Biomass Energy
Native Village of Kaltag

Preliminary Feasibility Assessment

This preliminary feasibility assessment considers the potential for heating community buildings in Kaltag with woody biomass from regional forests and river logs.

Dalson Energy Inc.

308 G St. Ste 303

Anchorage, Alaska 99501

907-277-7900

8/19/2012

Dalson Energy

Table of Contents

Project Summary

Interior Regional Housing Authority (IRHA) and Tanana Chiefs Conference (TCC) contracted Dalson Energy to do a Pre-Feasibility Study for biomass heating of community buildings in the Native Village of Kaltag.

Dalson Energy biomass specialists Thomas Deerfield and Wynne Auld visited the community on June 15, 2012 for the initial assessment. Deerfield and Auld made their assessment based on available data, interviews with local stakeholders and authorities, observations, and research and review of previous studies done in Kaltag.

It was noted that there are several other studies and reports that address various aspects of biomass energy in Kaltag, including Forestry Resource assessments done by TCC Forester Will Putman and DNR Division of Forestry. Clare Doig of Forest and Land Management Inc. is also completing a forest management plan for the regional corporation, Gana'A-Yoo. These studies are the foundation for further evaluation of community heating with woody biomass in Kaltag, as exercised in this pre-feasibility assessment.

This report was prepared by Thomas Deerfield, Wynne Auld, Louise Deerfield, and Clare Doig.

Contact and interviews with the following individuals in Kaltag assisted in some of the information gathering. Their contact information is as follows:

City - City of Kaltag
P.O. Box 9
Kaltag, AK 99748
Phone 907-534-2301
Fax 907-534-2236

Jackie Nicholas, City Manager, jdsnicholas@hotmail.com
Tommy Neglaska, Washateria Manager, tommyneglaska@yahoo.com

Tribe-- Kaltag Village, federally-recognized
P.O. Box 129
Kaltag, AK 99748
Phone 907-534-2224
Fax 907-534-2299
E-mail kaltag@aitc.org

Anne Esmailka, Tribal Administrator
Violet Burnham, Mayor and Kaltag Rep. for Gana'a'Yoo Natural Resources Committee

School—Kaltag School
PO Box 30
Main Street
Kaltag, AK 99748
Phone: (907) 534-2204
Fax: (907) 534-2227

Gale Bourne, YKSD Facilities, gbourne@yksd.com
Nancy Mason, Principal/Teacher, nmason@yksd.com
Bernice Moore, Secretary, bmoore@yksd.com

Summary of Findings

The three projects examined are (1) Kaltag School, (2) Washateria/ Waterplant, and (3) City & Tribal Office Cluster. All of the candidate facilities identified could be served by HELE (high efficiency, low emission) cordwood boiler systems; or, alternatively, the the Kaltag School could be served by a wood chip system.

There is strong technical feasibility for all projects examined. All projects could be heated by a cordwood boiler, with the Washateria and School projects being containerized units and the City and Tribal Office being a boiler installed in in the existing building. All projects would require a new fuel storage room.

Alternatively, the Kaltag School could be heated by a semi-automated wood chip system instead of a cordwood boiler. The feasibility of this technology is subject to a Harvest Plan and Operations Plan, as well as the preferences of the School administration and maintenance personnel.

The project's success is critically dependent on a Biomass Harvest Plan and an Operations Plan. The need for these project Plans are discussed in this Pre-Feasibility Analysis.

Dalson Energy provides this report to IRHA and TCC, and those agencies will determine the next steps forward.

Wood fuel supply in Kaltag

Kaltag, with a population of 205 (2011 Alaska Census Estimate), is located 75 miles west of Galena and 335 miles west of Fairbanks.

In 1990 Tanana Chiefs Conference completed a timber inventory of the ANCSA Native village lands around Kaltag. The village corporation, GANA-A'YOO, Limited, owns approximately 115,000 acres, of which approximately 23,000 acres are forested, holding an estimated 47.835 million cubic feet of saw timber and pole timber. Much of this material could be considered woody biomass suitable for wood fueled heating systems. Doyon, Limited, the regional corporation, is the other major landowner in the region, as indicated by Figure 1: Land Ownership Surrounding Kaltag, AK.

While these inventory figures indicate a substantial timber resource, sites supporting tree growth are widely distributed and may be difficult to access because of the area characteristics and the lack of existing roads. The Village is located along a major river system with expansive low elevation wetlands, resulting in widely distributed higher elevation sites that support tree growth.

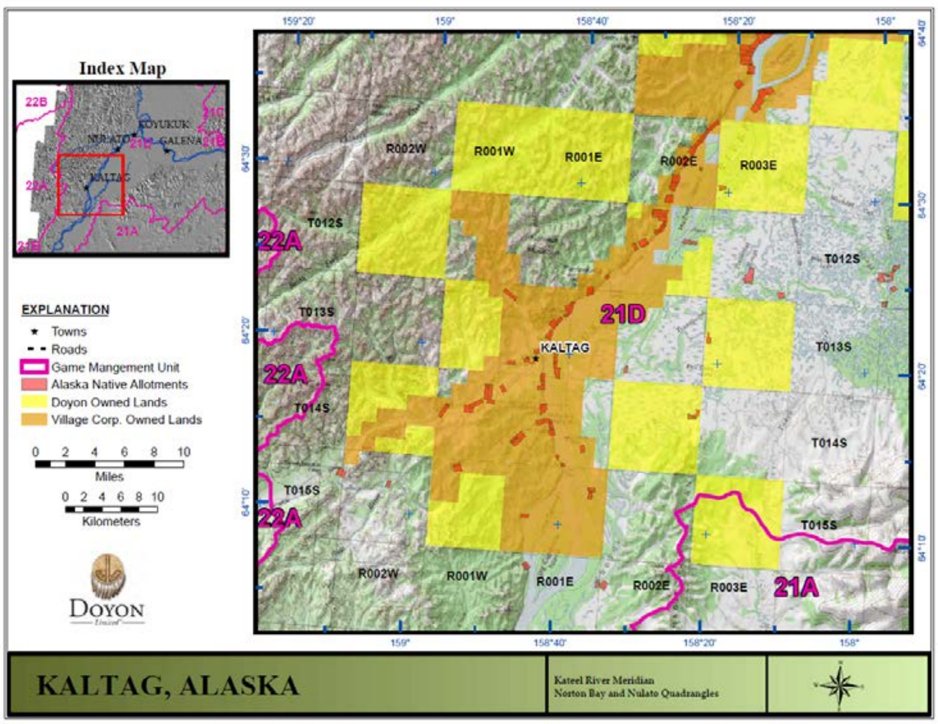

Figure 1: Land Ownership Surrounding Kaltag, AK

Kaltag, all owners

Proxiity to village (miles)	Total air-dry tons	AAC (tons/year)	Acreage
0 - 1	22,661	628	1,182
1 - 2	89,266	2,605	4,943
2 - 3	182,554	5,577	9,644
3 - 4	267,861	8,383	14,716
4 - 5	384,025	12,430	21,167
5 - 6	559,511	18,273	30,479
6 - 7	663,304	21,780	36,394
7 - 8	701,542	22,706	38,622
8 - 9	815,811	26,718	44,774
9 - 10	871,386	28,109	47,581
10 - 11	953,561	31,232	52,169
11 - 12	974,245	32,222	52,902
12 - 13	1,069,797	35,516	58,448
13 - 14	1,124,705	37,602	63,326
14 - 15	1,190,826	39,972	67,627
15 - 16	1,212,083	40,401	69,345
16 - 17	1,064,699	35,713	64,150
17 - 18	935,184	31,577	56,182
18 - 19	920,981	30,588	54,771
19 - 20	969,180	32,543	55,779
20 - 21	930,502	31,450	54,203
21 - 22	819,643	27,684	49,526
22 - 23	795,110	26,272	48,640
23 - 24	839,013	27,626	49,357
24 - 25	859,671	27,990	51,141
Total KALTAG:	19,217,121	635,598	1,097,068

Figure 2: Biomass stock and annual allowable cut surrounding Kaltag, AK from TCC Inventory

The community of Kaltag also practices river logging. Dependability and volume of river-caught logs have not been documented.

Community leaders in Kaltag suggested that firewood is the main residential heating fuel in Kaltag. The current market price, determined by TCC, is $275 per cord. There are 62 homes in Kaltag, using an estimated average of 5 – 7 cords per year.

If the projects described in this study were undertaken, the community of Kaltag would harvest up to 290 additional cords and/or up to 150 green tons of wood per year, increasing their annual volume by about 50% from currently estimated usage.

Biomass Energy Operations and Maintenance

Biomass Harvest Plan

Wood cutting is a subsistence activity in almost all interior villages adjacent to forest land. This subsistence resource must be carefully managed or biomass energy projects may be detrimental to the Community.

If biomass harvests are unmanaged, the natural tendency is to harvest the most accessible wood supply first, as illustrated below. The effect is increased scarcity and rising harvest cost, and, consequently, biomass fuel costs, for both the project and household woodcutters. This puts community members' energy security and the project's success at risk.

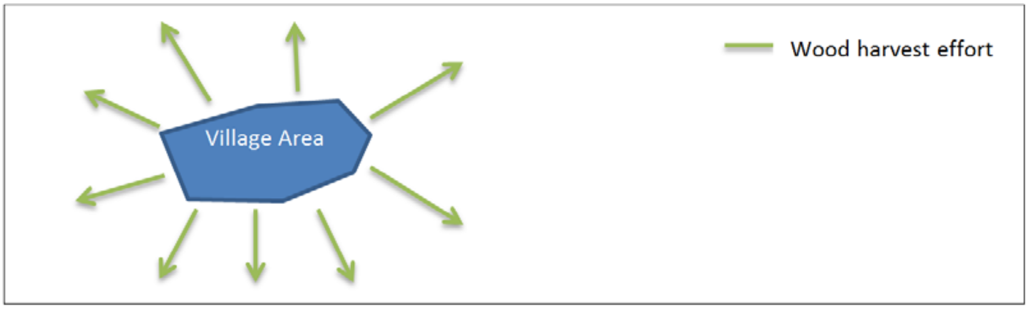

Figure 3: Illustration of Unmanaged Wood Harvesting Efforts

The project's success depends on a well-developed and executed Harvest Plan. The Harvest Plan accounts for the biomass harvests over the project lifetime, at least 20 years. It may also designate areas for Personal Use (household wood cutting). The Harvest Plan also describes how who is responsible for executing the Harvest Plan, and how access will be managed. Please see figure below.

