# Preliminary Feasibility Assessment for High Efficiency, Low Emission Wood Heating In Fort Yukon, Alaska

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Key words: HELE, LEHE, bulk fuel, cordwood

**ABSTRACT**

The potential for heating various facilities in Fort Yukon, Alaska with high efficiency, low emission (HELE) wood-fired boilers is evaluated for the Yukon Flats School District, the UAF Yukon Flats Center and the Council of Athabascan Tribal Governments.

Early in 2007, organizations were invited to submit a Statement of Interest (SOI) to the Alaska Wood Energy Development Task Group (AWEDTG). Task Group representatives reviewed all the SOIs and selected projects for further review based on selection criteria presented in Appendix A. Several AWEDTG representatives visited Fort Yukon during the summer of 2007 and information was obtained for the various facilities. Preliminary assessments were made and challenges identified. Potential wood energy systems were considered for the projects using AWEDTG, USDA and AEA objectives for energy efficiency and emissions. Preliminary findings are reported.

## SECTION 1. EXECUTIVE SUMMARY

### 1.1 Goals and Objectives

- Identify facilities in Fort Yukon 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 AWEDTG 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.

- Given fuel oil consumption estimates of 8,500, 18,000, 20,000 and 30,000 gallons per year, 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

Four facilities are considered in this report: UAF Yukon Flats Center, Vocational Education Center (and adjacent dormitory), new CATG Regional Health Clinic and Fort Yukon School and Gymnasium.

### 1.3.1. UAF Yukon Flats Center

• Overview. The UAF Yukon Flats Center (YFC) reportedly occupies approximately 7,100 square feet in two sections. The original log structure, built in 1980 and renovated in 2005, occupies about 3,600 square feet and the new addition (conventional frame construction), built in 2005, occupies about 3,500 square feet. Heat is provided by two new Weil-McLain Gold A/B-WGO-9 boilers, each rated at 257 MBH (net) with a maximum firing rate of 2.55 gallons per hour (each). Domestic hot water is supplied by a separate, oil-fired Bock 50ES water heater with a maximum firing rate of 1.0 gallons per hour. Heat is distributed via hot water baseboard heat exchangers.

• Fuel Consumption. The UAF Yukon Flats Center reportedly consumes approximately **8,500** gallons of **#1** fuel oil per year.

• Potential Savings. At the projected price of about $5.00 per gallon, the UAF YFC spends approximately $42,500 per year for fuel oil. The HELE *cordwood* fuel equivalent of 8,500 gallons of #1 fuel oil is approximately 100 cords, and at $225 per cord represents a potential annual fuel cost savings of $20,000 (debt service and non-fuel OM&R costs notwithstanding). The *bulk fuel* equivalent of 8,500 gallons of fuel oil is approximately 170 tons, and at $100/ton represents a potential annual fuel cost savings of $25,500 (debt service and non-fuel OM&R costs notwithstanding).

• Required boiler capacity. The estimated required boiler capacity (RBC) to heat the UAF YFC is approximately 284,395 Btu/hr during the coldest 24-hour period.

• 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 reasonably viable. 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 UAF Yukon Flats Center.

### 1.3.2. Vocational Education Center and Dormitory

• Overview. The Vocational Education Center (VEC) occupies approximately 9,000 square feet and is in reportedly fair to good condition. Heat is provided by two old (1982?) Burnham V-35 boilers, each rated at 209 MBH (net) with a maximum firing rate of 2.1 gallons per hour (each). These boilers appear to be ready for replacement. Adjacent to the VEC is a student dormitory, approximately 2,000 to 2,500 square feet in size. Heat is provided by a single Burnham boiler rated at 124 MBH with a firing rate of 1.05 gallons per hour. Domestic hot water is supplied by separate electric water heaters in each building. There are also a couple detached "out-buildings"; one that serves as the VEC mechanical/boiler room and the other that serves as the Ceramics Shop.

• Fuel Consumption. The Vocational Education Center reportedly consumes approximately **16,000** gallons of **#1** fuel oil per year, which seems excessive. Given its modest footprint of 9,000 square feet and comparing its fuel use with fuel consumption at the other facilities under study, it may be appropriate to conduct a formal energy audit of this facility. Invoking good energy conservation measures should be a priority. The student dormitory reportedly consumes **2,000** gallons of fuel oil per year.

• Potential Savings. At the projected price of about $5.00 per gallon, the VEC (and dormitory) spends approximately $90,000 per year for fuel oil. The HELE *cordwood* fuel equivalent of 18,000 gallons of #1 fuel oil is approximately 210 cords, and at $225 per cord represents a potential annual fuel cost savings of $42,750 (debt service and non-fuel OM&R costs notwithstanding). The *bulk fuel* equivalent of 18,000 gallons of fuel oil is approximately 360 tons, and at $100/ton represents a potential annual fuel cost savings of $54,000 (debt service and non-fuel OM&R costs notwithstanding).

• Required boiler capacity. The estimated required boiler capacity (RBC) to heat the VEC and Dormitory is approximately 601,489 Btu/hr during the coldest 24-hour period.

• 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. Further consideration is warranted. (See Section 6)

• Recommended action regarding a bulk fuel wood system. Given the heating demand and the probable costs of the project, a "bulk fuel" system is probably not cost-effective for the Vocational Education Center and dormitory. (See Section 7)

### 1.3.3. CATG Regional Health Clinic

• Overview. The new Council of Athabascan Tribal Governments (CATG) Regional Health Clinic (RHC) occupies approximately 15,000 square feet. Construction was completed in mid-2007. Heat is provided by two new Weil-McLain 1080 boilers, each rated at 965 MBH (net) with a maximum firing rate of 9.6 gallons per hour (each). The boiler room is located in the mezzanine above the ground floor at the rear of the building. The mechanical room is located in the mezzanine near the front of the building. Heat is distributed via hot air heated by hot water-to-air heat exchangers. A heat recovery ventilation (HRV) system is installed.

