Preliminary Feasibility Assessment for High Efficiency, Low Emission Wood Heating In Sitka, Alaska

Prepared on behalf of:

City and Borough of Sitka, Alaska
Jim Dinley,
Municipal Administrator

Prepared by:

Daniel Parrent,
Wood Utilization Specialist

Wednesday, August 06, 2008

Notice

This Preliminary Feasibility Assessment for High Efficiency, Low Emission Wood Heating was prepared by Daniel Parrent, Wood Utilization Specialist, Juneau Economic Development Council on behalf of the City and Borough of Sitka, AK. This report does not necessarily represent the views of the Juneau Economic Development Council (JEDC). JEDC, its Board, employees, contractors, and subcontractors make no warranty, express or implied, and assume no legal liability for the information in this report; nor does any party represent that the use of this information will not infringe upon privately owned rights. This report has not been approved or disapproved by JEDC nor has JEDC passed upon the accuracy or adequacy of the information in this report.

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

Table of Contents

List of Tables and Figures

Key words: HELE, LEHE, bulk fuel, cordwood

ABSTRACT

The potential for heating the Hames Physical Education (PE) Center in Sitka, AK with high efficiency, low emission (HELE) wood-fired boilers is evaluated for the City and Borough of Sitka.

Early in 2008, local governments and organizations were invited to submit a Statement of Interest (SOI) in wood heating 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. An AWEDTG representative conducted a site visit of the Hames PE Center in Sitka in July 2008 and information was collected and recorded. Preliminary assessments were made and challenges identified. Potential wood energy systems were considered for the project using AWEDTG, USDA and AEA objectives for energy efficiency and emissions. Preliminary findings are reported.

SECTION 1. EXECUTIVE SUMMARY

1.1 Goals and Objectives

- Inspect the Hames PE Center facility and physical site in Sitka as a potential candidate for heating with wood
- Evaluate the suitability of the facility and site 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 residues, sustainability of the wood supply, project implementation, operation and maintenance, and community support

- Using an estimate of 51,000 gallons per year, this project would be considered relatively large in terms of its scale.

- 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

• Overview. The Hames PE Center reportedly occupies 33,700 square feet and is approximately 22 years old, constructed of masonry, wood and steel. The Center houses a large heated swimming pool (approximately 200,000 gallons), full size basketball court, two racquetball/handball courts, weight room, two exercise rooms, locker rooms with showers, and restrooms.

The existing heating system consists of 2 large, oil-fired steam boilers that were designed to supply the heating needs of the entire Sheldon Jackson College campus. Since the campus is largely shut down, the steam pipes to most of the buildings have been capped, leaving the existing boilers to serve only the Hames PE Center, for which they are grossly over-sized.

NOTE: At the time that this project was being evaluated, issues regarding long-term ownership, operation and maintenance of the facility were in flux. Those issues will probably have to be resolved before a significant investment in any wood-fired heating system can be considered.

• Fuel Consumption. The Hames PE Center is reported to consume approximately 51,000 gallons of #2 fuel oil per year.

• Potential Savings. With fuel prices at or near $5.00 per gallon and a projected consumption of 51,000 gallons of fuel oil per year, the annual cost of heating the Hames PE Center is roughly $255,000. The HELE *cordwood* fuel equivalent of 51,000 gallons of fuel oil is approximately **567 cords**, and at $200/cord represents a potential annual fuel cost savings of $141,600 (Debt service and OM&R costs notwithstanding). The *bulk fuel* equivalent of 51,000 gallons of fuel oil is approximately **1,437 tons**, and at $80/ton represents a potential annual fuel cost savings of $140,040 (Debt service and OM&R costs notwithstanding).

• Required boiler capacity. The estimated required boiler capacity (RBC) to heat the Hames PE Center during the coldest 24-hour period is undeterminable, since an unknown portion of the fuel is used to maintain consistent water temperatures in the swimming pool. If all the fuel was used to provide space heat, the estimated required boiler capacity (RBC) would be approximately 1.4 million Btu/hr during the coldest 24-hour period.

• Recommended action regarding a cordwood system. The financial metrics of installing multiple large HELE cordwood boilers are strongly positive, with simple payback periods ranging from 3.48 to 5.65 years. Net present values are strongly positive and the internal rates of return at 20 years range from 12.92 to 22.96%. Formal consideration for a HELE cordwood system for the Hames PE Center is warranted.

• Recommended action regarding a bulk fuel wood system. A "bulk fuel" system appears financially feasible for the Hames PE Center, given a consistent and reasonably-priced fuel supply and moderate initial investment costs. Formal consideration of a bulk fuel system for the Hames PE Center would be warranted if the fuel supply issue can be addressed. 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 the criteria listed in Appendix A. The Hames PE Center project meets 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 a cordwood boiler system, the combination of wood supplied from forest-derived fuels, local processing residues (though limited), and potential, non-traditional municipal sources appears adequate and matches the application. Currently, the "bulk fuel" infrastructure is virtually non-existent locally. To supply bulk fuel to the Hames PE Center would entail developing that capability locally, or obtaining that supply, in the form of mill or forest residues, from Hoonah, Wrangell, Ketchikan, Prince of Wales Island or Canada.

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 very clear which organization would sponsor or implement a wood-burning project. (NOTE: This is not necessarily the case with the Hames PE Center, but the issue should be addressed.)

With manual systems, boiler stoking and/or maintenance is required for approximately 5-10 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. Though automated, bulk fuel systems 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. NOTE: Another option would be to hire a local vendor/contractor to provide such services.

The forest industry infrastructure in/around Sitka is limited to a few part-time loggers/sawmill operators. However, for this report, it is assumed that wood supplies are sufficient, as evidenced by a letter of support from the District Ranger, USDA Forest Service, Tongass National Forest, Sitka Ranger District.

2.3 Classes of Wood Energy Systems

There are, essentially, 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 and cost, 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 normally remain in place and be available for peak demand or backup in the event of 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

Currently, wood fuel supplies in Sitka are fairly limited; the result of relatively inexpensive alternatives (i.e., hydro-electric power). However, that picture is changing as a result of significantly higher fuel oil costs and finite amounts of hydro power. Wood fuels in Sitka are most likely to be in the form of cordwood or other stick-wood, as there is currently no demand for bulk fuels in the immediate area. However, that situation could change as large energy consumers, such as the Hames PE Center and others, consider converting to biomass fuels.

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, hemlock cordwood at 30 percent moisture content (MC30) and hemlock bulk fuel at 50 percent moisture content (MC50), calculated on the green wet weight basis (also called wet weight basis), are used as benchmarks. NOTE: Drier wood will have greater heater value, and less of it would be required to deliver a given amount of heat.

The HHV of hemlock at 0% moisture content (MC0) is 8,515 Btu/lb[1]. The GHV at 30% moisture content (MC30) is 5,961 Btu/lb, and the GHV at 50% moisture content (MC50) is 4,258 Btu/lb.