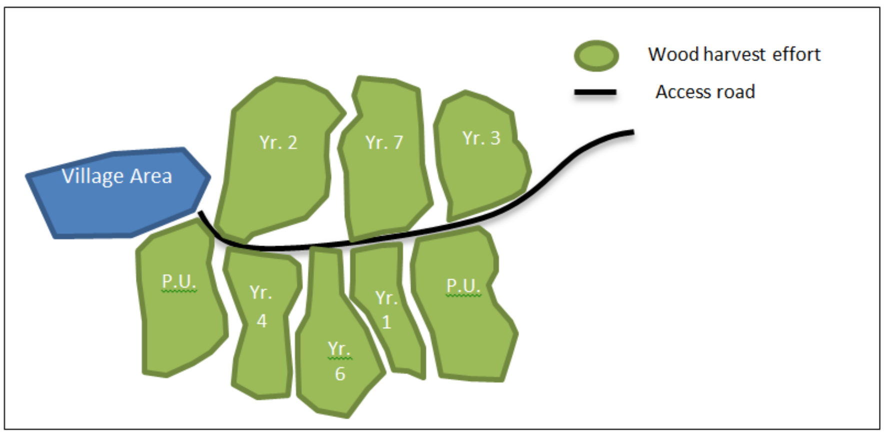

Figure 4: Illustration of Planned Wood Harvest by Harvest Area and Time Period.

Because the project's success is *critically dependent* on a Biomass Harvest Plan, the Consultant strongly recommends developing this Plan prior to project development.

In Kaltag, harvest of Cottonwood for cordwood and/or Black Spruce for wood chips would not be expected to interfere with the supply of personal-use firewood, since these species are not preferred for home heating.

Operations Plan

In many Villages biomass boiler projects will depend on collaboration among a variety of entities, including contract wood cutters, forest landowners, the boiler technician, building owners and operators, and various governmental entities.

Figure 5: Kaltag Washateria

A plan for collecting biomass, paying wood suppliers, allocating costs among heat users, and operating and maintaining the boiler and heat distribution system is crucial to the project's success. Persons responsible for each task must be identified.

Because the project's success is critically dependent on an Operations Plan, the Consultant strongly recommends developing this Plan prior to project development.

Community Facilities Information

The community buildings in Kaltag considered for biomass heating are Tribal building, City Building, Washateria/Water-plant, and Kaltag School. The City and Tribal buildings are considered a cluster and evaluated as a single heat plant. The Clinic, Fire-hall, and Community Hall are adjacent to this cluster, but were not considered for biomass heating, for reasons discussed below.

Figure 6: Kaltag community buildings. Washateria/ waterplant (8), City Hall (14), Tribal Hall (15), Clinic (12), Community Hall (13), Fire Hall (10), School (18).

Tribal Buildings

Tribal buildings include the Tribal Building.

Tribal Building

The Tribal Building also uses one (1) Buderus Boiler with a capacity of 120,000 btu/hr to heat about 3,500 sq. ft via hydronic baseboard heaters. The building has four zones. There is also an addition to the North side of the building that houses the boiler room. While the addition to the North side does not appear to be heated, it houses a separate boiler room that was observed to be extremely warm inside. There also may be maintenance issues with the controls, as the consultant observed that the boiler was firing even though it was over 65°F outside.

City Buildings

City Buildings include the City Office, Washateria/Water-plant, Fire-hall, Community Hall, and Clinic.

City Office

The City Building uses one (1) Buderus Boiler with a capacity of 106,000 btu/hr to heat 3,300 sq. ft. The City Building used 775 gallons in FY 2012. The building was reportedly recently weatherized.

Washateria/Waterplant

The Washateria/Water-plant is a single heating system providing space and domestic hot water for the Washateria as well as water heating for residences for a portion of uptown. The Washateria/ Water-plant is heated with three boilers: two (2) Weil McClain 76 model boilers, 416,000 BTU; and one (1) Weil McClain 213,000 BTU boiler. Heat loads often require one large and the small boiler to fire. The heat distribution system is in its second year of operation and is performing well.

The Washateria/Water-plant was operated by Tommy Neglaska at the time of consultant's visit. Mr. Neglaska meticulously maintained the facility and kept records of the fuel consumption. The fuel consumption for 2012 follows:

Washateria/ Waterplant (gallons fuel oil #1)	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	**TOTAL**
	131	77	232	220	330	687	654	919	792	812	561	381	5,796

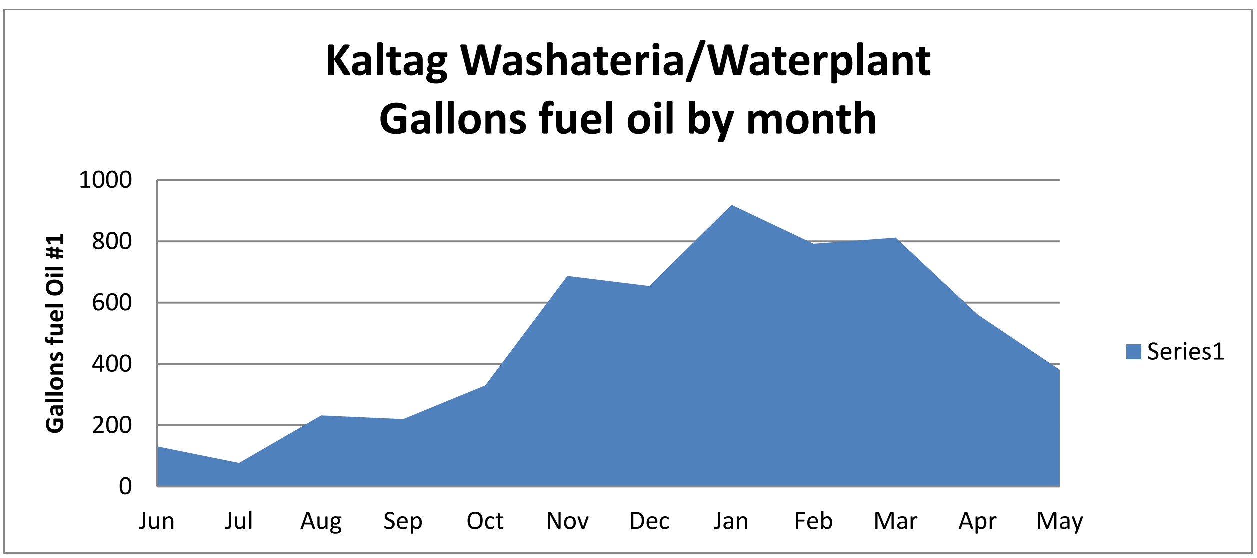

Figure 7: Kaltag Washateria/ Waterplant Gallons of Fuel by Month

Community Hall

The Community Hall is heated only for events. It holds a Toyo-stove and a woodstove. Because it is not heated regularly, it was not considered for biomass heating.

Firehall

The Fire-hall is usually rented out and used by the Iditarod Race Organizers. However, the City has decided to close the Fire-hall this winter to reduce utility costs. Last year, the Fire-hall used 875 gallons of fuel oil. Because the Fire-hall is not expected to have any heat demand in the near future, it was not considered for biomass heating.

Clinic

A new Clinic is planned in Kaltag. Given the biomass resource base and local climatic conditions, it is strongly recommended that a biomass heating system, along with passive solar design, super-insulation, and protected artic entry be considered for the building design.

This Clinic may also have the ability to cost-effectively integrate a District Heating system. The Consultants recommend that the designers of the Clinic consider clustering heat loads when designing the building. The location of the Clinic has already been chosen. Because a new Clinic is planned in Kaltag, the existing Clinic was not considered for biomass heating.

School

The Kaltag School was not toured during this visit, but information was gathered from the YKSD Facilities Department. The Kaltag School is a new school building with a newly engineered heating system. The School has a separate boiler building housing five (5) fuel oil boilers. Over the past five years, the School and adjacent buildings (such as teacher housing) have averaged 19,000 gallons per year of oil. The heat is distributed via hydronic heat pipes, and converted to hot air for heating some areas. Over the past five years, the average price per gallon was $3.10; AEA has projected the cost per gallon in 2012 to be $4.10 per gallon.

Mr. Bourne of YKSD Facilities Department stressed the important of reliability from any heating source.

Building Name	Tribal Office	City Office	Washateria/ Waterplant	School
Annual Gallons (Fuel Oil #1)	775 gal/yr	1,294 gal/ yr	5,796	19,000 gal/ yr
Building Usage	During workdays only. No weekends.	During workdays only. No weekends.	Seven days per week.	During the School year
Heat Transfer Mechanism	Hydronic	Hydronic	Hydronic	Hydronic
Heating infrastructure need replacement?	No	No	Unknown	No
Maximum cords to heat the building	17		49	160

Recommended technology and fuel requirements

The suggested system design for all three projects is a pre-fabricated, modular, containerized wood biomass boiler unit. The suggested unit has been shown to be reliable and highly efficient. Because it is modular, it has a lower installation cost and offers financing advantages. Either cordwood or wood chips may be recommended as the system fuel, as described below.

