Juneau Economic
Development Council

PRELIMINARY FEASIBILITY ASSESSMENT FOR HIGH EFFICIENCY, LOW EMISSION WOOD HEATING IN KAKE, ALASKA

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Submitted May 21, 2008

Notice
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Funding for this report was provided by USDA Forest Service, Alaska Region, Office of State and Private Forestry

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Key words: HELE, LEHE, bulk fuel, cordwood

ABSTRACT

The potential for heating the Community Hall and School in Kake, AK with high efficiency, low emission (HELE) cordwood boilers is evaluated for the City of Kake and the Kake School District.

SECTION 1. EXECUTIVE SUMMARY

1.1 Goals and Objectives

- Identify the facilities in Kake as potential candidates for heating with wood
- Evaluate the suitability of the facilities and sites for siting a wood-fired boiler
- Assess the type(s) and availability of wood fuel(s)
- Size and estimate the capital costs of suitable wood-fired system(s)
- Estimate the annual operation and maintenance costs of a wood-fired system
- Estimate the potential economic benefits from installing a wood-fired heating system

1.2 Evaluation Criteria, Project Scale, Operating Parameters, General Observations

- This project meets the basic objectives for petroleum fuel displacement, use of hazardous forest fuels or forest treatment/processing residues, sustainability of the wood supply, community support, and project implementation, operation and maintenance.

- Using an estimate of 10,250 gallons of fuel oil per year for the Community Hall and 20,000 gallons of fuel oil per year for the School, these projects would be considered medium to large in terms of their relative scales.

- Medium and large energy consumers have the best potential for feasibly implementing a wood-fired heating system. Where preliminary feasibility assessments indicate positive financial metrics, detailed engineering analyses are usually warranted.

- Cordwood systems are generally appropriate for applications where the maximum heating demand ranges from 100,000 to 1,000,000 Btu per hour. "Bulk fuel" systems are generally applicable for situations where the heating demand exceeds 1 million Btu per hour. However, these are general guidelines; local conditions can exert a strong influence on the best system choice.

- Efficiency and emissions standards for Outdoor Wood Boilers (OWB) changed in 2006, which could increase costs for small systems

1.3 Assessment Summary and Recommended Actions

1.3.1 Community Hall

- Overview. The Community Hall consists of single structure, approximately 15,000 square feet in size (100x150). It serves a variety of functions, including housing city administrative offices, bingo hall, kitchen and gymnasium.

Heat is provided by a single Weil McLain model 1078 boiler, rated at 982 MBH (net), in fair condition. Supplemental heat (in the Conference Room) is supplied by a small propane space heater. Domestic hot water is supplied by two 41-gallon Amtrol WH7-CDW electric water heaters located in the boiler room.

The heat distribution system appears partially compromised. Heat is distributed in the offices, hallways and restrooms via fin tube baseboard plumbing that appears to be functional. In the kitchen and bingo hall, heat is provided by ceiling mounted heat exchangers which either don't work or overheat the room. There are two very large heat exchangers in the gymnasium (reportedly installed in 1972), one of which hasn't worked in several years; the other works occasionally. Overall, substantial improvements/upgrades to the heating and/or heat distribution system may be necessary. Consultation with a HVAC specialist or mechanical engineer is strongly recommended.

The area around the Community Hall is level and there is sufficient space behind the Hall for a building in which to house a wood-fired boiler. The distance to the existing mechanical room is minimal.

• Fuel Consumption. The Community Hall is reported to consume approximately **10,250** gallons of **#2** fuel oil per year.

• Potential Savings. At the current price of $5.50 per gallon, the City pays approximately $56,375 per year for fuel oil to heat the Community Hall. The HELE cordwood fuel equivalent of 10,250 gallons of #2 fuel oil is approximately 114 cords, and at $175 per cord represents a potential annual fuel cost savings of $36,425 (debt service and non-fuel OM&R costs notwithstanding).

• Required boiler capacity. The estimated required boiler capacity (RBC) to heat the Community Hall is approximately 355,525 Btu/hr during the coldest 24-hour period. One 425,000 Btu/hr HELE cordwood boiler could theoretically supply 100% of that RBC (although this is not necessarily the recommended alternative).

• Recommended action regarding a cordwood system. Given the initial assumptions and cost estimates for the alternatives presented in this report, this project appears to be viable and cost-effective. Further consideration is warranted. (See Section 6)

• Recommended action regarding a bulk fuel wood system. Given the relatively small heating demand and the probable costs of the project, a "bulk fuel" system is not cost-effective for the Kake Community Hall.

1.3.2 Kake School

• Overview. The Kake School consists of several distinct entities, but all, except the Band Room, are heated from a central source. There are approximately 100 students in Head Start and K through 12th grade.

Heat is provided by a pair of Burnham boilers outfitted with Power Flame model CR2-OA burners rated at 52.3 nominal boiler horsepower (approx. 3.5 MMBH), each. Heat is distributed by a variety of means. Domestic hot water is supplied by two 119-gallon Amtrol model WHS 120Z CDW electric water heaters located in the central boiler room. There is an additional 190 gallon Ajax Boiler Co. model VG3004MW hot water tank located in the Elementary school building.

The area around the school is level to gentle. The best apparent location for a wood-fired boiler would be in the space currently occupied by the Band Room building, which could be relocated. There is suitable space nearby for wood storage.

- Fuel Consumption. The Kake School is reported to consume approximately **20,000** gallons of **#2** fuel oil per year.

- Potential Savings. At the current price of $5.50 per gallon, the Kake School District spends approximately $110,000 per year for fuel oil. The HELE cordwood fuel equivalent of 20,000 gallons of #2 fuel oil is approximately 222 cords, and at $175 per cord represents a potential annual fuel cost savings of $71,150 (debt service and non-fuel OM&R costs notwithstanding.)

- Required boiler capacity. The estimated required boiler capacity (RBC) to heat the Kake School facility is approximately 693,370 Btu/hr during the coldest 24-hour period. One 950,000 Btu/hr HELE cordwood boiler could theoretically supply 100% of that RBC (although this is not necessarily the recommended alternative).

- Recommended action regarding a cordwood system. Given the initial assumptions and cost estimates for the alternatives presented in this report, this project appears to be viable and cost-effective. Further consideration is warranted. (See Section 6)

- Recommended action regarding a bulk fuel wood system. Given the relatively small heating demand and the probable costs of the project, a "bulk fuel" system is probably not cost-effective for the Kake School.

SECTION 2. EVALUATION CRITERIA, IMPLEMENTATION, WOOD HEATING SYSTEMS

The approach being taken by the Alaska Wood Energy Development Task Group (AWEDTG) regarding biomass energy heating projects follows the recommendations of the Biomass Energy Resource Center (BERC), which advises that, "[*T*]*he most cost-effective approach to studying the feasibility for a biomass energy project is to approach the study in stages*." Further, BERC advises "*not spending too much time, effort, or money on a full feasibility study before discovering whether the potential project makes basic economic sense*" and suggests, "[*U*]*ndertaking a pre-feasibility study . . . a basic assessment, not yet at the engineering level, to determine the project's apparent cost-effectiveness*". [Biomass Energy Resource Center, Montpelier, Vermont. www.biomasscenter.org]

2.1 Evaluation Criteria

The Kake projects meet the basic criteria for potential petroleum fuel displacement, use of forest residues for public benefit, use of local processing residues, sustainability of the wood supply, community support, and the ability to implement, operate and maintain the project.

In the case of a cordwood boiler system, the wood supply from forest fuels or local processing residues appears adequate and matches the application. Currently, there are no significant supplies of "bulk fuel" (bark, sawdust, chips and planer shavings).

One of the objectives of the AWEDTG is to support projects that would use energy-efficient and clean burning wood heating systems, i.e., high efficiency, low emission (HELE) systems.

2.2 Successful Implementation

In general, four aspects of project implementation have been important to wood energy projects in the past: 1) a project “champion”, 2) clear identification of a sponsoring agency/entity, 3) dedication of and commitment by facility personnel, and 4) a reliable and consistent supply of fuel.

In situations where several organizations are responsible for different community services, it must be clear which organization(s) would sponsor or implement a wood-burning project. (NOTE: This is not necessarily the case with the projects in Kake but this issue should be addressed.)

With manual systems, boiler stoking and/or maintenance is required for approximately 5-15 minutes per boiler several times a day (depending on the heating demand), and dedicating personnel for the operation is critical to realizing savings from wood fuel use. For this report, it is assumed that new personnel would be hired or existing personnel would be assigned as necessary, and that “boiler duties” would be included in the responsibilities and/or job description of facility personnel.

There is some pre-existing forest industry infrastructure in/around Kake. And although there is little timber harvesting or processing activity currently taking place, the existing infrastructure appears sufficient to support the proposed projects with the cooperation of Kake Tribal Corp., Sealaska, and/or the USDA Forest Service . For this report, it is assumed that wood supplies are sufficient to meet the demand.

2.3 Classes of Wood Energy Systems

There are, basically, two classes of wood energy systems: manual cordwood systems and automated “bulk fuel” systems. Cordwood systems are generally appropriate for applications where the maximum heating demand ranges from 100,000 to 1,000,000 Btu per hour, although smaller and larger applications are possible. “Bulk fuel” systems are systems that burn wood chips, sawdust, bark/hog fuel, shavings, pellets, etc. They are generally applicable for situations where the heating demand exceeds 1 million Btu per hour, although local conditions, especially fuel availability, can exert strong influences on the feasibility of a bulk fuel system.