The RHV for cordwood (MC30) is calculated at 13.26 million Btu per **cord**, and the DHV, which is a function of boiler efficiency (assumed to be 75%), is 9.945 million Btu per cord. The delivered heating value of 1 **cord** of hemlock cordwood (MC30) equals the delivered heating value of **90.08** gallons of #2 fuel oil when oil is burned at 80% efficiency and wood is burned at 75% efficiency.

The RHV for bulk fuel (MC50) is calculated at 5.61 million Btu per **ton**, and the DHV, which is a function of boiler efficiency (assumed to be 70%), is 3.927 million Btu per ton. The delivered heating value of 1 **ton** of hemlock bulk fuel (MC50) equals the delivered heating value of **35.57** 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 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. In 2006, the State of New York instituted a moratorium on new LEHE OWB installations due to concerns over emissions and air quality[5]. Other states have also considered or implemented new regulations[6,7,8,9]. Since there are no standards for OWBs ("boilers" and "furnaces" were exempt from the 1988 EPA regulations[10]), OWB ratings are inconsistent and can be misleading. Prior to 2006, standard procedures for evaluating wood boilers did 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 other industrial boilers. Obviously, these results were deemed unsatisfactory and new OWB 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 I standard calls for emissions not to exceed 0.60 pounds of particulate emissions per million Btu of heat **input**. The Phase II 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 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 wood fuels cleanly and efficiently.

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

Table 4-1. HELE Cordwood Boiler Suppliers		
	Btu/hr ratings	Supplier
Tarm	100,000 to 198,000	HS Tarm/Tarm USA www.tarmusa.com/wood-gasification.asp
Greenwood	100,000 to 300,000	Greenwood www.GreenwoodFurnace.com
Garn	350,000 to 950,000	Dectra Corp. www.dectra.net/garn
Note: Listing of any manufacturer, distributor or service provider does not constitute an endorsement.		

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

Table 4-2 shows the results for a Garn WHS 1350 boiler that was tested at 157,000 to 173,000 Btu/hr 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 no wood-fired boiler is entirely smokeless; even very efficient wood boilers may smoke for a few minutes on startup.[4,15]

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

4.3 Bulk Fuel Boiler Systems

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% (MC40, calculated on a wet basis). NOTE: It is possible to incorporate fuel dryers when dealing with wetter feedstocks.

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 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 35,000 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 tons of material. A facility such as the Hames PE Center, replacing 51,000 gallons of fuel oil with hemlock bulk fuel (MC50) would use an estimated 1,437 tons per year, or about 1 tractor-trailer load every 5 to 6 days, year round.

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 Copper Center in 2007. A 4 MMBtu/hr wood chip gasifier is under construction at the Craig School and 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 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]	Decton
Logging & Milling Associates Delta Junction, AK	N/A	2	12,897[d]	Decton

Table 4-4 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 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 (if any), 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 and electricity to hemlock cordwood (MC30) and hemlock 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 and Electricity vs. Wood Fuels

FUEL	RHV[a] (Btu)	Conversion Efficiency[a]	DHV[a] (Btu)	Price per unit ($)	Cost per MMBtu (delivered, ($))
Fuel oil, #2, (per 1 gallon)	138,000	80%	110,400 per gallon	4.50/gallon	40.761
				5.00	45.29
				5.50	49.819
Electricity (per kilowatt-hour)	3,412	100%	3,412	$.092/kWh	26.964
Hemlock, (per 1 cord, MC30)	13.26 million	75%	9.945 million	175/cord	17.597
				200	20.111
				225	22.624
Hemlock (per 1 ton, MC50)	5.61 million	70%	3.927 million	70/ton	17.825
				80	20.372
				90	22.918

Notes:
[a] from Appendix D

5.2(a) Cost per MMBtu Sensitivity – Cordwood

Figure 5-1 illustrates the relationship between the price of hemlock cordwood (MC30) and the cost of delivered heat, (the slanted line). For each $25 per cord increase in the price of cordwood, the cost per million Btu increases by about $2.514. 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 $4.50, $5.00 and $5.50 per gallon ($40.761, $45.29 and $49.819 per million Btu respectively) and electricity at the current rate of 9.2 cents per kWh ($26.964 per million Btu).

At high efficiency, heat from hemlock cordwood (MC30) at $450.27 per cord is equal to the cost of oil at $5.00 per gallon, before considering the cost of the equipment and operation, maintenance and repair (OM&R) costs. At 75% efficiency and $200 per cord, a high-efficiency cordwood boiler will deliver heat at about 44.4% of the cost of fuel oil at $5.00 per gallon and 75% of the cost of electricity at $.092 per kWh ($20.111 versus $45.29 and $26.964 per MMBtu respectively). 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 and/or electricity.

