Pre-Feasibility Assessment for Integration of Wood-Fired Heating Systems Draft Report

July 16, 2013

Kiniaq Building Koyuk, Alaska

Presented by
CTA Architects Engineers
Nathan Ratz & Jesse Vigil

R&M Engineering-Ketchikan, Inc.
Trevor Sande

For
Native Village of Koyuk

In partnership with
Fairbanks Economic Development Corporation
Alaska Wood Energy Development Task Group

Funded by
Alaska Energy Authority and U.S. Forest Service

306 W. Railroad, Suite 104
Missoula, MT 59802
406.728.9522
www.ctagroup.com
CTA Project: FEDC_KOYUK

TABLE OF CONTENTS

1.0 Executive Summary 1
2.0 Introduction 3
3.0 Existing Building Systems 3
4.0 Energy Use 3
5.0 Biomass Boiler Size 3
6.0 Wood Fuel Use 4
7.0 Boiler Plant Location and Site Access 5
8.0 Integration with Existing Heating Systems 5
9.0 Air Quality Permits 6
10.0 Wood Heating Options 6
11.0 Estimated Costs 6
12.0 Economic Analysis Assumptions 6
13.0 Results of Evaluation 7
14.0 Project Funding 8
15.0 Summary 8
16.0 Recommended Action 8

Appendixes

Appendix A: Preliminary Estimates of Probable Cost .... 1 page
Appendix B: Cash Flow Analysis .... 3 pages
Appendix C: Site Plan .... 1 page
Appendix D: Air Quality Report .... 22 pages
Appendix E: Wood Fired Heating Technologies .... 4 pages

1.0 Executive Summary

The following assessment was commissioned to determine the preliminary technical and economic feasibility of integrating a wood fired heating system in the Kiniaq Building in Koyuk, Alaska.

The following tables summarize the current fuel use and the potential wood fuel use:

Table 1.1 - Annual Fuel Use Summary

Facility Name	Fuel Type	Avg. Use (Gallons)	Current Cost/Gal	Annual Cost
Kiniaq Building	Fuel Oil	1,500	$6.50	$9,750

Table 1.2 - Annual Wood Fuel Use Summary

	Fuel Oil (Gallons)	Cord Wood (Cords)	Wood Pellets (Tons)
Kiniaq Building	1,500	15.4	14.1

The wood heating system options reviewed were:

Cord Wood Boiler Options:
- C.1.A: A freestanding building with interior cordwood storage, 70% fuel oil offset.
- C.1.B: A freestanding building with interior cordwood storage, 50% fuel oil offset.

Wood Stove Options:
- D.1: Two freestanding wood stoves, 35% fuel oil offset.

Table 1.3 - Economic Evaluation Summary
Kiniaq Building Biomass Heating System

	Project Cost	Year 1 Operating Savings	NPV 20 yr at 3%	NPV 30 yr at 3%	20 Yr B/C Ratio	30 Yr B/C Ratio	ACF YR 20	ACF YR 30	YR ACF=PC
C.1.A	$226,000	-$9,709	-$114,067	-$129,668	-0.50	-0.57	-$150,022	-$181,797	31
C.1.B	$226,000	-$7,538	-$85,189	-$97,747	-0.38	-0.43	-$111,997	-$137,711	31
D.1	$18,000	$125	$18,914	$43,452	1.05	2.41	$28,631	$81,553	17

The Kiniaq Building appears to be a fair candidate for the use of a wood biomass heating system using wood stoves. With the current economic assumptions, the economic viability of the cord wood boiler options is poor as none of the options meet the minimum requirement of the 20 year B/C ratio exceeding 1.0. The amount of fuel oil use is not large enough to economically leverage much capital costs, even if the most of the fuel oil use could be eliminated. The wood stove option does appear to be economically viable, however, it is very sensitive to labor costs. For this analysis 2 hours a week of feeding the stoves was assumed. If this was 3 hours a week, then the 20 year B/C ratio would drop below 1.0. The wood stove option also assumed offsetting 35% of the current fuel oil use. This was due to the typical occupancy of the building (no one to feed the fire on nights and weekends) and because of the room layout of the building. The stoves would keep the large open areas heated, but the perimeter offices would likely still require supplemental heat from the boiler system.

The cord wood fuel source would benefit the community because the fuel is a renewable resource, has a lower energy cost, and the money paid for the fuel would remain in the local community and economy.

2.0 Introduction

The following assessment was commissioned to determine the preliminary technical and economic feasibility of integrating a wood fired heating system in the Kiniaq Building in Koyuk, Alaska.

3.0 Existing Building Systems

The Kiniaq Building is a single story wood framed building constructed in 1996. Because of poor soil conditions, the building is supported by piles and is elevated approximately four feet above native grade. The facility is approximately 3,700 square feet and is primarily heated by two 159,000 Btu/hr output hot water boilers. Domestic hot water is provided by a 41 gallon indirect water heater using the boiler water as a heating source. The existing boilers are original to the building and appear to be in fair condition. The heating system infrastructure is original to the building and appears to be in fair condition. A heat recovery ventilator is used to provide ventilation air to the building and exhaust air from the toilet rooms, kitchen, and health training area.

The US Postal Service rents a small portion of the building, and it is completely isolated from the rest of the building, including the heating system. It is served by a 57 MBH output fuel oil fired furnace, and is completely separated from the building heating system.

4.0 Current Heating Energy Use

A Fuel oil usage log for the facility was provided. The following table summarizes the data:

Table 4.1 - Annual Fuel Use Summary				
Facility Name	Fuel Type	Avg. Use (Gallons)	Current Cost/Gal	Annual Cost
Kiniaq Building	Fuel Oil	1,500	$6.50	$9,750

5.0 Biomass Boiler Size

The following table summarized the connected load of fuel fired boilers:

Table 5.1 - Connected Boiler Load Summary					
			Output MBH	Peak Load Factor	Likely System Peak MBH
Kiniaq Bldg	Boiler 1	Fuel Oil	159	0.60	95
	Boiler 2	Fuel Oil	159	0.60	95
Total			**318**		**191**

Typically a wood heating system is sized to meet approximately 85% of the typical annual heating energy use of the building. The existing heating boilers would be used for the other 15% of the time during peak heating conditions, during times when the biomass boiler is down for servicing, and during swing months when only a few hours of heating each day are required. Recent energy models have found that a boiler sized at 50% to 60% of the building peak load will typically accommodate 85% of the boiler run hours.

Table 5.2 - Proposed Biomass Boiler Size			
	Likely System Peak MBH	Biomass Boiler Factor	Biomass Boiler Size MBH
Kiniaq Building	191	0.6	114

6.0 Wood Fuel Use and Cost

The only type of wood fuel currently available in the area is cord wood. The majority of cordwood is harvested from the local forest land. Some wood is obtained from the Koyuk River banks as driftwood that comes from upriver and is deposited along the river banks during the spring break up. There are no commercial logging operations in the area. Most wood is collected and cut up by private individuals for use in residential wood stoves.

Although cord wood is the only fuel type currently available in the area, the cost and amount of pellets will be shown for comparison purposes only.

The estimated amount of wood fuel needed was calculated and is listed below:

Table 6.1 - Annual Wood Fuel Use Summary			
	Fuel Oil (Gallons)	Cord Wood (Cords)	Wood Pellets (Tons)
Kiniaq Building	1,500	15.4	14.1

The amount of wood fuel shown in the table is for supplanting the entire amount of fuel oil and is for comparison purposes only. It is extremely unlikely that wood fuel will be able to completely replace the entire amount of fuel oil use. The moisture content of the wood fuels and the overall wood burning system efficiencies were accounted for in these calculations. The existing fuel oil boilers were assumed to be 80% efficient. Cord wood was assumed to be 20% moisture content (MC) with a system efficiency of 65%. Wood pellets were assumed to be 7% MC with a system efficiency of 70%.

The unit fuel costs for fuel oil and the different wood fuel types were calculated and equalized to dollars per million Btu ($/MMBtu) to allow for direct comparison. The Delivered $/MMBtu is the cost of the fuel based on what is actually delivered to the heating system, which includes all the inefficiencies of the different systems. The Gross $/MMBtu is the cost of the fuel based on raw fuel, or the higher heating value and does not account for any system inefficiencies. The following table summarizes the equalized fuel costs at different fuel unit costs:

Table 6.2 - Unit Fuel Costs Equalized to $/MMBtu

Fuel Type	Units	Gross Btu/unit	System Efficiency	Net System Btu/unit	$/unit	Delivered $/MMBtu	Gross $/MMBtu
Fuel Oil	gal	134500	0.8	107600	$6.00	$55.76	$44.61
					$6.50	$60.41	$48.33
					$7.00	$65.06	$52.04
Cord Wood	cords	16173800	0.65	10512970	$300.00	$28.54	$18.55
					$350.00	$33.29	$21.64
					$400.00	$38.05	$24.73
Pellets	tons	16400000	0.7	11480000	$500.00	$43.55	$30.49
					$550.00	$47.91	$33.54
					$600.00	$52.26	$36.59

7.0 Boiler Plant Location and Site Access

The boiler room is not large enough to accommodate a new wood fired boiler so a new stand-alone plant would be required. The best location for a plant would be just north of the building. See Appendix C for a site plan of this building.

Any type of biomass boiler plant will require access by delivery vehicles. For cord wood systems this would likely be pick-up trucks, trucks with trailers, snow machines or ATV's. The existing road to the building is large enough to accommodate any type of delivery vehicle that would be used for wood delivery.

8.0 Integration with Existing Heating System

Integration of a wood fired boiler system would be relatively straight forward in the building. The field visit confirmed the location of the boiler room in order to identify an approximate point of connection from a biomass boiler to the existing building. Piping from the biomass boiler plant would likely be run below ground under the building in arctic pipe and extend up to the boiler room. Once the hot water supply and return piping enters the existing boiler room it would be connected to existing supply and return pipes in appropriate locations in order to utilize the existing pumping systems within the building. The wood heating system would inject heat into the existing heating hot water system. The USPS would remain stand alone and would not be connected into this system.

