Preliminary Feasibility Assessment for High Efficiency, Low Emission Wood Heating
In Copper Center and Kenny Lake, Alaska

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Key words: HELE, LEHE, bulk fuel, cordwood

ABSTRACT

The potential for heating the school facilities at Copper Center and Kenny Lake with high efficiency, low emission (HELE) wood boilers is evaluated for the Copper River School District (CRSD).

Early in 2006, organizations were invited to submit a Statement of Interest (SOI) to the Alaska Wood Energy Development Task Group (AWEDTG). Task Group members reviewed all the SOIs and selected projects for further review based on the selection criteria presented in Appendix A. AWEDTG representatives visited Copper Center and Kenny Lake during the summer of 2006 and information was obtained for each facility. Preliminary assessments were made and challenges identified. Potential wood energy systems were considered for each project using AWEDTG, USDA and AEA objectives for energy efficiency and emissions. Preliminary recommendations are made for each facility.

SECTION 1. EXECUTIVE SUMMARY

1.1 Goals and Objectives

- Identify CRSD school facilities in Copper Center and Kenny Lake as potential candidates for heating with wood
- Evaluate the suitability of the facility(s) and site(s) for siting a wood-fired boiler
- Assess the type(s) and availability of wood fuels
- 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

- All projects meet the AWEDTG objectives for petroleum fuel displacement, use of hazardous forest fuels or forest treatment residues, sustainability of the wood supply, project implementation, operation and maintenance, and community support

- Wood-fired systems are not feasible for very small applications. These may be satisfied with domestic wood appliances, such as wood stoves or pellet stoves/furnaces

- Facilities consuming less than 2,000 gallons per year represent minimal savings with wood-fired systems unless such systems can be enclosed in an existing structure, and wood and labor are very low cost or free

- Marginal economic metrics (such as those associated with small installations) can be improved with low-cost buildings and piping systems

- Medium and large energy consumers have the best potential for feasibly implementing a wood energy system and deserve detailed engineering analysis

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

1.3 Assessment Summary and Recommended Actions

1.3.1 Copper Center School

• Overview. The Copper Center School was built in 1985 and provides instruction for students in grades K through 6. The facility consists of one main building and two small satellite classrooms immediately adjacent to the main building. All facilities appeared to be well-maintained and in good condition.

In the main building heat is provided by a pair of Weil-McLain hot air furnaces (located in a mechanical room in the mezzanine above the first floor) capable of delivering a maximum of 526,000 Btu/hr (net, combined). Each of the satellite buildings has a small hot air furnace rated at about 112,000 Btu/hr (net). None of the buildings has a hydronic heating system.

The topography around the school is gentle, presenting no readily apparent physical impediments to an external boiler installation. There are several potential sites for a wood-fueled boiler within reasonable distances to the school buildings.

• Fuel consumption. Altogether, the reported total fuel consumption estimate is 6,000 gallons of fuel oil per year.

• Potential savings. At $2.90 per gallon and 6,000 gallons of fuel oil per year, CRSD pays $17,400 per year for fuel oil. The high-efficiency, low-emission (HELE) fuel equivalent of 6,000 gallons of fuel oil is about 60 cords, and at $100/cord represents a potential gross annual fuel cost savings of about $11,400.

• Required boiler capacity. The estimated required boiler capacity (RBC) to heat the Copper Center School is 207,500 Btu/hr during the coldest 24-hour period. It would appear that a single HELE cordwood boiler could supply 100% of that RBC with a margin similar to that of oil and/or gas fired furnaces or boilers.

• Recommended action regarding a bulk fuel wood system. Due to its small heating demand, a "bulk fuel" system is not feasible for the CRSD Copper Center School.

• Recommended action regarding a cordwood system. Two hypothetical boiler installations were compared: one medium boiler (Garn WHS 2000, rated at 425,000 Btu/hr) and one large boiler (Garn WHS 3200, rated at 950,000 Btu/hr). Under the stated assumptions and estimated costs, neither option was cost-effective; net present value was still negative at 20 years and internal rates of return, while positive, were low at approximately 0.5% and 1% respectively. However, this is a preliminary assessment; fuel oil prices are not static and annual savings are therefore likely to increase. Closer scrutiny by a professional engineer is warranted.

1.3.2 Kenny Lake School

• Overview. The Kenny Lake School (slab on grade construction) underwent extensive remodeling in 2006 and provides K through 12 instruction for 135 students. The facility consists of one large main building and several utility "outbuildings". The community library is also located nearby.

Heat is provided by two oil-fired Burnham boilers rated at 1.87 million Btu/hr (net, each), located in a single mechanical room at the rear of the main building. Heat is delivered via a hydronic heating system, with some supplemental hot air.

The topography around the school is gentle, presenting no apparent physical impediments to an external boiler installation. There are two potential sites for a wood-fueled boiler within reasonable distances to the school buildings.

• Fuel Consumption. The Kenny Lake School can be considered a relatively large energy consumer, given a reported annual fuel consumption estimate of 20,000 gallons of fuel oil.

• Potential Savings. At $2.90 per gallon and 20,000 gallons of fuel oil per year, the school pays $58,000 per year for fuel oil. The HELE cordwood fuel equivalent of 20,000 gallons of fuel oil is 200 cords, and at $100/cord represents a potential gross annual fuel cost savings of $38,000.

• Required boiler capacity. The estimated required boiler capacity (RBC) to heat the Kenny Lake School is 690,400 Btu/hr during the coldest 24-hour period. A single 950,000 Btu/hr HELE cordwood boiler operated at maximum capacity could, theoretically, supply 100% of that RBC and provide a significant annual economic benefit.

• Recommended action regarding a bulk fuel wood system. A "bulk fuel" system is not financially feasible for the Kenny Lake School, given the likely cost and projected savings.

• Recommended action regarding a cordwood system. The financial metrics of installing a single large HELE cordwood boiler are strongly positive, with a simple payback period under 6 years. Net present value becomes positive at year 10 and the internal rate of return at 20 years is 10.63%.

The financial metrics of installing two large HELE cordwood boilers was also considered for reasons of practicality. Under this scenario, the simple payback period is about 8 years. Net present value becomes positive at year 14, and the internal rate of return at 20 years is 6.64%

Further Design and Engineering for a HELE cordwood system for the Kenny Lake School is warranted.

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 AWEDTG selected projects for evaluation based on the criteria listed in Appendix A. Both of the Copper River School District projects meet the AWEDTG criteria for potential petroleum fuel displacement, use of forest residues for public benefit, use of local residues (though limited), sustainability of the wood supply, project implementation, operation and maintenance, and community support.

In the case of cordwood boiler applications, the wood supply from forest fuels or local processing residues appears adequate and matches the applications. Currently, "bulk fuel" (chips, bark, sawdust, etc.) supplies are very limited.

2.2 Successful Implementation

In general, three aspects of project implementation have been important to wood energy projects in the past: clear identification of a sponsoring agency/entity, dedication of personnel, and a reliable and consistent supply of fuel.