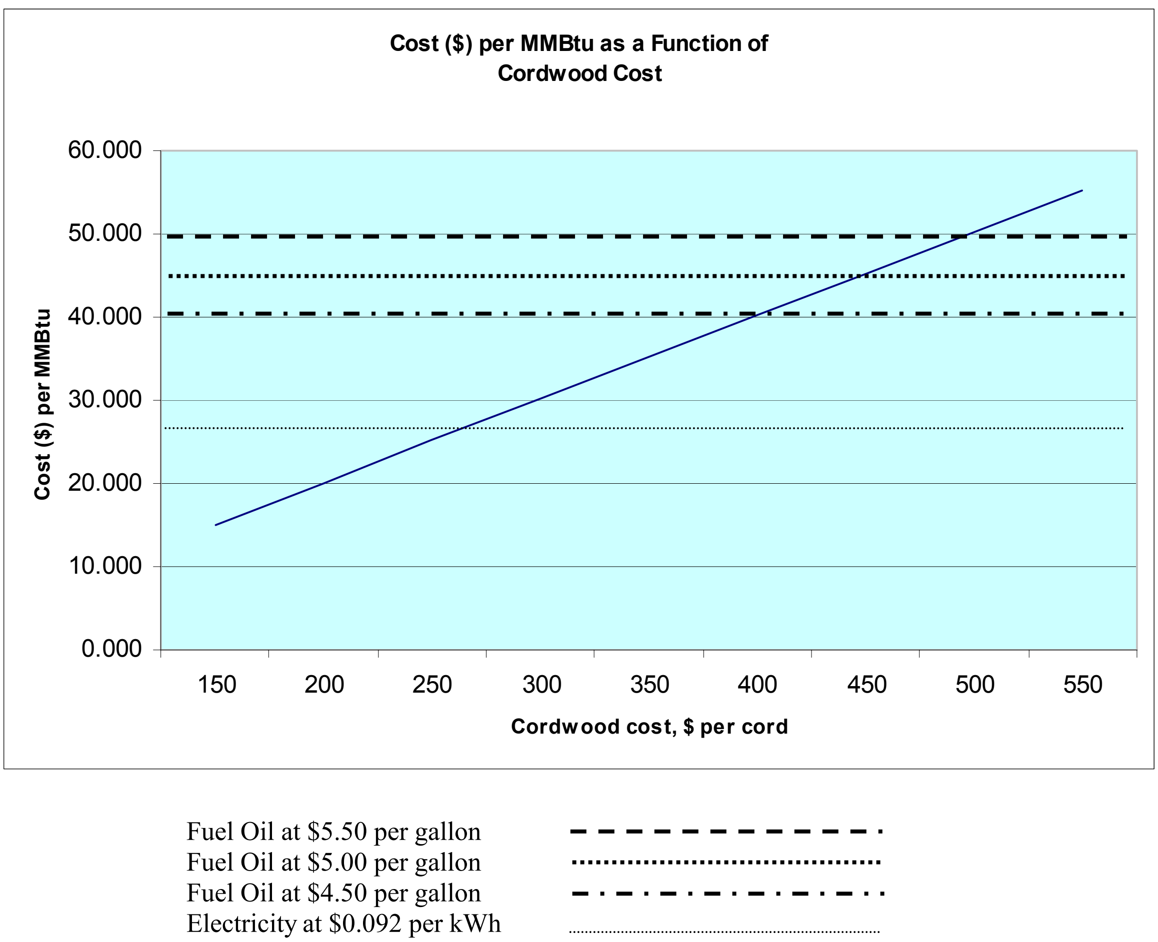
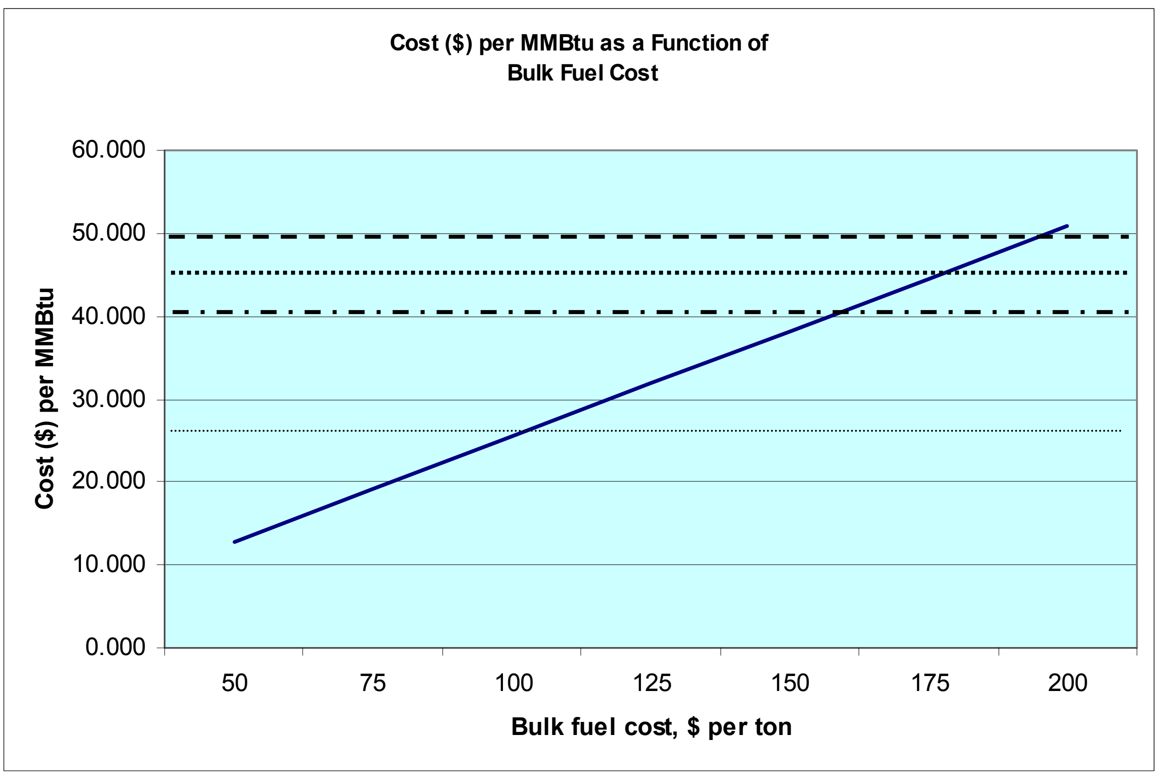


Figure 5-1. Effect of Hemlock Cordwood (MC30) Price on Cost of Delivered Heat

5.2(b) Cost per MMBtu Sensitivity – Bulk Fuels

Figure 5-2 illustrates the relationship between the price of hemlock bulk fuel (MC50) 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 $2.55. 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 $4.50, $5.00 and $5.50 per gallon ($40.761, $45.29 and $49.819 per million Btu respectively) and electricity at the current rate of 9.2 cents per kWh ($26.964 per million Btu).

At high efficiency, heat from hemlock bulk fuel (MC50) at $177.85 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 $80/ton, an efficient bulk fuel boiler will deliver heat at about 45% of the cost of fuel oil at $5.00 per gallon and 75.5% of the cost of electricity at $.092 per kWh ($20.37 versus $45.29 and $26.964 per MMBtu respectively). 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 or electricity.



Fuel Oil at $5.50 per gallon
Fuel Oil at $5.00 per gallon
Fuel Oil at $4.50 per gallon
Electricity at $0.092 per kWh

Figure 5-2. Effect of Hemlock Bulk Fuel (MC50) Price on Cost of Delivered Heat

5.3 Determining Demand

Table 5-2 shows the reported approximate amount of fuel oil used by the Hames PE Center.

Table 5-2. Reported Annual Fuel Oil Consumption, Hames PE Center		
Facility	**Reported Annual Fuel Consumption**	
	Gallons	*Cost ($) @ $5.00/gallon*
Hames PE Center	51,000	255,000
TOTAL	**51,000**	**255,000**

Wood boilers, especially cordwood boilers, are often sized to displace only a portion of the heating load since the oil system typically remains in place, in standby mode, for "shoulder seasons" and peak demand. Fuel oil consumption for the Hames PE Center 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), even though much of the heat is used to maintain the pool water temperature, not for space heating. 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. However, this information was not immediately available for the Hames Center. Given that the existing boilers were intended to supply heat to the entire Sheldon Jackson College campus, their "capacity" would far exceed the needs at the Hames Center alone.

Manual HELE cordwood boilers, equipped with special tanks for extra thermal storage, can supply heat at higher than their rated capacity for short periods. For example, while rated at 950,000 Btu/hr (heat into storage*), a single Garn® WHS 4400 can store nearly 3 million Btu, which would be enough to heat the Hames PE Center during the coldest 24-hour period for more than two hours (2,932,000 ÷ 1,406,000).