The existing hot water heating system appears to be designed for a heating supply water temperature of 180 deg. F. Perimeter finned tube heating elements are the primary devices used to heat the spaces. Heat emanates from these elements via radiation and natural convection. Because of this, the performance of the heating elements is greatly influenced by heating water supply temperature. At 140 deg. F heating water supply temperature, the heat output of these elements is approximately 50% of their output at 180 deg F. Wood chip and wood pellet boilers can consistently produce and maintain 180 deg. F water because the fuel is automatically and mechanically fed into the boiler. However, it can be difficult for manually fed cord wood systems to maintain this temperature unless they are continuously tended to and wood is constantly fed into the boiler. For this reason, cord wood boilers should be coupled with thermal storage tanks, so the boiler can be loaded, it can burn the wood hot and fast, and the water can be heated and "stored" in the tank. In this scenario as long as the boiler is checked and tended to regularly (3 to 5 times a day depending on heating load) a consistent 140 deg. F supply temperature generally can be maintained. A very basic and preliminary building heat load analysis was performed and it appears that a 140 deg. F heating water supply temperature could provide sufficient heat for the building down to approximately 22 deg. F outside air temperature, which would cover approximately 70% of the heating hours over the course of a year.

9.0 Air Quality Permits

Resource System Group (RSG) has done a preliminary review of potential air quality issues in the area and has found no significant concerns. The proposed boiler size at this location is small enough that the boiler is not likely to require any State or Federal permits. See the air quality memo in Appendix D for more detailed information including design criteria that has been suggested to minimize emissions and maximize dispersion.

10.0 Wood Heating Options

The technologies available to produce heating energy from wood based biomass are varied in their approach, but largely can be separated into three types of heating plants: cord wood, wood pellet and wood chip/ground wood fueled. See Appendix E for summaries on these types of systems.

A cord wood boiler system and a wood stove are the only viable options at this time in Koyuk. Two cord wood boiler options were developed, one offsetting 70% of the current fuel oil usage and one offsetting 50% of the current fuel oil usage. Both cord wood options have the same capital costs. A wood stove option was also developed. The concept would be to install a wood stove in each of the two large open areas. For this option, it is assumed that 35% of the fuel oil could be offset. An EPA certified wood stove is assumed to be used. The EPA certification ensures a wood stove is well designed to have a good combustion efficiency and good emissions.

The options reviewed were:

Cord Wood Boiler Options:

- C.1.A: A freestanding building with interior cordwood storage, 70% fuel oil offset.
- C.1.B: A freestanding building with interior cordwood storage, 50% fuel oil offset.

Wood Stove Options:

- D.1: Two freestanding wood stoves, 35% fuel oil offset.

11.0 Estimated Costs

The total project costs are at a preliminary level and are based on RS Means and recent biomass project construction cost data. The estimates are shown in Appendix A. These costs are conservative and if a deeper level feasibility analysis is undertaken and/or further design occurs, the costs may be able to be reduced.

12.0 Economic Analysis Assumptions

The cash flow analysis assumes fuel oil at $6.50/gal, electricity at $0.30/kwh, and cord wood delivered at $300/cord. The fuel oil and electricity costs are based on the costs reported by the facility and by the State of Alaska. Cord wood pricing is based on what was reported in the community.

It is assumed that the wood boiler would supplant 70% or 50% of the estimated heating use as indicated in the option description, and the existing heating systems would heat the remaining portion. Likewise, the wood stove option would supplant 35% of the estimated fuel oil use. Each option assumes the total project can be funded with grants and non obligated capital money. The following inflation rates were used:

O&M - 2% Fossil Fuel – 5%
Wood Fuel – 3% Discount Rate for NPV calculation – 3%

The fossil fuel inflation rate is based on the DOE EIA website. DOE is projecting a slight plateau with a long term inflation of approximately 5%. As a point of comparison, oil prices have increased at an annual rate of over 8% since 2001.

The analysis also accounts for additional electrical energy required for the wood fired boiler system as well as the system pumps to distribute heating hot water to the building. Wood fired boiler systems also will require more maintenance, and these additional maintenance costs are also factored into the analysis.

13.0 Results of Evaluation

The following table summarizes the economic evaluation for each option:

Table 13.1 - Economic Evaluation Summary
Kiniaq Building Biomass Heating System

	Project Cost	Year 1 Operating Savings	NPV 20 yr at 3%	NPV 30 yr at 3%	20 Yr B/C Ratio	30 Yr B/C Ratio	ACF YR 20	ACF YR 30	YR ACF=PC
C.1.A	$226,000	-$9,709	-$114,067	-$129,668	-0.50	-0.57	-$150,022	-$181,797	31
C.1.B	$226,000	-$7,538	-$85,189	-$97,747	-0.38	-0.43	-$111,997	-$137,711	31
D.1	$18,000	$125	$18,914	$43,452	1.05	2.41	$28,631	$81,553	17

The benefit to cost (B/C) ratio takes the net present value (NPV) of the net energy savings and divides it by the estimated construction cost of the project. A B/C ratio greater than or equal to 1.0 indicates an economically advantageous project.

Accumulated cash flow (ACF) is another evaluation measure that is calculated in this report and is similar to simple payback with the exception that accumulated cash flow takes the cost of financing and fuel escalation into account. For many building owners, having the accumulated cash flow equal the project cost within 15 years is considered necessary for implementation. If the accumulated cash flow equals project cost in 20 years or more, that indicates a challenged project. Positive accumulated cash flow should also be considered an avoided cost as opposed to a pure savings.

See Appendix D for the full cash flow spread sheets for each option.

14.0 Project Funding

The Native Village of Koyuk can pursue a biomass project grant from the Alaska Energy Authority. See the following website for more information:

http://www.akenergyauthority.org/refund7.html

The Native Village of Koyuk could also enter into a performance contract for the project. Companies such as Siemens, McKinstry, Johnson Controls and Chevron have expressed an interest in participating in funding projects of all sizes throughout Alaska. This allows the facility owner to pay for the project entirely from the guaranteed energy savings, and to minimize the project funds required to initiate the project. The scope of the project may be expanded to include additional energy conservation measures such as roof and wall insulation and upgrading mechanical systems.

15.0 Summary

The Kiniaq Building appears to be a fair candidate for the use of a wood biomass heating system using wood stoves. With the current economic assumptions, the economic viability of the cord wood boiler options is poor as none of the options meet the minimum requirement of the 20 year B/C ratio exceeding 1.0. The amount of fuel oil use is not large enough to economically leverage much capital costs, even if the most of the fuel oil use could be eliminated. The wood stove option does appear to be economically viable, however, it is very sensitive to labor costs. For this analysis 2 hours a week of feeding the stoves was assumed. If this was 3 hours a week, then the 20 year B/C ratio would drop below 1.0. The wood stove option also assumed offsetting 35% of the current fuel oil use. This was due to the typical occupancy of the building (no one to feed the fire on nights and weekends) and because of the room layout of the building. The stoves would keep the large open areas heated, but the perimeter offices would likely still require supplemental heat from the boiler system.

The cord wood fuel source would benefit the community because the fuel is a renewable resource, has a lower energy cost, and the money paid for the fuel would remain in the local community and economy.

16.0 Recommended Action

Pursue purchasing a wood stove. Determine best location to store wood.

APPENDIX A

Preliminary Estimates of Probable Cost

Preliminary Estimates of Probable Cost
Biomass Heating Options
Kiniaq Building
Koyuk, AK

Option C.1 Cord Wood Boiler

Biomass Boiler Building Including Wood Storage Area:	$55,000
Cord Wood Boiler and Thermal Storage Tank:	$19,000
Stack:	$5,000
Mechanical/Electrical within Boiler Building:	$25,000
Underground Piping:	$9,500
Integration in Boiler Room:	$8,500
Subtotal:	$122,000
40% Remote Factor	$48,800
Subtotal:	$170,800
Design Fees, Building Permit, Miscellaneous Expenses 15%:	$25,620
Subtotal:	$196,420
15% Contingency:	$29,463
Total Project Costs	**$ 225,883**

Option D.1 Wood Stove

(2) Wood Stoves:	$7,600
(2) Stack Assemblies:	$3,000
Subtotal:	$10,600
40% Remote Factor	$4,240
Subtotal:	$14,840
Design Fees, Building Permit, Miscellaneous Expenses 5%:	$742
Subtotal:	$15,582
15% Contingency:	$2,337
Total Project Costs	**$ 17,919**

APPENDIX B

Cash Flow Analysis

Kiniaq Building
Koyuk, Alaska

Option C.1.A
Cord Wood Boiler
70% Offset

Date: July 15, 2013
Analyst: CTA Architects Engineers - Nathan Ratz

EXISTING CONDITIONS	**Store**				**Total**
Existing Fuel Type:	Fuel Oil	Fuel Oil	Fuel Oil	Fuel Oil	
Fuel Units:	gal	gal	gal	gal	
Current Fuel Unit Cost:	$6.50				
Estimated Average Annual Fuel Usage:	1,500				1,500
Annual Heating Costs:	$9,750	$0	$0	$0	$9,750
ENERGY CONVERSION (to 1,000,000 Btu; or 1 dkt)					
Fuel Heating Value (Btu/unit of fuel):	134500	134500	134500	134500	
Current Annual Fuel Volume (Btu):	201,750,000	0	0	0	
Assumed efficiency of existing heating system (%):	80%	80%	80%	80%	
Net Annual Energy Produced (Btu):	161,400,000	0	0	0	161,400,000