From initial surveys of the Kaltag area, it appears that Cottonwood and Black Spruce are relatively abundant species, although neither is preferred for personal-use cordwood for home heating. Cordwood could be manufactured from Cottonwood, using chainsaws and a log splitter. Chips could be manufactured from Black Spruce trees using a hand-fed chipper. If the harvest were properly planned, use of these fuels would not threaten the supply of cordwood available for home heating.

Washateria/Waterplant

For the Washateria/ Water-plant, a containerized HELE (high efficiency, low emissions) cordwood boiler is suggested. These types of systems are produced by GARN, TARM USA and others. These units have 120,000 – 700,000 BTU/hr output capacity and store 415,000 or more BTU in hot water tanks. One such unit, the GarnPac, has an output of about 350,000 BTU output and is currently being employed in Thorne Bay.

This type of system is recommended because it has demonstrated reliability, uses an accessible fuel (cordwood), and meets the heat load requirements of the Washateria/ Water-plant.

Other communities operating HELE cordwood boilers of a similar size, such as Dot Lake and Ionia, report 2 cordwood stokings per day and 0.125 – 0.5 FTE[1] (Full-time equivalent employee) per boiler.

The Washateria/ Water-plant heat load is an estimated 150,000 – 275,000 btu/hr during the heating season. Correct boiler sizing could be subject to further feasibility study.

For the purposes of this study, Dalson Energy modeled a biomass boiler capacity of 350,000 btu/hr for the Washateria / Water-plant, serving 90% of the heat load.

Tribal and City Office Cluster

The Tribal and City Office Cluster load is quite small, requiring only the equivalent of about 17 cords per year. Because the existing fuel oil usage is relatively small, the amount of savings from using biomass (cordwood) are also relatively small.

The City and Tribal Office Cluster heat load is an estimated 50,000 – 105,000 btu/hr during the heating season. Correct boiler sizing could be subject to further feasibility study.

For the purposes of this study, Dalson Energy modeled a pre-fabricated, containerized cordwood boiler with a capacity of 120,000 btu/hr for the Tribal & City Office Cluster.

[1] Nicholls, David. 2009. Wood energy in Alaska–case study evaluations of selected facilities. Gen. Tech. Rep. PNW-GTR-793. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 33 p.

Kaltag School

The Kaltag School's heat load is the largest of any of the community buildings. The heat load is an estimated 200,000 btu/hr – 1,000,000 btu/hr.

The Kaltag School could employ a cordwood boiler system, a small wood chip system, or a wood pellet system, depending on user's preferences and access to biomass. Pellets would need to be imported from outside the Village, but woodchips and cordwood could be procured from local forests given an effective Harvesting Plan and investment in the appropriate equipment.

One challenge is that wood chip systems are operationally more complex than wood pellet or cordwood systems, because they require multi-step wood fuel manufacturing. They also require more machinery to process fuel. To produce woodchips, the Community would need an effective way of harvesting, processing, and handling chips. Trees could be hand-felled and hand-fed into a grinder and then automatically fed into a storage bin or chip van. Saw log or cordwood quality segments could be separated and merchandised separately. Screens would be utilized to control chip size and consistency. Additionally, woodchip storage would need to be managed with a bobcat or other loading device to improve airflow and decrease moisture content.

While the chip processing and handling infrastructure is more expensive, the Community would benefit from automated boiler operation and reduced operating costs, as well decreased pressure on the Cordwood supply and access to a wider range of tree species and sizes.

If a cordwood boiler were employed, the system could use up to 160 cords per year of Cottonwood and other available species.

If a wood chip boiler were employed, the system could use up to 250 tons of 40% MC chips.

To complete this prefeasibility analysis, the Consultant has chosen a representational boiler, a 350 BTU/hr containerized cordwood boiler. Running at maximum capacity, this boiler would offset only a portion of the load of the School (estimated 40-50%). However, with an effective fuel harvesting and operations plan, it would probably be the most reliable wood heating system available to the Community. Also, an effective fuel harvesting and procurement plan could prioritize fuels that do not interfere with cordwood gathering.

The buildings' existing Fuel Oil infrastructure would be retained to meet peak demand and as back up in every project building.

Fuel Consumption

Assumptions:	
16.00	MMBTU/ Cord Cottonwood
0.1350	MMBTU per gallon Oil #1
10.32	MMBTU per ton of chips

	Annual Gallons	Annual MMBTU	Annual Cords (maximum)	Annual wood chip demand (maximum)
Cluster: City and Tribal Office	**2,069**	**279**	**17**	**27**
Washateria/ Waterplant	**5,800**	**783**	**49**	**76**
School	**19,000**	**2,565**	**160**	**249**

Initial project development costs for a wood heating system costs *may* include:

- **Capital costs:** boiler, hydronic pipe and other hardware, wood storage shelter, fuel-handling equipment, shipping costs.
- **Engineering:** storage design, plumbing integration, fuel-handling infrastructure.
- **Permitting:** no permits required. In lieu of permits, all regulations must be met.
- **Installation:** Site work, installation, and integration into existing system.
- **Fuel storage:** storage building, firewood chutes, or preparation of existing storage room.
- **System building:** (if required).

Ongoing operational costs *may* include:

- **Financing:** Principal and interest payments from project debt, or profits from project equity investment. In Village projects, financing costs likely do not apply.
- **Wood fuel purchases.**
- **Amortization costs:** capital equipment and other infrastructure.[2] When projects are grant financed, amortization does not apply.
- **Operations and Maintenance (O&M) labor.**
- **Fossil fuel purchases and labor.**[3]

Initial investment

The City and Tribal Office Cluster has an estimated Capitalization Cost of $249,000.

The Waterplant/ Washateria has an estimated Capitalization Cost of $257,000.

The Kaltag School has an estimated Capitalization Cost of $277,000. This is for a system that will offset 40 % of the School's fuel oil consumption.

2 Cash and accrual basis are two different accounting methods for project investment. Accrual accounting amortizes project investment over the project lifetime ("lifecycle costs"). This method results in monies to reinvest in new equipment at the end of its lifetime. Cash basis is simply on the dollars spent to operate, maintain, and finance the project.
8 The existing oil heat infrastructure will be retained for supplement heat and back-up. Therefore, the fossil fuel system has ongoing O&M costs, albeit lower than if used as the primary heat source.

See charts below for cost estimates and sources. Full feasibility analysis and/or bids would provide more detailed numbers.

City & Tribal Office Cluster

Biomass System	
Rating -- Btu/hr	120,000
Btu stored	160,000

	footnote		*notes*
Building and Equipment Costs (B&E) $			
Fuel Storage Building (fabricated building, gravel pad, $27/sf)		$ 7,560	(14 cds @ 20 sq. ft. / cd.)
Pre-Fabricated Boiler System			
Base price	A	$ 93,000	
Shipping to hub	B	$ 20,000	
Bush delivery	B	$ 10,000	
Plumbing and electrical	B	$ 2,500	
Site Prep	B	$ 4,500	
Building integration	B	$ 30,000	$15,000 per building
Heat loop		$ 6,600	$33 per ft, 200 ft.
Subtotal-B&E Costs		***$ 167,560***	
Contingency -- 20%		***$ 33,512***	
Grand Total		**$ 201,072**	
Soft Costs $			
Project Management	B	$ 16,086	8% of B&E
A/E Design Services	B	$ 12,064	6% of B&E
Fire Marshall Plan Review	B		pre-approved
Equipment Commissioning and Training	B	$ 4,000	
Construction Management	B	$ 16,086	8% B&E
Subtotal -- Soft Costs		**$ 48,236**	
Recommended Project Budget -- Design and Construction C		**$ 249,308**	

footnote	
A	Based on quotes from viable suppliers
B	Estimate

Waterplant/ Washateria

Biomass System	
Rating -- Btu/hr	350,000
Btu stored	415,000

	footnote		*notes*
Building and Equipment Costs (B&E) $			
Fuel Storage Building (fabricated building, gravel pad, $27/sf)		$ 21,060	(39 cds @ 20 sq. ft. / cd.)
Pre-Fabricated Boiler System			
Base price	A	$ 100,000	
Shipping to Hub	B	$ 20,000	
Bush Delivery	B	$ 10,000	
Plumbing and electrical	B	$ 2,500	
Site Prep	B	$ 4,500	
Integration (Wash + Waterplant)	B	$ 15,000	
Subtotal-B&E Costs		***$ 173,060***	
Contingency -- 20%		***$ 34,612***	
Grand Total		**$ 207,672**	

Soft Costs $			
Project Management	B	$ 16,614	8% of B&E
A/E Design Services	B	$ 12,460	6% of B&E
Fire Marshall Plan Review	B		pre-approved
Equipment Commissioning and Training	B	$ 4,000	
Construction Management	B	$ 16,614	8% B&E
Subtotal -- Soft Costs		**$ 49,688**	

Recommended Project Budget -- Design and Construction Cost $ 257,360

footnote	
A	Based on quotes from viable suppliers
B	Estimate

Initial investment: Kaltag School

Biomass System	
Rating -- Btu/hr	350,000
Btu stored	415,000

	footnote		notes
Building and Equipment Costs (B&E) $			
Fuel Storage Building (fabricated building, gravel pad, $27/sf)	C	$ 24,300	(45 cds @ 20 sq. ft. / cd.)
Pre-Fabricated Boiler System			
Base price	A	$ 100,000	
Shipping to Hub	B	$ 20,000	
Bush Delivery	B	$ 10,000	
Plumbing and electrical	B	$ 2,500	
Site Prep	B	$ 4,500	
Integration	B	$ 15,000	
Subtotal-B&E Costs		***$ 176,300***	
Contingency -- 20%		***$ 35,260***	
Grand Total		**$ 211,560**	
Soft Costs $			
Fuel procurement plan		$ 15,000	
Project Coordination	B	$ 16,925	8% of B&E
A/E Design Services	B	$ 12,694	6% of B&E
Fire Marshall Plan Review	B		pre-approved
Equipment Commissioning and Training	B	$ 4,000	
Construction Management	B	$ 16,925	8% B&E
Subtotal -- Soft Costs		**$ 65,543**	
Recommended Project Budget -- Design and Construction Costs		**$ 277,103**	

footnote	
A	Based on quotes from viable suppliers
B	Estimate
C	64 cords total consumption throughout year. Inventory management with 19 cords stored offsite.

