USFS Juneau Ranger District & Mendenhall Glacier Visitor Center Biomass Pre-feasibility Report

Submitted to USFS and AWEDTG

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Table of Contents

1 EXECUTIVE SUMMARY

1.1 Acknowledgements

This feasibility study was supported by the Alaska Wood Energy Development Task Group and administered by the Fairbanks Economic Development Corporation. The USFS supported the field study with information and assistance while in Juneau.

1.2 Objective

The objective of this report is to document the results of a pre-feasibility study performed for the United States Forest Service (USFS) at two sites in Juneau. Site one contains five buildings (two separate dorms are treated as one building); the second site consists of only the Mendenhall Glacier Visitor Center (MGVC). The intent is to document the feasibility of replacing the existing oil and electrical heating sources with wood in these buildings.

In this report, we distinguish between the evaluation of a district heating plant (DH Plant) and the evaluation of a building-specific boiler. The analysis methodology is the same for both configurations, but the data presented for the DH Plant are much more extensive than that in the individual building analysis.

At the request of the USFS, the study was limited to chip and pellet-fired boilers; no stick fired boilers were considered. In addition, the USFS has access to three used boilers, which can fire on pellets or chips. For that reason, we evaluated each "fuel" twice; once with the purchased boiler (Base Case) and once with a relocated used boiler. The used boilers, manufactured by ACT Bioenergy, were considered to be free, except for freight and installation costs. Likewise, the USFS has access to three matched thermal storage tanks; again, these were considered free except for freight and installation.

Feasibility studies are often classified as Level 1 (L1), Level 2 (L2), or Level 3 (L3). Level 1 studies consist of very rough calculations on a small number of important metrics (unit fuel costs, etc) and can be done remotely. At the other end, L3 studies are commonly called "investment grade studies"; the level of detail and calculation is so high that one could use the results of an L3 study to get an outside entity to fund the implementation of the project. Level 2, then, is the bridge between L1 and L3. It is a Screening study is done to determine if it is worth the time and expense to initiate an L3 study and helps decision makers determine which aspects, if any, of a proposed project should be included in an L3 study. An L2 study requires at least a minimum amount of site observation of existing conditions, conversations with the affected parties, and research with second-order parties (local foresters, vendors, local contractors, etc). This is a Level 2 study. Level 3 studies are generally quite expensive and thus not entered into lightly.

Sustainability, Inc (SI) and efour, PLLC (efour) perform L2 and L3 studies across the state of Alaska, from cities to small villages in the bush. We use the same performance and economic models for each type of study. For us, the primary difference between the two studies is the quality of the inputs, which is generally a function of how much time has been spent gathering information and the depth of that information.

1.3 Sources

The primary sources of information for this study are data collected on site by SI and data provided by the USFS and the Fairbanks Economic Development Corporation (FEDC). Data collected on site by SI include existing site conditions, equipment nameplate data, current energy cost data, and equally important information gathered through discussions with the local stakeholders at the USFS.

In addition to the site knowledge gathered by SI, additional biomass boiler performance and cost data have been accumulated over the past several years from working with local engineers and contractors, and from performing multiple L2 and L3 wood-fired feasibility studies.

Hourly weather data for the performance model was extracted from data collected and reported by the Juneau Airport.

1.4 Scope

The scope of this study is limited to the USFS complex on Mendenhall Loop Road and the Mendenhall Glacier Visitors Center. The USFS complex consists of three USFS buildings (an office and two warehouses), two dorms (considered to be one building for this study) and a NOAA office building. An existing boiler in the USFS office building currently serves the two warehouses with heat via buried piping. The dorms and the NOAA building are heated with electric heat, so it would be too expensive to convert the entire buildings to hot water (the output of the biomass boilers).

The NOAA building uses forced air, with electric heating coils on the incoming air, and smaller coils located throughout the building for terminal (room level) heating control. Rather than try to capture all the heat by adding hot water coils in each duct that contains an electric coil, we attempted to maximize the displacement of electric heat while minimizing interconnection costs. We propose therefore to replace only the large coils that heat the air first. With minimal changes to controls, we believe we can displace 70 percent of the building heat with hot water in this way.

In the dorms (each two stories, an 8-plex and a 6-plex) the existing heating system consists of electric baseboard heat. The unit living rooms are the largest spaces, and front on the entry side of the unit. At each level, there is a covered walkway – new hot water piping could be run in a soffit in the overhang, and a new hydronic baseboard unit could be piped into each living room. Because the complex uses more domestic hot water than the NOAA building (which we can displace), we estimate 80 percent of the dorm heat can be displaced with "wood heat".

Biomass heating systems are expensive to install. The economics generally work better for larger buildings, or where two or more smaller buildings can be grouped together and served by a single biomass boiler, using buried piping between the buildings to distribute the heat. A significant part of the cost of a district heating plant (DH Plant) is the interconnections to the individual boilers.

The three USFS buildings are already tied together, which significantly helps the economics for this cluster of buildings. The economics of adding either/both the dorms and/or the NOAA building into a larger DH Plant, on the other hand, are not favorable. First, they are physically remote from the USFS building and each other. Second, because they use electric heat coils (in ducts and in baseboard units), all the heat cannot be displaced with hot water. Finally, the cost of the interconnections is higher than simply tying into a building with an existing hot water boiler/piping system.

This report models the performance of one set of (4) DH Plants, and one individual building. In the model, each configuration of DH Plant is labeled a Scenario; the model shows up to four Scenarios at a time (they are abbreviated Scenario 1, Scenario 2, and so on). The individual building is the Mendenhall Glacier Visitor Center, which is on a different site altogether from the rest of the buildings.