WOOD FUEL COST	**Cord Wood**
$/cord:	$300.00
Assumed efficiency of wood heating system (%):	65%
PROJECTED WOOD FUEL USAGE	
Estimated Btu content of wood fuel (Btu/cord) - **Assumed 20% MC, 6,700 Btu/lb x 28.4 lb/cf x 85 cf**	16,173,800
Cords of wood fuel to supplant net equivalent of 100% annual heating load.	15
Cords of wood fuel to supplant net equivalent of 85% annual heating load.	13
25 ton chip van loads to supplant net equivalent of 85% annual heating load.	N/A

Project Capital Cost	**-$226,000**

Project Financing Information	
Percent Financed	**0.0%**
Amount Financed	$0
Amount of Grants	$226,000
Interest Rate	5.00%
Term	10
Annual Finance Cost (years)	$0

Additional Power Use		
Est. Pwr Use	1700 kWh	
Elec Rate	$0.300 /kWh	

Additional Maintenance					
Type	Hr/Wk	Wk/Yr	Total Hr	Wage/Hr	Total
Biomass System	14.0	40	560	$20.00	$11,200
Other	0.0	40	0	$20.00	$0
1st 2 Year Learning	2.0	40	80	$20.00	$1,600

		Net Benefit	B/C Ratio
Simple Payback: Total Project Cost/Year One Operating Cost Savings:	-23.3 years		
Net Present Value (30 year analysis):	-$129,668	-$355,668	-0.57
Net Present Value (20 year analysis):	-$114,067	-$340,067	-0.50
Year Accumulated Cash Flow > 0	31		
Year Accumulated Cash Flow > Project Capital Cost	31		

Inflation Factors	
O&M Inflation Rate	2.0%
Fossil Fuel Inflation Rate	5.0%
Wood Fuel Inflation Rate	3.0%
Electricity Inflation Rate	3.0%
Discount Rate for Net Present Value Calculation	3.0%

Cash flow Descriptions	**Unit Costs**	**Heating Source Proportion**	**Annual Heating Source Volumes**	**Heating Units**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
Existing Heating System Operating Costs														
Displaced heating costs	$6.50		1500	gal	$9,750	$10,238	$10,749	$11,287	$11,851	$12,444	$13,066	$13,719	$14,405	$15,125
Displaced heating costs	$0.00		0	gal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Displaced heating costs	$0.00		0	gal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Displaced heating costs	$0.00		0	gal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Biomass System Operating Costs														
Wood Fuel ($/ton, delivered to boiler site)	$300.00	70%	11	cords	$3,224	$3,321	$3,420	$3,523	$3,629	$3,738	$3,850	$3,965	$4,084	$4,207
Small load existing fuel	$6.50	30%	450	gal	$2,925	$3,071	$3,225	$3,386	$3,555	$3,733	$3,920	$4,116	$4,322	$4,538
Small load existing fuel	$0.00	15%	0	gal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Small load existing fuel	$0.00	15%	0	gal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Small load existing fuel	$0.00	15%	0	gal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Additional Operation and Maintenance Costs					$11,200	$11,424	$11,652	$11,886	$12,123	$12,366	$12,613	$12,865	$13,123	$13,385
Additional Operation and Maintenance Costs First 2 years					$1,600	$1,632								
Additional Electrical Cost	$0.300				$510	$525	$541	$557	$574	$591	$609	$627	$646	$665
Annual Operating Cost Savings					***-$9,709***	***-$9,736***	***-$8,089***	***-$8,065***	***-$8,030***	***-$7,984***	***-$7,925***	***-$7,854***	***-$7,769***	***-$7,669***
Financed Project Costs - Principal and Interest					***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***
Displaced System Replacement Costs (year one only)					***0***									
Net Annual Cash Flow					***(9,709)***	***(9,736)***	***(8,089)***	***(8,065)***	***(8,030)***	***(7,984)***	***(7,925)***	***(7,854)***	***(7,769)***	***(7,669)***
Accumulated Cash Flow					***(9,709)***	***(19,445)***	***(27,534)***	***(35,599)***	***(43,629)***	***(51,613)***	***(59,539)***	***(67,393)***	***(75,162)***	***(82,831)***

Cash flow Descriptions	**Year 11**	**Year 12**	**Year 13**	**Year 14**	**Year 15**	**Year 20**	**Year 25**	**Year 30**
Existing Heating System Operating Costs								
Displaced heating costs	$15,882	$16,676	$17,510	$18,385	$19,304	$24,638	$31,445	$40,132
Displaced heating costs	$0	$0	$0	$0	$0	$0	$0	$0
Displaced heating costs	$0	$0	$0	$0	$0	$0	$0	$0
Displaced heating costs	$0	$0	$0	$0	$0	$0	$0	$0
Biomass System Operating Costs								
Wood Fuel ($/ton, delivered to boiler site)	$4,333	$4,463	$4,597	$4,735	$4,877	$5,653	$6,554	$7,598
Small load existing fuel	$4,765	$5,003	$5,253	$5,516	$5,791	$7,391	$9,433	$12,040
Small load existing fuel	$0	$0	$0	$0	$0	$0	$0	$0
Small load existing fuel	$0	$0	$0	$0	$0	$0	$0	$0
Small load existing fuel	$0	$0	$0	$0	$0	$0	$0	$0
Additional Operation and Maintenance Costs	$13,653	$13,926	$14,204	$14,488	$14,778	$16,316	$18,014	$19,889
Additional Operation and Maintenance Costs First 2 years								
Additional Electrical Cost	$685	$706	$727	$749	$771	$894	$1,037	$1,202
Annual Operating Cost Savings	***-$7,554***	***-$7,421***	***-$7,271***	***-$7,102***	***-$6,913***	***-$5,617***	***-$3,594***	***-$596***
Financed Project Costs - Principal and Interest								
Displaced System Replacement Costs (year one only)								
Net Annual Cash Flow	***(7,554)***	***(7,421)***	***(7,271)***	***(7,102)***	***(6,913)***	***(5,617)***	***(3,594)***	***(596)***
Accumulated Cash Flow	***(90,385)***	***(97,806)***	***(105,078)***	***(112,180)***	***(119,093)***	***(150,022)***	***(172,373)***	***(181,797)***

Kiniaq Building

Koyuk, Alaska

Date: July 15, 2013

Analyst: CTA Architects Engineers - Nathan Ratz

Option C.1.B

Cord Wood Boiler

50% Offset

EXISTING CONDITIONS	Store				Total
Existing Fuel Type:	Fuel Oil	Fuel Oil	Fuel Oil	Fuel Oil	
Fuel Units:	gal	gal	gal	gal	
Current Fuel Unit Cost:	$6.50				
Estimated Average Annual Fuel Usage:	1,500				1,500
Annual Heating Costs:	$9,750	$0	$0	$0	$9,750
ENERGY CONVERSION (to 1,000,000 Btu; or 1 dkt)					
Fuel Heating Value (Btu/unit of fuel):	134500	134500	134500	134500	
Current Annual Fuel Volume (Btu):	201,750,000	0	0	0	
Assumed efficiency of existing heating system (%):	80%	80%	80%	80%	
Net Annual Energy Produced (Btu):	161,400,000	0	0	0	161,400,000

WOOD FUEL COST	Cord Wood
$/cord:	$300.00
Assumed efficiency of wood heating system (%):	65%
PROJECTED WOOD FUEL USAGE	
Estimated Btu content of wood fuel (Btu/cord) - **Assumed 20% MC, 6,700 Btu/lb x 28.4 lb/cf x 85 cf**	16,173,800
Cords of wood fuel to supplant net equivalent of 100% annual heating load.	15
Cords of wood fuel to supplant net equivalent of 85% annual heating load.	13
25 ton chip van loads to supplant net equivalent of 85% annual heating load.	N/A

Project Capital Cost	**-$226,000**

Project Financing Information	
Percent Financed	**0.0%**
Amount Financed	$0
Amount of Grants	$226,000
Interest Rate	5.00%
Term	10
Annual Finance Cost (years)	$0

Additional Power Use	
Est. Pwr Use	1700 kWh
Elec Rate	$0.300 /kWh

Additional Maintenance					
Type	Hr/Wk	Wk/Yr	Total Hr	Wage/Hr	Total
Biomass System	10.0	40	400	$20.00	$8,000
Other	0.0	40	0	$20.00	$0
1st 2 Year Learning	2.0	40	80	$20.00	$1,600

		Net Benefit	B/C Ratio
Simple Payback: Total Project Cost/Year One Operating Cost Savings:	-30.0 years	Net Benefit	B/C Ratio
Net Present Value (30 year analysis):	-$97,747	-$323,747	-0.43
Net Present Value (20 year analysis):	-$85,189	-$311,189	-0.38
Year Accumulated Cash Flow > 0	31		
Year Accumulated Cash Flow > Project Capital Cost	31		

Inflation Factors	
O&M Inflation Rate	2.0%
Fossil Fuel Inflation Rate	5.0%
Wood Fuel Inflation Rate	3.0%
Electricity Inflation Rate	3.0%
Discount Rate for Net Present Value Calculation	3.0%