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

Boiler stoking and/or maintenance is required for approximately 9-15 minutes per boiler several times a day (depending on the heating demand) for manual wood-fueled systems, 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 facilities personnel.

The forest industry infrastructure in the Copper River Valley is small, but appears to be stable. For this report, it is assumed that wood supplies are sufficient.

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 a failure or other downtime (scheduled or unscheduled) in the wood system.

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.

SECTION 3. THE NATURE OF WOOD FUELS

3.1 Wood Fuel Forms and Current Utilization

Wood fuels in south-central Alaska are most likely to be in the form of cordwood and/or large, unprocessed sawmill residues, primarily slabwood. Sawdust and planer shavings currently supply the limited demand for bulk fuel in the immediate area. Other than sawdust and shavings, there is relatively little bulk fuel available. In the recent past, a whole tree harvesting and chipping operation took place near Glennallen, but that is no longer the case. And while there has been some discussion of building a pellet plant in the area, it does not currently exist and therefore pellets were not considered as a viable fuel option.

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 '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.

For this report, white spruce cordwood at 30 percent moisture content (MC30) and white spruce bulk fuel at 40 percent moisture content (MC40), calculated on the green wet weight basis (also called wet weight basis), are used as benchmarks.

The HHV of white spruce at 0% moisture content (MC0) is 8,890 Btu/lb[1]. The GHV at 30% moisture content (MC30) is 6,223 Btu/lb, and the GHV at 40% moisture content (MC30) is 5,334 Btu/lb.

The RHV for cordwood (MC30) is 14,860,000 Btu per **cord**, and the DHV, which is a function of boiler efficiency (assumed to be 75%), is 11,145,000 Btu per cord. The delivered heating value of 1 **cord** of white spruce cordwood (MC30) equals the delivered heating value of **101** gallons of #2 fuel oil when burned at 75% conversion efficiency.

The RHV for bulk fuel (MC40) is 7,360,000 Btu per **ton**, and the DHV, which is a function of boiler efficiency (assumed to be 70%), is 5,150,000 Btu per ton. The delivered heating value of 1 **ton** of white spruce bulk fuel (MC40) equals the delivered heating value of **46.7** gallons of #2 fuel oil when burned at 70% 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 manual outdoor wood boilers (OWBs) that burn cordwood are relatively low-cost and can save fuel oil but 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 recently instituted a moratorium on new LEHE OWB installations due to concerns over emissions and air quality[5]. Other states are also considering regulations[6,7,8,9]. Since there are no standards for OWBs ("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 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 four HELE boiler suppliers, two of which have units operating in Alaska. HS Tarm Co./Tarm USA, Inc. has 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 to provide heat to the washeteria and water plant.

Table 4-1. HELE Cordwood Boiler Suppliers

	Btu/hr ratings	Supplier
EKO-Line	85,000 to 275,000	New Horizon Corp www.newhorizoncorp.com
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.

Table 4-2 shows the results for a Garn WHS 1350 boiler that was tested at 157,000 to 173,000 Btu/hr by the State of Michigan 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	

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.

4.3 Bulk Fuel Boiler Systems

Commercial bulk fuel systems are generally efficient and meet typical federal and state air quality standards. They have been around for a long time and there is little new technological ground to break when installing one. Efficient bulk fuel boilers typically convert 70% of the energy in the wood fuel to hot water or low pressure steam when the fuel moisture is less than 40% moisture content (MC40, calculated on a wet basis).

Most vendors provide systems that can burn various bulk fuels (wood chips, sawdust, wood pellets and hog fuel), but each system, generally, has to be designed around the predominant fuel form. A system designed to burn clean chips will not necessarily operate well on a diet of hog fuel, for example. And most vendors will emphasize the need for good quality wood fuel and a consistent source of wood fuel, i.e., fuel with consistent size and moisture content from a common source is considerably more desirable than variations in chip size or moisture content. Table 4-3 presents a partial list of bulk fuel boiler system vendors.

Table 4-3. Bulk Fuel Boiler System Vendors	
Decton Iron Works, Inc Butler, WI (800) 246-1478 www.decton.com	New Horizon Corp. Sutton, WV (877) 202-5070 www.newhorizoncorp.com
Messersmith Manufacturing, Inc. Bark River, MI (906) 466-9010 www.burnchips.com	JMR Industrial Contractors Columbus, MS (662) 240-1247 www.jmric.com
Chiptec Wood Energy Systems South Burlington, VT (800) 244-4146 www.chiptec.com	**Note: Listing of any manufacturer, distributor or service provider does not constitute an endorsement**

Bulk fuel systems are available in a range of sizes between 300,000 and 60,000,000 Btu/hr. However, the majority of the installations range from 1 MMBtu/hr to 20 MMBtu/hr. Large energy consumers, consuming at least 40,000 gallons of fuel oil per year, have the best potential for installing bulk fuel boilers and may warrant detailed engineering analysis. Bulk fuel systems with their storage and automated fuel handling conveyances are generally not cost-effective for smaller applications.

Although there are several options, bulk fuel (chips, sawdust, bark, shavings, etc.) is best delivered in self-unloading tractor-trailer vans that hold about 22 to 24 tons of material. A facility such as the Kenny Lake School, replacing 20,000 gallons of fuel oil with white spruce bulk fuel (MC40) would use an estimated 428 tons per year, or about 20 tractor-trailer loads spread out over the school year.

There are three known bulk fuel boilers in Alaska (Table 4-4), all of which are installed at sawmills. The most recent was installed in Hoonah in 2006. A 4 MMBtu/hr wood chip boiler is under construction at the Craig Aquatic Center to replace the equivalent of 36,000 gallons of fuel oil per year. It is similar in size to boilers recently installed in Montana schools.

Table 4-4. Bulk Fuel Boilers in Alaska

Installation	Boiler Horsepower*	MMBtu/hr	Heating Degree Days**	Supplier
Craig Aquatic Center Craig, AK	120	4	7,209[a]	Chiptek
Icy Straits Lumber & Milling Hoonah, AK	72	2.4	8,496[b]	Decton
Regal Enterprises Copper Center, AK	N/A	N/A	13,486[c]	Messersmith
Logging & Milling Associates Delta Junction, AK	N/A	2	12,897[d]	Decton

Notes:

* Heat delivered as hot water or steam. 1 Boiler Horsepower = 33,475 Btu/hr or 34.5 pounds of water at a temperature of 100°C (212°F) into steam at 212°F

** assumes base = 65° F

[a] NOAA, July 1, 2005 through June 30, 2006, Ketchikan data

[b] NOAA, July 1, 2005 through June 30, 2006, Average of Juneau and Yakutat data

[c] NOAA, July 1, 2005 through June 30, 2006, Gulkana data

[d] NOAA, July 1, 2005 through June 30, 2006, Big Delta data

ftp://ftp.cpc.ncep.noaa.gov/htdocs/products/analysis_monitoring/cdus/degree_days/archives/Heating%20degree%20Days/Monthly%20City/2006/jun%202006.txt

Bulk fuel systems are discussed in greater detail in Section 7.