Usually, an automated bulk fuel boiler is tied-in directly with the existing oil-fired system. With a cordwood system, glycol from the existing oil-fired boiler system would be circulated through a heat exchanger at the wood boiler ahead of the existing oil boiler. A bulk fuel system is usually designed to replace 100% of the fuel oil used in the oil-fired boiler, and although it is possible for a cordwood system to be similarly designed, they are usually intended as a supplement, albeit a large supplement, to an oil-fired system. In either case, the existing oil-fired system would remain in place and be available for peak demand or backup in the event of downtime in the wood system.

SECTION 3. THE NATURE OF WOOD FUELS

3.1 Wood Fuel Forms and Current Utilization

Wood fuels around Kake generally take the form of cordwood. There is relatively little in the way of sawmill residues (slabwood, sawdust, shavings, bark and chips) and there is no local supply of bulk pellets.

Residential use of cordwood has increased significantly in the past 18 months due to sharply higher fuel oil costs. Given that higher demand, prices for firewood have gone up accordingly.

3.2 Heating Value of Wood

Wood is a unique fuel whose heating value is quite variable, depending on species of wood, moisture content, and other factors. There are also several recognized 'heating values': high heating value (HHV), gross heating value (GHV), recoverable heating value (RHV), and deliverable heating value (DHV)) that may be assigned to wood at various stages in the calculations.

A variety of species can be found in/around Kake, including Sitka spruce, western hemlock, alder, and limited amounts of red and yellow cedar; hemlock is the most common. For this report, hemlock cordwood at 30 percent moisture content (MC30), calculated on the wet weight basis (also called green weight basis), is used as the benchmark.

The HHV of hemlock at 0% moisture content (MC0) is 8,515 Btu/lb[1]. The GHV at 30% moisture content (MC30) is 5,961 Btu/lb.

The RHV for cordwood (MC30) is calculated at 13.26 million Btu per **cord**, and the DHV, which is a function of boiler efficiency (assumed to be 75%), is 9.942 million Btu per cord. The delivered heating value of 1 **cord** of hemlock cordwood (MC30) equals the delivered heating value of **90.05** gallons of #2 fuel oil when burned at 75% conversion efficiency.

A more thorough discussion of the heating value of wood can be found in Appendix B and Appendix D.

SECTION 4. WOOD-FUELED HEATING SYSTEMS

4.1 Low Efficiency High Emission (LEHE) Cordwood Boilers

Most outdoor wood boilers (OWBs) are relatively low-cost and can save fuel but most have been criticized for low efficiency and smoky operation. These could be called *low efficiency, high emission* (LEHE) systems and there are dozens of manufacturers. The State of New York instituted a moratorium in 2006 on new LEHE OWB installations due to concerns over emissions and air quality[5]. Other states are also considering regulations[6,7,8,9]. But since there are no standards for OWBs (wood-fired boilers and furnaces were exempted from the 1988 EPA regulations[10]), OWB ratings are inconsistent and can be misleading. Standard procedures for evaluating wood boilers do not exist, but test data from New York, Michigan and elsewhere showed a wide range of apparent [in-]efficiencies and emissions among OWBs.

In 2006, a committee was formed under the American Society for Testing and Materials (ASTM) to develop a standard test protocol for OWBs[11]. The standards included uniform procedures for determining performance and emissions. Subsequently, the ASTM committee sponsored tests of three common outdoor wood boilers using the new procedures. The results showed efficiencies as low as 25% and emissions **more than nine times** the standard for industrial boilers. Obviously, these results were deemed unsatisfactory and new boiler standards were called for.

In a news release dated January 29, 2007[12], the U.S. Environmental Protection Agency announced a new voluntary partnership agreement with 10 major OWB manufacturers to make cleaner-burning appliances. The new phase-one standard calls for emissions not to exceed 0.60 pounds of particulate emissions per million Btu of heat **input**. The phase-two standard, which will follow 2 years after phase-one, will limit emissions to 0.30 pounds per million Btus of heat **delivered**, thereby creating an efficiency standard as well.

To address local and state concerns over regulating OWB installations, the Northeast States for Coordinated Air Use Management (NeSCAUM), and EPA have developed model regulations that recommend OWB installation specifications, clean fuel standards and owner/operator training. (http://www.epa.gov/woodheaters/ and http://www.nescaum.org/topics/outdoor-hydronic-heaters)

Implementation of the new standard will improve air quality and boiler efficiency but will also increase costs as manufacturers modify their designs, fabrication and marketing to adjust to the new standards. Some low-end models will no longer be available.

4.2 High Efficiency Low Emission (HELE) Cordwood Boilers

In contrast to low efficiency, high emission cordwood boilers there are a few units that can correctly be considered *high* efficiency, *low* emission (HELE). These systems are designed to burn cordwood fuel cleanly and efficiently.

Table 4-1 lists three HELE cordwood boiler suppliers, all of which have units operating in Alaska. HS Tarm and Greenwood have a number of residential units operating in Alaska, and a Garn boiler manufactured by Dectra Corporation is used in Dot Lake, AK to heat several homes and the washeteria, replacing 7,000 gallons per year (gpy) of #2 fuel oil.[14] Two Garn boilers were recently installed in Tanana, AK (on the Yukon River) to provide heat to the washeteria and water plant, and two were installed near Kasilof on the Kenai Peninsula. Several other installations are being planned.

Table 4-1. HELE Cordwood Boiler Suppliers

	Btu/hr ratings	Supplier
Tarm	100,000 to 198,000	HS Tarm/Tarm USA www.tarmusa.com/wood-gasification.asp
Greenwood	100,000 to 300,000	Greenwood www.GreenwoodFurnace.com
Garn	350,000 to 950,000	Dectra Corp. www.dectra.net/garn

Note: Listing of any manufacturer, distributor or service provider does not constitute an endorsement.

As indicated, cordwood boilers are suitable for applications from 100,000 Btu/hr to 1,000,000 Btu/hr, although both larger and smaller applications are possible.

Table 4-2 shows the results for a Garn WHS 1350 boiler that was tested at 157,000 to 173,000 Btu/hr using the new ASTM testing procedures, compared with EPA standards for wood stoves and boilers. It is important to remember that wood fired boilers are not entirely smokeless; even very efficient wood boilers may smoke for a few minutes on startup.[4,15]

Table 4-2. Emissions from Wood Heating Appliances	
Appliance	Emissions (grams/1,000 Btu delivered)
EPA Certified Non Catalytic Stove	0.500
EPA Certified Catalytic Stove	0.250
EPA Industrial Boiler (many states)	0.225
GARN WHS 1350 Boiler*	0.179
Source: Intertek Testing Services, Michigan, March 2006. Note: *With dry oak cordwood; average efficiency of 75.4% based upon the high heating value (HHV) of wood	

4.3 Bulk Fuel Boiler Systems

The term "bulk fuel" refers, generically, to sawdust, wood chips, shavings, bark, pellets, etc. Since the availability of bulk fuel is virtually non-existent in Kake, the cost of bulk fuel systems being so high (i.e., $1 million and up), and the relatively small heating demand for the facilities under consideration, the discussion of bulk fuel boiler systems has been omitted from this report.

SECTION 5. SELECTING THE APPROPRIATE SYSTEM

Selecting the appropriate heating system is, primarily, a function of heating demand. It is generally not feasible to install automated bulk fuel systems in/at small facilities, and it is likely to be impractical to install cordwood boilers at very large facilities. Other than demand, system choice can be limited by fuel availability, fuel form, labor, financial resources, and limitations of the site.

The selection of a wood-fueled heating system has an impact on fuel economy. Potential savings in fuel costs must be weighed against initial investment costs and ongoing operating, maintenance and repair (OM&R) costs. Wood system costs include the initial capital costs of purchasing and installing the equipment, non-capital costs (engineering, permitting, etc.), the cost of the fuel storage building and boiler building (if required), the financial burden associated with loan interest, the fuel cost, and the other costs associated with operating and maintaining the heating system, especially labor.

5.1 Comparative Costs of Fuels

Table 5-1 compares the cost of #2 fuel oil to hemlock cordwood (MC30). In order to make reasonable comparisons, costs are provided on a "per million Btu" (MMBtu) basis.

Table 5-1. Comparative Cost of Fuel Oil vs. Wood Fuels

FUEL	RHV[a] (Btu)	Conversion Efficiency[a]	DHV[a] (Btu)	Price per unit ($)	Cost per MMBtu (delivered, ($))
Fuel oil, #2, (per 1 gallon)	138,000	80%	110,400	5.00/gal	45.29
				5.50	49.818
				6.00	54.348
Hemlock, (per 1 cord, MC30)	13.26 million	75%	9.942 million	150/cord	15.088
				175	17.602
				200	20.117

Notes:

[a] from Appendix D

5.2(a) Cost per MMBtu Sensitivity – Cordwood

Figure 5-1 on the next page illustrates the relationship between the price of hemlock cordwood (MC30) on the horizontal axis, and the cost of delivered heat on the vertical axis, (i.e., the slanted line). For each $10 per *cord* increase in the price of cordwood, the cost per million Btu increases by $1.055. The chart assumes that the cordwood boiler delivers 75% of the RHV energy in the cordwood to useful heat and that oil is converted to heat at 80% efficiency. The dashed lines represent #2 fuel oil at $5.00, $5.50 and $6.00 per gallon ($45.29, $49.818 and $54.348 per million Btu respectively).