Cash flow Descriptions	Unit Costs	Heating Source Proportion	Annual Heating Source Volumes	Heating Units	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 20	Year 25	Year 30
Existing Heating System Operating Costs																						
Displaced heating costs	$6.50		1500	gal	$9,750	$10,238	$10,749	$11,287	$11,851	$12,444	$13,066	$13,719	$14,405	$15,125	$15,882	$16,676	$17,510	$18,385	$19,304	$24,638	$31,445	$40,132
Displaced heating costs	$0.00		0	gal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Displaced heating costs	$0.00		0	gal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Displaced heating costs	$0.00		0	gal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Biomass System Operating Costs																						
Wood Fuel ($/ton, delivered to boiler site)	$300.00	50%	8	cords	$2,303	$2,372	$2,443	$2,516	$2,592	$2,670	$2,750	$2,832	$2,917	$3,005	$3,095	$3,188	$3,283	$3,382	$3,483	$4,038	$4,681	$5,427
Small load existing fuel	$6.50	50%	750	gal	$4,875	$5,119	$5,375	$5,643	$5,926	$6,222	$6,533	$6,860	$7,203	$7,563	$7,941	$8,338	$8,755	$9,193	$9,652	$12,319	$15,722	$20,066
Small load existing fuel	$0.00	15%	0	gal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Small load existing fuel	$0.00	15%	0	gal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Small load existing fuel	$0.00	15%	0	gal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Additional Operation and Maintenance Costs					$8,000	$8,160	$8,323	$8,490	$8,659	$8,833	$9,009	$9,189	$9,373	$9,561	$9,752	$9,947	$10,146	$10,349	$10,556	$11,654	$12,867	$14,207
Additional Operation and Maintenance Costs First 2 years					$1,600	$1,632																
Additional Electrical Cost	$0.300				$510	$525	$541	$557	$574	$591	$609	$627	$646	$665	$685	$706	$727	$749	$771	$894	$1,037	$1,202
Annual Operating Cost Savings					***-$7,538***	***-$7,571***	***-$5,933***	***-$5,920***	***-$5,900***	***-$5,872***	***-$5,835***	***-$5,789***	***-$5,734***	***-$5,668***	***-$5,591***	***-$5,503***	***-$5,402***	***-$5,287***	***-$5,158***	***-$4,268***	***-$2,863***	***-$769***
Financed Project Costs - Principal and Interest					***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***								
Displaced System Replacement Costs (year one only)					***0***																	
Net Annual Cash Flow					*(7,538)*	*(7,571)*	*(5,933)*	*(5,920)*	*(5,900)*	*(5,872)*	*(5,835)*	*(5,789)*	*(5,734)*	*(5,668)*	*(5,591)*	*(5,503)*	*(5,402)*	*(5,287)*	*(5,158)*	*(4,268)*	*(2,863)*	*(769)*
Accumulated Cash Flow					*(7,538)*	*(15,108)*	*(21,041)*	*(26,961)*	*(32,861)*	*(38,732)*	*(44,567)*	*(50,357)*	*(56,091)*	*(61,759)*	*(67,350)*	*(72,853)*	*(78,255)*	*(83,542)*	*(88,700)*	*(111,997)*	*(129,360)*	*(137,711)*

Kiniaq Building

Koyuk, Alaska

Option D.1

Cord Wood Stove
35% Offset

Date: July 15, 2013
Analyst: CTA Architects Engineers - Nathan Ratz

EXISTING CONDITIONS	Store				Total
Existing Fuel Type:	Fuel Oil	Fuel Oil	Fuel Oil	Fuel Oil	
Fuel Units:	gal	gal	gal	gal	
Current Fuel Unit Cost:	$6.50				
Estimated Average Annual Fuel Usage:	1,500				1,500
Annual Heating Costs:	$9,750	$0	$0	$0	$9,750
ENERGY CONVERSION (to 1,000,000 Btu; or 1 dkt)					
Fuel Heating Value (Btu/unit of fuel):	134500	134500	134500	134500	
Current Annual Fuel Volume (Btu):	201,750,000	0	0	0	
Assumed efficiency of existing heating system (%):	80%	80%	80%	80%	
Net Annual Energy Produced (Btu):	161,400,000	0	0	0	161,400,000

WOOD FUEL COST	Cord Wood
$/cord:	$300.00
Assumed efficiency of wood heating system (%):	65%
PROJECTED WOOD FUEL USAGE	
Estimated Btu content of wood fuel (Btu/cord) - **Assumed 20% MC, 6,700 Btu/lb x 28.4 lb/cf x 85 cf**	16,173,800
Cords of wood fuel to supplant net equivalent of 100% annual heating load.	15
Cords of wood fuel to supplant net equivalent of 85% annual heating load.	13
25 ton chip van loads to supplant net equivalent of 85% annual heating load.	N/A

Project Capital Cost	-$18,000

Project Financing Information	
Percent Financed	0.0%
Amount Financed	$0
Amount of Grants	$18,000
Interest Rate	5.00%
Term	10
Annual Finance Cost (years)	$0

Additional Power Use	
Est. Pwr Use	250 kWh
Elec Rate	$0.300 /kWh

Additional Maintenance					
Type	Hr/Wk	Wk/Yr	Total Hr	Wage/Hr	Total
Biomass System	2.0	40	80	$20.00	$1,600
Other	0.0	40	0	$20.00	$0
1st 2 Year Learning	0.0	40	0	$20.00	$0

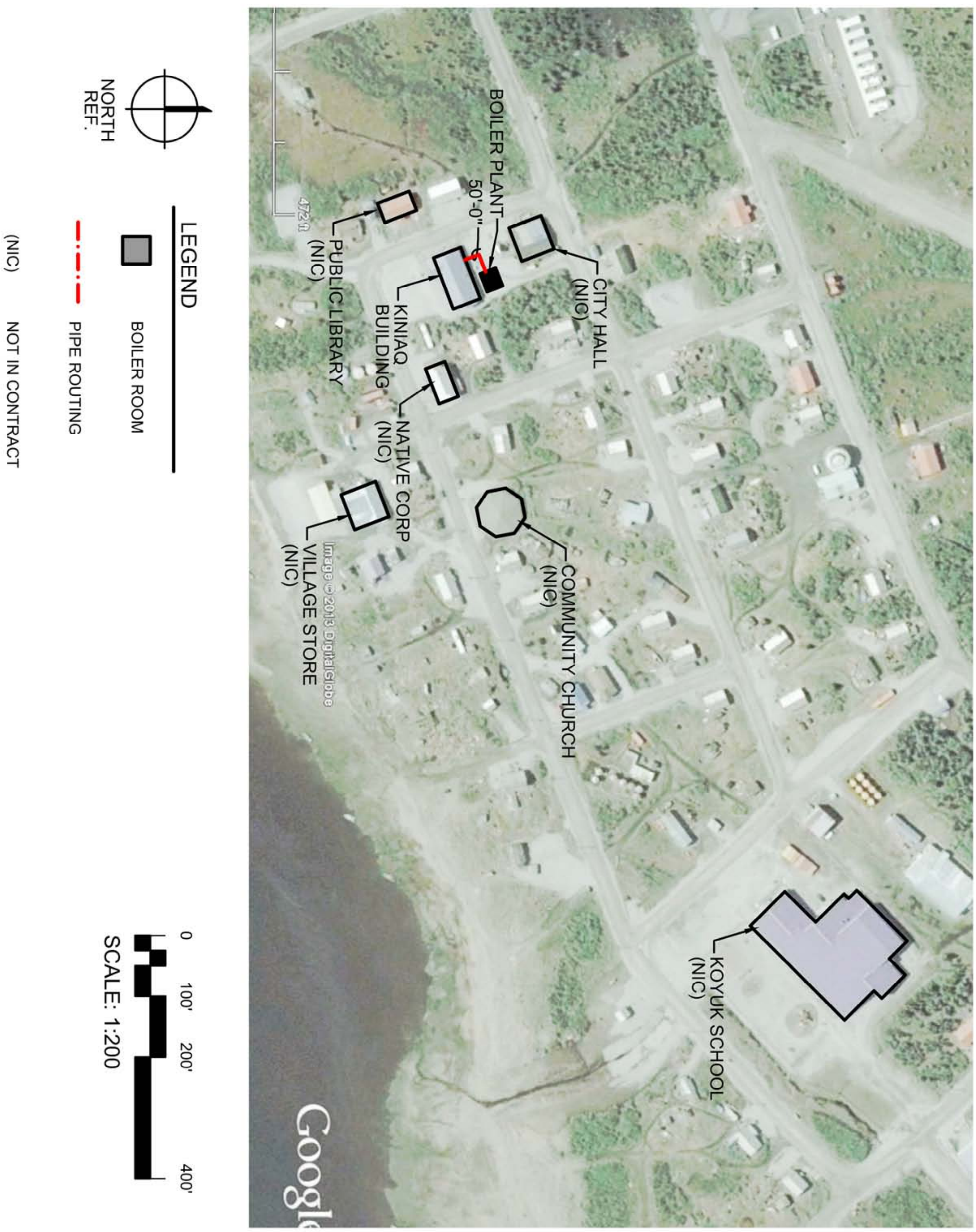
		Net Benefit	B/C Ratio
Simple Payback: Total Project Cost/Year One Operating Cost Savings:	143.4 years	Net Benefit	B/C Ratio
Net Present Value (30 year analysis):	$43,452	$25,452	2.41
Net Present Value (20 year analysis):	$18,914	$914	1.05
Year Accumulated Cash Flow > 0	#N/A		
Year Accumulated Cash Flow > Project Capital Cost	17		

Inflation Factors	
O&M Inflation Rate	2.0%
Fossil Fuel Inflation Rate	5.0%
Wood Fuel Inflation Rate	3.0%
Electricity Inflation Rate	3.0%
Discount Rate for Net Present Value Calculation	3.0%