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]
Hames PE Center	51,000	8,011	702,834	17	1,406,000	Not available

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

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

5.4 Summary of Findings

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 Hames PE Center. [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

HAINES SCHOOL	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 ($)		
		4.50	*5.00*	*5.50*							
Cordwood system	51,000	229,500	255,000	280,500	W. Hemlock, MC30, CE 75%	*175/cord*	*200/cord*	*225/cord*	*Low*	*Medium*	*High*
					567cords	99,225	113,400	127,575	101,925	141,600	181,275
Bulk fuel system					W. Hemlock, MC50, CE 70%	*70/ton*	*80/ton*	*90/ton*	*Low*	*Medium*	*High*
					1,437 tons	100,590	114,960	129,330	100,170	140,040	179,910

NOTES:
[a] From Table 5-2
[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 architects and/or 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 systems 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 readily 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 plumbing, 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 several cordwood systems in a large heating demand situation. Five alternatives are presented.

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 high cost of hard copper and/or iron 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.

Allowances 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 <u>estimates</u>.

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

Table 6-1. Initial Investment Cost Scenarios for Hypothetical Cordwood Systems					
Fuel oil consumption (gallons per year)	51,000				
Required boiler capacity (RBC), Btu/hr	1,406,000[f]				
Cordwood boiler Garn model Btu/hr[e]	(1) WHS 3200[g] 950,000	(2) WHS 3200 1,900,000	(3) WHS 3200 2,850,000	(4) WHS 3200 3,800,000	(5) WHS 3200 4,750,000
	Building and Equipment (B&E) Costs (for discussion purposes only)				
Fuel storage building[a] (fabric bldg, gravel pad, $15 per sf)	**$170,100** (567 cords; 11,340sf)				
Boiler building @ $150 per sf (minimum footprint w/concrete pad)[b]	$30,000 (10' x 20')	$60,000 (20' x 20')	$90,000 (30' x 20')	$120,000 (40' x 20')	$150,000 (50' x 20')
Boilers					
Base price	$33,000	$66,000	$99,000	$132,000	$165,000
Shipping[d]	$4,000	$8,000	$12,000	$16,000	$20,000
Plumbing/connections[d]	$50,000	$60,000	$70,000	$80,000	$90,000
Installation[d]	$25,000	$30,000	$35,000	$40,000	$45,000
Subtotal - B&E Costs	**312,100**	**394,100**	**476,100**	**558,100**	**640,100**
Contingency (25%)[d]	**78,025**	**98,525**	**119,025**	**139,525**	**160,025**
Grand Total	**390,125**	**492,625**	**595,125**	**697,625**	**800,125**

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

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 Assumes all fuel oil used is used to provide space heat, which is NOT the actual case; a significant though undetermined portion is used to maintain pool water temperatures

g A single Garn WHS 3200 would have to be fired 11 times per day, every day, in order to consume 567 cords of fuel. Since it requires at least 2 hours to consume a fuel charge, the boiler would essentially have to be fired continuously, which is not a viable operating scenario.

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 daily, year around.

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					
System (Garn Model)	(1) WHS 3200[c]	(2) WHS 3200	(3) WHS 3200	(4) WHS 3200	(5) WHS 3200
Total Daily labor (hrs/yr)[a] (hrs/day X 210 days/yr)	567.00	600.27	611.37	616.91	620.24
Total Periodic labor (hrs/yr)[b] (hrs/wk X 30 wks/yr)	567	567	567	567	567
Total Annual labor (hrs/yr)[b]	20	40	60	80	100
Total labor (hrs/yr)	1154.00	1207.27	1238.37	1263.91	1287.24
Total annual labor cost ($/yr) (total hrs x $20)	**23,080.00**	**24,145.40**	**24,767.40**	**25,278.20**	**25,744.80**

Notes:
[a] From Table F-2
[b] From Appendix F
[c] A single Garn WHS 3200 would have to be fired 11 times per day, every day in order to consume 567 cords of fuel. Since it requires at least 2 hours to consume a fuel charge, the boiler would essentially have to be fired continuously, which is not a viable operating scenario.

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 maintenance and repair items, such as fire brick, door gaskets, water treatment chemicals, etc. It is reasonable to assume that the more a given boiler is used, the more maintenance/repair it will require. However, some maintenance items, such as water treatment chemicals will breakdown regardless of usage. For this exercise, a flat rate of $2,000 is used, and that amount could all be spent on two intensively-used boilers, or spread out over several, less intensively-used boilers. (See Table 6-3 on the next page.)

Table 6-3. Summary of Total Annual Non-Fuel OM&R Cost Estimates					
Item	Cost/Allowance ($)				
	(1) WHS 3200[c]	(2) WHS 3200	(3) WHS 3200	(4) WHS 3200	(5) WHS 3200
Labor	23,080.00	24,145.40	24,767.40	25,278.20	25,744.80
Electricity	505.40				
Maintenance/Repairs	2,000				
Total non-fuel OM&R ($)	**25,585.40**	**26,650.80**	**27,272.80**	**27,783.60**	**28,250.20**

Notes for Table 6-3:

[a] From Table 6-2

[b] Electrical cost based on a formula of horsepower x kWh rate x operating time. Assumed kWh rate = $0.10

[c] A single Garn WHS 3200 would have to be fired 11 times per day, every day in order to consume 567 cords of fuel. Since it requires at least 2 hours to consume a fuel charge, the boiler would essentially have to be fired continuously, which is not a viable operating scenario.

6.4 Calculation of Financial Metrics

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

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

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

Simple Payback Period
Present Value (PV)
Net Present Value (NPV)
Internal Rate of Return (IRR)

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 Multiple 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[f]	(2) WHS 3200	(3) WHS 3200	(4) WHS 3200	(5) WHS 3200
Fuel oil cost ($ per year @ $5.00 per gallon)	255,000				
Cordwood cost ($ per year @ $200 per cord)	113,400				
Annual Fuel Cost Savings ($)	141,600				
Total Investment Costs ($)[b]	390,125	492,625	595,125	697,625	800,125
Simple Payback (yrs)[c]	2.76	3.48	4.20	4.93	5.65

Notes:
a From Table 6-3
b From Table 6-1
c Total Investment Costs divided by Annual Fuel Cost Savings
d Total Investment Costs divided by Net Annual Savings
f A single Garn WHS 3200 would have to be fired 11 times per day, every day in order to consume 567 cords of fuel. Since it requires at least 2 hours to consume a fuel charge, the boiler would essentially have to be fired continuously, which is not a viable operating scenario.