Financial Analysis

The following financial analyses make use of AEA's financial Benefit: Cost model.

Please note that the market price for household cordwood is reportedly determined by the TCC price, currently $300/cord. In the course of modeling this project, Dalson Energy has used $250/cord to represent the price per cord of Cottonwood and other non-preferred species, which is estimated to be more accessible than White Spruce and other preferred species.

For each building, Dalson Energy estimated the percentage of heating oil offset by considering a heating degree day model of the buildings' energy load. For the Kaltag School, a single 350,000 btu/hr boiler was assumed to offset 40-50% of the School's heating oil.

Operating Costs & Annual Savings

City and Tribal Office

Project Description	
Community	Kaltag
Nearest Fuel Community	
Region	Rural
RE Technology	Woody biomass heat
Project ID	
Applicant Name	Village of Kaltag
Project Title	Kaltag City and Tribal Hall Wood Heat
Category	

Results	
NPV Benefits	$71,126
NPV Capital Costs	$242,046
B/C Ratio	0.29
NPV Net Benefit	($170,921)

Performance	Unit	Value
Displaced Electricity	kWh per year	-
Displaced Electricity	total lifetime kWh	-
Displaced Petroleum Fuel	gallons per year	6,003
Displaced Petroleum Fuel	total lifetime gallons	64,685
Displaced Natural Gas	mmBtu per year	-
Displaced Natural Gas	total lifetime mmBtu	-
Avoided CO2	tonnes per year	61
Avoided CO2	total lifetime tonnes	657

Proposed System	Unit	Value
Capital Costs	$	$ 249,308
Project Start	year	2013
Project Life	years	25
Displaced Electric	kWh per year	-
Displaced Heat	gallons displaced per year	1,655
Displaced Transportation	gallons displaced per year	0.00
Renewable Generation O&	$ per BTU	
Electric Capacity	kW	0
Electric Capacity Factor	%	0
Heating Capacity	Btu/hr.	120,000
Heating Capacity Factor	%	86

Base System	Unit	Value
Diesel Generator O&M	$ per kWh	$ 0.033
Diesel Generation Efficier	kWh per gallon	

Parameters	Unit	Value
Heating Fuel Premium	$ per gallon	$ 2.00
Transportation Fuel Premi	$ per gallon	$ 1.00
Discount Rate	% per year	3%
Crude Oil	$ per barrel	EIA Mid
Natural Gas	$ per mmBtu	ISER - Mid

Annual Savings (Costs)		Units	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Entered Value	Project Capital Cost	$ per year	$ 249,308	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Electric Savings (Costs)	$ per year	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Heating Saving (Costs)	$ per year	($138)	$3,317	$3,391	$3,498	$3,648	$3,786	$3,915	$4,029	$4,130	$4,199	$4,269	$4,325	$4,372
	Transportation Savings (Costs)	$ per year	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Total Savings (Costs)	**$ per year**	($138)	$3,317	$3,391	$3,498	$3,648	$3,786	$3,915	$4,029	$4,130	$4,199	$4,269	$4,325	$4,372
	Net Benefit	**$ per year**	**($249,446)**	**$3,317**	**$3,391**	**$3,498**	**$3,648**	**$3,786**	**$3,915**	**$4,029**	**$4,130**	**$4,199**	**$4,269**	**$4,325**	**$4,372**

Annual Savings (Costs)		Units	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	PV
Entered Value	Project Capital Cost	$ per year	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	**$242,046**
	Electric Savings (Costs)	$ per year	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$0**
	Heating Saving (Costs)	$ per year	$4,406	$4,420	$4,413	$4,392	$4,354	$4,296	$4,220	$4,144	$4,062	$3,988	$9,332	$9,202	**$71,126**
	Transportation Savings (Costs)	$ per year	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$0**
	Total Savings (Costs)	**$ per year**	$4,406	$4,420	$4,413	$4,392	$4,354	$4,296	$4,220	$4,144	$4,062	$3,988	$9,332	$9,202	**$71,126**
	Net Benefit	**$ per year**	**$4,406**	**$4,420**	**$4,413**	**$4,392**	**$4,354**	**$4,296**	**$4,220**	**$4,144**	**$4,062**	**$3,988**	**$9,332**	**$9,202**	**($170,921)**

Heating		Units	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Proposed															
	Renewable Heat	gallons displace	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655
Entered Value	Renewable Heat Scheduled Re	$ per year	$ 300	$ 303	$ 306	$ 309	$ 312	$ 315	$ 318	$ 322	$ 325	$ 328	$ 331	$ 335	$ 338
Entered Value	Renewable Heat O&M	$ per year	$ 7,563	$ 7,639	$ 7,715	$ 7,792	$ 7,870	$ 7,949	$ 8,028	$ 8,109	$ 8,190	$ 8,272	$ 8,354	$ 8,438	$ 8,522
Entered Value	Renewable Fuel Use Quantity (	cords	14	14	14	14	14	14	14	14	14	14	14	14	14
Entered Value	Renewable Fuel Cost	$ per unit	$250.00	$253	$255	$258	$260	$263	$265	$268	$271	$273	$276	$279	$282
	Total Renewable Fuel Cost	$ per year	$ 3,491	$ 3,535	$ 3,570	$ 3,606	$ 3,642	$ 3,679	$ 3,715	$ 3,752	$ 3,790	$ 3,828	$ 3,866	$ 3,905	$ 3,944
	Remaining Fuel Oil (supplemen	gallons remainin	414	414	414	414	414	414	414	414	414	414	414	414	414
	Total Fuel Cost (supplement)	$ per year	$ 2,567	$ 2,608	$ 2,642	$ 2,682	$ 2,730	$ 2,777	$ 2,822	$ 2,864	$ 2,904	$ 2,938	$ 2,973	$ 3,005	$ 3,036
	Proposed Heat Cost	**$ per year**	**$13,921**	**$14,085**	**$14,233**	**$14,389**	**$14,555**	**$14,719**	**$14,884**	**$15,047**	**$15,209**	**$15,366**	**$15,525**	**$15,683**	**$15,840**
Base															
	Fuel Use	gallons per year	2,069	2,609	2,609	2,609	2,609	2,609	2,609	2,609	2,609	2,609	2,609	2,609	2,609
	Fuel Cost	$ per gallon	$6.20	$6.30	$6.38	$6.48	$6.60	$6.71	$6.82	$6.92	$7.02	$7.10	$7.18	$7.26	$7.34
Entered Value	Fuel Scheduled Repairs	$ per year	$ 200	$ 202	$ 204	$ 206	$ 208	$ 210	$ 212	$ 214	$ 217	$ 219	$ 221	$ 223	$ 225
Entered Value	Fuel O&M	$ per year	$ 750	$ 758	$ 765	$ 773	$ 780	$ 788	$ 796	$ 804	$ 812	$ 820	$ 828	$ 837	$ 845
	Fuel Cost	$ per year	$12,833	$16,442	$16,655	$16,909	$17,214	$17,508	$17,790	$18,058	$18,310	$18,526	$18,744	$18,948	$19,141
	Base Heating Cost	**$ per year**	**$13,783**	**$17,402**	**$17,624**	**$17,887**	**$18,203**	**$18,506**	**$18,799**	**$19,076**	**$19,339**	**$19,565**	**$19,793**	**$20,008**	**$20,212**

Heating		Units	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	PV
Proposed															
	Renewable Heat	gallons displaced	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655	
Entered Value	Renewable Heat Scheduled Re	$ per year	$ 341	$ 345	$ 348	$ 352	$ 355	$ 359	$ 362	$ 366	$ 370	$ 373	$ 377	$ 381	**$5,813**
Entered Value	Renewable Heat O&M	$ per year	$ 8,607	$ 8,694	$ 8,780	$ 8,868	$ 8,957	$ 9,047	$ 9,137	$ 9,228	$ 9,321	$ 9,414	$ 9,508	$ 9,603	**$146,536**
Entered Value	Renewable Fuel Use Quantity (	cords	14	14	14	14	14	14	14	14	14	14	14	14	
Entered Value	Renewable Fuel Cost	$ per unit	$285	$287	$290	$293	$296	$299	$302	$305	$308	$311	$314	$317	
	Total Renewable Fuel Cost	$ per year	$ 3,983	$ 4,023	$ 4,063	$ 4,104	$ 4,145	$ 4,187	$ 4,228	$ 4,271	$ 4,313	$ 4,357	$ 4,400	$ 4,444	
	Remaining Fuel Oil (supplemen	gallons remainin	414	414	414	414	414	414	414	414	414	414	414	414	
	Total Fuel Cost (supplement)	$ per year	$ 3,065	$ 3,090	$ 3,111	$ 3,129	$ 3,145	$ 3,158	$ 3,167	$ 3,176	$ 3,185	$ 3,195	$ 4,227	$ 4,227	
	Proposed Heat Cost	**$ per year**	**$15,997**	**$16,151**	**$16,303**	**$16,454**	**$16,603**	**$16,750**	**$16,895**	**$17,041**	**$17,188**	**$17,339**	**$18,512**	**$18,655**	**$272,203**
Base															
	Fuel Use	gallons per year	2,609	2,609	2,609	2,609	2,609	2,609	2,609	2,609	2,609	2,609	2,609	2,609	
	Fuel Cost	$ per gallon	$7.41	$7.47	$7.52	$7.56	$7.60	$7.63	$7.65	$7.68	$7.70	$7.72	$10.21	$10.21	
Entered Value	Fuel Scheduled Repairs	$ per year	$ 228	$ 230	$ 232	$ 235	$ 237	$ 239	$ 242	$ 244	$ 246	$ 249	$ 251	$ 254	**$3,875**
Entered Value	Fuel O&M	$ per year	$ 854	$ 862	$ 871	$ 879	$ 888	$ 897	$ 906	$ 915	$ 924	$ 934	$ 943	$ 952	**$14,531**
	Fuel Cost	$ per year	$19,322	$19,479	$19,613	$19,731	$19,832	$19,910	$19,966	$20,026	$20,080	$20,145	$26,650	$26,650	**$324,923**
	Base Heating Cost	**$ per year**	**$20,403**	**$20,571**	**$20,715**	**$20,845**	**$20,957**	**$21,046**	**$21,114**	**$21,186**	**$21,250**	**$21,327**	**$27,845**	**$27,856**	**$343,329**