• Fuel Consumption. The actual annual fuel consumption at the CATG RHC is unknown, since the facility is new. An engineer's estimate put the number at **20,000** gallons of **#1** fuel oil per year.

• Potential Savings. At the projected price of about $5.00 per gallon, the CATG RHC will spend approximately $100,000 per year for fuel oil. The HELE *cordwood* fuel equivalent of 20,000 gallons of #1 fuel oil is approximately 234 cords, and at $225 per cord represents a potential annual fuel cost savings of $47,350 (debt service and non-fuel OM&R costs notwithstanding). The *bulk fuel* equivalent of 20,000 gallons of fuel oil is approximately 400 tons, and at $100/ton represents a potential annual fuel cost savings of $60,000 (debt service and non-fuel OM&R costs notwithstanding).

• Required boiler capacity. The estimated required boiler capacity (RBC) to heat the CATG RHC is approximately 668,245 Btu/hr during the coldest 24-hour period.

• 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. Further consideration is warranted. (See Section 6)

• Recommended action regarding a bulk fuel wood system. Given the heating demand and the probable costs of the project, a "bulk fuel" system is probably not cost-effective for the CATG Clinic. (See Section 7)

### 1.3.4. Fort Yukon School and Gymnasium

*NOTE: Although the school and gymnasium are separate buildings, each with its own heating system, given their proximate location, the potential staging area behind the gym, and the pre-existing, 30' x 44' garage-type storage building, the most likely scenario would be to install a single wood fired heating system, consisting of one or more boilers, to serve both buildings.*

• Overview. The Fort Yukon School occupies approximately 34,000 square feet and provides instruction for approximately 130 students. Heat is provided by two Burnham PF-511 boilers, each rated at 1,545 MBH (net) with maximum firing rates of 15.6 gallons per hour (each). Heat is distributed via a hot water loop. The building and boilers appear to be in good condition and well-maintained.

The Fort Yukon Gymnasium occupies approximately 10,000 square feet and underwent extensive remodeling/renovation in 2007. Heat is provided by two new Burnham V904A boilers, each rated at 420 MBH (net) with maximum firing rates of 4.2 gallons per hour (each). Heat is distributed hydronically, via a hot water baseboard and radiator-type heat exchangers.

• Fuel Consumption. The Fort Yukon School is reported to consume approximately **17,000** gallons of **#1** fuel oil per year, and the Fort Yukon Gymnasium is reported to consume approximately **13,000** gallons of **#1** fuel oil per year.

• Potential Savings. At the projected price of about $5.00 per gallon, the Fort Yukon School and Gymnasium will spend approximately $150,000 per year for fuel oil. The HELE *cordwood* fuel equivalent of 30,000 gallons of #1 fuel oil is approximately 350 cords, and at $225 per cord represents a potential annual fuel cost savings of $71,250 (debt service and non-fuel OM&R costs notwithstanding). The *bulk fuel* equivalent of 30,000 gallons of fuel oil is approximately 600 tons, and at $100/ton represents a potential annual fuel cost savings of $90,000 (debt service and non-fuel OM&R costs notwithstanding).

• Required boiler capacity. The estimated required boiler capacity (RBC) to heat the Fort Yukon School and Gymnasium is approximately 1,002,000 Btu/hr during the coldest 24-hour period.

• 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. Further consideration is warranted. (See Section 6)

• Recommended action regarding a bulk fuel wood system. Given the heating demand and the probable costs of the project, a "bulk fuel" system is probably not cost-effective for the Fort Yukon School and Gymnasium. (See Section 7)

## 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 criteria listed in Appendix A. The Fort Yukon projects meet the AWEDTG criteria for potential petroleum fuel displacement, use of forest residues for public benefit, 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 potential to supply wood from local forests appears adequate and matches the application. Currently, "bulk fuel" in the form of sawmill and/or processing residues is non-existent. Any bulk fuel heating system would be reliant upon forest-derived whole tree chips.

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 would sponsor and/or implement a wood-burning project. (NOTE: This is not necessarily the case with the projects in Fort Yukon 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. Bulk fuel systems, although automated, also have a daily labor requirement. 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.

The forest industry infrastructure in/around Fort Yukon is very limited. However, for this report, it is assumed that wood supplies are sufficient to meet the demand.

### 2.3 Classes of Wood Heating Systems

There are, basically, two classes of wood heating 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

Currently, wood fuels in Fort Yukon will generally be in the form of cordwood. There is also a chance that whole tree chips might be developed as a fuel in the future, if they can be produced at a reasonable cost. There are no significant supplies of sawmill residues in the area, 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.

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 wet weight basis (also called green weight basis), are used as benchmarks. [It should be noted that other species are also present, including black spruce, birch, cottonwood/poplar, willow and aspen. And although white spruce is used as the "benchmark", any species of wood may be burned in either cordwood or bulk fuel systems; the most critical factor being moisture content, not species.]

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 (MC40) is 5,334 Btu/lb.

The RHV for white spruce *cordwood* (MC30) is calculated at 12.22 million Btu per **cord**, and the DHV, which is a function of boiler efficiency (assumed to be 75%), is 9.165 million Btu per cord. The delivered heating value of 1 **cord** of white spruce cordwood (MC30) equals the delivered heating value of **85.5** gallons of #1 fuel oil when the wood is burned at 75% conversion efficiency.