6.6 Present Value (PV), Net Present Value (NPV) and Internal Rate of Return (IRR) Values for Multiple HELE Cordwood Boilers

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

Table 6-5. PV, NPV and IRR Values for Multiple HELE Cordwood Boilers					
	(1) WHS 3200	(2) WHS 3200	(3) WHS 3200	(4) WHS 3200	(5) WHS 3200
Discount Rate[a] (%)	3				
Time, “t”, (years)	20				
Initial Investment ($)[b]	390,125	492,625	595,125	697,625	800,125
Annual Cash Flow ($)[c]	116,015	114,949	114,327	113,816	113,350
Present Value (of expected cash flows, $ at “t” years)	1,726,010	1,710,151	1,700,897	1,693,295	1,686,362
Net Present Value ($ at “t” years)	1,335,885	1,217,526	1,105,772	995,670	886,237
Internal Rate of Return (% at “t” years)	29.57	22.96	18.57	15.38	12.92
See Note #_ below	1	2	3	4	5

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. A single Garn WHS 3200 would have to be fired 11 times per day, every day in order to consume 567 cords of fuel. Since it requires at least 2 hours to consume a fuel charge, the boiler would essentially have to be fired continuously, which is not a viable operating scenario.

Note #2. With a real discount rate of 3.00% and after a span of 20 years, the projected cash flows are worth $1,710,151 today (PV), which is greater than the initial investment of $492,625. The resulting NPV of the project is $1,217,526 and the project achieves an internal rate of return of 22.96% at the end of 20 years. Given the assumptions and cost estimates, this alternative appears financially feasible, although the operational parameters are not ideal, i.e., approximately 5.5 firings per day.

Note #3. With a real discount rate of 3.00% and after a span of 20 years, the projected cash flows are worth $1,700,897 today (PV), which is greater than the initial investment of $595,125. The resulting NPV of the project is $1,105,772 and the project achieves an internal rate of return of 18.57% at the end of 20 years. While these metrics are less favorable than alternative 2, given the assumptions and cost estimates, this alternative appears quite feasible and provides improved operational parameters, i.e., approximately 3.6 firings per day.

Note #4. With a real discount rate of 3.00% and after a span of 20 years, the projected cash flows are worth $1,693,295 today (PV), which is greater than the initial investment of $697,625. The resulting NPV of the project is $995,670 and the project achieves an internal rate of return of 15.38% at the end of 20 years. While these metrics are less favorable than alternatives 2 and 3, given the assumptions and cost estimates, this alternative still appears quite feasible and may provide ideal operational parameters, i.e., approximately 2.7 firings per day.

Note #5. With a real discount rate of 3.00% and after a span of 20 years, the projected cash flows are worth $1,686,362 today (PV), which is greater than the initial investment of $800,125. The resulting NPV of the project is $886,237 and the project achieves an internal rate of return of 12.92% at the end of 20 years. While these metrics are less favorable than alternatives 2, 3 and 4, given the assumptions and cost estimates, this alternative still appears quite feasible and may provide some system redundancy and capacity for expansion. Required daily firings would average approximately 2.2.

SECTION 7. ECONOMIC FEASIBILITY OF BULK FUEL SYSTEMS

A typical bulk fuel boiler system includes bulk fuel storage, 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 or bunkers of various sizes for wood fuel storage, chip storage areas of various sizes, boiler buildings of various configurations, automated versus manual ash removal and cyclones for particulate removal (if necessary).[17]

7.1 Capital Cost Components

As indicated, bulk fuel systems are larger, more complex and often 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 (nest page) 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	Hames PE Center (51,000 gallons/year; 1,437 tons/year, (MC50))
	Capital Costs: Building and Equipment (B&E)
Fuel storage building	?
Material handling system	?
Boiler building	?
Boiler: base price *shipping*	?
Plumbing/connections	?
Electrical systems	?
Installation	?
	Non-capital Costs
Engineering , Permitting, Contingency, etc.	?
Initial Investment Total ($)	$1,000,000 to $2,000,000

The investment cost of bulk fuel systems installed in institutional settings can range from $500,000 to over $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 around $250,000, but an existing building was used and there were significant economies in fuel preparation and fuel handling that would be unacceptable in a non-industrial 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. The fuel storage and boiler building, fuel dryer, and system integration costs for the pool and two schools increased the project costs. NOTE: The City of Craig subsequently undertook construction of the project themselves using a "force account" and brought the final cost down to about $1.5 million.

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 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 readily available as a fuel in southeast 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	$1,001,000
City of Craig	Craig, AK	4 MMBtu	Stand-alone boiler building tied to existing hot water systems	Chips	$1,500,000
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 Hypothetical OM&R Cost Allowances

The primary operating cost is fuel. The estimated bulk fuel cost for the Hames PE Center is **$114,960** (1,437 tons @ $80/ton). 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 daily, year round.

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 **2** hours per week is allocated to perform routine maintenance tasks. Therefore, the total annual labor requirement is (365 x 0.5) + 104 = **286.5 hours per year**. At $20 per hour, the annual labor cost would be **$5,730**.

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 School system, 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 Hames PE Center is projected to use 1,437 tons of bulk fuel (1.9 times the amount used at Darby). If it is valid to apportion the electrical usage based on bulk fuel consumption, then the Hames PE Center would use about 44,960 kWh per year. At $0.10 per kWh, the annual electrical consumption would be **$4,496.**

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 Hames PE Center 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 ($)	*5,730*
Electricity ($)	*4,496*
Maintenance ($)	*5,000*
Total, non-fuel OM&R	15,226
Wood fuel ($)	114,960
Total OM&R ($)	**130,186**

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

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

Table 7-6. Simple Payback Period Analysis for Bulk Fuel Heating Systems						
	Hames PE Center (51,000 gpy; 1,437 tons/yr (MC50))					
Fuel oil cost ($ per year @ $5.00 per gallon	255,000					
Bulk wood fuel ($ per year @ $80 per ton)	114,960					
Annual Fuel Cost Savings ($)	140,040					
Total Investment Costs ($)	750,000	1,000,000	1,250,000	1,500,000	1,750,000	2,000,000
Simple Payback (yrs)[a]	5.36	7.14	8.93	10.71	12.50	14.28
[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 Hypothetical Bulk Fuel Boiler Installations

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

Table 7-7. PV, NPV and IRR Values for Bulk Fuel Systems						
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]	124,814					
Present Value (of expected cash flows), ($ at "t" years)	1,856,917					
Net Present Value ($ at "t" years)	1,106,917	856,917	606,917	356,917	106,917	-143,083
Internal Rate of Return (%)	15.75	10.91	7.73	5.43	3.65	2.21
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 Hames PE Center in Sitka, 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 this facility.

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/or heating system. The difference in the cost of heat derived from wood versus the cost of heat derived from fuel oil is significant, as illustrated in Table 5-1. It is this difference in the cost of heat, resulting in monetary savings that must "pay" for the substantially higher investment and OM&R costs associated with wood fuel systems.