Washateria/ Waterplant

Project Description	
Community	Kaltag
Nearest Fuel Community	
Region	Rural
RE Technology	Woody biomass heat
Project ID	
Applicant Name	Village of Kaltag
Project Title	Washateria/ Waterplant
Category	

Results	
NPV Benefits	$212,483
NPV Capital Costs	$249,864
B/C Ratio	0.85
NPV Net Benefit	($37,381)

Performance	Unit	Value
Displaced Electricity	kWh per year	-
Displaced Electricity	total lifetime kWh	-
Displaced Petroleum Fuel	gallons per year	6,003
Displaced Petroleum Fuel	total lifetime gallons	145,000
Displaced Natural Gas	mmBtu per year	-
Displaced Natural Gas	total lifetime mmBtu	-
Avoided CO2	tonnes per year	61
Avoided CO2	total lifetime tonnes	1,472

Proposed System	Unit	Value
Capital Costs	$	$ 257,360
Project Start	year	2013
Project Life	years	25
Displaced Electric	kWh per year	-
Displaced Heat	gallons displaced per year	5,220
Displaced Transportation	gallons displaced per year	0.00
Renewable Generation O&	$ per BTU	
Electric Capacity	kW	0
Electric Capacity Factor	%	0
Heating Capacity	Btu/hr.	350,000
Heating Capacity Factor	%	86

Base System	Unit	Value
Diesel Generator O&M	$ per kWh	$ 0.033
Diesel Generation Efficier	kWh per gallon	

Parameters	Unit	Value
Heating Fuel Premium	$ per gallon	$ 2.00
Transportation Fuel Premi	$ per gallon	$ 1.00
Discount Rate	% per year	3%
Crude Oil	$ per barrel	EIA Mid
Natural Gas	$ per mmBtu	ISER - Mid

Annual Savings (Costs)		Units	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Entered Value	Project Capital Cost	$ per year	$ 257,360	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Electric Savings (Costs)	$ per year	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Heating Saving (Costs)	$ per year	$9,455	$9,746	$9,940	$10,213	$10,589	$10,937	$11,262	$11,554	$11,813	$11,997	$12,182	$12,338	$12,468
	Transportation Savings (Costs)	$ per year	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Total Savings (Costs)	**$ per year**	$9,455	$9,746	$9,940	$10,213	$10,589	$10,937	$11,262	$11,554	$11,813	$11,997	$12,182	$12,338	$12,468
	Net Benefit	**$ per year**	**($247,905)**	**$9,746**	**$9,940**	**$10,213**	**$10,589**	**$10,937**	**$11,262**	**$11,554**	**$11,813**	**$11,997**	**$12,182**	**$12,338**	**$12,468**

Annual Savings (Costs)		Units	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	PV
Entered Value	Project Capital Cost	$ per year	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	**$249,864**
	Electric Savings (Costs)	$ per year	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$0**
	Heating Saving (Costs)	$ per year	$12,572	$12,626	$12,628	$12,600	$12,533	$12,417	$12,256	$12,099	$11,926	$11,774	$24,504	$24,216	**$212,483**
	Transportation Savings (Costs)	$ per year	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$0**
	Total Savings (Costs)	**$ per year**	$12,572	$12,626	$12,628	$12,600	$12,533	$12,417	$12,256	$12,099	$11,926	$11,774	$24,504	$24,216	**$212,483**
	Net Benefit	**$ per year**	**$12,572**	**$12,626**	**$12,628**	**$12,600**	**$12,533**	**$12,417**	**$12,256**	**$12,099**	**$11,926**	**$11,774**	**$24,504**	**$24,216**	**($37,381)**

Heating		Units	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Proposed																
	Renewable Heat	gallons displ	5,220	5,220	5,220	5,220	5,220	5,220	5,220	5,220	5,220	5,220	5,220	5,220	5,220	5,220
Entered Value	Renewable Heat Scheduled Re	$ per year	$ 500	$ 505	$ 510	$ 515	$ 520	$ 526	$ 531	$ 536	$ 541	$ 547	$ 552	$ 558	$ 563	$ 569
Entered Value	Renewable Heat O&M	$ per year	$ 12,361	$ 12,485	$ 12,610	$ 12,736	$ 12,863	$ 12,992	$ 13,122	$ 13,253	$ 13,385	$ 13,519	$ 13,654	$ 13,791	$ 13,929	$ 14,068
Entered Value	Renewable Fuel Use Quantity (	cords	44	44	44	44	44	44	44	44	44	44	44	44	44	44
Entered Value	Renewable Fuel Cost	$ per unit	$250.00	$253	$255	$258	$260	$263	$265	$268	$271	$273	$276	$279	$282	$285
	Total Renewable Fuel Cost	$ per year	$ 11,011	$ 11,121	$ 11,232	$ 11,345	$ 11,458	$ 11,573	$ 11,688	$ 11,805	$ 11,923	$ 12,043	$ 12,163	$ 12,285	$ 12,407	$ 12,531
	Remaining Fuel Oil (supplemen	gallons rema	580	580	580	580	580	580	580	580	580	580	580	580	580	580
	Total Fuel Cost (supplement)	$ per year	$ 3,597	$ 3,655	$ 3,702	$ 3,759	$ 3,827	$ 3,892	$ 3,955	$ 4,014	$ 4,070	$ 4,119	$ 4,167	$ 4,212	$ 4,255	$ 4,295
	Proposed Heat Cost	**$ per year**	**$ 27,469**	**$ 27,766**	**$ 28,054**	**$ 28,354**	**$ 28,668**	**$ 28,982**	**$ 29,296**	**$ 29,608**	**$ 29,920**	**$ 30,227**	**$ 30,536**	**$ 30,846**	**$ 31,155**	**$ 31,464**
Base																
	Fuel Use	gallons per y	5,800	5,800	5,800	5,800	5,800	5,800	5,800	5,800	5,800	5,800	5,800	5,800	5,800	5,800
	Fuel Cost	$ per gallon	$ 6.20	$ 6.30	$ 6.38	$ 6.48	$ 6.60	$ 6.71	$ 6.82	$ 6.92	$ 7.02	$ 7.10	$ 7.18	$ 7.26	$ 7.34	$ 7.41
Entered Value	Fuel Scheduled Repairs	$ per year	$ 200	$ 202	$ 204	$ 206	$ 208	$ 210	$ 212	$ 214	$ 217	$ 219	$ 221	$ 223	$ 225	$ 228
Entered Value	Fuel O&M	$ per year	$ 750	$ 758	$ 765	$ 773	$ 780	$ 788	$ 796	$ 804	$ 812	$ 820	$ 828	$ 837	$ 845	$ 854
	Fuel Cost	$ per year	$ 35,974	$ 36,552	$ 37,025	$ 37,589	$ 38,269	$ 38,921	$ 39,550	$ 40,143	$ 40,705	$ 41,185	$ 41,669	$ 42,123	$ 42,553	$ 42,954
	Base Heating Cost	**$ per year**	**$ 36,924**	**$ 37,512**	**$ 37,994**	**$ 38,568**	**$ 39,257**	**$ 39,919**	**$ 40,558**	**$ 41,162**	**$ 41,734**	**$ 42,224**	**$ 42,719**	**$ 43,183**	**$ 43,623**	**$ 44,035**

Heating		Units	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	PV
Proposed															
	Renewable Heat	gallons displ	5,220	5,220	5,220	5,220	5,220	5,220	5,220	5,220	5,220	5,220	5,220	5,220	
Entered Value	Renewable Heat Scheduled Re	$ per year	$ 569	$ 575	$ 580	$ 586	$ 592	$ 598	$ 604	$ 610	$ 616	$ 622	$ 629	$ 635	**$9,688**
Entered Value	Renewable Heat O&M	$ per year	$ 14,068	$ 14,209	$ 14,351	$ 14,494	$ 14,639	$ 14,786	$ 14,933	$ 15,083	$ 15,234	$ 15,386	$ 15,540	$ 15,695	**$239,497**
Entered Value	Renewable Fuel Use Quantity (	cords	44	44	44	44	44	44	44	44	44	44	44	44	
Entered Value	Renewable Fuel Cost	$ per unit	$285	$287	$290	$293	$296	$299	$302	$305	$308	$311	$314	$317	
	Total Renewable Fuel Cost	$ per year	$ 12,531	$ 12,657	$ 12,783	$ 12,911	$ 13,040	$ 13,171	$ 13,302	$ 13,435	$ 13,570	$ 13,705	$ 13,843	$ 13,981	
	Remaining Fuel Oil (supplemen	gallons rema	580	580	580	580	580	580	580	580	580	580	580	580	
	Total Fuel Cost (supplement)	$ per year	$ 4,295	$ 4,330	$ 4,360	$ 4,386	$ 4,409	$ 4,426	$ 4,439	$ 4,452	$ 4,464	$ 4,478	$ 5,925	$ 5,925	
	Proposed Heat Cost	**$ per year**	**$ 31,464**	**$ 31,771**	**$ 32,075**	**$ 32,378**	**$ 32,681**	**$ 32,980**	**$ 33,279**	**$ 33,580**	**$ 33,883**	**$ 34,192**	**$ 35,936**	**$ 36,236**	**$535,479**
Base															
	Fuel Use	gallons per y	5,800	5,800	5,800	5,800	5,800	5,800	5,800	5,800	5,800	5,800	5,800	5,800	
	Fuel Cost	$ per gallon	$ 7.41	$ 7.47	$ 7.52	$ 7.56	$ 7.60	$ 7.63	$ 7.65	$ 7.68	$ 7.70	$ 7.72	$ 10.21	$ 10.21	
Entered Value	Fuel Scheduled Repairs	$ per year	$ 228	$ 230	$ 232	$ 235	$ 237	$ 239	$ 242	$ 244	$ 246	$ 249	$ 251	$ 254	**$3,875**
Entered Value	Fuel O&M	$ per year	$ 854	$ 862	$ 871	$ 879	$ 888	$ 897	$ 906	$ 915	$ 924	$ 934	$ 943	$ 952	**$14,531**
	Fuel Cost	$ per year	$ 42,954	$ 43,304	$ 43,600	$ 43,864	$ 44,088	$ 44,261	$ 44,387	$ 44,520	$ 44,638	$ 44,783	$ 59,245	$ 59,245	**$729,556**
	Base Heating Cost	**$ per year**	**$ 44,035**	**$ 44,396**	**$ 44,703**	**$ 44,978**	**$ 45,213**	**$ 45,397**	**$ 45,535**	**$ 45,679**	**$ 45,809**	**$ 45,966**	**$ 60,440**	**$ 60,452**	**$747,962**