The RHV for white spruce *bulk fuel* (MC40) is calculated at 7.65 million Btu per **ton**, and the DHV, which is a function of boiler efficiency (assumed to be 70%), is 5.355 million Btu per ton. The delivered heating value of 1 **ton** of white spruce bulk fuel (MC40) equals the delivered heating value of **50** gallons of #1 fuel oil when the wood is 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

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. As a result, 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 cordwood boiler suppliers, two of which have units operating in Alaska. HS Tarm/Tarm USA 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 (on the Yukon River) to provide heat to the washeteria and water plant, and two were installed near Kasilof on the Kenai Peninsula.

| Table 4-1. HELE Cordwood Boiler Suppliers | | |
|---|---|---|
| | Btu/hr ratings | Supplier |
| EKO-Line | 85,000 to 275,000 | New Horizon Corp<br>www.newhorizoncorp.com |
| Tarm | 100,000 to 198,000 | HS Tarm/Tarm USA<br>www.tarmusa.com/wood-gasification.asp |
| Greenwood | 100,000 to 300,000 | Greenwood<br>www.GreenwoodFurnace.com |
| Garn | 350,000 to 950,000 | Dectra Corp.<br>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 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.<br>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

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 40% moisture content (MC40) or less.

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 as well as a consistent source, i.e., fuel with consistent size and moisture content from a common source is considerably more desirable than variations in chip size and/or moisture content from numerous suppliers. 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<br>Butler, WI<br>(800) 246-1478<br>www.decton.com | New Horizon Corp.<br>Sutton, WV<br>(877) 202-5070<br>www.newhorizoncorp.com |
| Messersmith Manufacturing, Inc.<br>Bark River, MI<br>(906) 466-9010<br>www.burnchips.com | JMR Industrial Contractors<br>Columbus, MS<br>(662) 240-1247<br>www.jmric.com |
| Chiptec Wood Energy Systems<br>South Burlington, VT<br>(800) 244-4146<br>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 (i.e., 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 delivery 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 replacing 20,000 gallons of #1 fuel oil with white spruce bulk fuel (MC40) would use an estimated 400 tons per year, or about 16 to 20 tractor-trailer loads.

There are three known bulk fuel boilers in Alaska (Table 4-4), all of which are installed at sawmills. The most recent was installed near Copper Center in 2007. A 4 MMBtu/hr wood chip gasifier 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 several Montana schools. Bulk fuel systems are discussed in greater detail in Section 7.

**Table 4-4. Bulk Fuel Boilers in Alaska**

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

Table 4-4 Footnotes:
* 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 temperature = 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

## 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 #1 fuel oil to white spruce *cordwood* (MC30) and white spruce *bulk fuel* (MC40). 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, #1, (per 1 gallon) | 134,000 | 80% | 107,200 per gallon | 4.00/gal | 37.313 |
| | | | | 5.00 | 46.642 |
| | | | | 6.00 | 55.97 |
| White spruce, (per 1 cord, MC30) | 12.22 million | 75% | 9.165 million | 200/cord | 21.822 |
| | | | | 225 | 24.55 |
| | | | | 250 | 27.278 |
| White spruce, (per 1 ton, MC40) | 7.65 million | 70% | 5.355 million | 75/ton | 14.006 |
| | | | | 100 | 18.674 |
| | | | | 125 | 23.343 |