The Hames PE Center provides recreational/sports/fitness opportunities for the entire community of Sitka, AK, population approximately 8,600. The facility consists of a single large building (approximately 34,000 square feet) and houses a large swimming pool, two handball courts, full size gymnasium/basketball court, weight room, two exercise rooms, locker rooms with showers, restrooms and office space. Heat is provided by oil-fired steam boilers located on the site of the former City incinerator. Heat is delivered within the Center via hot water and hot air distribution systems. The Hames PE Center can be considered "relatively large" in terms of its fuel oil consumption (51,000 gpy), and may be large enough to justify the installation of a bulk fuel wood heating system if investment costs can be controlled and a reliable consistent fuel supply identified.

The topography around the school is gentle, albeit somewhat constrained, presenting relatively minor physical impediments to a cordwood boiler installation. A bulk fuel heating plant would be somewhat more difficult to site in close proximity to the existing mechanical room. If the site of the former incinerator can be used, space constraints would not be a concern, although distances over which plumbing would have to be run would increase significantly, but not prohibitively.

8.1 Cordwood Systems

To replace 51,000 gallons of #2 fuel oil per year would require approximately 567 cords of reasonably dry (MC30) hemlock cordwood, other stick-type fuels or briquettes.

Examples of installing and operating multiple, large cordwood boilers are presented in Section 6. At a minimum, two such boilers would have to be installed in order to replace 51,000 gallons of fuel oil per year. However, such a minimal installation would mean firing those boilers every five hours every day of the year, which is probably impractical. The installation of three boilers would require an average of 3.6 firings per day; the installation of four boilers would require 2.7 firings per day; and the installation of five boilers would require 2.2 firings per day (See Appendix F).

Initial investment costs for the installation of multiple cordwood boilers ranged from about $493,000 to $800,000, with the cost of the 11,340 square foot fuel storage building being the single most costly item ($170,000). However, each boiler installation scenario returned positive financial metrics with simple payback periods ranging from 3.48 to 5.65 years, and internal rates of return ranging from 12.92 to 22.96 percent.

8.2 Bulk Fuel System

To replace 51,000 gallons of fuel oil per year would require approximately 1,437 tons (approximately sixty-five 40-foot tractor trailer loads) of bulk fuel (chips, sawdust, bark, shavings, etc.), assuming such fuel runs 50% moisture content (MC50).

Although it is beyond the scope of this assessment to delve into the detailed costs associated with the installation of bulk fuel systems, it is not unrealistic to say that, at 51,000 gallons of fuel oil per year, it appears possible that a bulk fuel system could be cost-effective for the Hames PE Center **IF**:

1. a reliable, consistent source of fuel can be identified
2. fuel can be delivered at a reasonable cost
3. total investment costs can be held to $1,750,000 or less

REFERENCES AND RESOURCES:

[1] Wilson, P.L., Funck, J.W., Avery, R.B., *Fuelwood Characteristics of Northwestern Conifers and Hardwoods*, Research Bulletin 60, Oregon State University, College of Forestry, 1987.

[2] Briggs, David, 1994. *Forest Products Measurements and Conversion Factors*, University of Washington Institute of Forest Resources, AR-10, Seattle, Washington 98195.

[3] Wood with moisture greater than about 67% MC will not support combustion. *Wood-Fired Boiler Systems For Space Heating*, USDA Forest Service, EM 7180-2, 1982.

[4] Feasibility Assessment for Wood Heating, T.R. Miles Technical Consultants, Inc., Portland, OR, 2006. http://www.jedc.org/forms/AWEDTG_WoodEnergyFeasibility.pdf

[5] Smoke Gets in Your Lungs: Outdoor Wood Boilers in New York State, October 2005, New York State Attorney General http://www.oag.state.ny.us/press/2005/aug/August%202005.pdf

[6] Proposal For A Particulate Matter Emissions Standard And Related Provisions For New Outdoor Wood-fired Boilers, Vermont Agency of Natural Resources Department of Environmental Conservation Air Pollution Control Division January 20, 2005 (revised July 6, 2005) http://www.vtwoodsmoke.org/pdf/TechSupp.pdf

[7] http://www.nescaum.org/topics/outdoor-hydronic-heaters/other-model-regulations

[8] http://www.nescaum.org/topics/outdoor-hydronic-heaters/state-and-federal-information

[9] Assessment of Outdoor Wood-Fired Boilers, Revised May 2006, NESCAUM, the Clean Air Association of the Northeast States http://www.nescaum.org/documents/assessment-of-outdoor-wood-fired-boilers

[10] Electronic Code of Federal Regulations, Title 40, Protection of Environment, Part 60, Standards of Performance for New Stationary Sources. http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=f0d500634add4f17c656e9d55ce0d0cf&rgn=div6&view=text&node=40:6.0.1.1.1.63&idno=40

[11] WK5982 Standard Test Method for Measurement of Particulate Emissions and Heating Efficiency of Outdoor Wood-Fired Hydronic Heating Units, Committee E06.54 on Solid Fuel Burning Appliances American Society of Testing and Materials. www.astm.org

[12] U.S. Environmental Protection Agency news release, http://yosemite.epa.gov/opa/admpress.nsf/4b729a23b12fa90c8525701c005e6d70/007f277470e6474585257272005 7353c!OpenDocument

[13] http://www.tarmusa.com, Tarm USA Inc. P.O. Box 285 Lyme, NH 03768

[14] http://www.dectra.net/garn, Dectra Corporation, 3425 33rd Ave. NE, St. Anthony, MN 55418

[15] Test of a Solid fuel Boiler for Emissions and Efficiency per Intertek's Proposed Protocol for Outdoor Boiler Efficiency and Emissions Testing. Intertek report No. 3087471 for State of Michigan, Air Quality Department. Intertek Testing Services NA Inc. 8431 Murphy Drive, Wisconsin 53562. March 2006.

[16] Keunzel, New Horizon and Alternate Heating Systems are sometimes recommended for high efficiency boilers, however none are installed in Alaska and no efficiency or emissions data was available for this report. www.newhorizoncorp.com, www.kuenzel.de/English/indexE.htm, www.alternateheatingsystems.com/Multi-Fuel_boilers.htm

[17] Biomass Boiler Market Assessment, CTA Architects and Engineers, Christopher Allen & Associates, Montana Community Development Corp., and Geodata Services, Inc. 2006. http://www.fuelsforschools.org/pdf/Final_Report_Biomass_Boiler_Market_Assessment.pdf

[18] Darby Fuels For Schools Second Season Monitoring Report, 2004-2005. http://www.fuelsforschools.org/pdf/Darby_FFS_Monitoring_Rpt_2004-2005.pdf

[19] Life Cycle Cost Analysis Handbook, Alaska Department of Education and Early Development, Education Support Services, 1st Edition, 1999.