For the four DH Plants, we looked at combinations of buildings at the USFS complex; the USFS building (plus warehouses) was in all four Scenarios. Figure 1.1 shows the makeup of all four Scenarios:

Building Information, Part 1

					0.79	0.79	0.79	0.79	oil
Bldg ID	No. ea	Res ?	Name	kWh	include in Sc 1	Sc 2	Sc 3	Sc 4	ann gal each
1	1		USFS Office Complex		1	1	1	1	10,852
2	1		Large warehouse		1	1	1	1	3,617
3	1		Small warehouse		1	1	1	1	1,809
4	1		Dorms	44,222		1		1	
5	1		NOAA	80,894			1	1	
6	1		MGVC						4,000

Figure 1.1

The red values are the amount of heat, in kWh, that we believe can be displaced from the dorms/NOAA, not the total amount of annual heat. For the "non-electric" buildings, the amount of annual oil use is shown. Scenario 1 is only the USFS 3-building group. Scenario 4 is all five buildings, and Scenario 2 and Scenario 3 are different combinations between those endpoints.

Due to site factors, 12 analyses were created for each Scenario. These are:

1. Base case, with pellets. This assumes a new pellet boiler
2. ACT case, with pellets. This assumes a relocated, used, ACT boiler is installed
3. Base case, with wood chips. This assumes a new chip boiler
4. ACT case, with wood chips. This assumes a relocated, used, ACT boiler is installed

Four sets of boiler configurations times three pricing alternates = 12 analyses per Scenario

Items 1 through 4 were analyzed first using the current costs for oil and wood products. These are not favorable to a biomass project because the USFS currently receives oil on a contract at a very low price of $2.93 per gallon. This low price of oil means there is not much of a unit cost differential between oil and wood (see Fig 1.2 below). However, when this contract runs out, the USFS may be forced to pay the same price as the rest of Juneau of $3.85 per gallon. The study therefore looked at the effect of changes in price in both oil and wood with sensitivity analyses.

The first set of four analyses listed above could be considered the Low Oil / Low Wood case, or we simply considered it the Base Case. We then looked at four more analyses, with High Oil / Low

Wood prices. For the final four analyses, we used High Oil / High Wood prices. The results are in subsection 1.7 below.

1.5 Financial Metrics

There are a number of financial metrics that can be employed to evaluate a project. Many of these require that the source and means of financing the project be known. Many require knowing the expected interest rate that money could be borrowed at, and even the rate of return the client would expect to achieve if they invested the capital elsewhere (not in the project).

At Level 2, we use two financial metrics. Net simple payback (NSP) does not require any assumptions about interest rates or escalation rates. It is simply: *the project implementation cost divided by the year one savings*, and the units are "years".

The Benefit / Cost ratio (B/C), on the other hand, requires assumptions on both interest rates and fuel escalation rates. The B/C is defined below:

> *The benefit to cost ratio is an attempt to capture the value of the project over the lifetime of the project; a lifetime of 20 years is commonly used. The output of the calculations included is actually two numbers, the actual benefit/cost ratio, and the net present value (NPV) benefit of the project.*
>
> *The project cost is a one-time event, but the savings accrue over the life of the project. Depending on the assumed inflation rate of the various fuel sources, the savings may actually increase each year (if, for instance, oil rises faster than biomass). On the other hand, a dollar saved in year 20 is not worth a dollar today; it is worth the NPV of one dollar at the assumed discount rate. The discount rate is the rate of return one assumes the Client could make if that dollar were invested in some other fashion – in a bank account, or on another project. The combination of one time and recurring costs, plus inflation and discount means that it would be very useful if the lifetime benefits, divided by the lifetimes costs, could be boiled down to one number; the benefit to cost ratio.*
>
> *The current year is always year zero for the calculation, and it is generally assumed that construction would be completed in year one (or, for a long process or project, year two). The NPV of the project cost for a project completed in year one is almost, but not quite the same as the project cost; it has only been discounted one year. This is the COST part of the ratio. The BENEFIT is the NPV of the cash stream of savings (fuel savings, in this case) that the project generates over the 20-year lifetime. Divide the Benefit (in dollars) by the Cost (in dollars), and you get the dimensionless Benefit to Cost ratio; generally, any value over 1.00 is considered good, but different agencies have different target values.*
>
> *The NPV benefit is simply the NPV of the combined (savings minus cost) Cost and Savings cash flow over 20 years. In the year the project is constructed, the "savings stream" is negative, because the discounted project cost is much greater than the yearly savings – all other years, the savings are positive. Take the NPV of that cash stream, and that is the NPV benefit of the project. Unlike the B/C ratio, this value only really tells one something useful when compared to another*

variant of the same project, or another project that would use the same initial cash input. The project with the higher NPV benefit (n dollars) is generally better.

The client discount rate and escalation assumptions used in the B/C and NPV Benefit calculations are shown in Figure 1.2 below. All Building Level and DH Plant summaries indicate the NSP, B/C and NPV Benefit values for that opportunity. These nominal rates reflect recent escalation rates in SE Alaska. Note again that while the escalation rates do not affect NSP, they strongly affect the Benefit to Cost Ratio, which is based on 20 years of energy costs inflated at the rates shown below.

Escalation Factors (nominal)	client discount rate	**0.040**
variable	rate	
oil	0.0675	per year
electrical energy	0.0400	per year
wood chips	0.0330	per year
wood pellets, bricks	0.0330	per year
maintenance, labor	0.0300	per year

Figure 1.2

At this level of study, it does not matter so much whether these values are correct (as it would in a Level 3 study) – as long as they are reasonable, and the same for all opportunities; they enable comparisons of the different configurations and Scenarios.