Cash flow Descriptions	Unit Costs	Heating Source Proportion	Annual Heating Source Volumes	Heating Units	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 20	Year 25	Year 30
Existing Heating System Operating Costs																						
Displaced heating costs	$6.50		1500	gal	$9,750	$10,238	$10,749	$11,287	$11,851	$12,444	$13,066	$13,719	$14,405	$15,125	$15,882	$16,676	$17,510	$18,385	$19,304	$24,638	$31,445	$40,132
Displaced heating costs	$0.00		0	gal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Displaced heating costs	$0.00		0	gal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Displaced heating costs	$0.00		0	gal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Biomass System Operating Costs																						
Wood Fuel ($/ton, delivered to boiler site)	$300.00	35%	5	cords	$1,612	$1,660	$1,710	$1,761	$1,814	$1,869	$1,925	$1,983	$2,042	$2,103	$2,166	$2,231	$2,298	$2,367	$2,438	$2,827	$3,277	$3,799
Small load existing fuel	$6.50	65%	975	gal	$6,338	$6,654	$6,987	$7,336	$7,703	$8,088	$8,493	$8,917	$9,363	$9,832	$10,323	$10,839	$11,381	$11,950	$12,548	$16,015	$20,439	$26,086
Small load existing fuel	$0.00	15%	0	gal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Small load existing fuel	$0.00	15%	0	gal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Small load existing fuel	$0.00	15%	0	gal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Additional Operation and Maintenance Costs					$1,600	$1,632	$1,665	$1,698	$1,732	$1,767	$1,802	$1,838	$1,875	$1,912	$1,950	$1,989	$2,029	$2,070	$2,111	$2,331	$2,573	$2,841
Additional Operation and Maintenance Costs First 2 years					$0	$0																
Additional Electrical Cost	$0.300				$75	$77	$80	$82	$84	$87	$90	$92	$95	$98	$101	$104	$107	$110	$113	$132	$152	$177
Annual Operating Cost Savings					***$125***	***$214***	***$308***	***$409***	***$517***	***$633***	***$757***	***$889***	***$1,030***	***$1,181***	***$1,341***	***$1,512***	***$1,694***	***$1,888***	***$2,094***	***$3,334***	***$5,003***	***$7,229***
Financed Project Costs - Principal and Interest					***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***								
Displaced System Replacement Costs (year one only)					***0***																	
Net Annual Cash Flow					***125***	***214***	***308***	***409***	***517***	***633***	***757***	***889***	***1,030***	***1,181***	***1,341***	***1,512***	***1,694***	***1,888***	***2,094***	***3,334***	***5,003***	***7,229***
Accumulated Cash Flow					***125***	***339***	***647***	***1,056***	***1,573***	***2,206***	***2,963***	***3,852***	***4,882***	***6,063***	***7,404***	***8,916***	***10,610***	***12,497***	***14,591***	***28,631***	***50,113***	***81,553***

APPENDIX C

Site Plan



BIOMASS PRE-FEASIBILITY ASSESSMENT

KINIAQ BUILDING

KOYUK, AK

CTA
MISSOULA, MT
(406)728-9522

SITE PLAN

Drawn By TW
Checked By NHR
Date 06/27/2013
CTA # FEDC
Cad File: KOYUK.DWG

APPENDIX D

Air Quality Report

RESOURCE SYSTEMS GROUP, INC.

Transportation & Environment Practice

Air Quality Feasibility Report For the:

FEDC Pre-Feasibility Studies on Wood-Fired Heating Projects

Prepared for:

CTA Architects Engineers
Missoula, MT

July, 2013

Prepared by:
RSG, Inc.

Resource Systems Group, Inc.
55 Railroad Row
White River Junction, VT 05001
TEL 802.295.4999 | FAX 802.295.1006
www.rsginc.com

Table of Contents

1.0 Introduction 1
2.0 Equipment Description 1
3.0 Site Descriptions 2
3.1 Emmonak 2
3.2 Koyuk 2
3.3 Lower Kalskag 2
3.4 Tuntutuliak 2
4.0 Meteorological Conditions 3
5.0 Regulatory Considerations 4
6.0 Design & Operation Recommendations 4

List of Figures

Figure 1: Wind Speed Data from Bethel, AK 3
Figure 2: Wind Speed Data from Nome, AK 3

1.0 INTRODUCTION

At the request of CTA, RSG has completed an air quality pre-feasibility study of implementing biomass energy systems in Emmonak, Koyuk, Lower Kalskag, and Tuntutuliak, Alaska. These systems will displace fossil fuel used in these locations and therefore displace fossil fuel-related emissions.

This report is broken into the following sections:

- Equipment description
- Site descriptions
- Meteorological conditions
- Regulatory considerations
- Design and operation recommendations

2.0 EQUIPMENT DESCRIPTION

The following details were provided for the boilers being considered. Equipment vendors have not been selected.

- Emmonak
  - Fuel: cord wood likely, wood chips also possible.
  - Heating capacity: 250,000 Btu/hr output.
- Koyuk
  - Fuel: cord wood.
  - Heating capacity: 150,000 Btu/hr output.
- Lower Kalskag
  - Fuel: cord wood.
  - Heating capacity.
    - Alternative A: one boiler at 625,000 Btu/hr output.
    - Alternative B: one boiler at 250,000 Btu/hr output coupled with several high efficiency wood stoves.
- Tuntutuliak
  - Fuel: cord wood
  - Heating capacity: 125,000 Btu/hr

3.0 SITE DESCRIPTIONS

Descriptions of each site are provided below. USGS maps, aerial photography, and site maps are provided in the Appendix.

3.1 Emmonak

Emmonak is a small village located near the west coast of Alaska, on the north bank of the Kwiguk Pass of the Yukon River. The area is relatively flat. No significant air pollution sources were identified in the review for this site. One biomass plant is being considered for this site at the Emmonak Corporate Store and Offices Building.

3.2 Koyuk

Koyuk is a small village located near the west coast of Alaska. It is situated on the north bank of the Koyuk River at Koyuk Inlet. The village is bordered by hills to the north and flat terrain to the south. The land slopes downhill from north to south, with ground elevation ranging from approximately 100 feet to 15 feet. No significant air pollution sources were identified in the review for this site. One Biomass plant is being considered for this site at the Kiniaq Building.

3.3 Lower Kalskag

Lower Kalskag is a small inland village located on the western bank of the Kuskowim River. The site is relatively flat. No significant air pollution sources were identified in the review for this site. Two biomass plants are considered for this site. One at the school and one near the clinic.

3.4 Tuntutuliak

Tuntutuliak is a relatively small inland village located on the northern bank of the Kinak River. The site is relatively flat. No significant air pollution sources were identified in the review for this site. One biomass plant is being considered for this site at the Community Hall.

4.0 METEOROLOGICAL CONDITIONS

Meteorological data from Bethel and Nome, AK, were reviewed to develop an understanding of weather conditions which will affect the dispersion of emissions. Bethel is the closest weather station approximating climactic conditions in the Emmonak, Lower Kalskag, and Tuntutuliak. Nome is the closest weather data approximating Koyuk. The data indicates calm winds occur approximately only 10% of the year. This suggests there will be minimal time periods when thermal inversions and therefore poor emission dispersion conditions can occur.[1]

Figure 1: Wind Speed Data from Bethel, AK

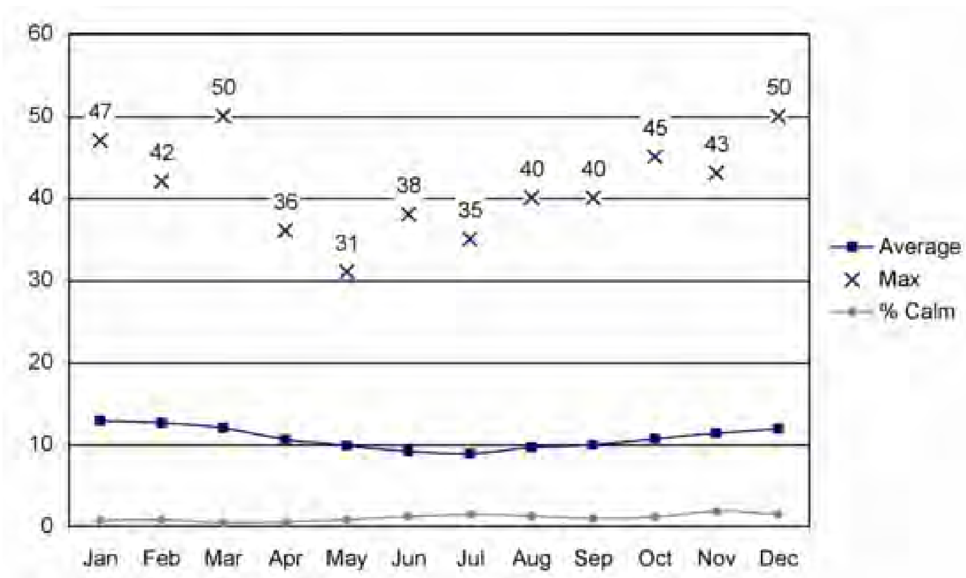
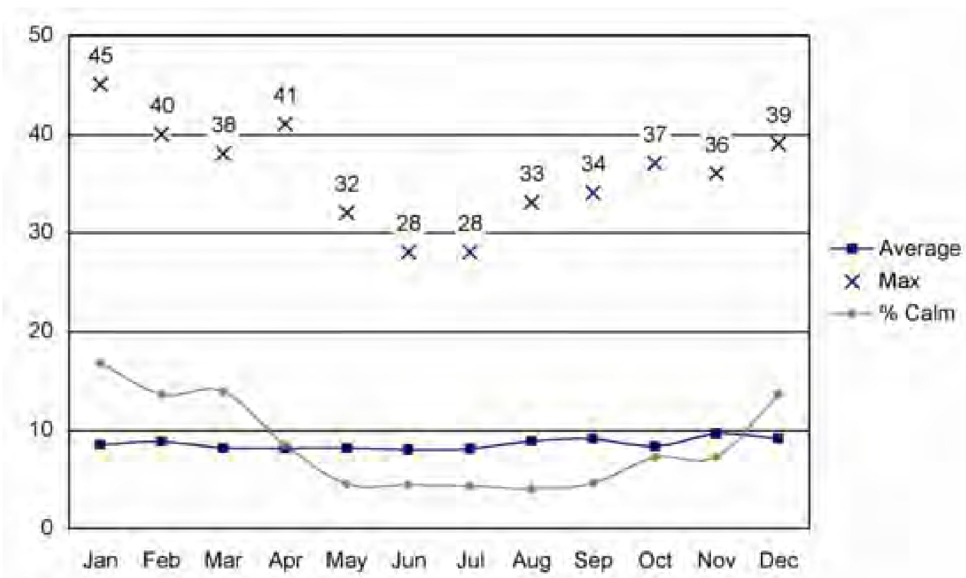