Kaltag School

Project Description	
Community	Kaltag
Nearest Fuel Community	
Region	Rural
RE Technology	Woody biomass heat
Project ID	
Applicant Name	Village of Kaltag
Project Title	Kaltag School
Category	

Results	
NPV Benefits	$414,583
NPV Capital Costs	$269,032
B/C Ratio	1.54
NPV Net Benefit	$145,551

Performance	Unit	Value
Displaced Electricity	kWh per year	-
Displaced Electricity	total lifetime kWh	-
Displaced Petroleum Fuel	gallons per year	6,003
Displaced Petroleum Fuel	total lifetime gallons	475,000
Displaced Natural Gas	mmBtu per year	-
Displaced Natural Gas	total lifetime mmBtu	-
Avoided CO2	tonnes per year	61
Avoided CO2	total lifetime tonnes	4,821

Proposed System	Unit	Value
Capital Costs	$	$ 277,103
Project Start	year	2013
Project Life	years	25
Displaced Electric	kWh per year	-
Displaced Heat	gallons displaced per year	7,600
Displaced Transportation	gallons displaced per year	0.00
Renewable Generation O&	$ per BTU	
Electric Capacity	kW	0
Electric Capacity Factor	%	0
Heating Capacity	Btu/hr.	350,000
Heating Capacity Factor	%	86

Base System	Unit	Value
Diesel Generator O&M	$ per kWh	$ 0.033
Diesel Generation Efficier	kWh per gallon	

Parameters	Unit	Value
Heating Fuel Premium	$ per gallon	$ 2.00
Transportation Fuel Premi	$ per gallon	$ 1.00
Discount Rate	% per year	3%
Crude Oil	$ per barrel	EIA Mid
Natural Gas	$ per mmBtu	ISER - Mid

	Units	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Project Capital Cost	$ per year	$ 277,103	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Electric Savings (Costs)	$ per year	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Heating Saving (Costs)	$ per year	$19,196	$19,675	$20,011	$20,465	$21,068	$21,632	$22,162	$22,644	$23,080	$23,406	$23,735	$24,022	$24,273
Transportation Savings (Costs)	$ per year	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Savings (Costs)	**$ per year**	$19,196	$19,675	$20,011	$20,465	$21,068	$21,632	$22,162	$22,644	$23,080	$23,406	$23,735	$24,022	$24,273
Net Benefit	**$ per year**	**($257,907)**	**$19,675**	**$20,011**	**$20,465**	**$21,068**	**$21,632**	**$22,162**	**$22,644**	**$23,080**	**$23,406**	**$23,735**	**$24,022**	**$24,273**

	Units	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	PV
Project Capital Cost	$ per year	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	**$269,032**
Electric Savings (Costs)	$ per year	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$0**
Heating Saving (Costs)	$ per year	$24,484	$24,625	$24,691	$24,712	$24,678	$24,574	$24,405	$24,242	$24,056	$23,902	$42,504	$42,153	**$414,583**
Transportation Savings (Costs)	$ per year	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$0**
Total Savings (Costs)	**$ per year**	$24,484	$24,625	$24,691	$24,712	$24,678	$24,574	$24,405	$24,242	$24,056	$23,902	$42,504	$42,153	**$414,583**
Net Benefit	**$ per year**	**$24,484**	**$24,625**	**$24,691**	**$24,712**	**$24,678**	**$24,574**	**$24,405**	**$24,242**	**$24,056**	**$23,902**	**$42,504**	**$42,153**	**$145,551**

Heating		Units	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Proposed															
	Renewable Heat	gallons displ	7,600	7,600	7,600	7,600	7,600	7,600	7,600	7,600	7,600	7,600	7,600	7,600	7,600
Entered Value	Renewable Heat Scheduled Re	$ per year	$ 500	$ 505	$ 510	$ 515	$ 520	$ 526	$ 531	$ 536	$ 541	$ 547	$ 552	$ 558	$ 563
Entered Value	Renewable Heat O&M	$ per year	$ 12,361	$ 12,485	$ 12,610	$ 12,736	$ 12,863	$ 12,992	$ 13,122	$ 13,253	$ 13,385	$ 13,519	$ 13,654	$ 13,791	$ 13,929
Entered Value	Renewable Fuel Use Quantity (	cords	64	64	64	64	64	64	64	64	64	64	64	64	64
Entered Value	Renewable Fuel Cost	$ per unit	$250	$253	$255	$258	$260	$263	$265	$268	$271	$273	$276	$279	$282
	Total Renewable Fuel Cost	$ per year	$ 16,031	$ 16,192	$ 16,353	$ 16,517	$ 16,682	$ 16,849	$ 17,017	$ 17,188	$ 17,360	$ 17,533	$ 17,708	$ 17,886	$ 18,064
	Remaining Fuel Oil (supplemen	gallons rema	11400	11400	11400	11400	11400	11400	11400	11400	11400	11400	11400	11400	11400
	Total Fuel Cost (supplement)	$ per year	$ 70,708	$ 71,844	$ 72,773	$ 73,882	$ 75,218	$ 76,499	$ 77,735	$ 78,903	$ 80,006	$ 80,950	$ 81,902	$ 82,794	$ 83,638
	Proposed Heat Cost	**$ per year**	**$ 99,600**	**$101,026**	**$102,246**	**$103,649**	**$105,283**	**$106,865**	**$108,405**	**$109,879**	**$111,292**	**$112,549**	**$113,817**	**$115,029**	**$116,194**
Base															
	Fuel Use	gallons per y	19,000	19,000	19,000	19,000	19,000	19,000	19,000	19,000	19,000	19,000	19,000	19,000	19,000
	Fuel Cost	$ per gallon	$ 6.20	$ 6.30	$ 6.38	$ 6.48	$ 6.60	$ 6.71	$ 6.82	$ 6.92	$ 7.02	$ 7.10	$ 7.18	$ 7.26	$ 7.34
Entered Value	Fuel Scheduled Repairs	$ per year	$ 200	$ 202	$ 204	$ 206	$ 208	$ 210	$ 212	$ 214	$ 217	$ 219	$ 221	$ 223	$ 225
Entered Value	Fuel O&M	$ per year	$ 750	$ 758	$ 765	$ 773	$ 780	$ 788	$ 796	$ 804	$ 812	$ 820	$ 828	$ 837	$ 845
	Fuel Cost	$ per year	$117,846	$119,741	$121,289	$123,136	$125,363	$127,498	$129,559	$131,504	$133,343	$134,916	$136,503	$137,991	$139,396
	Base Heating Cost	**$ per year**	**$118,796**	**$120,700**	**$122,258**	**$124,115**	**$126,351**	**$128,497**	**$130,567**	**$132,523**	**$134,372**	**$135,955**	**$137,552**	**$139,051**	**$140,467**