Appendix A. AWEDTG Evaluation Criteria

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

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

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

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

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

5. Sustainability of the wood fuel supply;

6. Community support and project advocacy;

7. Ability to implement the project;

8. Ability to operate and maintain the project.

Appendix B. Recoverable Heating Value Determination

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

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

H2: Heat required to vaporize the water in the wood

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

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

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

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

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

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

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

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

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

Appendix C. List of Abbreviations and Acronyms

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

CONVERSIONS

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

APPENDIX D - Wood Fuel Properties

Heating values for Alaska species are presented in Table D-1. High Heating Values (HHV), which are calculated on an oven-dry (OD) basis, are similar for *most* species on a weight basis, although resinous species typically have slightly higher HHV[1]. The recoverable heating value (RHV), which takes into account moisture content and other energy losses[2], ranges from 4,067 to 5,347 Btu/lb at 30 percent moisture content (MC30) and 2,554 to 3,468 Btu/lb at 50 percent moisture content (MC50) for species commonly found in southeast Alaska.

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

Bulk fuels (wood chips, sawdust, bark, etc.) are generally used 'as delivered' from the producer with little opportunity for additional drying. Ideally, bulk fuels should contain 40% water (MC40) or less, on a wet weight basis, but the in the real southeast Alaska world, 50% water content (MC50) is more realistic. Bulk fuels are usually traded on a weight (ton) basis and the price may be adjusted up or down to reflect the moisture content of the fuel.

The RHV of hemlock cordwood (the most common species in southeast Alaska) **at MC30 is about 13.26 million Btu (MMBtu) per cord** (assumed to contain 100 cubic of "fuel", both wood and bark). Hemlock bulk fuel at MC50 has a RHV of **5.61 million (MM) Btu per ton at MC50**. (NOTE: bark typically has a higher HHV than wood, but no allowance for that difference has been made here.)

Table D-1. Heating Values of Selected Alaska Species

		Cordwood			Bulk Fuel (chips, sawdust, etc.)		
SPECIES	HHV[1] Btu/lb (MC0)	GHV[2] Btu/lb (MC30)	RHV[2] BTU/lb (MC30)	RHV[2] MMBtu per cord[b]	GHV[2] Btu/lb (MC50)	RHV[2] Btu/lb (MC50)	RHV[2] MMBtu per ton
Alaska yellow-cedar	9,900	6,930	5,347	15.48	4,950	3,468	6.94
Western redcedar	9,144[a]	6,401	4,839	10.07	4,572	3,106	6.21
Western hemlock	**8,515[a]**	**5,961**	**4,417**	**13.26**	**4,258**	**2,804**	**5.61**
Sitka Spruce	8,100	5,670	4,138	10.83	4,050	2,604	5.21
White Spruce	8,890	6,223	4,669	12.22	4,445	2,984	5.97
Red Alder	7,995[a]	5,597	4,067	10.78	3,998	2,554	5.11
Paper (white) birch	8,334	5,834	4,295	15.44	4,167	2,717	5.43
Quaking aspen	No data	--	--	--	--	--	--
Black cottonwood	8,800	6,160	4,608	10.21	4,400	2,940	5.88
Black Spruce	No data	--	--	--	--	--	--

Notes:

HHV= Higher Heating Value, from *Fuelwood Characteristics of Northwestern Conifers and Hardwoods*
GHV = Gross Heating Value = HHV x (1-MCwb/100) MCwb = percent moisture content calculated on a wet basis
RHV = Recoverable Heat Value = GHV – Energy Losses (see Appendix B)
[a] average of published range of values[1]
[b] a cord is assumed to contain 100 cubic feet of "fuel" (wood plus bark)

Most bulk fuel boilers operate well when fuel(s) contain less than 40% water (MC40) and poorly or very poorly if the moisture content is above 50%. Bulk fuels that are stored unprotected outdoors can absorb rainwater and, in some areas, can reach moisture contents as high as 65%[3], so some consideration for dry storage or fuel drying may be appropriate. Schools in the northeast USA using wood chips select suppliers carefully and often pay a premium for chips below 40% MC[4].

D.1 Fuel Quality

Fuel quality, especially moisture content, has a large impact on the performance of wood-fueled boilers. For this assessment, it is assumed that cordwood has been seasoned and dried to 30% MC and bulk fuels average 50% water. As moisture content increases, heating values decrease, as shown in Table D-2.

Table D-2. Effect of Moisture Content on Gross Heating Value of Western Hemlock

SPECIES	HHV Btu/lb Oven-dry (OD)	GHV Btu/lb (MC20)	GHV Btu/lb (MC30)	GHV Btu/lb (MC40)	GHV Btu/lb (MC50)
Western hemlock	8,515	6,812	5,961	5,109	4,258

Notes:

HHV= Higher Heating Value, from *Fuelwood Characteristics of Northwestern Conifers and Hardwoods* [1]

GHV = Gross Heating Value = HHVx (1-MCwb/100); MCwb is moisture content (wet basis) [2]

D.2 Recoverable Heat and Fuel Oil Equivalence/Displacement

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

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

DHV= RHV X CE [2]

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

The fuel oil equivalence for hemlock bulk fuel (chips, sawdust, etc.) at MC50 is calculated at **36.63** gallons per ton (#1) and **35.57** gallons per ton (#2) at 70% conversion efficiency. The fuel oil equivalence for hemlock cordwood at MC30 in a HELE cordwood boiler is calculated at **92.77** gallons (#1) and **90.08** gallons (#2); three times as much as a low efficiency boiler at 30.9 and 30.0 gallons per cord for #1 and #2 respectively.

Table D-3. Deliverable Heating Values and Fuel Oil Equivalence				
Boiler and Fuel	RHV	CE	DHV	Fuel Oil Equivalent (1 unit = X gallons)
Oil boiler, #1 Fuel Oil	134,000 Btu/gallon	80%	107,200 Btu/gallon	1 gallon = 1 gallon
Oil boiler, #2 Fuel Oil	138,000 Btu/gallon	80%	110,400 Btu/gallon	1gallon = 1 gallon
Electric water heater	3,412 Btu/kWh	100%	3,412 Btu/kWh 3.412 MMBtu/MWh	1 MWh = 31.83 gal. #1 1 MWh = 30.91 gal. #2
Wood chip boiler, hemlock bulk fuel @ 50% MC	5.61 MMBtu/ton	70%	3.927 MMBtu/ton	1 ton = 36.63 gal. #1 1 ton = 35.57 gal. #2
HELE cordwood boiler, hemlock cordwood @ 30% MC	13.26 MMBtu/cord	75%	9.945 MMBtu/cord	1 cord = 92.77 gal. #1 1 cord = 90.08 gal. #2
LEHE cordwood boiler, hemlock cordwood @ 30% MC	13.26 MMBtu/cord	25%	3.312 MMBtu/cord	1 cord = 30.9 gal. #1 1 cord = 30.0 gal. #2

Notes:

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

APPENDIX E – Financial Metrics

6.1 Simple Payback Period

From: www.odellion.com:

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

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

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

HR Application Example

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

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

HR Application Example

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

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

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

6.2 Present Value

From: www.en.wikipedia.org:

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

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

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

6.3 Net Present Value

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

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

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

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

Or,

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

Definition of Terms

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

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

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

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

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

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

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

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

6.4 Internal Rate of Return (IRR))

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

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

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

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

From http://www.odellion.com:

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

The IRR uses the NPV equation as its starting point:

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

Definition of Terms

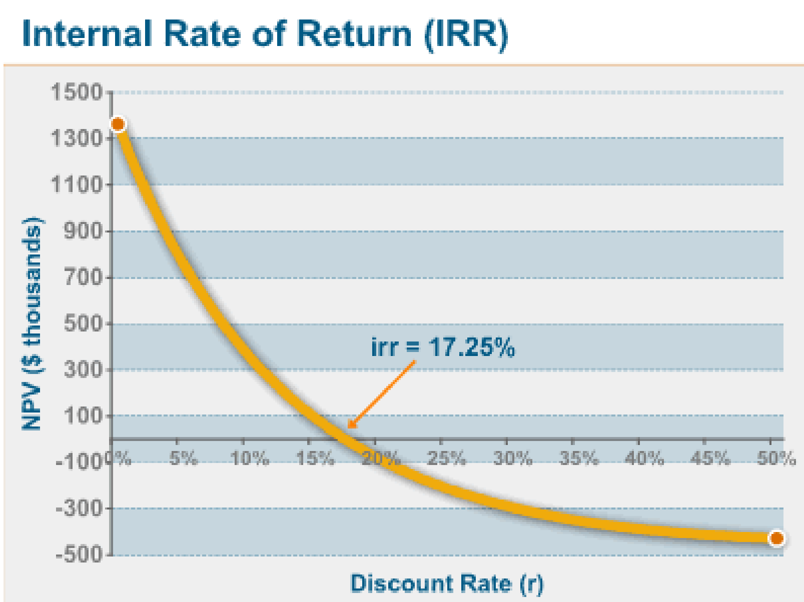
Initial investment: The investment at the beginning of the project.

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

IRR: Internal Rate of Return.

n: Last year of the lifetime of the project.

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



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

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

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

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

APPENDIX F – Operating Parameters of HELE Cordwood Boilers

Operating Parameters and Labor Requirements of HELE Cordwood Boilers

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

Daily labor. The major labor requirement is the "daily" labor associated with firing (or charging) the boiler.

Periodic labor. The second labor component is "periodic" (i.e., weekly) labor associated with boiler cleaning, ash disposal, and fuel re-stocking.

Annual labor. "Annual" labor is the time associated with conducting annual maintenance and/or repairs, such as firetube cleaning, firebrick replacement, flue cleaning and repair, etc.

Daily Labor

Estimating the amount of daily labor is a function of the total amount of wood to be consumed and the ability of the boiler to consume it. This analysis compares the capacities of multiple Garn WHS 3200 boilers. It is assumed that the boiler will operate at full capacity every day for 365 days (52 weeks) per year.

Table F-1. Operating parameters of Garn HELE cordwood boilers

Item	(1) WHS 3200	(2) WHS 3200	(3) WHS 3200	(4) WHS 3200	(5) WHS 3200
Firebox volume, gross (cu.ft.)	36	72	108	144	180
Fuel volume per charge (cu.ft.)[a]	18	36	54	72	90
Fuel volume per charge (cords)[b]	0.14	0.28	0.42	0.56	0.70
Cords/year (fuel volume per charge (cords) X 365 days/year)					
at 1 charge per day	51.1	102.2	153.3	204.4	255.5
at 2 charges per day	102.2	204.4	306.6	**408.8**	**511.0**
at 3 charges per day	153.3	306.6	**459.9**	**613.2**	**766.5**
at 4 charges per day	204.4	408.8	**613.2**	817.6	1022.0
at 5 charges per day	255.5	**511.0**	766.5	1022.0	1277.5
at 6 charges per day	306.6	**613.2**	919.8	1226.4	1533.0

Notes:
[a] Equals ½ of gross firebox volume
[b] Equals fuel volume per charge (cu.ft.) divided by 128 (cubic feet per cord)

NOTE: A single Garn WHS 3200 would have to be fired 11 times per day, every day in order to consume 567 cords of fuel. Since it requires at least 2 hours to consume a fuel charge, the boiler would essentially have to be fired continuously, which is not a viable operating scenario.

Daily labor requirements are assessed in Table F-2.

Table F-2. Daily labor requirements associated with HELE cordwood boilers					
Assumptions: 1. 365 full operating days per year					
	(1) WHS 3200	(2) WHS 3200	(3) WHS 3200	(4) WHS 3200	(5) WHS 3200
Annual wood consumption (cords/yr)	567				
Average daily fuel consumption (cords) (annual wood consumption ÷ 365)	1.553				
Average firings per day (cords/day ÷ cords/charge[a])	10.94	5.47	3.647	2.735	2.188
Labor required per firing (hours)[b]	.142	.301	.459	.618	.777
Labor required per day (hours) (time/firing X firings/day)	1.55	1.64	1.67	1.69	1.70
"Daily" labor per year (hours) (hours/day X 210 days/year)	**567.00**	**600.27**	**611.37**	**616.91**	**620.24**

Notes:
[a] Derived from Table F-1
[b] estimates based on operation of Garn boiler at Dot Lake, AK

NOTE: A single Garn WHS 3200 would have to be fired 11 times per day, every day in order to consume 567 cords of fuel. Since it requires at least 2 hours to consume a fuel charge, the boiler would essentially have to be fired continuously, which is not a viable operating scenario.

Periodic Labor

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

Options for moving fuel:

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

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

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

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

In the case of such a large system, the weekly wood demand amounts to almost 11 cords (567 cords per year ÷ 52 weeks per year). It is likely that a large system like this would have some degree of fuel automation, as discussed above. This example allows **11 hours** (1 hour per cord) per week for periodic labor including boiler inspection, cleaning, fuel management, etc.

Annual Labor

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

Total Labor Requirements

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

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

System (# Garn WHS 4400)	(1) WHS 3200	(2) WHS 3200	(3) WHS 3200	(4) WHS 3200	(5) WHS 3200
Total Daily labor (hrs/yr)	567.00	600.27	611.37	616.91	620.24
Total Periodic labor (hrs/yr)	567	567	567	567	567
Total Annual labor (hrs/yr)	20	40	60	80	100
Total labor (hrs/yr)	1154.00	1207.27	1238.37	1263.91	1287.24
Total annual cost ($) (Hrs x $20/hr)	**23,080**	**24,145.40**	**24,767.40**	**25,278.20**	**25,744.80**

APPENDIX G – Specifications of Garn Boilers

GARN WHS Specifications

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

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

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