Figure 2: Wind Speed Data from Nome, AK



[1] See: http://climate.gi.alaska.edu/Climate/Wind/Speed/Annette/ANN.html

5.0 REGULATORY CONSIDERATIONS

The size of the proposed boilers will not trigger state or federal permitting requirements. Hot water boilers burning wood which are less than 1.6 MMBtu/hr heat input are below the threshold for EPA boiler requirements. More information about EPA boiler requirements can be obtained here:

http://www.epa.gov/boilercompliance/

6.0 DESIGN & OPERATION RECOMMENDATIONS

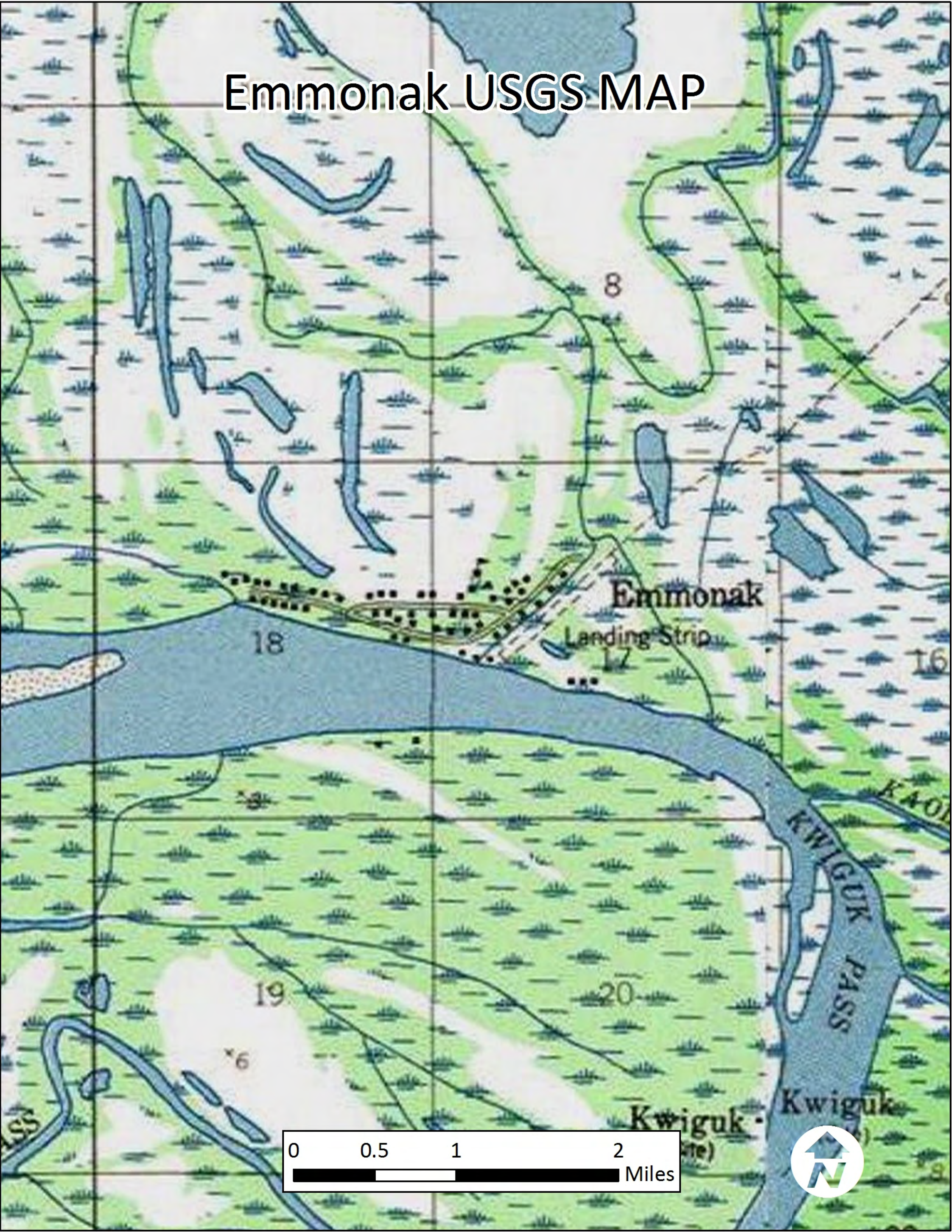
These design and operation recommendations are based on the assumption that state-of-the-art combustion equipment is installed. The following are suggested for designing this project:

- Burn natural wood, whose characteristics (bark content, species, geometry) optimizes combustion in the equipment selected for the project.
- Burn seasoned cord wood. Burning wet wood generates excess emissions.
- Do not install a rain cap above the stack. Rain caps obstruct vertical airflow and reduce dispersion of emissions.
- In situations where there are clusters of buildings, consider constructing the stack to at least 1.5 times the height of the tallest roofline of the adjacent building. Hence, a 20 foot roofline would result in a minimum 30 foot stack. *Special attention should be given to this in Koyuk due to the moderate slopes present.*
- Operate and maintain the boiler according to manufacturer's recommendations.
- Perform a tune-up at least every other year as per manufacturer's recommendations.
- Conduct regular observations of stack emissions. If emissions are not characteristic of good boiler operation, make corrective actions.

More information can be found about controlling wood boiler emissions can be obtained in a report written by RSG called "Emission Controls for Small Wood-Fired Boilers". The report can be downloaded here: http://www.wflccenter.org/news_pdf/361_pdf.pdf.

APPENDIX A

EMMONAK SITE INFORMATION


Emmonak USGS MAP
8
Emmonak
Landing Strip
18
17
16
KWIGUK
PASS
19
20
6
Kwiguk
Kwiguk
0
0.5
1
2
Miles


Emmonak Aerial Photography MAP
0
0.25
0.5
1
Miles
N

SITE PLAN

CTA
MISSOULA, MT
(406)728-9522

BIOMASS PRE-FEASIBILITY ASSESSMENT

EMMONAK CORPORATION

EMMONAK, AK

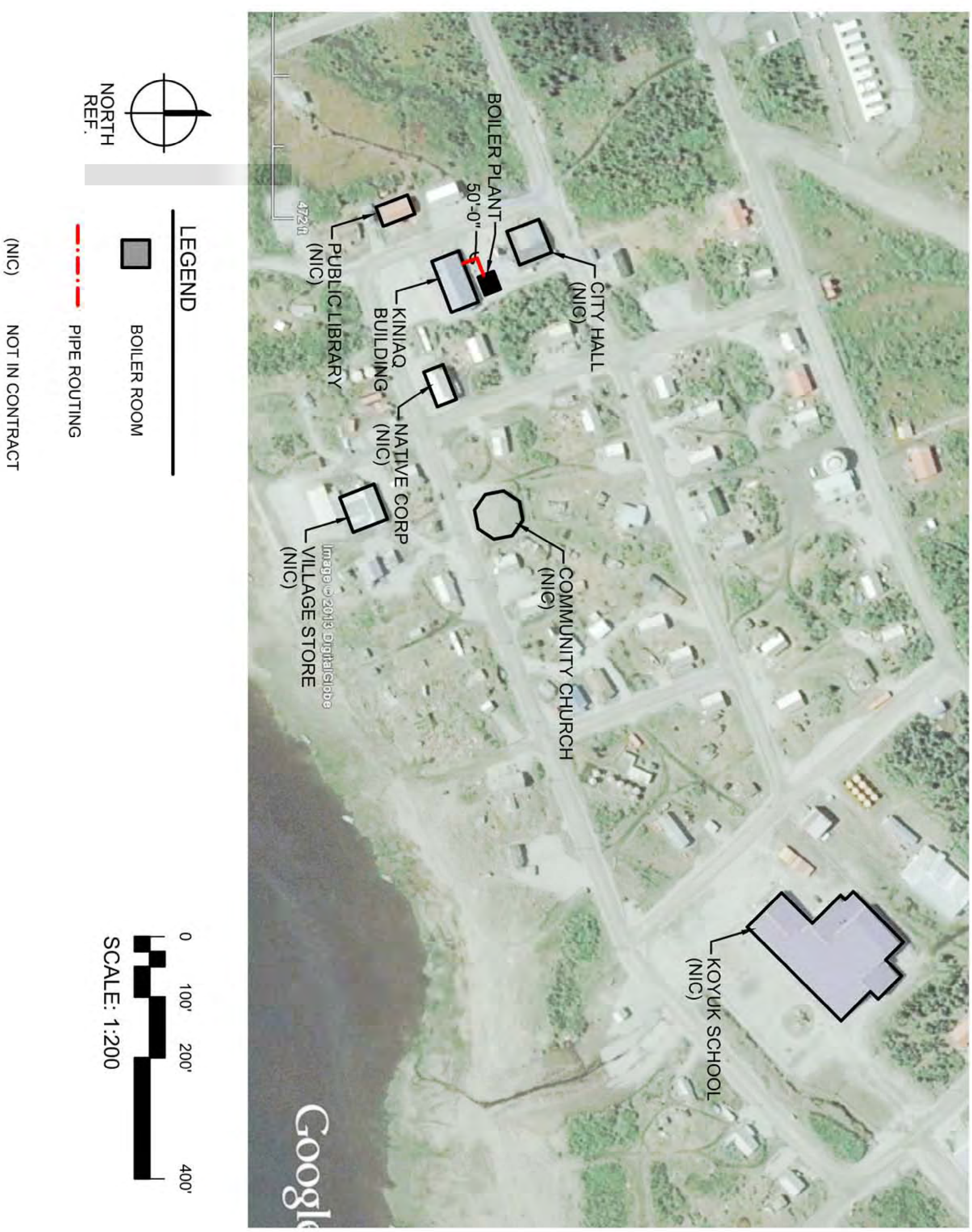
Drawn By	TW
Checked By	NHR
Date	06/27/2013
CTA #	FEDC
Cad File:	EMMONAK.DWG

