildings Total Estimated Floor Area (m2)	DHS Piping Length (m)	DHS Annual Heating Demand (GJ)	Pellet Boiler Sizing (MW)	Expected District Heating Pellet Use (tonnes)	Equivalent Heating Oil Usage (litres)	Annual Cost of Pellets	Annual Savings of Heating Oil	Annual Savings of Heating Oil	Boiler Cost	Piping/ Trenching Cost	Cost of Connections	Cost of Pellet Storage	TOTAL ESTIMATED SYSTEM COST
All Weather Road										2009	2008					
Enterprise	21	10	3,741	730	5,543	0.24	296	160,399	$47,066	$133,131	$205,311	$367,500	$281,050	$451,000	$52,500	$1,152,050
Kakisa	8	3	572	285	1,266	0.05	68	36,635	$11,041	$30,407	$49,457	$224,000	$123,690	$173,600	$56,000	$577,290
Fort Providence	65	4	8,514	1,700	14,120	0.61	754	408,557	$126,146	$384,043	$567,894	$562,500	$743,750	$912,500	$56,250	$2,275,000
Fort Resolution	69	4	6,616	1,425	12,588	0.55	673	364,233	$115,353	$327,810	$491,715	$527,500	$553,613	$854,700	$52,750	$1,988,563
Jean Marie River	19	5	1,270	540	2,944	0.13	157	85,179	$29,996	$80,069	$105,622	$252,000	$287,280	$440,800	$63,000	$1,043,080
Behchoko (Rae)	141	15	12,010	2,480	27,196	1.08	1,453	786,922	$281,333	$653,145	$975,783	$787,500	$954,800	$1,881,000	$52,500	$3,675,800
Dettah	17	7	2,750	435	4,728	0.19	253	136,797	$51,786	$113,542	$166,893	$358,750	$159,863	$325,500	$51,250	$895,363
Fort Liard	23	6	5,788	950	7,871	0.33	421	227,756	$89,795	$195,870		$414,750	$455,525	$479,500	$59,250	$1,409,025
Wrigley	4	2	1,465	100	2,092	0.08	112	60,518	$24,519	$72,622	$90,173	$240,000	$49,000	$112,000	$60,000	$461,000
Fort McPherson	40	9	8,530	1,130	14,892	0.47	796	430,889	$335,786	$473,978	$547,230	$411,250	$533,925	$783,000	$58,750	$1,786,925
Tsiigehtchic	30	4	1,835	730	5,533	0.18	296	160,106	$126,424	$193,729	$217,745	$451,500	$403,690	$600,400	$64,500	$1,520,090
Ice Road																
Trout Lake	5	4	1,150	250	1,590	0.07	85	46,010	$17,647	$50,151	$69,016	$233,000	$116,375	$172,900	$116,500	$638,775
What'i	18	8	5,840	670	8,546	0.33	457	247,279	$97,812	$242,333	$348,663	$444,500	$361,130	$523,600	$381,000	$1,710,230
Nahanni Butte	10	3	740	275	1,621	0.07	87	46,901	$18,102	$49,716	$72,228	$252,000	$146,300	$243,200	$126,000	$767,500
Gameti	0	4	2,360	85	2,716	0.11	145	78,576	$33,722	$107,649	$114,721	$235,000	$40,163	$108,000	$117,500	$500,663
Wekweeti	22	4	1,930	610	4,453	0.17	238	128,837	$59,955	$197,120	$207,427	$446,250	$330,925	$465,000	$255,000	$1,497,175
Tulita	10	5	5,820	275	7,711	0.30	412	223,130	$112,240	$278,913	$220,899	$416,500	$132,825	$276,000	$357,000	$1,182,325
Deline	43	5	5,700	650	10,921	0.42	584	316,001	$168,410	$312,841	$429,761	$420,000	$318,500	$742,000	$360,000	$1,840,500
Norman Wells	137	9	9,613	1,940	24,959	0.97	1,334	722,205	$385,960	$551,909	$960,532	$575,000	$882,700	$2,015,000	$805,000	$4,277,700
Fort Good Hope	8	3	4,750	240	6,277	0.24	335	181,634	$106,930	$225,226	$236,124	$416,500	$115,920	$193,200	$238,000	$963,620
Colville Lake	0	3	820	65	944	0.04	50	27,302	$17,585	$33,308	$42,591	$325,000	$51,188	$135,000	$162,500	$673,688
Aklavik	80	4	5,510	1,410	16,168	0.50	864	467,828	$400,337	$421,045	$734,490	$414,750	$676,095	$1,205,600	$592,500	$2,888,945
Tuktoyaktuk	60	9	7,600	1,110	17,403	0.56	930	503,565	$445,425	$805,704	$770,454	$600,000	$543,900	$1,092,000	$600,000	$2,835,900