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 (form) availability, 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 white spruce cordwood (MC30) and white spruce bulk fuel (MC40). In order to make reasonable comparisons, costs are calculated 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, 1 gallon	138,000	80%	110,400 per gallon	3.00/gal	27.17
				3.50	31.70
				4.00	36.23
White spruce, 1 cord, MC30	14,860,000	75%	11,145,000 per cord	100/cord	8.97
				125	11.22
				150	13.46
White spruce 1 ton, MC40	7,360,000	70%	5,152,000 per ton	30/ton	5.82
				40	7.76
				50	9.70

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 white spruce cordwood (MC30) and the cost of delivered heat, (the slanted line). For each $10 per cord increase in the price of cordwood, the cost per million Btu increases by about $0.90. 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 fuel oil at $3.00, $3.50 and $4.00 per gallon ($27.17, $31.70 and $36.23 per million Btu respectively).

At high efficiency heat from white spruce cordwood (MC30) at $302.80 per cord is equal to the cost of oil at $3.00 per gallon, before considering the cost of the equipment and operation, maintenance and repair (OM&R) costs. At 75% efficiency and $125 per cord, a high-efficiency cordwood boiler will deliver heat at about 41% of the cost of fuel oil at $3.00 per gallon ($11.22 versus $27.17 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.

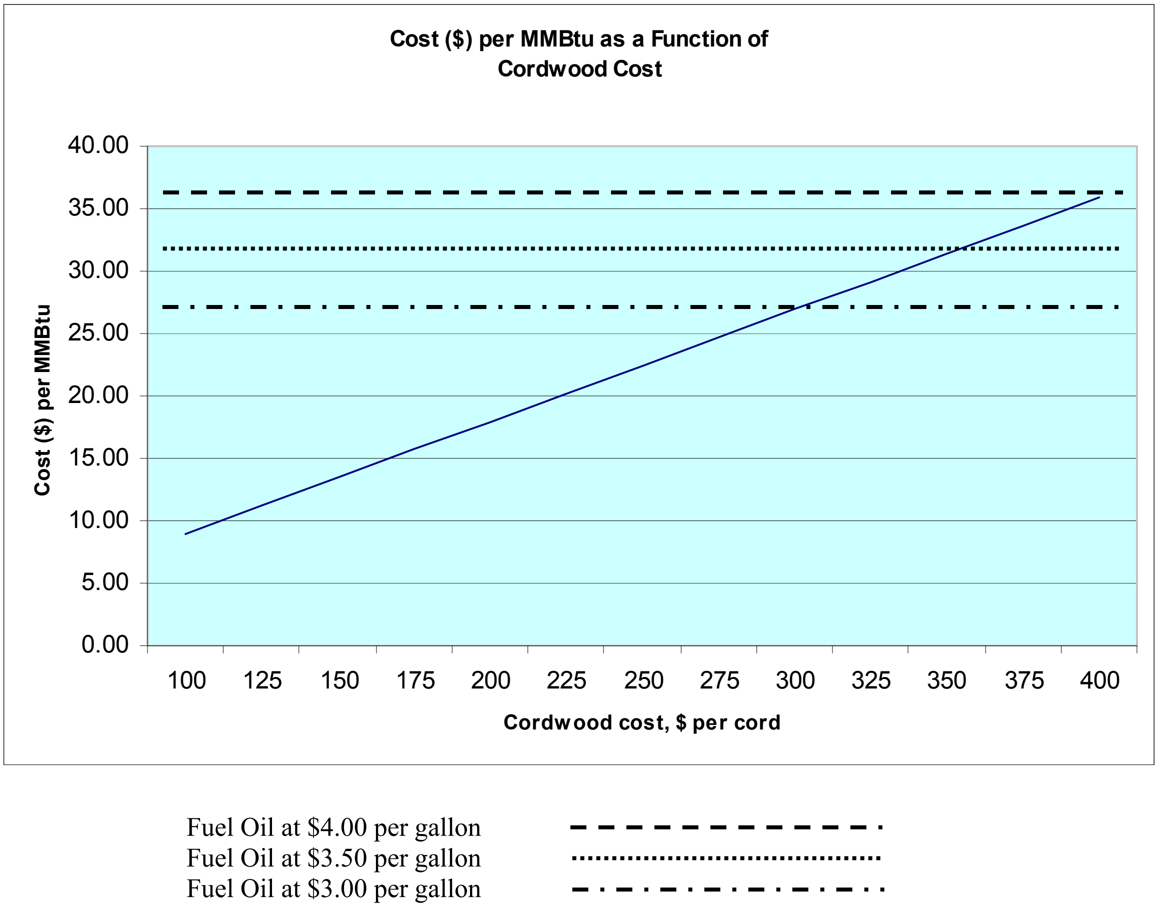
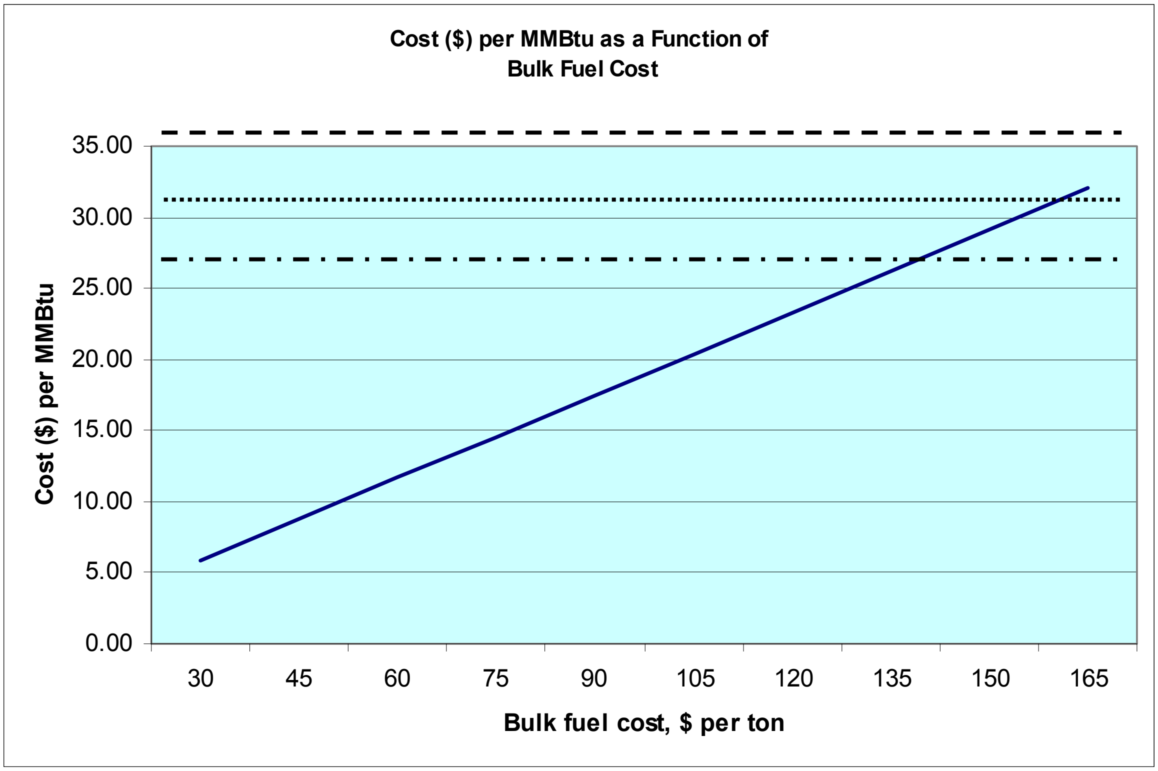