At high efficiency, heat from hemlock cordwood (MC30) at $495.50 per cord is equal to the cost of #2 fuel oil at $5.50 per gallon (i.e., $49.82 per MMBtu). At 75% efficiency and $175 per cord, a high-efficiency cordwood boiler will deliver heat at about 35% of the cost of #2 fuel oil at $5.50 per gallon ($17.602 versus $49.82 per MMBtu). Figure 5-1 indicates that, at a given efficiency, savings increase significantly with decreases in the delivered price of cordwood and/or with increases in the price of fuel oil.

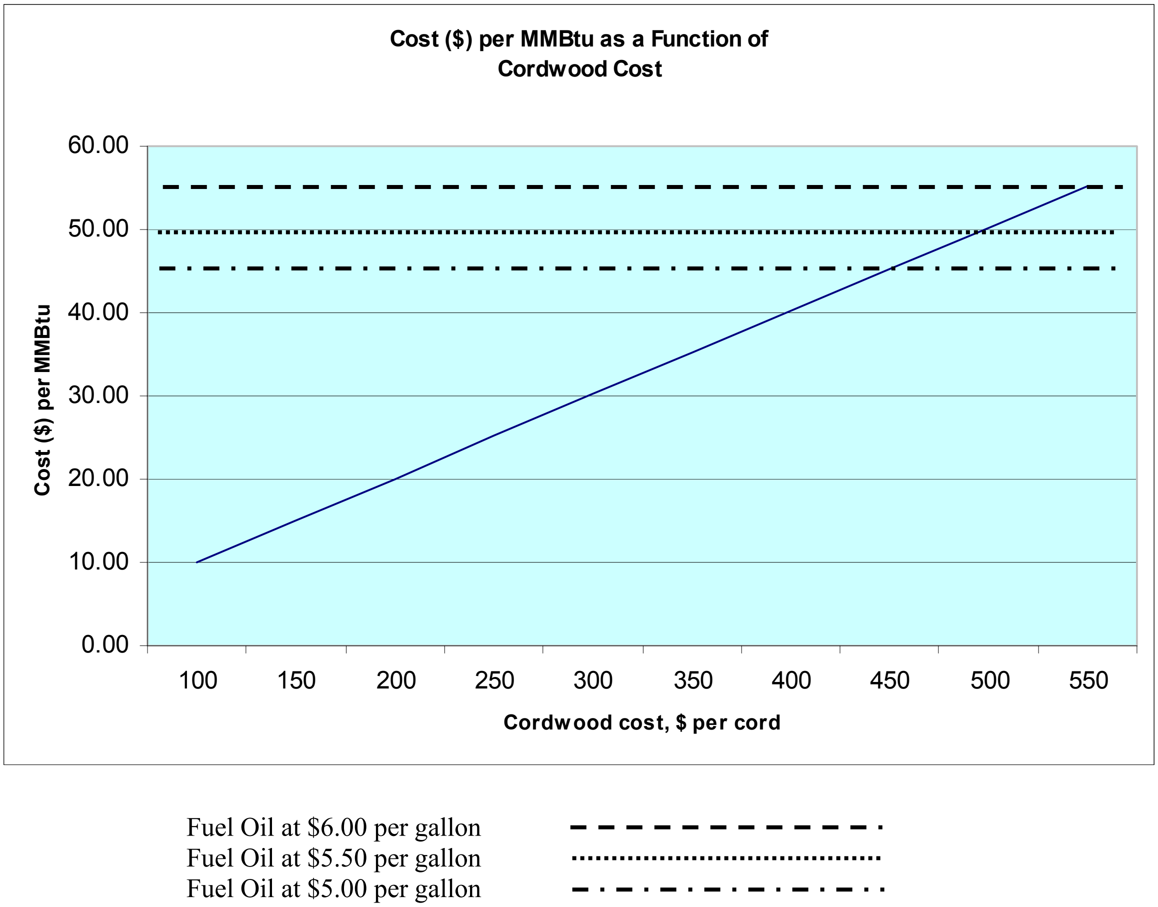

Figure 5-1. Effect of Hemlock Cordwood Price on Cost of Delivered Heat

5.2(b) Cost per MMBtu Sensitivity – Bulk Fuels

Not included in this report

5.3 Determining Demand

Table 5-2 shows the reported approximate amount of fuel oil used by the facilities in Kake.

Table 5-2. Reported Annual Fuel Oil Consumption, Kake Facilities

Facility	Reported Annual Fuel Consumption	
	Gallons	*Cost ($) @ $5.50/gallon*
Community Hall	10,250	56,375
Kake School	20,000	110,000
TOTAL	**30,250**	**166,375**

Wood boilers, especially cordwood boilers, are often sized to displace only a portion of the heating load since the oil system will remain in place, in standby mode, for “shoulder seasons” and peak demand. Fuel oil consumption for the Kake facilities was compared with heating demand based on heating degree days (HDD) to determine the required boiler capacity (RBC) for heating during the coldest 24-hour period (Table 5-3). While there are many factors to consider when sizing heating systems it is clear that, in most cases, a wood system of less-than-maximum size could still replace a substantial quantity of fuel oil.

Table 5-3. Estimate of Heat Required in Coldest 24-Hour Period

Facility	Fuel Oil Used gal/year[a]	Heating Degree Days[d]	Btu/DD[c]	Design Temp[d] F	RBC[e] Btu/hr	Installed Btu/hr[a]
Community Hall	10,250	8,527	133,189	1 (Juneau, AK)	355,525	982,000
Kake School	20,000	8,527	259,880	1 (Juneau, AK)	693,370	3,501,485

Table 3-7 Notes:

[a] From SOI and site visit; net total Btu/hr

[b] NOAA, July 1, 2005 through June 30, 2006: ftp://ftp.cpc.ncep.noaa.gov/htdocs/products/analysis_monitoring/cdus/degree_days/archives/Heating%20degree%20Days/Monthly%20City/2006/jun%202006.txt

[c] Btu/DD= Btu/year x oil furnace conversion efficiency (0.85) /Degree Days

[d] Alaska Housing Manual, 4th Edition Appendix D: Climate Data for Alaska Cities, Research and Rural Development Division, Alaska Housing Finance Corporation, 4300 Boniface Parkway, Anchorage, AK 99504, January 2000.

[e] RBC = Required Boiler Capacity for the coldest Day, Btu/hr= [Btu/DD x (65 F-Design Temp)+DD]/24 hrs

Typically, installed oil-fired heating capacity at most sites is two-to-four times greater than the demand for the coldest day. The installed capacity at the Community Hall falls within this range while the installed capacity at the Kake School appears to be about five times greater than the demand for the coldest day.

Manual HELE cordwood boilers equipped with special tanks for extra thermal storage can supply heat at higher than their rated capacity for short periods. For example, while rated at 950,000 Btu/hr (heat into storage)*, a single Garn WHS 3200 can store more than 2 million Btu, which would be enough to heat the Community Hall during the coldest 24-hour period for nearly 6 hours (2,064,000 ÷ 355,525). However, this is not necessarily the correct or optimum boiler configuration. Consultation with a qualified engineer is strongly recommended.

** Btu/hr into storage is extremely fuel dependent. The data provided for Garn boilers by Dectra Corp. are based on the ASTM standard of split, 16-inch oak with 20 percent moisture content and reloading once an hour.*

5.4 Summary of Findings and Potential Savings

Table 5-4 summarizes the findings thus far: annual fuel oil usage, range of annual fuel oil costs, estimated annual wood fuel requirement, range of estimated annual wood fuel costs, and potential gross annual savings for the Community Hall and School. [Note: potential gross annual fuel cost savings do not consider capital costs and non-fuel operation, maintenance and repair (OM&R) costs.]

Table 5-4. Estimate of Total Wood Consumption, Comparative Costs and Potential Savings

	Fuel Oil Used gal/year[a]	Annual Fuel Oil Cost (@ $ ___ /gal)			Approximate Wood Requirement[b]	Annual Wood Cost (@ $ ___ /unit)			Potential Gross Annual Fuel Cost Savings ($)		
		5.00/gal	*5.50/gal*	*6.00/gal*	W. Hemlock, MC30, CE 75%	*150/cord*	175/cord	*200/cord*	*Low*	*Medium*	*High*
Community Hall	10,250	51,250	56,375	61,500	**114**	17,100	19,950	22,800	28,450	36,425	44,400
Kake School	20,000	100,000	110,000	120,000	**222**	33,300	38,850	44,400	55,600	71,150	86,700
Total	30,250	151250	166375	181500	**336**	50,400	58,800	67,200	84,050	107,575	131,100

NOTES:

[a] From Table 5-2

[b] From Table D-3, Fuel Oil Equivalents; 90.05 gallons per cord (MC30)

SECTION 6. ECONOMIC FEASIBILITY OF CORDWOOD SYSTEMS

6.1 Initial Investment Cost Estimates

DISCLAIMER: Short of having an actual Design & Engineering Report prepared by a team of architects and/or professional engineers, actual costs for any particular system at any particular site cannot be positively determined. Such a report is beyond the scope of this preliminary assessment. However, several hypothetical, though hopefully realistic, system scenarios are offered as a means of comparison. Actual costs, assumptions and "guess-timates" are identified as such, where appropriate. Recalculations of financial metrics, given different/updated cost estimates, are relatively easy to accomplish.

Wood heating systems include the cost of the fuel storage building (if necessary), boiler building (if necessary), boiler equipment (and shipping), plumbing and electrical connections (including heat exchangers, pumps, fans, and electrical service to integrate with existing distribution systems), installation, and an allowance for contingencies.