APPENDIX B

KOYUK SITE INFORMATION

Koyuk USGS MAP

Koyuk Aerial Photography MAP
0
0.25
0.5
1
Miles
N



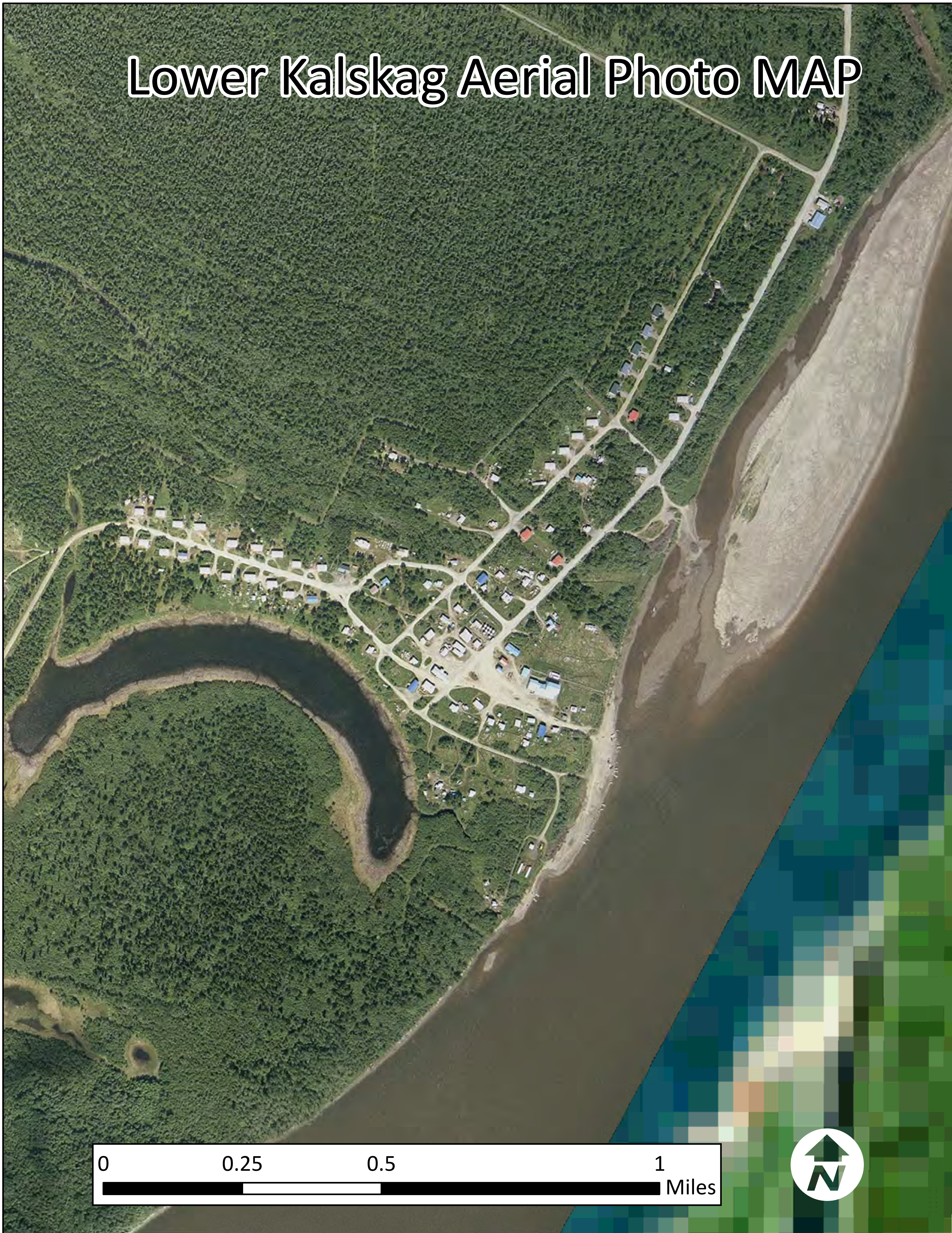
SITE PLAN	CTA MISSOULA, MT (406)728-9522	**BIOMASS PRE-FEASIBILITY ASSESSMENT** KINIAQ BUILDING KOYUK, AK