Figure 5-1. Effect of White Spruce Cordwood Price on Cost of Delivered Heat

5.2(b) Cost per MMBtu Sensitivity – Bulk Fuels

Figure 5-2 on the next page illustrates the relationship between the price of white spruce bulk fuel (MC40) and the cost of delivered heat, (the slanted line). For each $10 per ton increase in the price of bulk fuel, the cost per million Btu increases by about $1.94. The chart assumes that the bulk fuel boiler converts 70% of the RHV energy in the wood to useful heat and that fuel oil is converted to heat at 80% efficiency. The dashed lines represent fuel oil at $3.00, $3.50 and $4.00 per gallon ($27.17, $31.70 and $36.23 per million Btu respectively).

At high efficiency, heat from white spruce bulk fuel (MC40) at $140 per ton is equal to the cost of oil at $3.00 per gallon, before considering the investment and OM&R costs. At 70% efficiency and $40/ton, an efficient bulk fuel boiler will deliver heat at about 28.6% of the cost of fuel oil at $3.00 per gallon ($7.76 versus $27.17 per MMBtu), before considering the cost of the equipment and OM&R. Figure 5-2 shows that, at a given efficiency, savings increase significantly with decreases in the delivered price of bulk fuel and/or with increases in the price of fuel oil.



Fuel Oil at $4.00 per gallon – – – – – – – – – – – – –
Fuel Oil at $3.50 per gallon ....
Fuel Oil at $3.00 per gallon – · – · – · – · – · – · – · –

Figure 5-2. Effect of White Spruce Bulk Fuel Price on Cost of Delivered Heat

5.3 Determining Demand

Table 5-2 shows the reported approximate amount of fuel oil used by the CRSD Copper Center School and Kenny Lake School.

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

Facility	Reported Annual Fuel Consumption	
	Gallons	*Cost ($) @ $3.00/gallon*
Copper Center School	6,000	18,000
Kenny Lake School	20,000	60,000
TOTAL	**26,000**	**78,000**

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 Copper Center School and Kenny Lake School was compared with heating demand based on heating degree days (HDD) to determine the required boiler capacity (RBC) for heating only on the coldest 24 hour day (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.

Typically, installed oil-fired heating capacity at most sites is two to four times the demand for the coldest day, and this appears to be the case at Copper Center. It appears that the installed capacity at Kenny Lake is more than five times the maximum RBC.

Manual HELE cordwood boilers, equipped with special tanks for extra thermal storage, can supply heat at higher than their rated capacity for short periods. While rated at 950,000 Btu/hr, the Garn WHS 3200 can store more than 2 million Btu, which would be enough to heat the Copper Center School during the coldest 24-hour period for nearly 10 hours (2,064,000 ÷ 207,500).

Table 5-3. Estimate of Heat Required in Coldest 24 Hr 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]
Copper Center School	6,000	14,004	47,301	-40	207,500	750,000
Kenny Lake School	20,000	14,004	157,669	-40	690,400	3,746,000

Table 3-7 Notes:

[a] From SOI and site visit; net 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

According to these calculations (Table 5-3):

- It appears that the Copper Center School could supply 100% of its heating needs (207,500 Btu/hr during the coldest 24-hour period) with a medium Garn boiler rated at 425,000 Btu/hr. The Garn WHS 2000 can store more than 1¼ million Btu, which, theoretically, would be enough to heat the facility for more than 6 hours (1,272,000 ÷ 207,500). NOTE: This need to be confirmed by a qualified engineer.

- It appears that the Kenny Lake School could supply 100% of its heating needs (690,400 Btu/hr during the coldest 24-hour period) with an extra-large Garn boiler rated at 950,000 Btu/hr. The Garn WHS 4400 can store nearly 3 million Btu, which, theoretically, would be enough to heat the facility for more than 4¼ hours (2,932,000 ÷ 690,400). Note: installing multiple large boilers might be a better option than a single extra-large boiler. Consultation with a qualified engineer is recommended.

5.4 Summary of Findings

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 Copper Center School and the Kenny Lake 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

Facility	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 ($)		
POTENTIAL CORDWOOD SYSTEMS		*3.00*	*3.50*	*4.00*	White spruce, MC30, CE 75%	*100/cord*	*125/cord*	*150/cord*	*Low*	*Medium*	*High*
Copper Center School	6,000	18,000	21,000	24,000	60	6,000	7,500	9,000	9,000	13,500	12,000
Kenny Lake School	20,000	60,000	70,000	80,000	200	20,000	25,000	30,000	30,000	45,000	60,000
Total	26,000	78,000	91,000	104,000	260	26,000	32,500	39,000	39,000	58,500	72,000
POTENTIAL BULK FUEL SYSTEMS					White spruce, MC40, CE 70%	*30/ton*	*40/ton*	*50/ton*			
Kenny Lake School	20,000	60,000	70,000	80,000	428	12,840	17,120	21,400	38,600	52,880	67.160

NOTES:
a From Table 5-3; used the numerical average where a range was indicated
b From Table D-3, Fuel Oil Equivalents

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 civil and mechanical 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, two hypothetical 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 easily accomplished.

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 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 small and large heating demand situations. Two options are presented for each.

Building(s) 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 cost of hard copper pipe normally used in Alaska now precludes its use in nearly all 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.