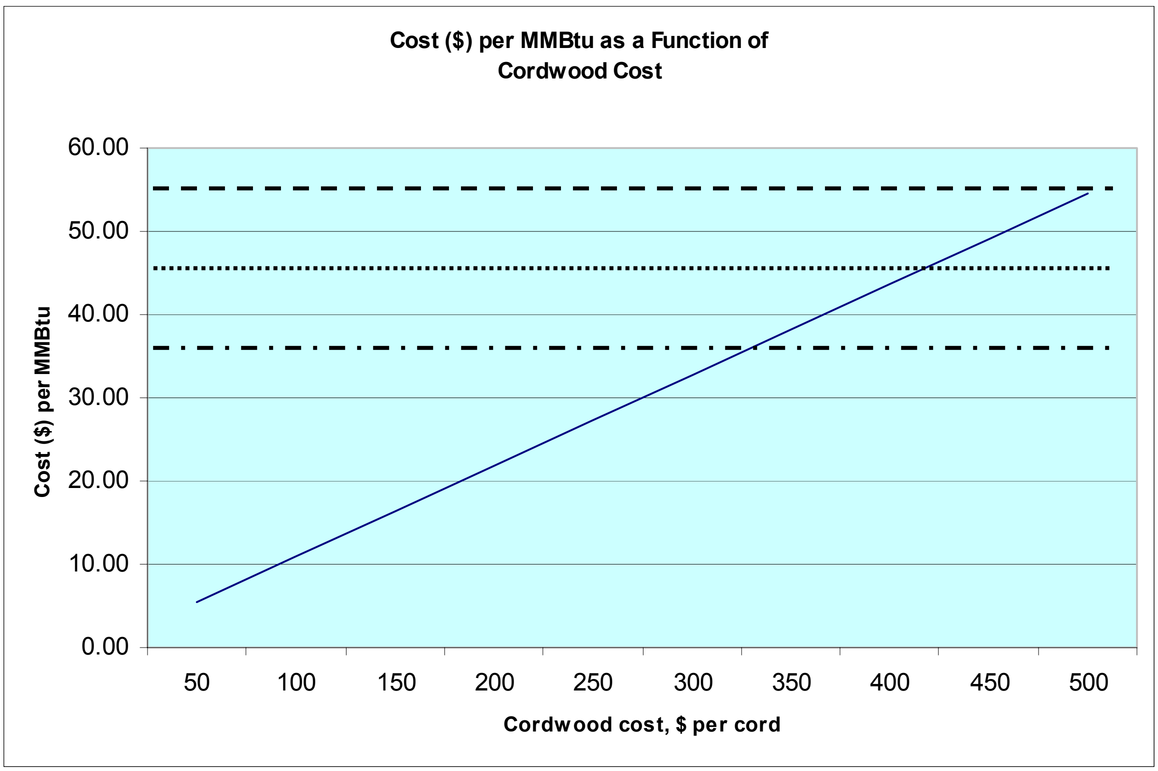
Notes:
[a] from Appendix D

### 5.2(a) Cost per MMBtu Sensitivity – Cordwood

Figure 5-1 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 $1.091. 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 #1 fuel oil at $4.00, $5.00 and $6.00 per gallon ($37.313, $46.642 and $55.97 per million Btu respectively).

At high efficiency, heat from white spruce cordwood (MC30) at $427.47 per cord is equal to the cost of #1 fuel oil at $5.00 per gallon (i.e., $46.642 per MMBtu), before considering the cost of the equipment and operation, maintenance and repair (OM&R) costs. At 75% efficiency and $225 per cord, a high-efficiency cordwood boiler will deliver heat at about 52.6% of the cost of #1 fuel oil at $5.00 per gallon ($24.55 versus $46.642 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.



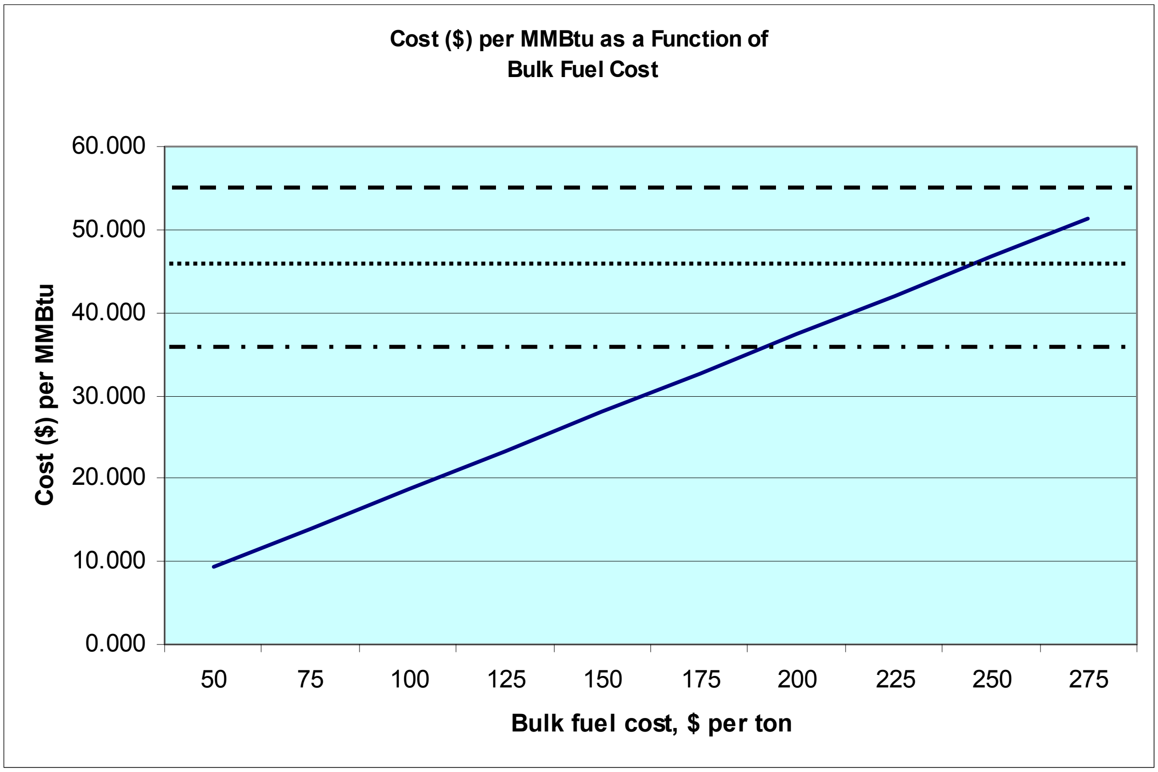

Fuel Oil at $6.00 per gallon
Fuel Oil at $5.00 per gallon
Fuel Oil at $4.00 per gallon

**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 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 $1.867. 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 #1 fuel oil at $4.00, $5.00 and $6.00 per gallon ($37.313, $46.642 and $55.97 per million Btu respectively).

At high efficiency, heat from white spruce bulk fuel (MC40) at $249.77 per ton is equal to the cost of oil at $5.00 per gallon, before considering the investment and OM&R costs. At 70% efficiency and $100/ton, an efficient bulk fuel boiler will deliver heat at about 40% of the cost of fuel oil at $5.00 per gallon ($18.674 versus $46.642 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 $6.00 per gallon
Fuel Oil at $5.00 per gallon
Fuel Oil at $4.00 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 various facilities in Fort Yukon, Alaska.

**Table 5-2. Reported Annual Fuel Oil Consumption, Fort Yukon, AK**

| **Facility** | **Reported Annual Fuel Consumption** | |
|---|---|---|
| | *Gallons* | *Cost ($) @ $5.00/gallon* |
| UAF Yukon Flats Center | 8,500 | 42,500 |
| Vocational Education Center and dormitory | 18,000 | 90,000 |
| CATG Health Clinic | 20,000 | 100,000 |
| School and Gymnasium | 30,000 | 150,000 |
| **TOTAL** | **76,500** | **382,500** |

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 Fort Yukon facilities 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. Only the new Health Clinic falls within this range. The installed capacity at the school is about 5.4 times greater than the RBC, and all the rest are less than twice the RBC. Furthermore, it appears that the installed capacity of the boilers at the Vocational Education Center is less than 80% of the minimum required RBC, which may, in part, explain why the building feels cold during extremely cold periods, i.e. -50$^{O}$F and less.