1.6 Resource Assumptions

As noted above, the only forms of biomass considered in this report are wood pellets and wood chips. The oil used by USFS is No. 2 oil.

Figure 1.3 below shows the unit prices and heat contents used for various energy sources in this report. Note that the units cost values ($/mmBTU) are output heat units; they include the assumed efficiency of the boiler. Thus, if a gallon of fuel X has 1000 BTU/gal of heat content, using an 80 percent efficient boiler would mean the same fuel had a heat output of 800 BTU/gal. Electric heat is assumed to be 100 percent efficient. All heat sources prices are converted to dollars per million BTU ($/mmBTU) so they can be directly compared. The price as purchased (i.e. in the units in which one buys them) are listed in the "description" column. The values in the far left column are input heat content, per unit in which the heat is purchased (per kWh, per gal, etc).

Unit Energy Costs, comparison (to village, boiler eff accounted for)				**per mmBTU**	
kBTU/ unit	fuel	value	units	delta from Low Oil	delta from High Oil
138.5	No. 2 oil, at $2.92/gal	$25.18	per mmBTU		
138.5	No. 2 oil, at $3.85/gal	$33.09	per mmBTU	$7.91	
3.4	electrical, energy, at $0.110/kWh	$32.24	per mmBTU	$7.05	($0.85)
11,422.2	wood chips, at $200/ton	$20.60	per mmBTU	($4.59)	($12.49)
11,422.2	wood chips, at $250/ton	$25.75	per mmBTU	$0.56	($7.34)
16,400.0	pellets, at $325/ton	$22.21	per mmBTU	($2.97)	($10.88)
16,400.0	pellets, at $375/ton	$25.63	per mmBTU	$0.45	($7.46)

Figure 1.3

As Fig 1.3 shows, at the "Low Oil" price of $2.93 a gallon, the "High Wood" prices are actually higher per mmBTU. USFS would be losing money to convert to wood in such a price configuration. At the High Oil price, the Low Wood shows a relatively good price differential of $12.49 (chips) or $10.88 (pellets). In rural Alaska, wood is often $20 to $30 less per mmBTU than oil, thus economy of scale and low implementation costs are even more important in this case.

1.7 Summary of Findings

As noted above, 12 analyses were performed for each Scenario. In order to structure the information effectively, each Scenario has three tables, and each table has four results. In order, the results are for: 1) Base Case (pellets), 2) ACT boiler (pellets), 3) Base Case (chips) and 4) ACT boiler (chips). To re-iterate, the two differences between the Base Case and ACT boiler are: A) in the Base Case, we assume the project buys a brand new pellet or chip boiler, and B) the actual savings may vary as the parasitic electric consumption of the boilers vary.

The three tables vary only in the cost of the inputs (thus, the second and third tables constitute a sensitivity analysis on the price of oil and wood), showing first "Current Oil / Low Wood, then High Oil / Low Wood, and finally, High Oil / High Wood. Low Oil / High Wood is unworkable for any Scenario, so, pricing configuration is not presented. In fact, Current (Low) Oil / Low Wood does not work well for any Scenario and is presented because it is in the current configuration of prices. As long as the oil prices remain at the current low level, any project would be marginal, at best.

The Tables below each have three footnotes; due to space considerations, these are included here instead of just below each set of tables:

(1) Implementation cost includes all construction costs, OH&P, and all soft costs (design, etc)
(2) Includes wood pellets, any oil for periods when load exceeds DH Plant capacity, and added electrical pumping and parasitic energy
(3) Maintenance (chips only) is assumed to be contract labor, and is assumed to be 5 hours a week, or 1/8th of an FTE – annual FTE cost is assumed to be $60,000/yr, fully burdened

<u>Chip boilers</u>: Viessmann 150 and ACT 1400 | <u>Pellet boilers</u>: (3) x MES 56 and ACT 1400.

Summary of Scenario Financial Results				**Sc 1**
$2.93 oil, per gallon			client discount rate	**4.00%**
$325.00 pellets,per ton			term for net present value calcs	**20.0 yrs**
$200.00 chips, per green ton				
	pellets		**chips**	
Low Oil - Low Wood	Base	ACT boiler	Base	ACT Boiler
(1) project implementation cost	**$253,549**	**$128,273**	**$379,772**	**$143,899**
Base Fuel cost (oil only)	$47,695	$47,695	$47,695	$47,695
(2) Proposed Fuel costs (wood, oil, elec)	$42,678	$44,738	$40,478	$41,310
estimated annual savings	$5,017	$2,956	$7,217	$6,384
(3) Increased maintenance costs			$7,500	$7,500
total savings	**$5,017**	**$2,956**	**($283)**	**($1,116)**
net simple payback	50.5 yrs	43.4 yrs	-1,339.8 yrs	-129.0 yrs
benefit to cost ratio	**2.048**	**3.663**	**1.085**	**2.555**
NPV of savings, including imp cost	$264,991	$334,269	$43,435	$220,458
Base oil displaced	100.0%	100.0%	99.8%	100.0%