Heating		Units	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	PV
Proposed															
	Renewable Heat	gallons displ	7,600	7,600	7,600	7,600	7,600	7,600	7,600	7,600	7,600	7,600	7,600	7,600	
Entered Value	Renewable Heat Scheduled Re	$ per year	$ 569	$ 575	$ 580	$ 586	$ 592	$ 598	$ 604	$ 610	$ 616	$ 622	$ 629	$ 635	**$9,688**
Entered Value	Renewable Heat O&M	$ per year	$ 14,068	$ 14,209	$ 14,351	$ 14,494	$ 14,639	$ 14,786	$ 14,933	$ 15,083	$ 15,234	$ 15,386	$ 15,540	$ 15,695	**$239,497**
Entered Value	Renewable Fuel Use Quantity (	cords	64	64	64	64	64	64	64	64	64	64	64	64	
Entered Value	Renewable Fuel Cost	$ per unit	$285	$287	$290	$293	$296	$299	$302	$305	$308	$311	$314	$317	
	Total Renewable Fuel Cost	$ per year	$ 18,245	$ 18,428	$ 18,612	$ 18,798	$ 18,986	$ 19,176	$ 19,367	$ 19,561	$ 19,757	$ 19,954	$ 20,154	$ 20,355	
	Remaining Fuel Oil (supplemen	gallons rema	11400	11400	11400	11400	11400	11400	11400	11400	11400	11400	11400	11400	
	Total Fuel Cost (supplement)	$ per year	$ 84,427	$ 85,115	$ 85,697	$ 86,215	$ 86,656	$ 86,995	$ 87,243	$ 87,505	$ 87,738	$ 88,023	$116,448	$116,448	
	Proposed Heat Cost	**$ per year**	**$117,310**	**$118,326**	**$119,240**	**$120,093**	**$120,873**	**$121,555**	**$122,148**	**$122,759**	**$123,344**	**$123,985**	**$152,770**	**$153,133**	**$1,993,748**
Base															
	Fuel Use	gallons per y	19,000	19,000	19,000	19,000	19,000	19,000	19,000	19,000	19,000	19,000	19,000	19,000	
	Fuel Cost	$ per gallon	$ 7.41	$ 7.47	$ 7.52	$ 7.56	$ 7.60	$ 7.63	$ 7.65	$ 7.68	$ 7.70	$ 7.72	$ 10.21	$ 10.21	
Entered Value	Fuel Scheduled Repairs	$ per year	$ 228	$ 230	$ 232	$ 235	$ 237	$ 239	$ 242	$ 244	$ 246	$ 249	$ 251	$ 254	**$3,875**
Entered Value	Fuel O&M	$ per year	$ 854	$ 862	$ 871	$ 879	$ 888	$ 897	$ 906	$ 915	$ 924	$ 934	$ 943	$ 952	**$14,531**
	Fuel Cost	$ per year	$140,712	$141,859	$142,828	$143,692	$144,426	$144,992	$145,405	$145,841	$146,229	$146,704	$194,080	$194,080	**$2,389,925**
	Base Heating Cost	**$ per year**	**$141,794**	**$142,951**	**$143,931**	**$144,806**	**$145,551**	**$146,128**	**$146,553**	**$147,001**	**$147,400**	**$147,887**	**$195,274**	**$195,286**	**$2,408,331**

Life cycle cost analysis (LCCA) for School

Life Cycle Costs of Project Alternatives	
District:	Yukon Koyukuk
School:	Kaltag School
Project:	Kaltag School chip boiler
Project No.	NA
Study Period:	20
Discount Rate:	3.50%

	Alternative #1 (low)	Alternative #2 (high)
Initial Investment Cost	$ 332,195	$ 398,508
O&M and Repair Cost	$ 588,985	$ 914,198
Replacement Cost	$ 121,621	$ 133,783
Residual Value	$ (78,655)	$ (86,521)
Total Life Cycle Cost	$ 964,146	$ 1,359,967
GSF of Project	14,749	14,749
Initial Cost/ GSF	$ 22.52	$ 27.02
LCC/ GSF	$ 65.37	$ 92.21

YEAR		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Alt. 1		Discount Rate		3.50%																	
		Gen'l Inflation for O&M		1.50%																	
	NPV																				
O&M	$588,985	$ 36,457	$ 37,003	$ 37,558	$ 38,122	$ 38,694	$ 39,274	$ 39,863	$ 40,461	$ 41,068	$ 41,684	$ 42,309	$ 42,944	$ 43,588	$ 44,242	$ 44,906	$ 45,579	$ 46,263	$ 46,957	$ 47,661	$ 48,376
Replacement	$121,621	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	$242,000
Residual	$78,655	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	$156,508
Alt 2		Discount Rate		3.50%																	$398,508
		Gen'l Inflation for O&M		1.50%																	
	NPV																				
O&M	$914,198	$ 40,102	$ 40,102	$ 40,704	$ 41,314	$ 41,934	$ 42,563	$ 43,201	$ 43,849	$ 44,507	$ 45,175	$ 45,852	$ 46,540	$ 47,238	$ 47,947	$ 48,666	$ 49,396	$ 50,137	$ 50,889	$ 51,652	$ 52,427
Replacement	$133,783	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	$266,200
Residual	$86,521	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	$172,159

Summary of Financial Analysis

	Estimated System Description (abbreviated)	NPV Benefits	PV	B/C Ratio	Simple Payback
Kaltag City and Tribal Office	One (2) 120,000 btu containerized cordwood boiler	$71,000	$249,000	0.29	75
Kaltag Washateria/ Waterplant	One 350,000 btu containerized cordwood boiler	$212,400	$257,300	0.85	26.5
Kaltag School	One 350,000 btu containerized cordwood boiler, offsetting 40% of fuel oil load	$414,500	$277,000	1.54	14.1

Conclusion

The village of Kaltag has significant opportunities for biomass heating, owing to the high cost of fuel oil, community capacity for operating and maintaining heating systems, and existing heat loads that could be adequately served by containerized biomass heating units. One of the most significant assets to any potential biomass project is the dedicated services of maintenance personnel in the Community.

There is strong technical feasibility for biomass heating of the Washateria and Kaltag School. All projects could be heated by containerized cordwood boiler systems. All projects would require a new fuel storage room. Additionally, the Kaltag School could be heated by a semi-automated wood chip system instead of a cordwood boiler. The feasibility of this technology is subject to a Harvest Plan and Operations Plan, as well as the preferences and capacity of the School administration and maintenance personnel.

Of the projects identified, the Kaltag School appears to have the strongest financial feasibility, based on amount of heating oil usage.

Additionally, because the project's success is critically dependent on both Harvest and Operations Plan, Dalson Energy strongly recommends developing these Plans prior to project development.

Finally, Dalson Energy recommends that a request in any grant application include funding for O&M training from the system manufacturer for the first two years of operation. This training would improve the efficiency of O&M and also offer the opportunity to train new maintenance personnel if necessary.

Consultant/Authors of this report:

Dalson Energy is a Renewable Energy Consulting and Technology Research firm based in Anchorage. Dalson staff and partners have decades of experience in construction project management, project development consulting and renewable energy technology research. Dalson teams with licensed engineers, architects and designers in Alaska, Canada and Lower 48.

Dalson Energy has worked with Alaska Energy Authority, Alaska Center for Energy & Power, University of Alaska Fairbanks, Washington State CTED (Community Trade & Economic Development) and California Energy Commission on biomass energy technology research.

Dalson's President, Thomas Deerfield, has been involved in biomass energy RD&D since 2001, winning grants and managing projects with NREL (National Renewable Energy Labs), USFS (US Forest Service), and CEC (California Energy Commission).

Thomas managed the field-testing of biomass CHP systems, including the first grid-connected biomass gasification CHP system in the US. (2007). Thomas coordinated the design and creation of the first prototype Biomass "Boiler in a Box" in Alaska, in 2010. That Garn-based system is now deployed in Elim, in the Bering Sea region.

Thomas founded Shasta Energy Group (SEG), a 501c3 nonprofit, and managed wind energy research, biomass energy feasibility studies, energy efficiency for buildings, and hydronic heating system research design and development (RD&D). He also initiated a rural economic development think tank and has engaged his writing skills to assist many other renewable energy project initiatives.

Wynne Auld is a Biomass Energy Specialist with Dalson Energy. She focuses on assessing and developing woody biomass energy projects. Over the past few years, she has supported the business development of integrated biomass energy campuses in Oregon and Idaho, especially related to their energy initiatives. Her efforts have included marketing Campus biomass heating products to major wholesalers and retail buyers, and planning and developing Campus sort yards and small-scale CHP.

Wynne also specializes in assisting commercial and municipal building managers in assessing the feasibility of biomass heating, and implementing their projects. She works to ensure vibrant rural communities through sustainable natural resource utilization.

Supplement: **Community Wood Heating Basics**


Figure 8: Cordwood

Wood fuel as a heating option

When processed, handled, and combusted appropriately, wood fuels are among the most cost-effective and reliable sources of heating fuel for communities adjacent to forestland.

Compared to other heating energy fuels, wood fuels are characterized by lower energy density and higher associated transportation and handling costs. This low bulk density results in a shorter viable haul distance for wood fuels compared to fossil fuels. However, this "limit" also creates an advantage for local communities to utilize locally-sourced wood fuels, while simultaneously retaining local energy dollars and exercising local resource management.


Figure 10: Ground wood chips used for mulch.

Most Interior villages are particularly vulnerable to high energy prices because the region has over 13,500 heating degree days[4] (HDD) per year – 160% of Anchorage's HDDs, or 380% of Seattle's HDDs. For many communities, wood-fueled heating lowers fuel costs. For example, cordwood sourced at $250 per cord is just 25% of the cost per MMBTU as fuel oil #1 sourced at $7 per gallon. Besides the financial savings, local communities benefit from the multiplier effect of circulating fuel money in the community longer, more stable energy prices, job creation, and more active forest management.


Figure 9: Wood briquettes, as a substitute for cordwood. Cross sections of these briquettes make "wafers" which can be automatically handled in biomass boiler systems.

In all the Interior villages studied, the community's wood supply and demand are isolated from outside markets. Instead, the firewood market is influenced by land ownership, existing forest management and ecological conditions, local demand and supply, and the State of Alaska Energy Assistance program.


Figure 11: Wood pellets

The nature of wood fuels

Wood fuels are specified by moisture content, granulometry, energy density, ash content, dirt and rocks, and fines and coarse particles. Each of these characteristics affects the wood fuel's handling characteristics, storage requirements, and combustion process. Fuels are considered higher quality if they have lower moisture, ash, dirt, and rock contents; consistent granulometry; and higher energy density.

[4] Heating degree days are a metric designed to reflect the amount of energy needed to heat the interior of a building. It is derived from measurements of outside temperature.

Many types of fuel quality can be used in wood heating projects so long as the infrastructure specifications match the fuel content characteristics. Typically, lower quality fuel will be the lowest cost fuel, but it will require more expensive storage, handling, and combustion infrastructure, as well as additional maintenance.

Projects in interior Alaska must be designed around the availability of wood fuels. Some fuels can be manufactured on site, such as cordwood, woodchips, and briquettes. The economic feasibility of manufacturing on site can be determined by a financial assessment of the project; generally speaking, larger projects offer more flexibility in terms of owning and operating harvesting and manufacturing equipment, such as a wood chipper, than smaller projects.