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) each, a pair of Garn WHS 3200s can store up to 4.128 million Btu, which, theoretically, would be enough to heat the VEC and dorm during the coldest 24-hour period for nearly 7 hours (4,128,000 ÷ 601,489).

| 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] |
| UAF YFC | 8,500 | 16,326 | 55,813 | -57 | 284,395 | 514,000 |
| VEC<br>Dorm<br>VEC + Dorm | 16,000<br>2,000<br>18,000 | | 105,059<br>13,132<br>118,192 | | 534,742<br>67,437<br>601,489 | 418,000<br>124,000<br>542,000 |
| CATG RHC | 20,000 | | 131,324 | | 668,245 | 1,930,000 |
| School<br>Gymnasium<br>School + Gym | 17,000<br>13,000<br>30,000 | | 111,626<br>85,361<br>196,987 | | 568,111<br>434,598<br>1,002,000 | 3,090,000<br>840,000<br>3,930,000 |

Table 5-3 Footnotes:

[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

According to these calculations (Table 5-3), it appears that the Fort Yukon facilities could each supply 100% of their heating needs with one or more high efficient low emission cordwood boilers. Consultation with a qualified engineer is strongly recommended.

## 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 facilities in Fort Yukon. [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 ($) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CORDWOOD SYSTEMS | | *4.00/gal* | *5.00/gal* | *6.00/gal* | W. spruce, MC30, CE 75% | *200/cord* | 225/cord | *250/cord* | *Low* | *Medium* | *High* |
| UAF Yukon Flats Center | 8,500 | 34,000 | 42,500 | 51,000 | **100 cds** | 20,000 | 22,500 | 25,000 | 9,000 | 20,000 | 31,000 |
| VEC & dormitory | 18,000 | 72,000 | 90,000 | 108,000 | **210 cds** | 42,000 | 47,250 | 52,500 | 19,500 | 42,750 | 66,000 |
| CATG Health Clinic | 20,000 | 80,000 | 100,000 | 120,000 | **235 cds** | 47,000 | 52,875 | 58,750 | 21,250 | 47.125 | 73,000 |
| School & Gym | 30,000 | 120,000 | 150,000 | 180,000 | **350 cds** | 70,000 | 78,750 | 87,500 | 35,500 | 71,250 | 110,000 |
| Total | 76,500 | 306,000 | 382,500 | 459,000 | **895 cds** | 179,000 | 201,375 | 223,750 | 82,250 | 181,125 | 280,000 |
| | | | | | | | | | | | |
| BULK FUEL SYSTEMS | | *4.00/gal* | *5.00/gal* | *6.00/gal* | W. spruce, MC40, CE 70% | *75/ton* | *100/ton* | *125/ton* | *Low* | *Medium* | *High* |
| VEC & dormitory | 18,000 | 72,000 | 90,000 | 108,000 | **360 tons** | 27,000 | 36,000 | 45,000 | 27,000 | 54,000 | 81,000 |
| CATG Health Clinic | 20,000 | 80,000 | 100,000 | 120,000 | **400 tons** | 30,000 | 40,000 | 50,000 | 30,000 | 60,000 | 90,000 |
| School & Gym | 30,000 | 120,000 | 150,000 | 180,000 | **600 tons** | 45,000 | 60,000 | 75,000 | 45,000 | 90,000 | 135,000 |
| Total | 68,000 | 272,000 | 340,000 | 408,000 | **1,360 tons** | 102,000 | 136,000 | 170,000 | 102,000 | 204,000 | 306,000 |

NOTES:
[a] From Table 5-2
[b] From Table D-3, Fuel Oil Equivalents; 85.5 gallons per cord (MC30), 50 gallons per ton (MC40)

## 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 and large heating demand situations. Four scenarios 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 HELE Cordwood Systems | | | | | |
|---|---|---|---|---|---|
| Fuel oil consumption (gallons per year) | | 8,500 (UAF YFC) | 18,000 (VEC & Dorm) | 20,000 (CATG RHC) | 30,000 (School & Gym) |
| Required boiler capacity (RBC), Btu/hr | | 284,395 | 601,489 | 668,245 | 1,002,000 |
| Cordwood boiler | Garn model | (1) Garn WHS 3200 | (2) WHS 3200 | (2) WHS 4400 | (3) WHS 4400 |
| | Rating -Btu/hr [e] | 950,000 | 1,900,000 | 1,900,000 | 2,850,000 |
| | Btu stored | 2,064,000 | 4,128,000 | 5,864,000 | 8,796,000 |
| | | Building and Equipment (B&E) Costs, **$** (for discussion purposes only) | | | |
| Fuel storage building[a] (fabric bldg, gravel pad, $25 per sf) | | 50,000 (100 cds @ 20 sf/cd) | 105,000 (210 cds @ 20 sf/cd) | 117,500 (235 cds @ 20 sf/cd) | 175,000 (350 cds @ 20 sf/cd) |
| Boiler building @ $150 per sf (minimum footprint w/concrete pad)[b] | | 30,000 (10'x20') | 60,000 (20'x20') | 66,000 (20'x22') | 99,000 (30'x22') |
| Boilers | | | | | |
| Base price[c] | | 32,900 | 65,800 | 80,000[f] | 120,000[f] |
| Shipping to Fairbanks[d] | | 4,500 | 8,000 | 8,000 | 12,000 |
| Bush delivery [d] | | 2,000 | 4,000 | 4,800 | 7,200 |
| Plumbing and electrical[d] | | 50,000 | 75,000 | 75,000 | 100,000 |
| Installation[d] | | 25,000 | 35,000 | 35,000 | 50,000 |
| **Subtotal - B&E Costs** | | **194,400** | **352,800** | **386,300** | **563,200** |
| **Contingency (25%)**[d] | | **48,600** | **88,200** | **96,575** | **140,800** |
| **Grand Total** | | **243,000** | **441,000** | **482,875** | **704,000** |

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, Alaskan Heat Technologies, April 2008

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

[e] 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.