Summary of Scenario Financial Results				**Sc 1**
$3.85 oil, per gallon			client discount rate	**4.00%**
$325.00 pellets,per ton			term for net present value calcs	**20.0 yrs**
$200.00 chips, per green ton				
	pellets		**chips**	
High Oil - Low Wood	Base	ACT boiler	Base	ACT Boiler
(1) project implementation cost	**$253,549**	**$128,273**	**$379,772**	**$143,899**
Base Fuel cost (oil only)	$62,670	$62,670	$62,670	$62,670
(2) Proposed Fuel costs (wood, oil, elec)	$42,678	$44,738	$40,506	$41,310
estimated annual savings	$19,992	$17,932	$22,164	$21,360
(3) Increased maintenance costs			$7,500	$7,500
total savings	**$19,992**	**$17,932**	**$14,664**	**$13,860**
net simple payback	12.7 yrs	7.2 yrs	25.9 yrs	10.4 yrs
benefit to cost ratio	**3.766**	**7.060**	**2.230**	**5.434**
NPV of savings, including imp cost	$685,980	$755,274	$463,659	$618,876
Base oil displaced	100.0%	100.0%	99.8%	100.0%

Summary of Scenario Financial Results				**Sc 1**
$3.85 oil, per gallon			client discount rate	**4.00%**
$375.00 pellets,per ton			term for net present value calcs	**20.0 yrs**
$250.00 chips, per green ton				
	pellets		**chips**	
High Oil - High Wood	Base	ACT boiler	Base	ACT Boiler
(1) project implementation cost	**$253,549**	**$128,273**	**$379,772**	**$143,899**
Base Fuel cost (oil only)	$62,670	$62,670	$62,670	$62,670
(2) Proposed Fuel costs (wood, oil, elec)	$49,104	$51,135	$50,114	$50,848
estimated annual savings	$13,566	$11,535	$12,556	$11,823
(3) Increased maintenance costs			$7,500	$7,500
total savings	**$13,566**	**$11,535**	**$5,056**	**$4,323**
net simple payback	18.7 yrs	11.1 yrs	75.1 yrs	33.3 yrs
benefit to cost ratio	**3.252**	**6.049**	**1.717**	**4.149**
NPV of savings, including imp cost	$560,043	$629,907	$275,348	$441,052
Base oil displaced	100.0%	100.0%	99.8%	100.0%

Figure 1.4 Results for Scenario 1, office building and two warehouses.

Summary of Scenario Financial Results				**Sc 2**
$2.93 oil, per gallon		client discount rate		**4.00%**
$325.00 pellets,per ton		term for net present value calcs		**20.0 yrs**
$200.00 chips, per green ton				
	pellets		**chips**	
Low Oil - Low Wood	**Base**	**ACT boiler**	**Base**	**ACT Boiler**
(1) project implementation cost	**$320,490**	**$192,992**	**$443,129**	**$206,712**
Base Fuel cost (oil only)	$52,320	$52,320	$52,320	$52,320
(2) Proposed Fuel costs (wood, oil, elec)	$51,329	$52,968	$47,255	$48,870
estimated annual savings	$990	($648)	$5,065	$3,450
(3) Increased maintenance costs			$7,500	$7,500
total savings	**$990**	**($648)**	**($2,435)**	**($4,050)**
net simple payback	323.6 yrs	-297.9 yrs	-181.9 yrs	-51.0 yrs
benefit to cost ratio	**1.402**	**2.117**	**0.856**	**1.558**
NPV of savings, including imp cost	$134,804	$214,677	($47,353)	$118,473
Base oil displaced	100.0%	100.0%	99.8%	100.0%

Summary of Scenario Financial Results				**Sc 2**
$3.85 oil, per gallon		client discount rate		**4.00%**
$325.00 pellets,per ton		term for net present value calcs		**20.0 yrs**
$200.00 chips, per green ton				
	pellets		**chips**	
High Oil - Low Wood	**Base**	**ACT boiler**	**Base**	**ACT Boiler**
(1) project implementation cost	**$320,490**	**$192,992**	**$443,129**	**$206,712**
Base Fuel cost (oil only)	$67,296	$67,296	$67,296	$67,296
(2) Proposed Fuel costs (wood, oil, elec)	$51,335	$52,968	$47,384	$48,870
estimated annual savings	$15,961	$14,328	$19,912	$18,426
(3) Increased maintenance costs			$7,500	$7,500
total savings	**$15,961**	**$14,328**	**$12,412**	**$10,926**
net simple payback	20.1 yrs	13.5 yrs	35.7 yrs	18.9 yrs
benefit to cost ratio	**2.761**	**4.375**	**1.830**	**3.562**
NPV of savings, including imp cost	$555,652	$635,683	$370,039	$516,891
Base oil displaced	100.0%	100.0%	99.8%	100.0%

Summary of Scenario Financial Results				**Sc 2**
$3.85 oil, per gallon		client discount rate		**4.00%**
$375.00 pellets,per ton		term for net present value calcs		**20.0 yrs**
$250.00 chips, per green ton				
	pellets		**chips**	
High Oil - High Wood	**Base**	**ACT boiler**	**Base**	**ACT Boiler**
(1) project implementation cost	**$320,490**	**$192,992**	**$443,129**	**$206,712**
Base Fuel cost (oil only)	$67,296	$67,296	$67,296	$67,296
(2) Proposed Fuel costs (wood, oil, elec)	$59,067	$60,614	$58,719	$60,270
estimated annual savings	$8,229	$6,682	$8,577	$7,025
(3) Increased maintenance costs			$7,500	$7,500
total savings	**$8,229**	**$6,682**	**$1,077**	**($475)**
net simple payback	38.9 yrs	28.9 yrs	411.6 yrs	-435.6 yrs
benefit to cost ratio	**2.271**	**3.572**	**1.312**	**2.493**
NPV of savings, including imp cost	$404,111	$485,826	$147,882	$304,330
Base oil displaced	100.0%	100.0%	99.8%	100.0%

Figure 1.5 Results for the office building, 2 warehouses and dorms.