Before a true economic analysis can be performed, all of the costs (investment and OM&R) must be identified, and this is where the services of qualified experts are necessary.

Table 6-1 (next page) presents hypothetical scenarios of initial investment costs for cordwood systems in medium to large heating demand situations. Three alternatives are presented.

Buildings and plumbing/connections are the most significant costs besides the boiler(s). Building costs deserve more site-specific investigation and often need to be minimized to the extent possible. Piping from the wood-fired boiler is another area of potential cost saving. Long plumbing runs and additional heat exchangers substantially increase project costs. The exorbitant cost of hard copper pipe normally used in Alaska now precludes its use in most applications. If plastic or PEX® piping is used, significant cost savings may be possible.

Allowance for indirect non-capital costs such as engineering and contingency are most important for large systems that involve extensive permitting and budget approval by public agencies. This can increase the cost of a project by 25% to 50%. For the examples in Table 6-1, a 25% contingency allowance was used.

NOTES:

a. With the exception of the list prices for Garn boilers, all of the figures in Table 6-1 are gross estimates.

b. The cost estimates presented in Table 6-1 do not include the cost(s) of any upgrades or improvements to the existing heating/heat distribution system currently in place.

Table 6-1. Initial Investment Cost Scenarios for Hypothetical Cordwood Systems

	Kake Facilities		
	Community Hall		Kake School
Fuel oil consumption (gallons per year)	10,250		20,000
Required boiler capacity (RBC), Btu/hr	355,525		693,370
Cordwood boiler Model Rating - Btu/hr Btu stored	(1) Garn WHS 3200 950,000 2,064,000	(2) Garn WHS 2000 850,000 combined 2,544,000 combined	(2) Garn WHS 3200 1,900,000 combined 4,128,000 combined
Building and Equipment (B&E) Costs (for discussion purposes only), $			
Fuel storage building[a] (fabric bldg, gravel pad, $20 per s.f.)	45,600 *(114 cords, 2280 s.f.)*		88,800 *(222 cords, 4400 s.f.)*
Boiler building @ $125 per s.f. (minimum footprint, w/concrete pad)[b]	25,000 *(10' x 20')*	32,000 *(16' x 16')*	50,000 *(20' x 20')*
Boilers Base price[c] Shipping[d]	 32,900 6,000	 29,800 6,000	 65,800 12,000
Plumbing/connections[d]	10,000	12,000	15,000
Installation[d]	15,000	17,000	20,000
Subtotal - B&E Costs	**134,500**	**132,400**	**251,600**
Contingency (25%)[d]	**33,625**	**33,100**	**62,900**
Grand Total	**168,125**	**165,500**	**314,500**

Notes:

[a] A cord occupies 128 cubic feet. If the wood is stacked 6½ feet high, the area required to store the wood is 20 square feet per cord.

[b] Does not allow for any fuel storage within the boiler building

[c] List price, Dectra Corp, May 2006 NOTE: Dectra Corp does not publish a list price for the WHS 4400. The price quote for a WHS 4400 is an estimate.

[d] "guess-timate"; for illustrative purposes only

6.2 Operating Parameters of HELE Cordwood Boilers

A detailed discussion of the operating parameters of HELE cordwood boilers can be found in Appendix F.

6.3 Hypothetical OM&R Cost Estimates

The primary operating cost of a cordwood boiler, other than the cost of fuel, is labor. Labor is required to move fuel from its storage area to the boiler building, fire the boiler, clean the boiler and dispose of ash. For purposes of this analysis, it is assumed that the boiler system will be operated every day for 210 days (30 weeks) per year between mid-September and mid-April.

Table 6-2 presents labor/cost estimates for various HELE cordwood systems. A detailed analysis of labor requirement estimates can be found in Appendix F.

Table 6-2. Labor/Cost Estimates for HELE Cordwood Systems

	Community Hall		Kake School
	(1) Garn WHS 3200	(2) Garn WHS 2000	(2) Garn WHS 3200
Total Daily labor (hrs/yr)[a] (hrs/day X 210 days/yr)	160.44	187.96	195.42
Total Periodic labor (hrs/yr)[b] (hrs/wk X 30 wks/yr)	57		111
Total Annual labor (hrs/yr)[b]	20	40	40
Total labor (hrs/yr)	237.44	284.96	346.42
Total annual labor cost ($/yr) (total hrs x $20)	**4,748.80**	**5,699.20**	**6,928.40**

Notes:
a From Table F-2
b From Appendix F

There is also an electrical cost component to the boiler operation. An electric fan creates the induced draft that contributes to boiler efficiency. The cost of operating circulation pumps and/or blowers would be about the same as it would be with the oil-fired boiler or furnaces in the existing heating system.

Lastly there is the cost of wear items, such as fire brick, door gaskets, and water treatment chemicals. This has been suggested at $300-$500 per boiler per year[4].

Table 6-3. Summary of Total Annual Non-Fuel OM&R Cost Estimates

Item	Cost/Allowance ($)		
	(1) Garn WHS 3200	(2) Garn WHS 2000	(2) Garn WHS 3200
Labor	4,748.80	5,699.20	6,928.40
Electricity	609.17	1,904.06	1,186.45
Maintenance/Repairs	500.00	700.00	1,000.00
Total non-fuel OM&R ($)	**5,857.97**	**8,303.26**	**9,114.85**

6.4 Calculation of Financial Metrics

Biomass heating projects are viable when, over the long run, the annual fuel cost savings generated by converting to biomass are greater than the cost of the new biomass boiler system plus the additional operation, maintenance and repair (OM&R) costs associated with a biomass boiler (compared to those of a fossil fuel boiler or furnace).

Converting from an existing boiler to a wood biomass boiler (or retrofitting/integrating a biomass boiler with an existing boiler system) requires a greater initial investment and higher annual OM&R costs than for an equivalent oil or gas system alone. However, in a viable project, the savings in fuel costs (wood vs. fossil fuel) will pay for the initial investment and cover the additional OM&R costs in a relatively short period of time. After the initial investment is paid off, the project continues to save money (avoided fuel cost) for the life of the boiler. Since inflation rates for fossil fuels are typically higher than inflation rates for wood fuel, increasing inflation rates result in greater fuel cost savings and thus greater project viability.[17]

The potential financial viability of a given project depends not only on the relative costs and cost savings, but also on the financial objectives and expectations of the facility owner. For this reason, the impact of selected factors on potential project viability is presented using the following metrics:

Simple Payback Period
Present Value (PV)
Net Present Value (NPV)
Internal Rate of Return (IRR)
Life Cycle Cost (LCC) (Kake School only)

Total initial investment costs include all of the capital and non-capital costs required to design, purchase, construct and install a biomass boiler system in an existing facility with an existing furnace or boiler system.

A more detailed discussion of Simple Payback Period, Present Value, Net Present Value and Internal Rate of Return can be found in Appendix E.

6.5 Simple Payback Period for HELE Cordwood Boilers

Table 6-4 presents a Simple Payback Period analysis for hypothetical multiple HELE cordwood boiler installations.

Table 6-4. Simple Payback Period Analysis for HELE Cordwood Boilers

	(1) Garn WHS 3200	(2) Garn WHS 2000	(2) Garn WHS 3200
Fuel oil cost ($ per year @ $5.50 per gallon)	56,375		110,000
Cordwood cost ($ per year @ $175 per cord)	19,950		38,850
Annual Fuel Cost Savings ($)	**36,425**		**71,150**
Annual, Non-fuel OM&R costs[a]	5,858	8,303	9,115
Net Annual Savings ($) (Annual Cash Flow)	30,567	28,122	62,035
Total Investment Costs ($)[b]	168,125	165,500	314,500
Simple Payback (yrs)[c]	4.62	4.54	4.42

Notes:
a From Table 6-3
b From Table 6-1
c Total Investment Costs divided by Annual Fuel Cost Savings

6.6 Present Value (PV), Net Present Value (NPV) and Internal Rate or Return (IRR) Values for Various HELE Cordwood Boiler Installation Options

Table 6-5 presents PV, NPV and IRR values for hypothetical various HELE cordwood boiler installations.

Table 6-5. PV, NPV and IRR Values for Various HELE Cordwood Boilers Options

	(1) Garn WHS 3200	(2) Garn WHS 2000	(2) Garn WHS 3200
Discount Rate[a] (%)	3		
Time, "t", (years)	20		
Initial Investment ($)[b]	168,125	165,500	314,500
Annual Cash Flow($)[c] (Net Annual Savings)	30,567	28,122	62,035
Present Value (of expected cash flows, $ at "t" years)	454,760	418,384	922,924
Net Present Value ($ at "t" years)	286,635	252,884	608,424
Internal Rate of Return (% at "t" years)	17.45	16.14	19.13
See Note #_ below	1	2	3

Notes:

[a] real discount (excluding general price inflation) as set forth by US Department of Energy, as found in NIST publication NISTIR 85-3273-22, Energy Price Indices and Discount Factors for Life Cycle Cost Analysis, April 2007

[b] From Table 6-1

[c] Equals annual cost of fuel oil minus annual cost of wood minus annual non-fuel OM&R costs (i.e., Net Annual Savings)

Note #1. With a real discount rate of 3.00% and after a span of 20 years, the projected cash flows are worth $454,760 today (PV), which is greater than the initial investment of $168,125. The resulting NPV of the project is $286,635 and the project achieves an internal rate of return of 17.45% at the end of 20 years. Given the assumptions and cost estimates, this alternative appears financially and operationally feasible.