It is unlikely that interior communities will be able to manufacture pellets, from both a financial, operational, and fuel sourcing perspective. However, some interior communities may be able to manufacture bricks or firelogs made from pressed wood material. These products can substitute for cordwood in woodstoves and boilers, while reducing supply pressure on larger diameter trees than are generally preferred for cordwood. At their simplest, brick presses are operated by hand, but require chipped, dry fuel.

The basics of wood-fueled heating

Biomass heating systems fit into two typical categories: first, stoves and fireplaces that heat space directly through convection and radiation by burning cordwood or pellets; second, hydronic systems where the boiler burns cordwood, woodchips or pellets to heat liquid that is distributed to radiant piping, radiators or heat exchangers. The heated liquid is distributed out to users, then returned to the heat source for re-heating.

Hydronic systems are appropriate for serving individual buildings, or multiple buildings with insulated piping called heat loops. Systems that serve multiple buildings are called district heating loops. District heating is common in Europe, where larger boilers sometimes serve entire villages.

Biomass boilers are dependent on the compatibility of the chosen fuel, handling system, and combustion system. General categories for typically available biomass fuel systems follow:

- Batch load solid chunk boiler
- Semi-automated or fully-automated chipped or ground biomass boilers
- Fully-automated densified-fuel boiler, using pellets, bricks, or pucks

The system application is typically determined by size of heat load, available wood fuels, and available maintenance personnel. General categories for heat load and wood fuel follow:

- Loads < 1 MMBTU often use cordwood or pellet boilers
- Loads > 1MMBTU often use pellet or woodchip boilers
- Loads > 10MMTU often use hog-fuel (mixed ground wood)

Each wood fuel type has different handling requirements and is associated with different emission profiles. For example, industrial systems greater than 10 MMBTU often require additional particulate and emission controls because of the combustion properties of hog-fuel.

One category of system that is particularly appropriate for remote rural communities is cordwood boilers. Cordwood boilers are batch-loaded with seasoned cordwood. A significant advantage to cordwood is that very little infrastructure is needed to manufacture or handle the heating fuel. At its most basic, cordwood can be "manufactured" with a chainsaw (or handsaw) and an ax, and residents of rural communities are often accustomed to harvesting wood to heat their homes and shops. Harvesting in most Interior villages is accomplished with ATV's, river skiffs, sleds and dog teams, and snow machines. Since cordwood systems are batch loaded by hand, they do not require expensive automated material handling systems. Covered storage is required; such storage may be as simple as an existing shed or a vented shipping container, rather than newly constructed storage structures.

Challenges to cordwood include higher labor costs associated with manual loading. Some LEHE (low efficiency, high emission) technologies such as Outdoor Wood Boilers (OWBs) have been criticized for their high emissions and excessive wood consumption.

Cordwood systems are typically less than 1 MMBTU. However, if needed, some types of cordwood boilers can be "cascaded," meaning multiple boilers can meet heat demand as a single unit. However, above a certain heat load, automated material handling and larger combustion systems become viable.

Woodchip systems can be automated and thereby less labor intensive. However, woodchip systems have significantly higher capital costs than both cordwood and pellet systems. Additionally, a reliable stream of woodchips typically depends on a regionally active forest products manufacturing base in the area, and active forest management. In most Interior communities, institutional heating with woody biomass does not justify the purchase of log trucks, harvesting, handling, and manufacturing equipment.

Pellet systems are the most automated systems, and have lower capital equipment costs than woodchip systems. Lower costs are due to the smaller size of required infrastructure and simplified handling and storage infrastructure. However, pellet fuel and other densified fuels tend to be more expensive than other wood fuels, and require reliable access to pellet fuels.

For any system, the mass of feedstock required annually is determined by three parameters:

1) Building heat load
2) Net BTU content of the fuel
3) Efficiency of the boiler system

Building heat loads are determined by square footage, orientation and usage, as well as energy efficiency factors such as insulation, moisture barriers and air leakage. Usage is particularly important because it influences peak demand. For example, a community center which is used only a few times per month for events, and otherwise kept at a storage temperature of 55 d. F, would have a much different usage profile than a City Office which is fully occupied during the work day and occasionally during evenings and weekends.

Building heat load analysis, including the building usage profile, is a particularly important part of boiler right-sizing. A full feasibility analysis would conduct analyses that optimize the return on investment (ROI) of systems. Typically, optimizing a biomass project's ROI depends on a supplementary heating system, such as an oil fired system, to meet peak demand and prevent short-cycling of the biomass boiler. Full feasibility analyses may not be necessary for small projects, especially for those employing cordwood boilers.

Biomass boiler efficiencies vary from 60% to 80%, depending on the manufacturer and the field conditions of the equipment. The efficiency is strongly influenced by the BTU value and MC (moisture content) of the fuel. Wood fuels with greater than 50% MC generally result in lower efficiency systems, because some energy is used to drive off moisture from the fuel during the combustion process. The reduction in energy output is mathematically equal; 50% MC generally means 50% reduction in potential BTU value.

Like other combustion-based energy systems, woody biomass boilers produce emissions in the combustion process. Compared to fossil fuels (coal, natural gas, and fuel oil), wood fuel emissions are low in nitrogen oxides (NOx); carbon monoxide (CO, a product of incomplete combustion); sulfur dioxide (SO2); and mercury (Hg). Because these compounds are all products of the forest and CO would release naturally during the process of decay or wildfire, they generally do not concern regulatory agencies. For emission control agencies, the real interest is particulate matter (PM) emissions, which affect the air quality of human communities. Some wood systems are extremely sophisticated, producing less than 0.06 lb/ MMBTU of PM.

Effective methods of PM control have been developed to remove most of the particles from the exhaust air of wood combustion facilities. These include introduction of pre-heated secondary air, highly controlled combustion, and PM collection devices.

Biomass boiler systems typically integrate a hot water storage tank, or buffer tank. The storage tank prevents short cycling for automated boilers and improves efficiency and performance of batch-fired systems, by allowing project buildings to draw on the boiler's hot water long after the combustion process. The GarnPac boiler design incorporates hot water storage into the boiler jacket itself, storing approximately 2,200 gallons of hot water. Other boilers are typically installed with a separate hot water storage tank.

Available wood heating technology

This section will focus generally on manufacturers of the types of technology discussed previously.

Cordwood Boilers

High Efficiency Low Emission (HELE) cordwood boilers are designed to burn cordwood fuel cleanly and efficiently.

Cordwood used at the site will ideally be seasoned to 25% MC (moisture content) and meet the dimensions specified by the chosen boiler. The actual amount of cordwood used would depend on the buildings' heat load profile, and the utilization of a fuel oil system as back up.

The following table lists three HELE cordwood boiler suppliers, all of which have units operating in Alaska. Greenwood and TarmUSA, Inc. have a number of residential units operating in Alaska, and several GARN boilers, manufactured by Dectra Corporation, are used in Tanana, Kasilof, Dot Lake, Thorne Bay and other locations to heat homes, Washaterias, and Community Buildings.

HELE Cordwood Boiler Suppliers		
Vendor	**Btu/hr ratings**	**Supplier**
Tarm	100,000 to 198,000	Tarm USA www.tarmusa.com
Greenwood	100,000 to 300,000	Greenwood www.greenwoodusa.com
GARN	250,000 to 700,000	Dectra Corp. www.dectra.net/garn
Note: These lists are representational of available systems, and are not inclusive.		

Bulk Fuel Boilers

The term "bulk fuel" refers to systems that utilize wood chips, pellets, pucks, or other loose manufactured fuel. Numerous suppliers of these boilers exist. Since this report focuses on village-scale heating, the following chart outlines manufacturers of chip and pellet fuel boilers < 1 MMBTU.

HELE Bulk Fuel Boiler Suppliers		
Vendor	**Btu/hr ratings**	**Supplier**
Froling	35,800 to 200,000; up to 4 can be cascaded as a single unit at 800,000 BTU	Tarm USA www.tarmusa.com
KOB	512,000 – 1,800,000 BTU (PYROT model)	Ventek Energy Systems Inc. peter@ventekenergy.com
Binder	34,000 BTU – 34 MMBTU	BINDER USA contact@binder-boiler.com
Note: These lists are representational of available systems, and are not inclusive		

The following is a review of Community Facilities being considered for biomass heating. The subsequent section will recommend a certain type of biomass heating technology, based on the Facility information below.

District Heat Loops

District heat loops refers to a system for heating multiple buildings from a central power plant. The heat is transported in a piping system to consumers in the form of hot water or steam.

These are the key factors that affect the cost of installing and operating a district heating system[5]:

- Heat load density.
- Distance between buildings. Shorter distances between buildings will allow use of smaller diameter (less expensive) pipes and lesser pumping costs.
- Permafrost. In the Interior, frozen soil could affect construction costs and project feasibility. Aboveground insulated piping may be preferred to underground piping, such as the cordwood system recently installed in Tanana, Alaska.
- Piping materials used. Several types of tubing are available for supply and return water. Pre-insulated PEX tubing may be the preferred piping material for its flexibility and oxygen barrier.
- District loop design. Water can be piped in one direction (i.e., one pipe enclosed) or two directions (two pipes enclosed) for a given piping system. Design affects capital costs and equality of heat distribution.
- Other considerations. Pump size, thermal load (BTUs per hour), water temperature, and electrical use are other variables.

For the purposes of this study, the consultants have chosen to estimate the costs of district heat loops using the RET Screen, a unique decision support tool developed with the contribution of numerous experts from government, industry, and academia. The software, provided free-of-charge, can be used worldwide to evaluate the energy production and savings, costs, emission reductions, financial viability and risk for various types of Renewable-energy and Energy-efficient Technologies (RETs), including district heat loops from biomass.

---

5 Nicholls, David; Miles, Tom. 2009. Cordwood energy systems for community heating in Alaska−an overview. Gen. Tech. Rep. PNW-GTR-783. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research
Station. 17 p.