Summary of Scenario Financial Results				Sc 3
$2.93 oil, per gallon			client discount rate	4.00%
$325.00 pellets,per ton			term for net present value calcs	20.0 yrs
$200.00 chips, per green ton				
	pellets		**chips**	
Low Oil - Low Wood	**Base**	**ACT boiler**	**Base**	**ACT Boiler**
(1) project implementation cost	**$316,878**	**$189,380**	**$429,682**	**$203,100**
Base Fuel cost (oil only)	$56,191	$56,191	$56,191	$56,191
(2) Proposed Fuel costs (wood, oil, elec)	$53,849	$55,449	$49,625	$51,147
estimated annual savings	$2,342	$742	$6,567	$5,044
(3) Increased maintenance costs			$7,500	$7,500
total savings	**$2,342**	**$742**	**($933)**	**($2,456)**
net simple payback	135.3 yrs	255.1 yrs	-460.3 yrs	-82.7 yrs
benefit to cost ratio	**1.532**	**2.356**	**0.968**	**1.781**
NPV of savings, including imp cost	$173,271	$254,305	$872	$160,023
Base oil displaced	100.0%	100.0%	99.7%	100.0%

Summary of Scenario Financial Results				Sc 3
$3.85 oil, per gallon			client discount rate	4.00%
$325.00 pellets,per ton			term for net present value calcs	20.0 yrs
$200.00 chips, per green ton				
	pellets		**chips**	
High Oil - Low Wood	**Base**	**ACT boiler**	**Base**	**ACT Boiler**
(1) project implementation cost	**$316,878**	**$189,380**	**$429,682**	**$203,100**
Base Fuel cost (oil only)	$71,167	$71,167	$71,167	$71,167
(2) Proposed Fuel costs (wood, oil, elec)	$53,867	$55,449	$49,855	$51,147
estimated annual savings	$17,300	$15,718	$21,312	$20,020
(3) Increased maintenance costs			$7,500	$7,500
total savings	**$17,300**	**$15,718**	**$13,812**	**$12,520**
net simple payback	18.3 yrs	12.0 yrs	31.1 yrs	16.2 yrs
benefit to cost ratio	**2.906**	**4.657**	**1.967**	**3.821**
NPV of savings, including imp cost	$593,778	$675,311	$415,412	$558,440
Base oil displaced	100.0%	100.0%	99.7%	100.0%

Summary of Scenario Financial Results				Sc 3
$3.85 oil, per gallon			client discount rate	4.00%
$375.00 pellets,per ton			term for net present value calcs	20.0 yrs
$250.00 chips, per green ton				
	pellets		**chips**	
High Oil - High Wood	**Base**	**ACT boiler**	**Base**	**ACT Boiler**
(1) project implementation cost	**$316,878**	**$189,380**	**$429,682**	**$203,100**
Base Fuel cost (oil only)	$71,167	$71,167	$71,167	$71,167
(2) Proposed Fuel costs (wood, oil, elec)	$61,977	$63,476	$61,695	$63,115
estimated annual savings	$9,190	$7,691	$9,472	$8,052
(3) Increased maintenance costs			$7,500	$7,500
total savings	**$9,190**	**$7,691**	**$1,972**	**$552**
net simple payback	34.5 yrs	24.6 yrs	217.9 yrs	368.0 yrs
benefit to cost ratio	**2.386**	**3.797**	**1.408**	**2.678**
NPV of savings, including imp cost	$434,841	$517,989	$183,343	$335,291
Base oil displaced	100.0%	100.0%	99.7%	100.0%

Figure 1.6 Results for the office building, 2 warehouses and the NOAA building.

Summary of Scenario Financial Results				Sc 4
$2.93 oil, per gallon		client discount rate		4.00%
$325.00 pellets,per ton		term for net present value calcs		20.0 yrs
$200.00 chips, per green ton				
	pellets		chips	
Low Oil - Low Wood	Base	ACT boiler	Base	ACT Boiler
(1) project implementation cost	$340,751	$213,253	$461,941	$226,973
Base Fuel cost (oil only)	$60,816	$60,816	$60,816	$60,816
(2) Proposed Fuel costs (wood, oil, elec)	$58,948	$60,481	$54,410	$55,765
estimated annual savings	$1,868	$335	$6,406	$5,052
(3) Increased maintenance costs			$7,500	$7,500
total savings	**$1,868**	**$335**	**($1,094)**	**($2,448)**
net simple payback	182.4 yrs	635.8 yrs	-422.3 yrs	-92.7 yrs
benefit to cost ratio	**1.428**	**2.110**	**0.907**	**1.645**
NPV of savings, including imp cost	$152,187	$235,752	($26,460)	$149,120
Base oil displaced	100.0%	100.0%	99.7%	100.0%

Summary of Scenario Financial Results				Sc 4
$3.85 oil, per gallon		client discount rate		4.00%
$325.00 pellets,per ton		term for net present value calcs		20.0 yrs
$200.00 chips, per green ton				
	pellets		chips	
High Oil - Low Wood	Base	ACT boiler	Base	ACT Boiler
(1) project implementation cost	$340,751	$213,253	$461,941	$226,973
Base Fuel cost (oil only)	$75,792	$75,792	$75,792	$75,792
(2) Proposed Fuel costs (wood, oil, elec)	$59,008	$60,481	$54,852	$55,765
estimated annual savings	$16,785	$15,311	$20,940	$20,028
(3) Increased maintenance costs			$7,500	$7,500
total savings	**$16,785**	**$15,311**	**$13,440**	**$12,528**
net simple payback	20.3 yrs	13.9 yrs	34.4 yrs	18.1 yrs
benefit to cost ratio	**2.702**	**4.154**	**1.822**	**3.470**
NPV of savings, including imp cost	$571,526	$656,757	$382,117	$547,538
Base oil displaced	100.0%	100.0%	99.7%	100.0%