Note #2. With a real discount rate of 3.00% and after a span of 20 years, the projected cash flows are worth $418,384 today (PV), which is greater than the initial investment of $165,500. The resulting NPV of the project is $252,884 and the project achieves an internal rate of return of 16.14% at the end of 20 years. While these metrics are somewhat less favorable than alternative 1, given the assumptions and cost estimates, this alternative still appears quite feasible and may provide improved operational parameters.

Note #3. With a real discount rate of 3.00% and after a span of 20 years, the projected cash flows are worth $922,924 today (PV), which is greater than the initial investment of $314,500. The resulting NPV of the project is $608,424 and the project achieves an internal rate of return of 19.13% at the end of 20 years. Given the assumptions and cost estimates, this alternative appears financially and operationally feasible.

6.7 The Case for Fuel Purchase Planning and Fuel Storage

Too often, a fuel storage building is omitted from a project in order to save the initial investment cost and improve the cost-effectiveness of the project. This is FALSE ECONOMY. The importance of a fuel storage building cannot be stressed enough, especially in southeast Alaska. With good planning, fuel could be purchased a year or more in advance and be given sufficient time to dry, while incurring no additional cost. And a fuel storage building can pay for itself in less time than the boiler!

Protected from the elements and provided with good air circulation, it is not unreasonable to expect split and well-stacked cordwood to achieve moisture contents in the neighborhood of fiber saturation point (approximately 23% on the wet weight basis). The difference in heating value between hemlock cordwood at MC30 (partially air-dried) and hemlock cordwood at MC23 (well air-dried) is notable – about 13 percent more recoverable heat value (RHV) in the drier wood, which amounts to about 1,700,000 Btu per cord. And instead of a cord replacing 90.05 gallons of **#2 fuel oil**, it can now replace 101.5 gallons.

For the Community Hall, this would mean that instead of having to buy 114 cords per year, that fuel requirement becomes 101 cords, a savings of 13 cords and $2,275 per year (at $175 per cord). The implications for the Kake School are even greater: instead of having to buy 222 cords per year, that fuel requirement becomes 197 cords, a savings of 25 cords and $4,375 per year (at $175 per cord). NOTE: There is also a labor cost *savings* that can be realized due to fewer boiler stokings, less ash removal/disposal, and less fuel handling.

The opposite is also true. Cordwood left exposed to the elements in southeast Alaska will not dry much at all and may, in fact, gain moisture. The difference in total RHV Btu value between a cord of hemlock at MC30 (partially air-dried) and a cord of hemlock at MC50 ("green") is more than 4.84 million Btu. The wetter wood has roughly 63.5% of the heating value of the drier wood. In terms of its **#2 fuel oil** equivalence, the value is 57.16 gallons per cord at MC50 compared to 90.05 gallons per cord at MC30.

For the Community Hall it would mean that instead of having to buy 114 cords (MC30) per year, that cordwood equivalent becomes 179 cords ("dead green"), an increase of 65 cords and $11,375 per year (at $175 per cord). The implications for the Kake School are even greater: instead of having to buy 222 cords, that cordwood equivalent becomes 350 cords, an increase of 128 cords and $22,400 per year (at $175 per cord). NOTE: There is also a labor cost *increase* that would have to be incurred due to more frequent boiler stokings, more ash removal/disposal, and additional fuel handling.

Finally, cordwood purchased in the "off-season" can often be purchased at a discount from the heating season price. A seasonal discount of $25 per cord may be possible to negotiate, and could save an additional $2,850/yr in the case of the Community Hall and $5,550/yr at the School.

In summary:

> <u>Community Hall</u>: 179 cords of green wood per year at $175 = $31,325 versus 101 cords of dried wood per year at $150 = $15,150. Savings between green wood bought during the heating season and green wood purchased during the off-season and allowed to dry: **$16,175**. Given a fuel storage building costing $57,000 ($45,600 plus 25% contingency) as shown in Table 6-1, the simple payback would be about 3.5 years.
>
> <u>Kake School</u>: 350 cords of green wood per year at $175 = $61,250 versus 197 cords per year at $150 = $29,550. Savings between green wood bought during the heating season and green wood purchased during the off-season and allowed to dry: **$31,700**. Given a fuel storage building costing $111,000 ($88,800 plus 25% contingency) as shown in Table 6-1, the simple payback would be about 3.5 years.

6.8 Life Cycle Cost Analysis

The National Institute of Standards and Technology (NIST) Handbook 135, 1995 edition, defines Life Cycle Cost (LCC) as "the total discounted dollar cost of owning, operating, maintaining, and disposing of a building or a building system" over a period of time. Life Cycle Cost Analysis (LCCA) is an economic evaluation technique that determines the total cost of owning and operating a facility over a period of time. Alaska Statute 14.11.013 directs the Department of Education and Early Development (EED) to review school capital projects to ensure they are in the best interest of the state, and AS 14.11.014 stipulates the development of criteria to achieve cost effective school construction.[19]

While a full-blown life cycle cost analysis is beyond the scope of this preliminary feasibility assessment, an attempt is made to address some of the major items and run a rudimentary LCCA using the Alaska EED LCCA Handbook and spreadsheet.

According to the EED LCCA Handbook, the life cycle cost equation can be broken down into three variables: the **costs** of ownership, the period of **time** over which the costs are incurred (recommended period is 20 years), and the **discount rate** that is applied to future costs to equate them to present costs.

There are two major costs of ownership categories: **initial expenses** and **future expenses**. Initial expenses are all costs incurred prior to occupation (or use) of a facility, and future expenses are all costs incurred upon occupation (or use) of a facility. Future expenses are further categorized as **operation costs**, **maintenance and repair costs**, **replacement costs**, and **residual value**. A comprehensive list of items in each of these categories is included in the EED LCCA Handbook.

The discount rate is defined as, "the rate of interest reflecting the investor's time value of money", or, the interest rate that would make an investor indifferent as to whether s/he received payment now or a greater payment at some time in the future. NIST takes the definition a step further by separating it into two types: **real** discount rates and **nominal** discount rates. The **real discount rate** *excludes* the rate of inflation and the **nominal discount rate** *includes* the rate of inflation.[19] The EED LCCA Handbook and spreadsheet focuses on the use of real discount rates in the LCC analysis.

To establish a standard discount rate for use in the LCCA, EED adopted the US Department of Energy's (DOE) real discount rate. This rate is updated and published annually in the Energy Price Indices and Discount Factors for Life Cycle Cost Analysis – Annual Supplement to NIST Handbook 135 (www1.eere.energy.gov). The DOE discount and inflation rates for 2008 are as follows:

Real rate (excluding general price inflation)	3.0%
Nominal rate (including general price inflation)	4.9%
Implied long term average rate of inflation	1.8%

Other LCCA terms

Constant dollars: dollars of uniform purchasing power tied to a reference year and *exclusive of* general price inflation or deflation

Current dollars: dollars of non-uniform purchasing power, *including* general price inflation or deflation, in which actual prices are stated

Present value: the time equivalent value of past, present or future cash flows as of the beginning of the base year.

NOTE: When using the *real discount rate* in present value calculations, costs must be expressed in *constant* dollars. When using the *nominal discount rate* in present value calculations, costs must be expressed in *current* dollars. In practice, the use of constant dollars simplifies LCCA, and any change in the value of money over time will be accounted for by the real discount rate.

LCCA Assumptions

As stated earlier, it is beyond the scope of this pre-feasibility assessment to go into a detailed life cycle cost analysis. However, a limited LCCA is presented here for purposes of discussion and comparison.

Time is assumed to be 20 years, as recommended by EED
The **real discount rate** is 3%
Initial expenses as per Table 6.1
Future expenses as per Table 6.3
Replacement costs – not addressed
Residual value – not addressed

Cordwood Boiler Alternatives

Alternative 1 represents the existing oil-fired boiler systems. The initial investment was assumed to be $50,000. The operation costs included 20,000 gallons of #2 fuel oil at $5.50 per gallon and 40 hours of labor per year at $20 per hour. The annual maintenance and repairs costs were assumed to be $1,000 and no allowances were made for replacement costs or residual value.

NOTE: The value of the existing boiler system ($50,000), the amount and cost of labor (40 hours, $800), and maintenance and repair costs ($1,000) are fictitious, but are held constant for comparative purposes as appropriate.

Alternative 2 represents the existing oil-fired boiler systems, which would remain in place, plus the installation of **two Garn WHS 3200** wood fired boilers. The initial investment was assumed to be $364,500, which includes the hypothetical value of the existing oil-fired boilers (valued at $50,000 as per Alternative 1) plus the initial investment cost of the Garn boiler system ($314,500, as per Table 6-1). The operation costs include 222 cords of fuelwood at $175 per cord and 346.42 hours of labor per year at $20 per hour (as per Table 6-2). The annual utility, maintenance and repair costs were assumed to be $2,186.45 (as per Table 6-3) for the system and no allowances were made for replacement costs or residual value.

The hypothetical EED LCCA results for the Kake School cordwood boiler alternative are presented in Table 6-6.

Table 6-6. Estimated Life Cycle Costs of Cordwood System Alternative		
	Alternative 1 (existing boilers)	Alternative 2 (existing boilers plus HELE cordwood boilers)
Initial Investment Cost	$50,000	$364,500
Operations Cost	$1,648,424	$681,067
Maintenance & Repair Cost	$14,877	$32,529
Replacement Cost	$0	$0
Residual Value	$0	$0
Total Life Cycle Cost	1,713,302	1,078,096

SECTION 7. ECONOMIC FEASIBILITY OF BULK FUEL SYSTEMS

The term "bulk fuel" refers, generically, to sawdust, wood chips, shavings, bark, pellets, etc. Since the availability of bulk fuel is virtually non-existent in Kake, the cost of bulk fuel systems being so high (i.e., $1 million and up), and the relatively small heating demand for the facilities under consideration, the discussion of bulk fuel boiler systems has been omitted from this report.