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

Table 6-1. Initial Investment Cost Scenarios for Hypothetical Cordwood Systems				
	Copper Center School (small facility)		Kenny Lake School (large facility)	
Fuel oil consumption (gallons per year)	6,000		20,000	
Required boiler capacity (RBC), Btu/hr	207,500		690,400	
Cordwood boiler — Model / Rating - Btu/hr	Garn WHS 2000 425,000	Garn WHS 3200 950,000	(1) Garn WHS 4400 950,000	(2) Garn WHS 4400 1,900,000
Building and Equipment (B&E) Costs (for discussion purposes only)				
Fuel storage building[a] (fabric bldg, gravel pad, $20 per sf)	$24,000 (60 cords;1,200 sf)		$80,000 (200 cords; 4,000 sf)	
Boiler building @ $100 per sf (minimum footprint, concrete pad)[b]	$12,800 (16' x 8')	$20,000 (20' x 10')	$22,000 (22' x10')	$44,000 (22' x 20')
Boilers Base price[c] Shipping[d]	 $14,460 $3,500	 $27,700 $5,000	 $32,700[e] $5,500	 $65,400 $10,000
Plumbing/connections[d]	$20,000		$35,000	$40,000
Installation[d]	$7,500		$10,000	$15,000
Subtotal - B&E Costs	**$82,260**	**$ 104,200**	**$185,200**	**$254,400**
Contingency (25%)[d]	**$20,565**	**$ 26,050**	**$ 46,300**	**$ 63,600**
Grand Total	**$102,825**	**$130,250**	**$231,500**	**$318,000**

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

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

[e] Published list price not available; this represents list price for WHS 3200 + $5,000

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 will operate 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				
Facility	Small (60 cords/yr)		Single Large (200 cords/yr)	Double Large (200 cords/year)
System (Garn Model)	WHS 2000	WHS 3200	(1) WHS 4400	(2) WHS 4400
Total Daily labor (hrs/yr)[a] (hrs/day X 210 days/yr)	198.5	105	351.75	281.4
Total Periodic labor (hrs/yr)[b] (hrs/wk X 30 wks/yr)	90	90	180	180
Total Annual labor (hrs/yr)[b]	20	20	20	40
Total labor (hrs/yr)	308.5	215	551.75	501.4
Total annual labor cost ($/yr) (total hrs x $20)	**6,170**	**4,300**	**11,035**	**10,028**

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. One estimate predicted that, at $0.30 per kWh, the cost of operating the fan would be approximately $100-$200 per year[4]. The cost of operating circulation pumps and/or blowers would be about the same as it would be with the oil-fired boiler or furnace in an 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 year[4].

Table 6-3. Summary of Total Annual Non-Fuel OM&R Cost Estimates				
Item	Cost/Allowance ($)			
	Small (60 cords/yr)		Single Large (200 cords/yr)	Double Large (200 cords/yr)
	WHS 2000	WHS 3200	(1) WHS 4400	(2) WHS 4400
Labor	6,170	4,300	11,035	10,028
Electricity	100	100	200	300
Maintenance/Repairs	300	300	400	500
Total non-fuel OM&R ($)	**6,570**	**4,700**	**11,635**	**10,828**

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 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 and Modified Simple Payback Period
Present Value (PV)
Net Present Value (NPV)
Internal Rate of Return (IRR)
Life Cycle Cost (LCC)

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 and "Modified Simple" Payback Period for Small and Large HELE Cordwood Boilers

Table 6-4 presents a Payback Period analysis for hypothetical small and large HELE cordwood boiler installations.

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

Facility	Small		Single Large	Double Large
Fuel	(6,000 gpy; 60 cds/yr)		(20,000 gpy; 200 cords/yr)	
Boiler model	WHS 2000	WHS 3200	(1) WHS 4400	(2) WHS 4400
Fuel oil cost ($ per year @ $3.00 per gallon)	18,000		60,000	
Cordwood cost ($ per year @ $100 per cord)	6,000		20,000	
Gross annual fuel cost savings ($)	12,000		40,000	
Annual, non-fuel OM&R costs[a]	6,570	4,700	11,635	10,828
Net Annual Savings ($)	5,430	7,300	28,365	29,172
Total Investment Costs ($)[b]	102,825	130,250	231,500	318,000
Simple Payback (yrs)[c]	8.57	10.85	5.79	7.95
Modified Simple Payback (yrs)[d]	18.94	17.84	8.16	10.9

Notes:
a From Table 6-3
b From Table 6-1
c Total investment costs divided by Gross annual fuel cost savings
d Total Investment Costs divided by Net Annual Savings

6.6 Present Value (PV), Net Present Value (NPV) and Internal Rate or Return (IRR) Values for Small and Large HELE Cordwood Boilers

Table 6-5 presents PV, NPV and IRR values for hypothetical small and large HELE cordwood boilers.

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

Facility	Small		Single Large	Double Large
Fuel	(6,000 gpy; 60 cds/yr)		(20,000 gpy; 200 cords/yr)	
Boiler model	WHS 2000	WHS 3200	(1) WHS 4400	(2) WHS 4400
Discount Rate[a]	3%			
Time, "t", (years)	20			
Initial Investment ($)[b]	102,825	130,250	231,500	318,000
Annual Cash Flow ($)[c]	5,430	7,300	28,365	29,172
Present Value (of expected cash flows, $ at "t" years)	80,785	108,606	422,000	434,006
Net Present Value ($ at "t" years)	-22,040	-21,644	190,500	116,006
Internal Rate of Return (% at "t" years)	0.53	1.11	10.63	6.64
See Note #__ below	1	2	3	4

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 $80,785 today (PV), which is less than the initial investment of $102,825. The resulting NPV of the project is -$22,040, which means that the project, given the stated assumptions and cost estimates, will not achieve the stated return [i.e., 3%] at the end of 20 years.

Given the assumptions and cost estimates for this example, this project does not appear to be financially feasibility. However, the initial investment cost estimates could be too high. Furthermore, annual cash flows *will* increase if oil prices continue to increase above the general rate of inflation and/or disproportionately to the cost of wood fuel.

Note #2. With a real discount rate of 3.00% and after a span of 20 years, the projected cash flows are worth $108,606 today (PV), which is less than the initial investment of $130,250. The resulting NPV of the project is -$21,644, which means that the project, given the stated assumptions and estimates, will not achieve the stated return [i.e., 3%] at the end of 20 years.

Given the assumptions and cost estimates for this example, this project does not appear to be financially feasibility. However, the initial investment cost estimates could be too high. Furthermore, annual cash flows *will* increase if oil prices continue to increase above the general rate of inflation and/or disproportionately to the cost of wood fuel.

NOTE: In this hypothetical example, it appears that the labor savings associated with the larger, more costly boiler provides improved financial metrics over the less costly, more labor-intensive smaller boiler. As a practical matter, having to fire the boiler 2 times per day versus 6 times per day could be the deciding factor.

Note #3. With a real discount rate of 3.00% and after a span of 20 years, the projected cash flows are worth $422,000 today (PV), which is greater than the initial investment of $231,500. The resulting NPV of the project is $190,500, and the project achieves an internal rate of return of 10.63% at the end of 20 years. (NPV becomes positive at year 10.)

Given the assumptions and cost estimates for this example, the project appears feasible. However, the cost estimates could be low. Areas where significant cost increases could be incurred include the fuel storage building, the boiler building, the plumbing and connections, and the contingency allowance.

Note #4. With a real discount rate of 3.00% and after span of 20 years, the projected cash flows are worth $434,006 today (PV), which is greater than the initial investment of $318,000. The resulting NPV of the project is -$116,006, and the project achieves an internal rate of return of 6.64% at the end of 20 years. (NPV becomes positive at year 14.)

Given the assumptions and cost estimates for this example, the project appears feasible. However, the cost estimates could be low. Areas where significant cost increases could be incurred include the fuel storage building, the boiler building, the plumbing and connections, and the contingency allowance.