Summary of Scenario Financial Results				Sc 4
$3.85 oil, per gallon		client discount rate		4.00%
$375.00 pellets,per ton		term for net present value calcs		20.0 yrs
$250.00 chips, per green ton				
	pellets		chips	
High Oil - High Wood	Base	ACT boiler	Base	ACT Boiler
(1) project implementation cost	$340,751	$213,253	$461,941	$226,973
Base Fuel cost (oil only)	$75,792	$75,792	$75,792	$75,792
(2) Proposed Fuel costs (wood, oil, elec)	$67,875	$69,281	$67,713	$68,885
estimated annual savings	$7,918	$6,511	$8,079	$6,907
(3) Increased maintenance costs			$7,500	$7,500
total savings	**$7,918**	**$6,511**	**$579**	**($593)**
net simple payback	43.0 yrs	32.8 yrs	797.3 yrs	-382.6 yrs
benefit to cost ratio	**2.174**	**3.317**	**1.258**	**2.349**
NPV of savings, including imp cost	$397,741	$484,286	$130,064	$302,900
Base oil displaced	100.0%	100.0%	99.7%	100.0%

Figure 1.7 Results for the office, 2 warehouses, dorms, and NOAA building.

To summarize:

- The Base Case values (with new purchased boilers) have much longer paybacks than the ACT boiler cases (where the USFS relocates a used boiler).
- The Base Cases were presented because they are the "normal" means of implementing a project, and as such, illustrate the value of having the used ACT boilers available.
- For that reason, it will be assumed that any project implemented will use the ACT boilers; no further comments will be made about the Base Cases.
- Likewise, none of the Scenarios show strong economics with the current price of oil (Scenario 1 comes the closest, with a 14.6 year payback on chips) and it is not recommend proceeding with any of these projects at the current oil price.
- For that reason, <u>all further comments below assume the High Oil price is in effect</u>.
- Due to the increased maintenance associated with the chip-fired boilers, there is only one chip-fired DH Plant configuration out of the 12 that offers a payback that would be considered worth pursuing. Scenario 1 (USFS buildings only), with High Oil and Low Wood prices would be considered. <u>This virtually eliminates a chip-fired DH Plant</u> as an option, unless USFS assumes the High Oil / Low Wood pricing is very likely to occur.
- **Scenario 1** is a relatively strong project on pellets, regardless of High or Low Wood price (although much better on Low Wood), due to existence of the necessary piping and interconnections.
- **Scenarios 2, 3 and 4** (USFS cluster plus various combinations of NOAA / dorms) are reasonable projects which might be worth further study, <u>but only</u> in the High Oil / Low Wood pricing configuration.
- Many of these Scenario results show very favorable benefit to cost ratios (B/C), even when the simple payback is negative. This is a result of the very high rate of escalation of the Base fuel, oil, compared to the escalation rate of the alternate, wood. Although the values used are historically accurate, implementing a project with a negative Year 1 payback, but a very high NPV and B/C ratio is assuming future commodity prices. AWEA does not recommend such projects.

Scenario 1 is easily the most viable project of all those analyzed, especially with High Oil / Low Wood. Figure 1.8 below shows both the monthly fuel values, as well as the costs, for this configuration:

Scenario 1: Inputs and Costs														High Oil / Low Wood
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	total
BASE oil	gal	2,051	1,703	1,891	1,434	1,044	708	633	675	904	1,335	1,801	2,099	16,278
BASE oil cost	$3.85	$7,895	$6,556	$7,279	$5,520	$4,021	$2,725	$2,439	$2,600	$3,482	$5,139	$6,934	$8,081	$62,670
Proposed														
biomass	tons	16.1	13.4	14.9	11.3	8.2	5.5	5.0	5.3	7.1	10.5	14.2	16.5	127.9
oil	gal													
electrical	kWh	2,638	2,383	2,638	2,553	2,638	2,553	2,638	2,638	2,553	2,638	2,553	2,638	31,061
biomass cost	$325	$5,247	$4,353	$4,833	$3,659	$2,663	$1,804	$1,614	$1,721	$2,305	$3,405	$4,603	$5,370	$41,578
oil cost	$3.850													
electrical cost	$0.111	$292	$264	$292	$282	$292	$228	$236	$236	$228	$236	$282	$292	$3,161
total Scenario cost		$5,538	$4,617	$5,125	$3,942	$2,955	$2,032	$1,850	$1,957	$2,534	$3,641	$4,886	$5,662	$44,738
savings		**$2,357**	**$1,939**	**$2,154**	**$1,578**	**$1,066**	**$693**	**$588**	**$643**	**$948**	**$1,498**	**$2,048**	**$2,419**	**$17,932**

Figure 1.8

In addition to the DH Plants listed above, the MGVC was evaluated for an individual boiler. In this case, only with wood pellets were considered. The Information package that came from the USFS noted the importance of maintaining the appearance of the area around the Center. Wood pellets are both much more energy dense than chips (less storage space required), they are virtually dust-free and often stored indoors in dedicated bins. The needs of the Center would not be satisfied using wood chips as a fuel. They are, however, slightly less expensive than pellets on a $/mmBTU basis, so if some means of maintaining the required level of appearance could be met with stored chips, the economics would be slightly better.

As with the DH Plants, a Base Case was evaluated utilizing brand new boilers, but none are economically viable. In all cases, it was assumed the ACT boilers would be used. As above, results, are shown from top to bottom, with Current (Low) Oil / Low Wood, then High Oil / Low Wood, and finally High Oil / High Wood. Note that the "22" in the upper right corner of each Table is simply a code which corresponds to the selected boiler.