[f] Published list price not available; this represents the current list price for WHS 3200 + $7,100

## 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 | | | | |
|---|---|---|---|---|
| System | (1) WHS 3200 | (2) WHS 3200 (combined capacity) | (2) WHS 4400 (combined capacity) | (3) WHS 4400 (combined capacity) |
| Total Daily labor (hrs/yr)[a] (hrs/day X 210 days/yr) | 70.35 | 147.84 | 206.85 | 271.74 |
| Total Periodic labor (hrs/yr)[b] (hrs/wk X 30 wks/yr) | 50.0 | 105.0 | 117.6 | 175.2 |
| Total Annual labor (hrs/yr)[b] | 20 | 40 | 40 | 60 |
| Total labor (hrs/yr) | **140.35** | **292.84** | **364.45** | **506.94** |
| Total annual labor cost ($/yr) (total hrs x $20) | **2,807.00** | **5,856.80** | **7,289.00** | **10,138.80** |
| Notes:<br>a From Table F-2<br>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, water treatment chemicals, etc. For this example, a value of $1,000 per boiler is used.

| Table 6-3. Summary of Total Annual Non-Fuel OM&R Cost Estimates | | | | |
|---|---|---|---|---|
| Item | Cost/Allowance ($) | | | |
| | (1) WHS 3200 | (2) WHS 3200 (combined capacity) | (2) WHS 4400 (combined capacity) | (3) WHS 4400 (combined capacity) |
| Labor | 2,807.00 | 5,856.80 | 7,289.00 | 10,138.80 |
| Electricity[a] | 445.18 | 935.55 | 1,047.18 | 1,562.79 |
| Maintenance/Repairs | 1,000.00 | 2,000.00 | 2,000.00 | 3,000.00 |
| **Total non-fuel OM&R ($)** | **4,252.18** | **8,792.35** | **10,336.18** | **14,701.59** |
| Notes:<br>a Electrical cost based on a formula of horsepower x kWh rate x operating time | | | | |

### 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 economic 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)

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) WHS 3200 | (2) WHS 3200 (combined capacity) | (2) WHS 4400 (combined capacity) | (3) WHS 4400 (combined capacity) |
|---|---|---|---|---|
| Fuel oil cost, $ per year @ $5.00 per gallon | 42,500 (8,500 gal) | 90,000 (18,000 gal) | 100,000 (20,000 gal) | 150,000 (30,000 gal) |
| Cordwood cost $ per year @ $225per cord | 22,500 (100cd) | 47,250 (210cd) | 52,875 (235cd) | 78,750 (350cd) |
| Annual Fuel Cost Savings, $/yr | 20,000 | 42,750 | 47,125 | 71,250 |
| Total Investment Costs [b], $ | 243,000 | 441,000 | 482,875 | 704,000 |
| **Simple Payback[c], yrs** | **12.15** | **9.33** | **10.25** | **9.88** |
| Annual, Non-fuel OM&R costs[a] | 4,252 | 8,792 | 10,336 | 14,702 |
| Net Annual Savings ($) (Annual Cash Flow) | 15,748 | 33,958 | 36,789 | 56,548 |

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) WHS 3200 | (2) WHS 3200 (combined capacity) | (2) WHS 4400 (combined capacity) | (3) WHS 4400 (combined capacity) |
| Discount Rate[a] (%) | 3 | | | |
| Time, "t", (years) | 20 | | | |
| Initial Investment ($)[b] | 243,000 | 441,000 | 482,875 | 704,000 |
| Annual Cash Flow($)[c] (Net Annual Savings) | 15,748 | 33,958 | 36,789 | 56,548 |
| Present Value (of expected cash flows, $ at "t" years) | 234,290 | 505,209 | 547,327 | 841,291 |
| Net Present Value ($ at "t" years) | -8,710 | 64,209 | 64,452 | 137,291 |
| Internal Rate of Return (% at "t" years) | 2.61 | 4.52 | 4.40 | 5.01 |
| 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

[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 $234,290 today (PV), which is less than the initial investment of $243,000. The resulting NPV of the project is -$8,710, 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. However, the NPV is only *slightly* negative and the internal rate of return *is* positive (2.61%), and given that this report is only a pre-feasibility assessment, this option could "pencil out" given "real" numbers.

Note #2. With a real discount rate of 3.00% and after a span of 20 years, the projected cash flows are worth $505,209 today (PV), which is greater than the initial investment of $441,000. The resulting NPV of the project is $64,209 and the project achieves an internal rate of return of 4.52% at the end of 20 years. Given the assumptions and cost estimates, this alternative appears financially and operationally feasible.

Note #3. With a real discount rate of 3.00% and after a span of 20 years, the projected cash flows are worth $547,327 today (PV), which is greater than the initial investment of $482,875. The resulting NPV of the project is $64,452 and the project achieves an internal rate of return of 4.4% at the end of 20 years. Given the assumptions and cost estimates, this alternative appears financially and operationally feasible.