NOTE: In this hypothetical example, it appears that the labor savings associated with installing 2 boilers has a negative impact on the overall financial metrics. However, as a practical matter, having to fire the boiler 3 times per day versus 7 times per day could be the deciding factor.

6.7 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 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 cost 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 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/femp/pdfs/ashb07.pdf). The DOE discount and inflation rates for 2007 are as follows:

Real rate (excluding general price inflation)	3.0%
Nominal rate (including general price inflation)	5.0%
Implied long term average rate of inflation	1.9%

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 each of the schools) 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

6.7.1 Copper Center School

Alternative 1 represents the existing oil-fired furnaces. The initial investment was assumed (arbitrarily) to be $50,000. The operation costs included 6,000 gallons of fuel oil at $3.00 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.

Alternative 2 represents the existing oil-fired furnaces, which would remain in place, *plus* the installation of a Garn WHS 2000 wood fired boiler. The initial investment was assumed to be

$152,825, which includes the value of the existing oil-fired furnaces (valued at $50,000, as above) plus the initial investment cost of the Garn boiler ($102,825, as per Table 6-1). The operation costs include 60 cords of fuelwood at $100 per cord and 308.5 hours of labor per year at $20 per hour. The annual maintenance and repairs costs were assumed to be $400 and no allowances were made for replacement costs or residual value.

Alternative 3 represents the existing oil-fired furnaces, which would remain in place, *plus* the installation of a Garn WHS 3200 wood fired boiler. The initial investment was assumed to be $180,250, which includes the value of the existing oil-fired furnaces (valued at $50,000 as above) plus the initial investment cost of the Garn boiler ($130,250, as per Table 6-1). The operation costs include 60 cords of fuelwood at $100 per cord and 215 hours of labor per year at $20 per hour. The annual maintenance and repairs costs were assumed to be $400 and no allowances were made for replacement costs or residual value.

The EED LCCA results for the Copper Center School are presented in Table 6-6.

Table 6-6. Life Cycle Costs of Copper Center School Project Alternatives

	Alternative #1	Alternative #2	Alternative #3
Initial Investment Costs	$50,000	$152,825	$180,250
Operation Costs	$282,672	$207,838	$180,017
Maintenance & Repair Costs	$14,877	$5,951	$5,951
Replacement Costs	$0	$0	$0
Residual Values	$0	$0	$0
Total Life Cycle Cost	**$347,549**	**$366,614**	**$366,218**

6.7.2 Kenny Lake School

Alternative 1 represents the existing oil-fired boiler system. The initial investment was assumed (arbitrarily) to be $50,000. The operation costs included 20,000 gallons of fuel oil at $3.00 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.

Alternative 2 represents the existing oil-fired furnaces, which would remain in place, plus the installation of a single Garn WHS 4400 wood fired boiler. The initial investment was assumed to be $281,500, which includes the value of the existing oil-fired furnaces (valued at $50,000 as above) plus the initial investment cost of the Garn boiler ($231,500, as per Table 6-1). The operation costs include 200 cords of fuelwood at $100 per cord and 551.75 hours of labor per year at $20 per hour. The annual maintenance and repairs costs were assumed to be $600 and no allowances were made for replacement costs or residual value.

Alternative 3 represents the existing oil-fired furnaces, which would remain in place, plus the installation of two Garn WHS 4400 wood fired boilers. The initial investment was assumed to be

$368,000, which includes the value of the existing oil-fired furnaces (valued at $50,000 as above) plus the initial investment cost of the Garn boilers ($318,000, as per Table 6-1). The operation costs include 200 cords of fuelwood at $100 per cord and 501.4 hours of labor per year at $20 per hour. The annual maintenance and repairs costs were assumed to be $800 and no allowances were made for replacement costs or residual value. 501.4

The EED LCCA results for the Kenny Lake School are presented in Table 6-7.

Table 6-7. Life Cycle Costs of Kenny Lake School Project Alternatives

	Alternative #1	Alternative #2	Alternative #3
Initial Investment Cost	$50,000	$281,500	$368,000
Operations Cost	$904,550	$461,722	$446,741
Maintenance & Repair Cost	$14,877	$8,926	$11,902
Replacement Cost	$0	$0	$0
Residual Value	$0	$0	$0
Total Life Cycle Cost	**$969,428**	**$752,149**	**$826,643**

SECTION 7. ECONOMIC FEASIBILITY OF BULK FUEL SYSTEMS

A typical bulk fuel boiler system includes bulk fuel storage, a boiler building, wood-fuel handling systems, combustion chamber, boiler, ash removal, cyclone, exhaust stack and electronic controls. The variables in this list of system components include the use of silos of various sizes for wood fuel storage, chip storage areas of various sizes, boiler buildings of various sizes, automated versus manual ash removal and cyclones for particulate removal.[17]

7.1 Capital Cost Components

As indicated, bulk fuel systems are larger, more complex and more costly to install and integrate with existing boiler and distribution systems. Before a true economic analysis can be performed, *all* of the costs (capital, non-capital and OM&R) must be identified, and this is where the services of architects and civil and mechanical engineers are necessary.

Table 7-1 outlines the various general components for a hypothetical, small bulk fuel system; however it is beyond the scope of this report to offer estimates of costs for those components. As an alternative, a range of likely total costs is presented and analyzed for comparison purposes.

Table 7-1. Initial Investment Cost Components for Bulk Fuel Systems		
Facility	Kenny Lake School (20,000 gallons/year; 428 tons/year)	
Capital Costs: Building and Equipment (B&E)		
Fuel storage building		
Material handling system		
Boiler building		
Boiler: base price *shipping*		
Plumbing/connections		
Electrical systems		
Installation		
Total Capital (B&E) Costs[a]		
Non-capital Costs		
Engineering , Contingency, Permitting, etc.		
Initial Investment Total ($)	$500,000 to $2,000,000	

The investment cost of bulk fuel systems can range from $500,000 to $2 million, with about $350,000 to $900,000 in equipment costs. Fuel handling and boiler equipment for an 8 MMBtu/hr (300 BHP) system was recently quoted to a school in the northeast USA for $900,000. The cost of a boiler and fuel handling equipment for a 3 to 4 MMBtu/hr system is about $350,000 to $500,000. The 2.4 MMBtu/hr system in Hoonah was installed at a sawmill for $250,000, but an existing building was used and there were significant economies in fuel preparation and handling that would be unacceptable in a non-industrial, institutional setting. Fuel and boiler equipment for a 1 MMBtu per hour system is estimated at $250,000 to $300,000 (buildings are extra). Several schools in New England have been able to use existing buildings or boiler rooms to house new equipment and realize substantial savings, but recent school projects in Montana were all installed in new buildings.[4]

The Craig Schools and Aquatic Center project in Craig, AK was originally estimated at less than $1 million to replace propane and fuel oil equivalent to 36,000 gallons of fuel oil, but the results of a January 2007 bid opening brought the cost to over $1.8 million. The fuel storage and boiler building, and system integration costs for the pool and two schools increased the project costs.