SECTION 8. CONCLUSIONS

This report discusses conditions found "on the ground" at the Community Hall and School in Kake, Alaska, and attempts to demonstrate, by use of realistic, though hypothetical examples, the feasibility of installing high efficiency, low emission cordwood or bulk fuel wood boilers to heat these facilities.

Wood is a viable heating fuel in a wide range of institutional applications, however, below a certain minimum and above a certain maximum, it may be impractical to heat with wood, or it may require a different form of wood fuel and heating system. The difference in the cost of heat derived from wood versus the cost of heat derived from fuel oil is significant, as illustrated in Table 5-1. It is this difference in the cost of heat, resulting in monetary savings that must "pay" for the substantially higher investment and OM&R costs associated with wood-fuel systems.

Kake Facilities

Two facilities in Kake were identified as potential heating projects. The first consists of the Community Hall and the second is the Kake School. Each is analyzed in this report.

8.1. The Community Hall is medium-sized in terms of its energy usage; consuming a reported 10,250 gallons of #2 fuel oil per year. It is a good example of a medium-sized facility suitable to a HELE cordwood boiler installation.

With a single large HELE boiler being fired approximately 4 times per day, the simple payback period would be 4.62 years given current fuel costs and a cordwood boiler installation costing around $168,000. The present value, net present value and internal rate of return after 20 years, assuming a discount rate of 3%, are $454,760, $286,635 and 17.45% respectively.

8.2. The Kake School is medium to large in terms of its energy usage; consuming a reported 20,000 gallons of #2 fuel oil per year. It too is a good example of facility apparently suitable to a HELE cordwood boiler installation.

With a pair of large HELE boilers being fired approximately 4 times per day, the simple payback period would be 4.4 years given current fuel costs and a cordwood boiler installation costing around $314,500. The present value, net present value and internal rate of return after 20 years, assuming a discount rate of 3%, are $922,924, $608,424 and 19.13% respectively. The theoretical difference in life cycle costs between the currently installed system and a wood-fired system is more than $635,000 over 20 years.

Closer scrutiny of these projects by qualified professionals appears justified.

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Appendix A. AWEDTG Evaluation Criteria

The following criteria were used to evaluate and recommend projects for feasibility assessments:

1. The opportunity for displacing fuel oil, natural gas, propane or diesel-generated electricity used by targeted facilities for heating needs (i.e., current fuel type, gallons of fuel per year, annual cost per year);

2. Local presence of high-hazard forest fuels and potential for utilizing these fuels for heating schools, other public facilities, and buildings owned and operated by not-for-profit organizations;

3. Availability of local wood processing residues (e.g., sawdust, planer shavings, and sawmill residues);

4. Project cost versus yearly savings (cost-effectiveness);

5. Sustainability of the wood fuel supply;

6. Community support and project advocacy;

7. Ability to implement the project;

8. Ability to operate and maintain the project.

Appendix B. Recoverable Heating Value Determination

The Recoverable Heating Value (RHV) of wood is equal to the Gross Heating Value minus various energy losses (H1 through H8). Those losses are described as:

H1: Heat used to raise the temperature of water in the wood to the boiling point

H2: Heat required to vaporize the water in the wood

H3: Heat require to separate the bound water (water below fiber saturation point) from the cell walls

H4: Heat required to raise the temperature of the vaporized water to the temperature of the exhaust gases

H5: Heat required to evaporate water that forms when the hydrogen component of wood is combusted

H6: Heat from combustion other than water vapor (dry gases)

H7: Heat required to raise the temperature of wood to the combustion temperature

H8: Other heat losses (radiation, conduction, convection, incomplete combustion, etc.)

Each of these energy loss factors is a calculated value based on published formulae. For more information, please refer to: Briggs, D.G., *Forest Products Measurements and Conversion Factors* (Chapter 9), College of Forest Resources, University of Washington, 1994

In order to calculate RHV, certain factors must be known or assumed. In calculating RHV for this paper, the following assumptions were made (Except for ambient temperature and exhaust temperature, the values used here are the same as per Example 1 in Briggs):

- Higher Heating Values (HHV): as presented in Table D-1
- Moisture Content (MC): water content (calculated on wet basis). For calculations involving cordwood, moisture (water) content was assumed to be 30 percent on a wet basis. For calculations involving bulk fuel, moisture content was assumed to be 40% or 50%, as per the report.
- Wood Content: 100 minus moisture content percent (calculated on wet basis).
- Ambient Temperature (T1): assumed to be 25 degrees F
- Exhaust Temperature (T2): assumed to be 300 degrees F
- Combustion Temperature (T3): assumed to be 450 degrees F
- Fiber Saturation Point (FSP): assumed to be 23 percent (calculated on a green/wet basis), which is equal to 30% calculated on a dry weight basis
- Excess Air (EA): assumed to be 20 percent
- Other Losses (OL): assumed to be 4 percent

Appendix C. List of Abbreviations and Acronyms

AEA	Alaska Energy Authority
AWEDTG	Alaska Wood Energy Development Task Group
Btu	British Thermal Unit (MBtu, thousand Btu ; MMBtu, million Btu)
CE	Conversion Efficiency (fuel to heat)
Cord	80 ft3 of solid wood; 100 cubic feet of wood + bark; 128 cubic feet of wood, bark and air space
DB	Dry Basis ((wet weight – dry weight)/dry weight * 100))
DD	Degree Days (Heating Degree Days)
EPA U.S.	Environmental Protection Agency, U.S.
GHV	Gross Heating Value
Gm	Gram
Gpy	Gallons per year
HHV	High[er] Heating Value
JEDC	Juneau Economic Development Council
KBtu	Thousand Btu
KWe	Kilowatts, electric
KWt	Kilowatts, thermal
MC	Moisture Content (e.g. MC30 = 30 % moisture content)
MBtu	Thousand Btu (also kBtu)
MMBtu	Million Btu
NHV	Net Heating Value
NPV	Net Present Value
OD	Oven Dry
O&M	Operating and Maintenance
OM&R	Operation, Maintenance and Repair
OWB	Outdoor Wood Boiler
POW	Prince of Wales [Island], Alaska
PV	Present Value
RHV	Recoverable Heating Value
WB	Wet basis ((wet weight-dry weight)/wet weight * 100)

CONVERSIONS

1 grams = 0.00220462262 pounds
1 pounds = 453.59237 grams
Btu: A BTU is defined as the amount of heat required to raise the temperature of one pound (approx. 1 pint) of water by one degree Fahrenheit.

APPENDIX D - Wood Fuel Properties

Heating values for Alaska species are presented in Table D-1. High Heating Values (HHV), which are calculated on an oven-dry (OD) basis, are similar for *most* species on a weight basis, although resinous species typically have slightly higher HHV[1] than non-resinous species. The recoverable heating value (RHV), which takes into account moisture content and other energy losses[2], ranges from 4,067 to 5,347 Btu/lb at 30 percent moisture content (MC30) for species commonly found in southeast Alaska.

Ideally, cordwood should be air dried to 20% moisture content (MC20) or less, and one of the benefits of using cordwood is that the user could, with good planning, realize a substantial economic benefit by buying it green and allowing it to dry. However, the ideal situation is not always reality, and for this report cordwood at 30% moisture content (MC30) has been used in the calculations.

The RHV of hemlock cordwood (the most common species in southeast Alaska) at MC30 is about 13.26 million Btu (MMBtu) per cord (assumed to contain 100 cubic of "fuel", both wood and bark).

Table D-1. Heating Values of Selected Alaska Species

		Cordwood		
SPECIES	HHV[1] Btu/lb (MC0)	GHV[2]	RHV[2]	
		Btu/lb (MC30)	BTU/lb (MC30)	MMBtu per cord[b]
Alaska yellow-cedar	9,900	6,930	5,347	15.48
Western redcedar	9,144[a]	6,401	4,839	10.07
Western hemlock	**8,515[a]**	**5,961**	**4,417**	**13.26**
Sitka Spruce	8,100	5,670	4,138	10.83
White Spruce	8,890	6,223	4,669	12.22
Red Alder	7,995[a]	5,597	4,067	10.78
Paper (white) birch	8,334	5,834	4,295	15.44
Quaking aspen	No data	--	--	--
Black cottonwood	8,800	6,160	4,608	10.21
Black Spruce	No data	--	--	--

Notes:

HHV= Higher Heating Value, from *Fuelwood Characteristics of Northwestern Conifers and Hardwoods*

GHV = Gross Heating Value = HHV x (1-MCwb/100) MCwb = percent moisture content calculated on a wet basis

RHV = Recoverable Heat Value = GHV – Energy Losses (see Appendix B)

[a] average of published range of values[1]

[b] a cord is assumed to contain 100 cubic feet of "fuel" (wood plus bark)

D.1 Fuel Quality

Fuel quality, especially moisture content, has a large impact on the performance of wood-fueled boilers. For this assessment, it is assumed that cordwood has been seasoned and dried to 30% MC. As moisture content increases, heating values decrease, as shown in Table D-2.