Note #4. With a real discount rate of 3.00% and after a span of 20 years, the projected cash flows are worth $841,291 today (PV), which is greater than the initial investment of $704,000. The resulting NPV of the project is $137,291 and the project achieves an internal rate of return of 5.01% at the end of 20 years. Given the assumptions and cost estimates, this alternative appears financially and operationally feasible. It should also be noted that the initial investment cost estimate includes $99,000 (plus a 25% contingency allowance) for a boiler building. Given that there appears to be an adequate structure already in place, significant savings may be achieved. By reducing the initial investment cost by $123,750, the NPV and IRR become $261,041, and 7.41% respectively (PV doesn't change).

## 6.7 Life Cycle Cost Analysis – Fort Yukon School and Gymnasium

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 <u>**costs**</u> of ownership, the period of <u>**time**</u> over which the costs are incurred (recommended period is 20 years), and the <u>**discount rate**</u> 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 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 <u>real</u> 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 (<u>ex</u>cluding general price inflation) | 3.0% |
| Nominal rate (<u>in</u>cluding general price inflation) | 4.9% |
| Implied long term average rate of inflation | 1.8% |

<u>**Other LCCA terms**</u>

**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 30,000 gallons of #1 fuel oil at $5.00 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.

*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 **three Garn WHS 4400** wood fired boilers. The initial investment was assumed to be $754,000, 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 ($704,000, as per Table 6-1). The operation costs include 350 cords of fuelwood at $225 per cord and 506.94 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 $4,652.79 (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 Fort Yukon School and gymnasium 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 | $754,000 |
| Operations Cost | $2,243,523 | $1,322,441 |
| Maintenance & Repair Cost | $14,877 | $69,222 |
| Replacement Cost | $0 | $0 |
| Residual Value | $0 | $0 |
| Total Life Cycle Cost | 2,308,401 | 2,145,663 |

## SECTION 7. ECONOMIC FEASIBILITY OF BULK FUEL SYSTEMS

*NOTE: Given the relatively small demand at the UAF Yukon Flats Center (i.e., 8,500 gpy), an analysis of bulk fuel systems was not prepared for that facility. The analysis for the VEC/dormitory and Health Clinic was combined (i.e., 19,000 gpy), since the two facilities are relatively close, demand-wise. A separate analysis was done for the School/gym.*

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 typically 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 professional 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 individual costs for those components. As an alternative, a *range* of likely *total* costs is presented and analyzed for comparative purposes.

| Table 7-1. Initial Investment Cost Components for Bulk Fuel Systems | | |
|---|---|---|
| Facility | VEC or Clinic | School/gym |
| | **Capital Costs: Building and Equipment (B&E)** | |
| *Fuel storage building* | ? | |
| *Material handling system* | ? | |
| *Boiler building* | ? | |
| *Boiler: base price*<br>*shipping* | ? | |
| *Plumbing/connections* | ? | |
| *Electrical systems* | ? | |
| *Installation* | ? | |
| | **Non-capital Costs** | |
| *Engineering , Contingency, Permitting, etc.* | ? | |
| **Initial Investment Total ($)** | $750,000 to $2,000,000 | |

The investment cost of bulk fuel systems can range from $500,000 to over $2 million, with about $350,000 to $900,000 in equipment costs alone. 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 about $250,000, but an existing building was used and there were significant economies in fuel preparation, storage 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 $1.85 million, not including probable cost overruns. 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 2004-5 Darby School (Darby, MT) project at $1,001,000 including $268,000 for repairs and upgrades to the pre-existing heating 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. 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 bulk fuel in 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 |
| Univ. MT 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 costs for Fort Yukon facilities are presented in Table 5-4. Other O&M costs would include labor, electricity and maintenance and repair costs. 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.

*NOTE: "Turn-down ratios" for bulk fuel boilers are quite restricted; they rarely operate very well at less than 40 percent of capacity. Therefore, a large bulk fuel system could not be used very effectively during the shoulder seasons, and a small bulk fuel system might fail to deliver enough heat during peak demand periods.*

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 VEC or Clinic are projected to use about 380 tons of bulk fuel (about 50.3 percent of the amount used at Darby). If it is valid to apportion the electrical usage based on bulk fuel consumption, then the VEC or Clinic would use about 11,832 kWh per year. At $0.50 per kWh, the annual electrical consumption would be about **$5,916**. Using the same formulas, the School/gym would use about 18,800 kWh per year at a cost of about **$9,400**.

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 **$5,000** is made to cover these costs.

Total annual operating, maintenance and repair cost estimates for a bulk fuel boiler at the Fort Yukon VEC or Clinic and School/gym summarized in Table 8-2

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

| Item | Cost/Allowance | |
|---|---|---|
| | VEC or Clinic (19,000 gpy, 380 tons ) | School/gym (30,000 gpy, 600 tons) |
| Non-Fuel OM&R | | |
| *Labor ($)* | *2,700* | *2,700* |
| *Electricity ($)* | *5,955* | *9,400* |
| *Maintenance ($)* | *5,000* | *5,000* |
| *Total, non-fuel OM&R* | *13,655* | *17,100* |
| Wood fuel ($) | 38,000 | 60,000 |
| **Total OM&R ($)** | **51,655** | **77,100** |

### 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 Payback Period for Generic Bulk Fuel Boilers

Tables 7-6a and 7-6b present Simple Payback Period analysis for a range of initial investment cost estimates for generic bulk fuel boiler systems at the VEC/Clinic and School/Gym.