Table 7-2 shows the total costs for the Darby School (Darby, MT) project at $1,001,000 including $268,000 for repairs and upgrades to the pre-existing system. Integration with any pre-existing system will likely require repairs and rework that must be included in the wood system cost. Adding the indirect costs of engineering, permits, etc. to the equipment cost put the total cost at Darby between $716,000 and $766,000 for the 3 million Btu/hr system to replace 47,000 gallons of fuel oil per year. (NOTE: although the Darby School replaces more than twice the amount of fuel used at the Kenny Lake School, it would not be safe to estimate the cost of a 50% smaller bulk fuel system at half the cost.) Since the boiler was installed at Darby, building and equipment costs have increased from 10% to 25%. A new budget price for the Darby system might be closer to $800,000 excluding the cost of repairs to the existing system.[4]

Table 7-2. Darby, MT Public School Wood Chip Boiler Costs [a]	
Boiler Capacity	3 MMBtu/hr
Fuel Oil Displaced	47,000 gallons
Heating Degree Days	7,186
System Costs:	
Building, Fuel Handling	$ 230,500
Boiler and Stack	$ 285,500
Boiler system subtotal	$ 516,000
Piping, integration	$ 95,000
Other repairs, improvements	$ 268,000
Total, Direct Costs	$ 879,000
Engineering, permits, indirect	$ 122,000
Total Cost	$1,001,000
[a] Biomass Energy Resource Center, 2005 [4]	

The following is an excerpt from the Montana *Biomass Boiler Market Assessment*[17]:

> "To date, CTA [*CTA Architects and Engineers, Billings, MT*] has evaluated more than 200 buildings throughout the northwestern United States and designed 13 biomass boiler projects, six of which are now operational. Selected characteristics of these projects, including total project cost, are presented in Table 1 [*7-3*]. As can be seen from Table 1 [*7-3*], total costs for these projects do not correlate directly with boiler size. The least expensive biomass projects completed to date cost $455,000 (not including additional equipment and site improvements made by the school district) for a wood chip system in Thompson Falls, Montana. The least expensive wood pellet system is projected to cost $269,000 in Burns, Oregon. The general breakdown of costs for these two projects is presented in Tables 2 [*7-4*] and 3."

NOTE: Information related to wood pellet systems was not included in this report as wood pellets are not available as a fuel in south-central Alaska.

Table 7-3. Characteristics of Biomass Boiler Projects[17]					
Facility Name	**Location**	**Boiler Size** (MMBtu/hr output)	**Project Type**	**Wood Fuel Type**	**Total Project Cost**
Thompson Falls School District	Thompson Falls, MT	1.6 MMBtu	Stand-alone boiler building tied to existing steam system	Chips	$ 455,000
Glacier High School	Kalispell, MT	7 MMBtu	New facility with integrated wood chip and natural gas hot water system	Chips	$ 480,000
Victor School District	Victor, MT	2.6 MMBtu	Stand-alone boiler building tied to existing steam system	Chips	$ 615,000
Philipsburg School District	Philipsburg, MT	3.87 MMBtu	Stand-alone boiler building tied to existing hot water system	Chips	$ 684,000
Darby School District	Darby, MT	3 MMBtu	Stand-alone boiler building tied to existing steam & hot water system	Chips	$ 970,000
City of Craig	Craig, AK	4 MMBtu	Stand-alone boiler building tied to existing hot water systems	Chips	$1,400,000
UM Western	Dillon, MT	14 MMBtu	Addition to existing steam system	Chips	$1,400,000

Table 7-4. Cost Breakdown for the Least Expensive Wood Chip Boiler System Installed in a New Free-Standing Building [17]		
System Component	**Cost**	**% of Total**
Wood Boiler System Equipment	$136,000	30%
Building	$170,000	38%
Mechanical/Electrical	$100,000	22%
Mechanical Integration	$15,000	3%
Fees, Permits, Printing, Etc.	$34,000	7%
Total*	**$455,000***	100%

* not including additional equipment and site improvements made by the school district

7.2 Generic OM&R Cost Allowances

The primary operating cost is fuel. The estimated bulk fuel cost for the Kenny Lake School is **$12,840** (428 tons @ $30/ton). NOTE: $30 per ton is probably unrealistically low. Higher wood fuel costs would only serve to have a more negative impact on project feasibility.

Other O&M costs would include labor, electricity and maintenance/repairs. For purposes of this analysis, it is assumed that the boiler will operate every day for 210 days (30 weeks) per year between mid-September and mid-April.

Daily labor would consist of monitoring the system and performing daily inspections as prescribed by the system manufacturer. It is assumed that the average daily labor requirement is ½ hour. An additional 1 hour per week is allocated to perform routine maintenance tasks. Therefore, the total annual labor requirement is (210 x 0.5) + 30 = **135 hours per year**. At $20 per hour, the annual labor cost would be **$2,700**.

There is also an electrical cost component to the boiler operation. Typically, electrically-powered conveyors of various sorts are used to move fuel from its place of storage to a metering bin and into the boiler. There are also numerous other electrical systems that operate various pumps, fans, etc. The Darby High School system in Darby, MT, which burned 755 tons of bulk fuel in 2005, used electricity in the amount of $2,035,[18] however the actual kWh or cost per kWh were not reported. Another report[17] proffered an average electricity cost for Montana of $0.086 per kWh. If that rate is true for Darby, then the electrical consumption would have been about 23,663 kWh. The Kenny Lake School is projected to use 428 tons of bulk fuel (57% of the amount used at Darby). If it is valid to apportion the electrical usage based on bulk fuel consumption, then Kenny Lake would use about 13,414 kWh per year. At $0.30 per kWh, the annual electrical consumption would be **$4,024**.

Lastly, there is the cost of maintenance and repair. Bulk fuel systems with their conveyors, fans, bearings, motors, etc. have more wear parts. An arbitrary allowance of **$2,000** is made to cover these costs.

Total annual operating, maintenance and repair cost estimates for a bulk fuel boiler at the Kenny Lake School are summarized in Table 8-2

Table 7-5. Total OM&R Cost Allowances for a Bulk Fuel System

Item	Cost/Allowance
Non-Fuel OM&R	
Labor ($)	*2,700*
Electricity ($)	*4,024*
Maintenance ($)	*2,000*
Total, non-fuel OM&R	8,724
Wood fuel ($)	12,840
Total OM&R ($)	21,564

7.3 Calculation of Financial Metrics

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

7.4 Simple and "Modified Simple" Payback Period for Generic Bulk Fuel Boilers

Table 7-6 presents Payback Period analysis for a range of initial investment cost estimates for generic bulk fuel boiler systems.