1	**Pellet-Fired Boiler**			ACT Bioenergy 500	boiler 1	22
in No.					boiler 2	
B6	**MGVC**				boiler 3	
current oil	4,000 gal	chips req	31 tons	boiler(s)		
unit price	$2.930	unit price	$325	building		
annual cost	$11,720	annual cost	$10,195	mechanical	$9,635	
				electrical	$600	
proposed oil		electrical	14,727 kWh	controls	$4,400	
unit price		unit price	$0.110	project costs	$6,586	
annual cost		annual cost	$1,620	total cost	$21,221	
oil displaced	4,000 gal			ann savings	($95)	
fraction disp	100.0%			**NSP**		
NPV benefit	**$75,768**			**B / C ratio**	**4.662**	

1 in No. B6	**Pellet-Fired Boiler** MGVC			ACT Bioenergy 500		boiler 1 boiler 2 boiler 3	22
current oil	4,000 gal	chips req	31 tons	boiler(s)			
unit price	$3.850	unit price	$325	building			
annual cost	$15,400	annual cost	$10,195	mechanical	$9,635		
				electrical	$600		
proposed oil		electrical	14,727 kWh	controls	$4,400		
unit price		unit price	$0.110	project costs	$6,586		
annual cost		annual cost	$1,620	total cost	$21,221		
oil displaced	4,000 gal			ann savings	$3,585		
fraction disp	100.0%			**NSP**	**5.9 yrs**		
NPV benefit	**$179,222**			**B / C ratio**	**9.707**		

1 in No. B6	**Pellet-Fired Boiler** MGVC			ACT Bioenergy 500		boiler 1 boiler 2 boiler 3	22
current oil	4,000 gal	chips req	31 tons	boiler(s)			
unit price	$3.850	unit price	$375	building			
annual cost	$15,400	annual cost	$11,763	mechanical	$9,635		
				electrical	$600		
proposed oil		electrical	14,727 kWh	controls	$4,400		
unit price		unit price	$0.110	project costs	$6,586		
annual cost		annual cost	$1,620	total cost	$21,221		
oil displaced	4,000 gal			ann savings	$2,017		
fraction disp	100.0%			**NSP**	**10.5 yrs**		
NPV benefit	**$148,483**			**B / C ratio**	**8.208**		

Figure 1.9

With the Low Oil price, savings are actually negative; the fuel is slightly less expensive, but cost of the added parasitic electrical load was greater than the small fuel savings. Assuming a High Oil price, however, the project can be attractive, depending on the price of pellets.

Generally a 20-year cash flow analysis is presented for the Scenarios, however, because of the number of options, and the fact that most of the numbers would never be used, they are not presented here. If the USFS indicates an interest in specific Scenarios and price configurations, the report could be amended with the specific associated cash flows of interest.

The project cost estimates, however, do not change much, one set for pellets, and one for chips, which are independent of the cost of oil/wood. Figures 1.10 and 1.11 show summaries of these estimates (these are for the ACT boiler case only, not the Base Case). For pellets:

Discipline Totals		Sc 1	Sc 2	Sc 3	Sc 4
controls hard costs		$15,013	$18,140	$17,905	$19,937
general conditions	0.035	$525	$635	$627	$698
equip rental, tools	0.010	$150	$181	$179	$199
margin	0.100	$1,743	$2,106	$2,079	$2,315
total controls		**$17,432**	**$21,063**	**$20,790**	**$23,149**
electrical hard costs		$2,480	$2,480	$2,480	$2,480
general conditions	0.035	$87	$87	$87	$87
equip rental, tools	0.015	$37	$37	$37	$37
margin	0.100	$289	$289	$289	$289
total electrical		**$2,893**	**$2,893**	**$2,893**	**$2,893**
site hard costs		$27,609	$62,723	$60,409	$75,228
general conditions	0.025	$690	$1,568	$1,510	$1,881
equip rental, tools	0.030	$828	$1,882	$1,812	$2,257
margin	0.100	$3,236	$7,353	$7,081	$8,818
total site		**$32,364**	**$73,525**	**$70,813**	**$88,184**
mechanical hard costs		$35,123	$42,611	$42,611	$42,611
general conditions	0.025	$878	$1,065	$1,065	$1,065
equip rental, tools	0.020	$702	$852	$852	$852
margin	0.100	$4,078	$4,948	$4,948	$4,948
total mechanical		**$40,782**	**$49,476**	**$49,476**	**$49,476**

total construction		**$93,471**	**$146,958**	**$143,973**	**$163,703**
final design/study	0.075	$7,010	$11,022	$10,798	$12,278
bid assistance	0.005	$467	$735	$720	$819
construction admin (with Force Contract)	0.005	$467	$735	$720	$819
construction admin (without Force Contract)					
Cx/start up	0.010	$935	$1,470	$1,440	$1,637
contingency	0.100	$9,347	$14,696	$14,397	$16,370
do CA with force contract	1				
weekly cost, force contract	4,000	$4,000	$4,000	$4,000	$4,000
construction, weeks		1	1	1	1
total soft costs		**$22,227**	**$32,657**	**$32,075**	**$35,922**
subtotal, less permitting		**$115,698**	**$179,615**	**$176,047**	**$199,625**
permit fee, fraction of construction cost	0.015	**$1,402**	**$2,204**	**$2,160**	**$2,456**
permit review fee		**$750**	**$750**	**$750**	**$750**
total implementation		**$117,850**	**$182,569**	**$178,957**	**$202,830**