Table D-2. Effect of Moisture Content on Gross Heating Value of Western Hemlock					
SPECIES	HHV Btu/lb Oven-dry (OD)	GHV Btu/lb (MC20)	GHV Btu/lb (MC30)	GHV Btu/lb (MC40)	GHV Btu/lb (MC50)
Western hemlock	8,515	6,812	5,961	5,109	4,258

Notes:

HHV= Higher Heating Value, from *Fuelwood Characteristics of Northwestern Conifers and Hardwoods* [1]
GHV = Gross Heating Value = HHVx (1-MCwb/100); MCwb is moisture content (wet basis) [2]

D.2 Recoverable Heat and Fuel Oil Equivalence/Displacement

Wood boilers are more expensive to install, own and operate than fuel oil boilers. Fuel cost savings (the difference between the cost of wood fuel and the cost of fuel oil) must pay for these higher investment and operating costs. The potential fuel oil displacement depends on the recoverable heating value (RHV) of the wood and the efficiency with which the boiler converts wood to energy (CE). Table D-3 shows the potential amount of fuel oil displaced by wood at typical efficiencies with the heating values from Table D-1. Wood system boiler conversion efficiency (CE) can be expected to vary from 25% for LEHE systems to 75% for HELE cordwood systems.

Deliverable heating value (DHV) is calculated using the equation:

DHV= RHV X CE [2]

Where DHV = Deliverable Heating Value
RHV = Recoverable Heating Value
CE = Conversion Efficiency

The fuel oil equivalence for hemlock cordwood at MC30 in a HELE cordwood boiler is calculated at **92.74** gallons (#1 fuel oil) and **90.05** gallons (#2 fuel oil); three times as much as a low efficiency boiler at 30.91 and 30.02 gallons per cord for #1 and #2 respectively. (See Table D-3)

Table D-3. Deliverable Heating Values and Fuel Oil Equivalence				
Boiler and Fuel	**RHV**	**CE**	**DHV**	**Fuel Oil Equivalent (1 unit = X gallons)**
Oil boiler, #1 Fuel Oil	134,000 Btu/gallon	80%	107,200 Btu/gallon	1 gallon = 1 gallon
Oil boiler, #2 Fuel Oil	138,000 Btu/gallon	80%	110,400 Btu/gallon	1gallon = 1 gallon
HELE cordwood boiler, hemlock cordwood @ 30% MC	13.26 MMBtu/cord	75%	9.942 MMBtu/cord	1 cord = 92.74 gal. #1 1 cord = 90.05 gal. #2
LEHE cordwood boiler, hemlock cordwood @ 30% MC	13.26 MMBtu/cord	25%	3.314 MMBtu/cord	1 cord = 30.91 gal. #1 1 cord = 30.02 gal. #2

Notes:

RHV = Recoverable Heating Value
DHV = Deliverable Heating Value
HELE = High efficiency. low emission
LEHE = Low efficiency, high emission
MMBtu = million British thermal units

APPENDIX E – Financial Metrics

6.1 Simple Payback Period

From: www.odellion.com:

The [Simple] Payback Period is defined as the length of time required to recover an initial investment through cash flows generated by the investment. The Payback Period lets you see the level of profitability of an investment in relation to time. The shorter the time period the better the investment opportunity:

$$\text{Payback Period} = \frac{\text{investment}}{\text{cash flow (year)}}$$

As an example, consider the implementation of a Human Resources (HR) software application that costs $150 thousand and will generate $50 thousand in annual savings in four years (the project duration):

HR Application Example

Initial	**Year 1**	**Year 2**	**Year 3**	**Year 4**
cost: $150K	benefit: $50K	benefit: $50K	benefit: $50K	benefit: $50K

Using the formula above, the Payback Period is calculated to be three years by dividing the initial investment of $150 thousand over the annual cash flows of $50 thousand. This equation is only applicable when the investment produces equal cash flows each year. Now consider the software implementation with the same initial cost but with variable annual cash flows:

HR Application Example

Initial	**Year 1**	**Year 2**	**Year 3**	**Year 4**
cost: $150K	benefit: $60K	benefit: $60K	benefit: $40K	benefit: $20K

Given the variable cash flows, the payback is calculated by looking at the cash flows and establishing the year the investment is paid off. At the beginning of Year 2, the company has recovered $120 thousand of the original $150 thousand. At the end of Year 2, the remaining $30 thousand is recovered with the cash flow of $40 thousand earned during this period. The payback period is then 2 + ($30 thousand/$40 thousand) or 2.8 years.

The Payback Period is a tool that is easy to use and understand, but it does have its limitations. Payback period analysis does not address the time value of money, nor does it go beyond the recovery of the initial investment.

6.2 Present Value

From: www.en.wikipedia.org:

The present value of a single or multiple future payments (known as cash flow(s)) is the nominal amounts of money to change hands at some future date, discounted to account for the time value of money, and other factors such as investment risk. A given amount of money is always more valuable sooner than later since this enables one to take advantage of investment opportunities. Present values are therefore smaller than corresponding future values. Present value calculations are widely used in business and economics to provide a means to compare cash flows at different times on a meaningful "like to like" basis.

One hundred dollars 1 year from now at 5% interest rate is today worth:

$$\text{Present value} = \frac{\text{future amount}}{(1 + \text{interest rate})^{\text{term}}} = \frac{100}{(1 + .05)^1} = 95.23.$$

6.3 Net Present Value

From: http://www.odellion.com:

The Net Present Value (NPV) of a project or investment is defined as the *sum* of the present values of the annual cash flows *minus* the initial investment. The annual cash flows are the Net Benefits (revenues minus costs) generated from the investment during its lifetime. These cash flows are discounted or adjusted by incorporating the uncertainty and time value of money. NPV is one of the most robust financial evaluation tools to estimate the value of an investment.

The calculation of NPV involves three simple yet nontrivial steps. The first step is to identify the size and timing of the expected future cash flows generated by the project or investment. The second step is to determine the discount rate or the estimated rate of return for the project. The third step is to calculate the NPV using the equations shown below:

$$\text{NPV} = \text{inital investment} + \frac{\text{Cash flow Year 1}}{(1+r)^1} + \dots \frac{\text{Cash flow Year n}}{(1+r)^n}$$

Or,

$$\text{NPV} = \text{inital investment} + \sum_{t=1}^{t = \text{end of project}} \frac{\text{(Cash Flows at Year t)}}{(1+r)^t}$$

Definition of Terms

Initial Investment: This is the investment made at the beginning of the project. The value is usually negative, since most projects involve an initial cash outflow. The initial investment can include hardware, software licensing fees, and startup costs.

Cash Flow: The net cash flow for each year of the project: Benefits minus Costs.

Rate of Return: The rate of return is calculated by looking at comparable investment alternatives having similar risks. The rate of return is often referred to as the discount rate, interest rate, or hurdle rate, or company cost of capital. Companies frequently use a standard rate for the project, as they approximate the risk of the project to be on average the risk of the company as a whole.

Time (t): This is the number of years representing the lifetime of the project.

A company should invest in a project only if the NPV is greater than or equal to zero. If the NPV is less than zero, the project will not provide enough financial benefits to justify the investment, since there are alternative investments that will earn at least the rate of return of the investment.

In theory, a company will select all the projects with a positive NPV. However, because of capital or budget constraints, companies usually employ a concept called NPV Indexes to prioritize projects having the highest value. The NPV Indexes are calculated by dividing each project's NPV by its initial cash outlay. The higher the NPV Index, the greater the investment opportunity.

The NPV analysis is highly flexible and can be combined with other financial evaluation tools such as Decision Tree models, and Scenario and Monte Carlo analyses. Decision Trees are used to establish the expected cash flows of multiple cash flows each one having a distinct probability of occurring.

The expected cash flows are then calculated from all the possible cash flows and their associated probabilities. NPV and Scenario Analysis are combined by varying a predetermined set of assumptions to determine the overall impact on the NPV value of the project. Finally, Monte Carlo analysis provides a deeper understanding of the relationship between the assumptions and the final NPV value. The Monte Carlo analysis calculates the standard deviation or ultimate change of NPV by using a set of different assumptions that dominate the end result."

6.4 Internal Rate of Return (IRR))

From: http://en.wikipedia.org/wiki/Internal_rate_of_return:

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The internal rate of return (IRR) is a capital budgeting method used by firms to decide whether they should make long-term investments. The IRR is the return rate which can be earned on the invested capital, i.e. the yield on the investment.

A project is a good investment proposition if its IRR is greater than the rate of interest that could be earned by alternative investments (investing in other projects, buying bonds, even putting the money in a bank account). The IRR should include an appropriate risk premium. Mathematically the IRR is defined as any discount rate that results in a net present value of zero of a series of cash flows.

In general, if the IRR is greater than the project's cost of capital, or hurdle (i.e., discount) rate, the project will add value for the company.

From http://www.odellion.com:

The Internal Rate of Return (IRR) is defined as the discount rate that makes the project have a zero Net Present Value (NPV). IRR is an alternative method of evaluating investments without estimating the discount rate. IRR takes into account the time value of money by considering the cash flows over the lifetime of a project. The IRR and NPV concepts are related but they are not equivalent.