| Table 7-6a. Simple Payback Period Analysis for Bulk Fuel Heating Systems | | | | | | |
|---|---|---|---|---|---|---|
| | **VEC/dorm or CATG Clinic (19,000 gpy; 380 tons/yr)** | | | | | |
| Fuel oil cost ($ per year @ $5.00 per gallon | 95,000 | | | | | |
| Bulk wood fuel ($ per year @ $100 per ton) | 38,000 | | | | | |
| Annual Fuel Cost Savings ($) | 57,000 | | | | | |
| Total Investment Costs ($) | 750,000 | 1,000,000 | 1,250,000 | 1,500,000 | 1,750,000 | 2,000,000 |
| Simple Payback (yrs)[a] | 13.16 | 17.54 | 21.93 | 26.32 | 30.7 | 35.09 |
| [a] Simple Payback equals Total Investment Costs divided by Annual Fuel Cost Savings | | | | | | |

| Table 7-6b. Simple Payback Period Analysis for Bulk Fuel Heating Systems | | | | | | |
|---|---|---|---|---|---|---|
| | **Fort Yukon School & Gym (30,000 gpy; 600 tons/yr)** | | | | | |
| Fuel oil cost ($ per year @ $5.00 per gallon | 150,000 | | | | | |
| Bulk wood fuel ($ per year @ $100 per ton) | 60,000 | | | | | |
| Annual Fuel Cost Savings ($) | 90,000 | | | | | |
| Total Investment Costs ($) | 750,000 | 1,000,000 | 1,250,000 | 1,500,000 | 1,750,000 | 2,000,000 |
| Simple Payback (yrs)[a] | 8.33 | 11.11 | 13.89 | 16.67 | 19.44 | 22.22 |
| [a] Simple Payback equals Total Investment Costs divided by Annual Fuel Cost 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 of Return (IRR) Values for Bulk Fuel Boilers

Tables 7-7a and 7-7b present PV, NPV and IRR values for hypothetical bulk fuel boilers at the VEC/Clinic and School/Gym.

| Table 7-7a. PV, NPV and IRR Values for Bulk Fuel Systems (VEC/dorm or CATG Clinic) | | | | | | |
|---|---|---|---|---|---|---|
| Discount Rate | 3 | | | | | |
| Time, "t", (years) | 20 | | | | | |
| Initial Investment ($)[a] | 750,000 | 1,000,000 | 1,250,000 | 1,500,000 | 1,750,000 | 2,000,000 |
| Annual Cash Flow ($)[b] | 43,345 | | | | | |
| Present Value (of expected cash flows), ($ at "t" years) | 644,864 | | | | | |
| Net Present Value ($ at "t" years) | -105,136 | -355,136 | -605,136 | -855,136 | -1,105,136 | -1,355,136 |
| Internal Rate of Return (%) | 1.42 | -1.32 | -3.26 | -4.74 | -5.92 | -6.91 |

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

| Table 7-7b. PV, NPV and IRR Values for Bulk Fuel Systems (Fort Yukon School and Gymnasium) | | | | | | |
|---|---|---|---|---|---|---|
| Discount Rate | 3 | | | | | |
| Time, "t", (years) | 20 | | | | | |
| Initial Investment ($)[a] | 750,000 | 1,000,000 | 1,250,000 | 1,500,000 | 1,750,000 | 2,000,000 |
| Annual Cash Flow ($)[b] | 72,900 | | | | | |
| Present Value (of expected cash flows), ($ at "t" years) | 1,084,568 | | | | | |
| Net Present Value ($ at "t" years) | 334,568 | 84,568 | -165,432 | -415,432 | -665,432 | -915,432 |
| Internal Rate of Return (%) | 7.38 | 3.90 | 1.51 | -0.27 | -1.68 | -2.84 |

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 various facilities in Fort Yukon, 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.

The facilities in Fort Yukon consist of several distinct entities and are described in greater detail in Section 1.3.

1. UAF Yukon Flats Center (YFC)
2. Vocational Education Center (VEC) and student dormitory
3. CATG Regional Health Clinic
4. School and Gymnasium

In terms of sites, the School/gym, VEC/dormitory, and the UAF Yukon Flats Center do not appear to present any geo-physical constraints for the construction of a wood-fired heating plant. In fact, each site appears to be quite favorable.

The same cannot be said for the CATG Clinic however. It appears that the Clinic site was brought up to grade with a considerable amount of fill. Native vegetation occupies the ground to the right and rear of the Clinic, while the ground slopes down 6 to 10 feet to a dirt roadway on the left; a parking lot occupies the ground in front of the building. Future site development plans include duplexes and elder housing in the area to the right, and an ambulance garage in the rear. Complicating the project a bit more perhaps is the fact that the boiler and mechanical rooms are located in the building mezzanine above the main floor of the clinic. None of this necessarily precludes the installation of a wood-fired heating system; however site development and installation costs could hurt the economics of the project.

## 8.1 Cordwood Systems

Each of the facilities under consideration could be heated with a HELE cordwood boiler system consisting of one or more large cordwood boilers. None of the facilities is too small and none is too large, although the UAF Yukon Flats Center is close to being to too small and the School/gym is close to being too large.

Typically, the greater the fuel oil replacement the better the cost-effectiveness and that is generally the case in Fort Yukon with the UAF YFC showing the weakest economic metrics and the School/gymnasium showing the strongest metrics. However, all of these metrics are predicated on two assumptions: 1) that sufficient volumes of wood can be provided at a reasonable cost and 2) that someone will tend the boilers. Failure on either count will compromise the success of the project.

## 8.2 Bulk Fuel System

It appears that none of the facilities under consideration are large enough to warrant installing a bulk fuel system, given the probable cost of such an installation and the availability and cost of bulk wood fuel.