Drawn By: TW
Checked By: NHR
Date: 06/27/2013
CTA #: FEDC
Cad File: KOYUK.DWG

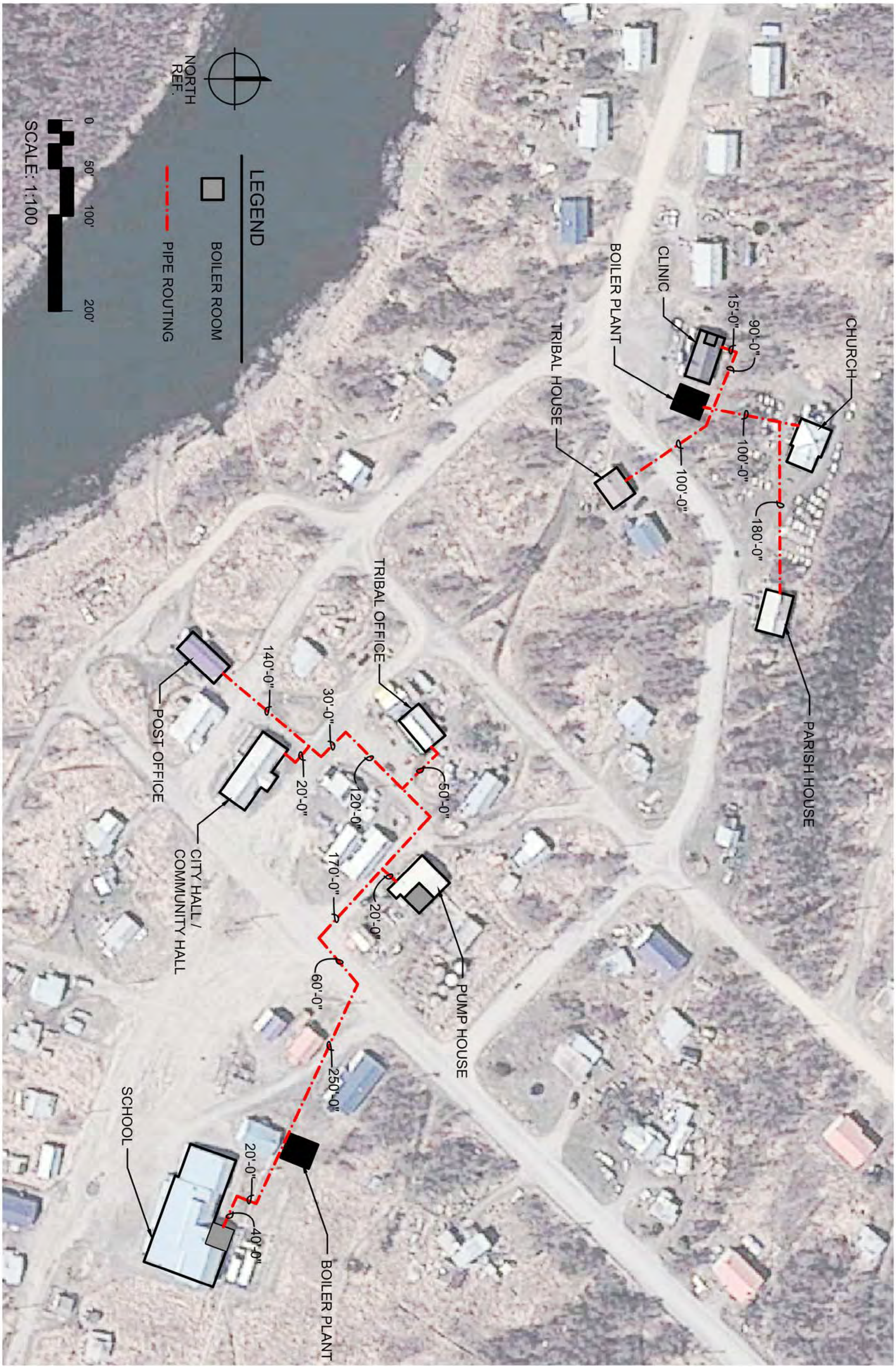
APPENDIX C

LOWER KALSKAG SITE INFORMATION

Lower Kalskag USGS MAP



Lower Kalskag Aerial Photo MAP
0
0.25
0.5
1
Miles
N



SITE PLAN

CTA
MISSOULA, MT
(406)728-9522

BIOMASS PRE-FEASIBILITY ASSESSMENT

LOWER KALASKAG CLUSTER

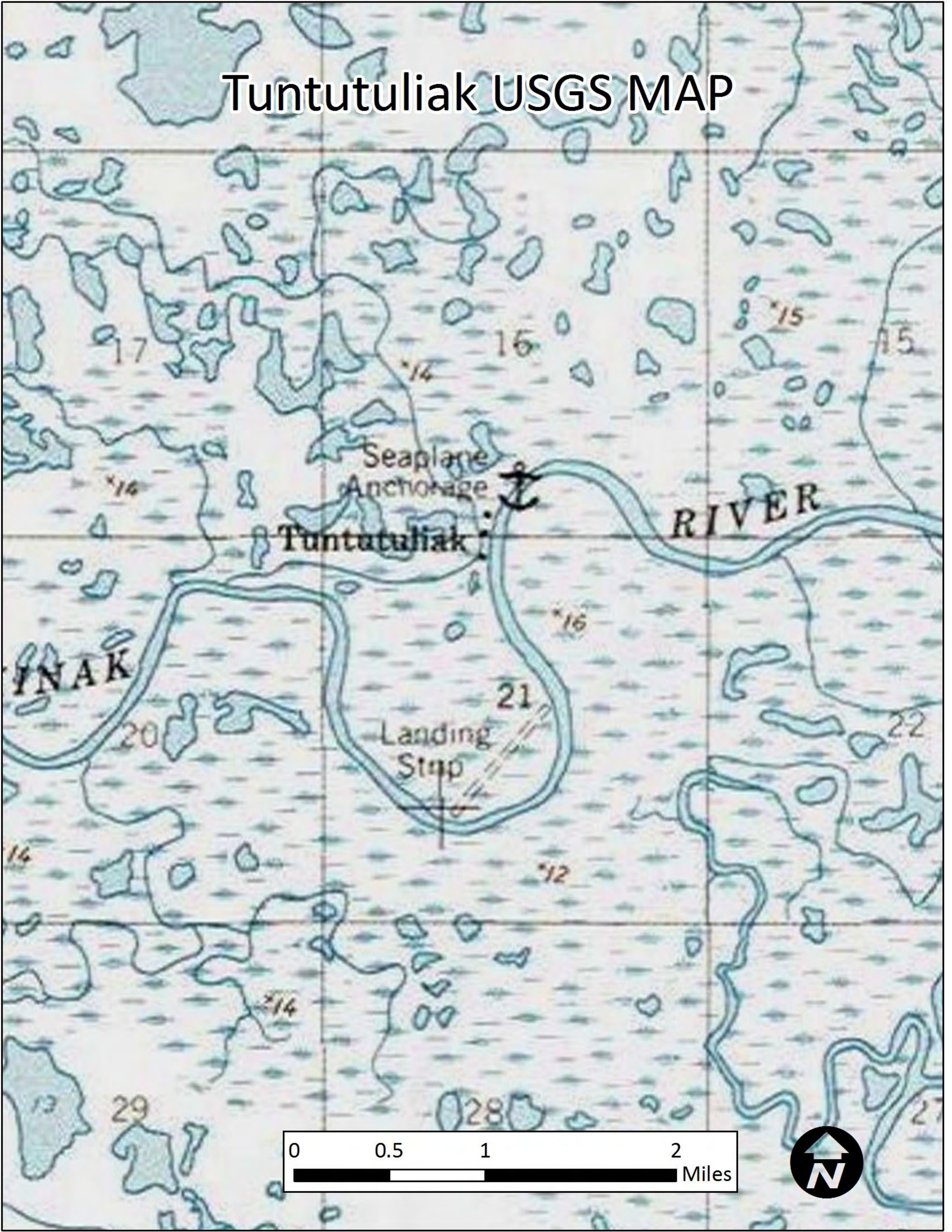
LOWER KALASKAG, AK

Drawn By	TW
Checked By	NHR
Date	06/27/2013
CTA #	FEDC
Cad File:	KALASKAG.DWG

APPENDIX D

TUNTUTULIAK SITE INFORMATION

Tuntutuliak USGS MAP




Tuntutuliak Aerial Photo
0
0.25
0.5
1
Miles
N

SITE PLAN

CTA
MISSOULA, MT
(406)728-9522

BIOMASS PRE-FEASIBILITY ASSESSMENT

TUNTUTULIAK COMMUNITY HALL

TUNTUTULIAK, AK

Drawn By TW

Checked By NHR

Date 06/27/2013

CTA # FEDC

Cad File: TUNTUTULIAK.DWG

APPENDIX E

Wood Fired Heating Technologies

WOOD FIRED HEATING TECHNOLOGIES

CTA has developed wood-fired heating system projects using cord wood, wood pellet and wood chips as the primary feedstock. A summary of each system type with the benefits and disadvantages is noted below.

Cord Wood

Cord wood systems are hand-stoked wood boilers with a limited heat output of 150,000-200,000 British Thermal Units per hour (Btu/hour). Cord wood systems are typically linked to a thermal storage tank in order to optimize the efficiency of the system and reduce the frequency of stoking. Cord wood boiler systems are also typically linked to existing heat distribution systems via a heat exchanger. Product data from Garn, HS Tarm and KOB identify outputs of 150,000-196,000 Btu/hr based upon burning eastern hardwoods and stoking the boiler on an hourly basis. The cost and practicality of stoking a wood boiler on an hourly basis has led most operators of cord wood systems to integrate an adjacent thermal storage tank, acting similar to a battery, storing heat for later use. The thermal storage tank allows the wood boiler to be stoked to a high fire mode 3 times per day while storing heat for distribution between stoking. Cord wood boilers require each piece of wood to be hand fed into the firebox, hand raking of the grates and hand removal of ash. Ash is typically cooled in a barrel before being stock piled and later broadcast as fertilizer.

Cordwood boilers are manufactured by a number of European manufacturers and an American manufacturer with low emissions. These manufacturers currently do not fabricate equipment with ASME (American Society of Mechanical Engineers) certifications. When these non ASME boilers are installed in the United States, atmospheric boilers rather than pressurized boilers are utilized. Atmospheric boilers require more frequent maintenance of the boiler chemicals.

Emissions from cord wood systems are typically as follows:

PM2.5	>0.08 lb/MMbtu
NOx	0.23 lb/MMbtu
SO2	0.025 lb/MMbtu
CO2	195 lb/MMbtu

Benefits:

Small size
Lower cost
Local wood resource
Simple to operate

Disadvantages:

Hand fed - a large labor commitment
Typically atmospheric boilers (not ASME rated)
Thermal Storage is required

Wood Pellet

Wood pellet systems can be hand fed from 40 pound bags, hand shoveled from 2,500 pound sacks of wood pellets, or automatically fed from an adjacent agricultural silo with a capacity of 30-40 tons. Pellet boilers systems are typically linked to existing heat distribution systems via a heat exchanger. Product data from KOB, Forest Energy and Solagen identify outputs of 200,000-5,000,000 Btu/hr based upon burning pellets made from waste products from the western timber industry. A number of pellet fuel manufacturers produce all tree pellets utilizing bark and needles. All tree pellets have significantly higher ash content, resulting in more frequent ash removal. Wood pellet boilers typically require hand raking of the grates and hand removal of ash 2-3 times a week. Automatic ash removal can be integrated into pellet boiler systems. Ash is typically cooled in a barrel before being stock piled and later broadcast as fertilizer. Pellet storage is very economical. Agricultural bin storage exterior to the building is inexpensive and quick to install. Material conveyance is also borrowed from agricultural technology. Flexible conveyors allow the storage to be located 20 feet or more from the boiler with a single auger.

Emissions from wood pellet systems are typically as follows:

PM2.5	>0.09 lb/MMbtu
NOx	0.22 lb/MMbtu
SO2	0.025 lb/MMbtu
CO2	220 lb/MMbtu

Benefits:

Smaller size (relative to a chip system)
Consistent fuel and easy economical storage of fuel
Automated

Disadvantages:

Higher system cost
Higher cost wood fuel ($/MMBtu)

Wood Chip
Chip systems utilize wood fuel that is either chipped or ground into a consistent size of 2-4 inches long and 1-2 inches wide. Chipped and ground material includes fine sawdust and other debris. The quality of the fuel varies based upon how the wood is processed between the forest and the facility. Trees which are harvested in a manner that minimizes contact with the ground and run through a chipper or grinder directly into a clean chip van are less likely to be contaminated with rocks, dirt and other debris. The quality of the wood fuel will also be impacted by the types of screens placed on the chipper or grinder. Fuel can be screened to reduce the quantity of fines which typically become airborne during combustion and represent lost heat and increased particulate emissions.

Chipped fuel is fed from the chip van into a metering bin, or loaded into a bunker with a capacity of 60 tons or more. Wood chip boilers systems are typically linked to existing heat distribution systems via a heat exchanger. Product data from Hurst, Messersmith and Biomass Combustion Systems identify outputs of 1,000,000 - 50,000,000 Btu/hr based upon burning western wood fuels. Wood chip boilers typically require hand raking of the grates and hand removal of ash daily. Automatic ash removal can be integrated into wood chip boiler systems. Ash is typically cooled in a barrel before being stock piled and later broadcast as fertilizer.

Emissions from wood chip systems are typically as follows:

PM2.5	0.21 lb/MMbtu
NOx	0.22 lb/MMbtu
SO2	0.025 lb/MMbtu
CO2	195 lb/MMbtu

Benefits:
Lowest fuel cost of three options ($/MMBtu)
Automated
Can use local wood resources

Disadvantages:
Highest initial cost of three types
Larger fuel storage required
Less consistent fuel can cause operational and performance issues

Wood Stove
Wood stove systems are typically cast iron, hand-stoked wood heaters with a limited output range of 10,000 – 50,000 BTU/hour. Wood stove systems are stand-alone systems that heat a space or building and are required to be hand-fed. As these systems are hand-fed, stoking is required. New wood stoves are feature improved safety and efficiency over older models. Wood stoves are either catalytic or non-catalytic combustion. Catalytic wood stoves are cleaner burning and more efficient than non-catalytic wood stoves. However, catalytic wood stoves have a ceramic catalytic piece which requires maintenance and eventual replacement. Wood stoves should be EPA certified. For more information on wood stoves and a list of EPA certified wood stoves, go to this website: http://www.epa.gov/burnwise/woodstoves.html

Wood stoves burn cord wood in smaller sizes than the cord wood boilers. Each piece of wood must be hand fed into the stove, hand raking of the grate, and hand removal of ash. Ash is typically cooled in a barrel before being stock piled and later broadcast as fertilizer.

Emissions from wood stove systems are typically as follows:

$PM_{2.5}$	>0.08 lb/MMbtu
NO_x	0.23 lb/MMbtu
SO_2	0.025 lb/MMbtu
CO_2	195 lb/MMbtu

Benefits:
Small size
Local wood resource
Simple to operate
Optional cooking appliance

Disadvantages:
Equipment sits in the space being heated
Catalytic systems require maintenance
Non-catalytic systems are not as efficient as catalytic systems