The IRR uses the NPV equation as its starting point:

$$NPV = 0 = \text{inital investment} + \frac{\text{Cash flow Year 1}}{(1+IRR)^{1}} + \ldots \frac{\text{Cash flow Year n}}{(1+IRR)^{n}}$$

Definition of Terms

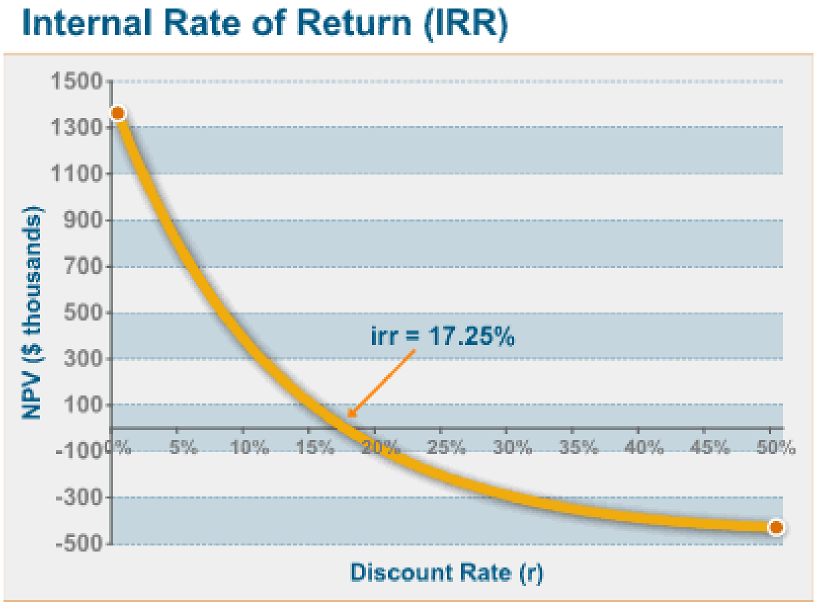
Initial investment: The investment at the beginning of the project.

Cash Flow: Measure of the actual cash generated by a company or the amount of cash earned after paying all expenses and taxes.

IRR: Internal Rate of Return.

n: Last year of the lifetime of the project.

Calculating the IRR is done through a trial-and-error process that looks for the Discount Rate that yields an NPV equal to zero. The trial-and-error calculation can by accomplished by using the IRR function in a spreadsheet program or with a programmable calculator. The graph below was plotted for a wide range of rates until the IRR was found that yields an NPV equal to zero (at the intercept with the x-axis).



As in the example above, a project that has a discount rate less than the IRR will yield a positive NPV. The higher the discount rate the more the cash flows will be reduced, resulting in a lower NPV of the project. The company will approve any project or investment where the IRR is higher than the cost of capital as the NPV will be greater than zero.

For example, the IRR for a particular project is 20%, and the cost of capital to the company is only 12%. The company can approve the project because the maximum value for the company to make money would be 8% more than the cost of capital. If the company had a cost of capital for this particular project of 21%, then there would be a negative NPV and the project would not be considered a profitable one.

The IRR is therefore the maximum allowable discount rate that would yield value considering the cost of capital and risk of the project. For this reason, the IRR is sometimes referred to as a break-even rate of return. It is the rate at which the value of cash outflow equals the value of cash inflow.

There are some special situations where the IRR concept can be misinterpreted. This is usually the case when periods of negative cash flow affect the value of IRR without accurately reflecting the underlying performance of the investment. Managers may misinterpret the IRR as the annual equivalent return on a given investment. This is not the case, as the IRR is the breakeven rate and does not provide an absolute view on the project return.

APPENDIX F – Operating Parameters of HELE Cordwood Boilers

Operating Parameters and Labor Requirements of HELE Cordwood Boilers

One of the most important OM&R costs associated with a HELE cordwood boiler is the labor factor. There are three components:

> Daily labor. The major labor requirement is the "daily" labor associated with firing the boiler.
>
> Periodic/Weekly labor. The second labor component is "periodic" (i.e., weekly) labor associated with boiler cleaning, ash disposal, and fuel re-stocking.
>
> Annual labor. "Annual" labor is the time associated with conducting annual maintenance and/or repairs, such as firetube cleaning, firebrick replacement, flue cleaning and repair, etc.

Daily Labor

Estimating the amount of daily labor is a function of the total amount of wood to be consumed and the ability of the boiler to consume it. This analysis compares the capacities of a single Garn WHS 3200 boiler, a pair of Garn WHS 2000 boilers, and a pair of Garn WHS 3200 boilers. It is assumed that the boiler(s) will operate at full capacity every day for 210 days (30 weeks) per year between mid-September and mid-April.

Table F-1. Operating parameters of a Garn HELE cordwood boiler

Item	(1) WHS 3200	(2) WHS 2000 (combined capacity)	(2) WHS 3200 (combined capacity)
Firebox volume, gross (cu.ft.)	36.36	23.3	72.72
Fuel volume per charge (cu.ft.)[a]	18.18	11.65	36.36
Fuel volume per charge (cords)[b]	0.142	0.091	0.284
Cords/year (fuel volume per charge (cords) X 210 days/year)			
at 1 charge per day	29.82	19.11	59.64
at 2 charges per day	59.64	38.22	119.28
at 3 charges per day	89.46	57.33	178.92
at 4 charges per day	**119.28**	76.44	**238.56**
at 5 charges per day	149.10	95.55	298.20
at 6 charges per day	178.92	**114.66**	357.84
at 7 charges per day	208.74	133.77	417.48

Notes:

[a] Equals ½ of gross firebox volume

[b] Equals fuel volume per charge (cu.ft.) divided by 128 (cubic feet per cord)

Daily labor requirements are assessed in Table F-2.

Table F-2. Daily labor requirements associated with HELE cordwood boilers

Assumptions:
1. 210 full operating days per year

	(1) WHS 3200	(2) WHS 2000 (combined capacity)	(2) WHS 3200 (combined capacity)
Annual wood consumption (cords/yr)	114		222
Average daily fuel consumption (cords) (annual wood consumption ÷ 210)	0.543		1.06
Average firings per day (cords/day ÷ cords/charge[a])	3.82	5.97	3.72
Labor required per firing (hours)[b]	.20	.15	.25
Labor required per day (hours) (time/firing X firings/day)	0.764	0.895	0.93
"Daily" labor per year (hours) (hours/day X 210 days/year)	**160.44**	**187.96**	**195.42**

Notes:

[a] From Table F-1

b estimate based on operation of Garn boiler at Dot Lake, AK

Periodic Labor

Periodic labor is the weekly labor associated with boiler inspection, boiler cleaning, ash disposal, and fuel re-stocking. Of these, fuel re-stocking may be the most time-intensive. However, with good planning, even that can be minimized.

Options for moving fuel:

a. The most labor intensive option would be hand-loading the fuel at the fuel storage area into a wheelbarrow, cart, truck or trailer, transporting the fuel to the boiler building, and then hand-unloading the fuel

b. Fuel can be hand-loaded onto a motorized conveyor belt and transferred from the fuel storage area to the boiler building

c. Fuel can be either hand-loaded or scooped into a bucket with a backhoe, loader or tractor equipped with a bucket

d. Fuel can be palletized or stored in racks that can be moved with a forklift.

In Kake, there are two facilities; the Community Hall and the School. The weekly labor demand would be as follows (allowing approximately 30 minutes per cord):

	Weekly wood requirement	Weekly labor requirement	Annual Periodic Labor
Community Hall	3.8 cords	1.9 hours	57
Kake School	7.4 cords	3.7 hours	111

Annual Labor

Annual labor is the time associated with conducting annual maintenance and/or repairs, such as firetube cleaning, firebrick replacement, flue cleaning, etc. It is difficult to anticipate and/or estimate. This example allows **20** hours per boiler per year.

Total Labor Requirements

Total daily, periodic and annual labor/labor cost assumptions associated with hypothetical HELE cordwood systems are provided in Table F-3.

Table F-3. Total Labor/Cost Assumptions for Hypothetical HELE Cordwood Systems

System (Garn Models)	(1) WHS 3200	(2) WHS 2000 (combined capacity)	(2) WHS 3200 (combined capacity)
Total Daily labor (hrs)	160.44	187.96	195.42
Total Periodic labor (hrs)	57		111
Total Annual labor (hrs)	20	40	40
Total labor (hrs)	237.44	284.96	346.42
Total annual cost ($) (Hrs x $20/hr)	**4,748.80**	**5,699.20**	**6,928.40**

APPENDIX G – Specifications of Garn Boilers

GARN WHS Specifications

	1500	2000	3200	4400
Width x Height (inches)	72”x75”	72”x75”	86”x93”	86”x93”
Overall Length	111”	135”	172”	192”
Recommended wood length (in)	24-32	24-32	32-48	32-48
Weight, empty (lb)	3,550	3,980	7,500	
Weight, filled (lb)	15,400	19,000	34,500	
Approximate gallons of storage	1,420	1,825	3,200	4,400
Firebox length (in)	41	41	50	50
Firebox diameter (in)	25	25	40	40
Firebox volume (cf)	11.65	11.65	36.36	36.36
Burn Rate Btu/hr into storage*	350,000	425,000	950,000	950,000
Btu's stored 120º- 200º F	920,000	1,272,000	2,064,000	2,932,000
Btus/degree of temp. rise	11,500	15,900	25,800	
Time between firing = Btu/hr used divided into Btus stored				
MSRP ($) (boiler only)	12,400	14,900	32,900	No data

All material, 2008 Dectra Corp. and Alaskan Heat Technologies

*Btu/hr storage is extremely fuel dependent. These numbers based on the use of split, 16" oak with 20% moisture and a reloading once an hour.

GARN® equipment is certified to burn; cord or slab wood; pallet and other scrap wood; densified wood briquettes; and air dried corn on the cob. As part of a program of continuous product improvement, **DECTRA CORPORATION** reserves the right to change models, specifications and pricing without notice. **GARN®** is a Registered Trademark.