Table 7-6. Simple and "Modified Simple" Payback Period Analysis						
Facility	Kenny Lake School (20,000 gpy; 428 tons/yr)					
Fuel oil ($ per year @ $3.00 per gallon	60,000					
Bulk wood fuel ($ per year @ $30 per ton)	12,840					
Gross Annual Savings ($) (fuel cost savings)	47,160					
Net Annual Savings ($) (Gross savings minus non-fuel OM&R Costs)	38,436					
Total Investment Costs ($)	750,000	900,000	1,050,000	1,200,000	1,350,000	1,500,000
Simple Payback (yrs)[a]	15.9	19.08	22.26	25.45	28.63	31.81
Modified simple payback (yrs)[b]	19.51	23.42	27.32	31.22	35.12	39.03

[a] Simple payback equals total investment cost divided by gross annual savings
[b] Modified simple payback equals total investment cost divided by net annual savings

While simple payback has its limitations in terms of project evaluations, one of the conclusions of the Montana Biomass Boiler Market Assessment was that viable projects had simple payback periods of 10 years or less.[17]

7.5 Present Value (PV), Net Present Value (NPV) and Internal Rate or Return (IRR) Values for a Hypothetical Bulk Fuel Boiler Installed at the Kenny Lake School

Table 7-7 presents PV, NPV and IRR values for hypothetical bulk fuel boilers.

Table 7-7. PV, NPV and IRR Values for Bulk Fuel Systems						
Discount Rate	3					
Time, "t", (years)	20					
Initial Investment ($)[a]	750,000	900,000	1,050,000	1,200,000	1,350,000	1,500,000
Annual Cash Flow ($)[b]	38,436					
Present Value (of expected cash flows), ($ at "t" years)	571,831					
Net Present Value ($ at "t" years)	-178,169	-328,169	-478,169	-628,169	-778,169	-928,169
Internal Rate of Return (%)	0.24	-1.46	-2.80	-3.91	-4.85	-5.67

Notes:
a from Table 7-6
b Equals annual cost of fuel oil minus annual cost of wood minus annual non-fuel OM&R costs

SECTION 8. CONCLUSIONS

This report discusses conditions found "on the ground" at the Copper River School District school facilities at Copper Center and Kenny Lake, AK in south-central Alaska, and attempts to demonstrate, by use of realistic, though hypothetical examples, the feasibility of installing high efficiency low emission cordwood and/or bulk fuel wood boilers for heating 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 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.

8.1 "Small" Applications – Copper Center School

The Copper River School District owns, operates and manages the K-6 school in Copper Center, AK, which consists of one large primary building and two smaller satellite buildings. These facilities are in close proximity to one another, and each has its own heating system.

The individual fuel oil consumption for each of these buildings was not reported, but taken all together, these buildings consume a reported 6,000 gallons of fuel oil per year. Physically, it appears very possible that these buildings could be served by one cordwood boiler. Although connective plumbing is not cheap, the distances between buildings and the prospective sites for a boiler do not appear excessive. These buildings do not already have hydronic heating systems, so some additional expenses will have to be incurred to retrofit the existing hot air systems.

In the hypothetical examples presented in Section 6 for a small facility with a cordwood boiler, the gross annual (fuel cost) savings would amount to $12,000. Two scenarios were then presented:

1. With a small boiler (Garn WHS 2000) being fired approximately 6 times per day, the simple payback period would be 8.57 years (given a cordwood boiler installation costing an estimated $102,825). However, when annual OM&R costs are considered, modified simple payback period is nearly 19 years and the present value, net present value and internal rate of return after **20** years, assuming a real discount rate of 3%, are $80,785, -$22,040 and 0.53% respectively.

2. With a large boiler (Garn WHS 3200) being fired twice per day, the simple payback period would be 10.85 years (given a cordwood boiler installation costing an estimated $130,250). However, when annual OM&R costs are considered, modified simple payback becomes 17.84 years and the present value, net present value and internal rate of return after **20** years, assuming a discount rate of 3%, are $180,606, -$21,644 and 1.11% respectively.

While neither of these scenarios presents a positive outcome given the stated assumptions and cost estimates, the net present value becomes positive at year 20 if the initial project cost is reduced by approximately $22,000 (in either case). Furthermore, the financial metrics (simple payback period notwithstanding) appear to favor scenario 2, with the larger boiler and the labor savings associated with fewer firings per day. Closer scrutiny of this project by qualified professionals would be justified.

8.2 "Large Applications – Kenny Lake School

The Kenny Lake School provides K through 12 instruction for 135 students. The facility consists of one large main building and several utility "outbuildings". Heat is provided by two oil-fired Burnham boilers rated at 1.87 million Btu/hr (net, each), located in a single mechanical room at the rear of the main building. Heat is delivered via a hydronic heating system, with some supplemental hot air. The Kenny Lake School could be considered "large" in terms of its fuel oil consumption (20,000 gpy), but it is not large enough to justify the installation of a bulk fuel wood heating system.

The topography around the school is gentle, presenting no apparent physical impediments to an external boiler installation. There are at least two potential sites for a wood-fueled boiler within reasonable distances to the school buildings.

<u>Cordwood Systems</u>:

To replace 20,000 gallons of fuel oil per year would require approximately 200 cords of reasonably dry (MC30) white spruce cordwood and/or large sawmill residues (i.e., slabwood).

In the example presented in Section 6 for a "large" facility, with a *single* large cordwood boiler (Garn WHS 4400), requiring 6.7 firings per day, the gross annual (fuel cost) savings would amount to $40,000, and yield a simple payback of 5.79 years (given a cordwood boiler installation costing $231,500). When annual OM&R costs are considered, the modified simple payback period becomes 8.16 years and the present value, net present value and internal rate of return after **20** years, assuming a discount rate of 3%, are $422,000, $190,500 and 10.63% respectively. These results indicate that, under the assumed conditions, the project is economically viable.

In the example presented in Section 6 for a "large" facility, with *two* large cordwood boilers (2 Garn WHS 4400), requiring 3.35 firings per day, the gross annual (fuel cost) savings would amount to $40,000, and yield a simple payback of 7.95 years (given a cordwood boiler installation costing $318,000). When annual OM&R costs are considered, the modified simple payback period is 10.9 years, and the present value, net present value and internal rate of return after **20** years, assuming a discount rate of 3%, are $434,006, $116,006 and 6.64% respectively. These results indicate that, under the assumed conditions, the project is also economically viable.

<u>Bulk Fuel System</u>:

To replace 20,000 gallons of fuel oil per year would require approximately 428 tons (approximately twenty 40-foot tractor trailer loads) of bulk fuel (chips, sawdust, bark, shavings, etc.), assuming such fuel runs 40% moisture content (MC40).

Although it is beyond the scope of this assessment to delve into the costs associated with bulk fuel systems, it is not unrealistic to say that, at 20,000 gallons of fuel oil per year, it is unlikely that a bulk fuel system would be cost-effective for the Kenny Lake School. To be cost-effective, a bulk fuel system would have to be designed, engineered and installed for less than $575,000, which is highly improbable. While such systems exist in Alaska, they do so in industrial settings that can tolerate the noise, fugitive dust and vehicle traffic that would be unacceptable in an institutional setting such as a school or hospital. Furthermore, supplies of bulk fuels within reasonable proximity to Kenny Lake are limited at best or non-existent altogether, and the bulk fuel cost estimate used in this report ($30 per ton) is probably unrealistically low.