Figure 1.10

For wood chips:

Discipline Totals		Sc 1	Sc 2	Sc 3	Sc 4
controls hard costs		$15,013	$18,140	$17,905	$19,937
general conditions	0.035	$525	$635	$627	$698
equip rental, tools	0.010	$150	$181	$179	$199
margin	0.100	$1,743	$2,106	$2,079	$2,315
total controls		**$17,432**	**$21,063**	**$20,790**	**$23,149**
electrical hard costs		$608	$2,480	$2,480	$2,480
general conditions	0.035	$21	$87	$87	$87
equip rental, tools	0.015	$9	$37	$37	$37
margin	0.100	$71	$289	$289	$289
total electrical		**$709**	**$2,893**	**$2,893**	**$2,893**
site hard costs		$27,609	$62,723	$60,409	$75,228
general conditions	0.025	$690	$1,568	$1,510	$1,881
equip rental, tools	0.030	$828	$1,882	$1,812	$2,257
margin	0.100	$3,236	$7,353	$7,081	$8,818
total site		**$32,364**	**$73,525**	**$70,813**	**$88,184**
mechanical hard costs		$55,545	$59,795	$59,795	$59,795
general conditions	0.025	$1,389	$1,495	$1,495	$1,495
equip rental, tools	0.020	$1,111	$1,196	$1,196	$1,196
margin	0.100	$6,449	$6,943	$6,943	$6,943
total mechanical		**$64,494**	**$69,429**	**$69,429**	**$69,429**
total construction		**$114,999**	**$166,911**	**$163,925**	**$183,655**
final design/study	0.075	$8,625	$12,518	$12,294	$13,774
bid assistance	0.005	$575	$835	$820	$918
construction admin (with Force Contract)	0.005	$575	$835	$820	$918
construction admin (without Force Contract)					
Cx/start up	0.010	$1,150	$1,669	$1,639	$1,837
contingency	0.100	$11,500	$16,691	$16,393	$18,366
do CA with force contract	1				
weekly cost, force contract	4,000	$4,000	$4,000	$4,000	$4,000
construction, weeks		1	1	1	1
total soft costs		**$26,425**	**$36,548**	**$35,965**	**$39,813**
subtotal, less permitting		**$141,424**	**$203,458**	**$199,891**	**$223,468**
permit fee, fraction of construction cost	0.015	**$1,725**	**$2,504**	**$2,459**	**$2,755**
permit review fee		**$750**	**$750**	**$750**	**$750**
total implementation		**$143,899**	**$206,712**	**$203,100**	**$226,973**

Figure 1.11

All of these potential projects would benefit from higher oil costs and lower wood costs. There is also a possibility that, as wood pellets and chips become more common in SE Alaska, there will be more suppliers and more economy of Scale, causing unit prices to drop rather than rise. USFS must evaluate the risks of movements in the costs of inputs (oil, electrical energy, chips and pellets).

1.8 Next steps

From a purely financial point of view, at the current low oil price, the projects may not be very attractive. If current oil price is projected to remain for some time, the USFS may want to postpone further work on biomass until the price rises, then re-evaluate.

If, however, that contract will soon expire and may not be offered again, it remains to be determined what elements are required for a successful project, and the possibility of delivering those elements within parameters appropriate for the Service.

In addition to financial performance, SI and efour believe that wood energy projects generate benefits to the Village beyond the obvious monetary ones, called VBECS (value beyond energy cost savings), a term borrowed from the Rocky Mountain Institute. Among these VBECS are:

- Use of renewable resources
- Reliance on regional, rather than remote energy sources
- Reduced carbon footprint
- Reduced secondary emissions (NOx, S, CO, etc)
- Increased fuel price stability (for future budget planning)
- Energy money spent remains in the regional economy
- Support for developing a stable regional chip or pellet supply

There are, no doubt, others as well. As was noted above, a Level 2 study is a Screening study, meant to provide enough information to the stakeholders to A) determine how to proceed next, B) determine whether to proceed, or C) halt the project until conditions improve. This study provides the information needed to help the USFS and other stakeholders make these decisions.

2 TECHNICAL SUMMARY

2.1 Existing Conditions

There are a number of buildings involved in this study, spread across two sites. The existing conditions at each are summarized in Figure 2.1 below:

Existing Conditions		
USFS Study		
USFS Site:		
No. buildings	5	(2 dorms count as 1 bldg)
USFS Office		
approx area	20,244	sf
age	8	yrs
system type		forced air with HW coils
USFS Large Warehouse		
approx area	11,678	sf
age	8	yrs
system type		radiant slab
USFS Small Warehouse		
approx area	4,088	sf
age	8	yrs
system type		forced air with HW coils
NOTE that all three buildings above are served by a single HW boiler in the office building, connected with buried piping		
total oil consumption, all 3	16,278	gallons per year
Dorms		
approx area	18,400	sf
age	unk	
system type		electric baseboard
total estimated energy to heat	55,278	kWH per year
NOAA Office Building		
approx area	13,300	sf
age	unk	
system type		forced air with electric coils
total estimated energy to heat	115,563	kWH per year
MGVC Site Site:		
No. buildings	1	
MG Visitors Center		
approx area	5,000	sf
age	18	yrs
system type		HW baseboard / HW coils

Figure 2.1

As noted above, we believe only about 70 percent of the heating energy can be displaced in the NOAA building, and 80 percent in the dorms.

2.2 Wood Fuels / Wood Fired Heating Equipment:

Figure 2.2 below shows the properties of the pellets and wood chips that were used in this study (pellets are assumed to come from the Ketchikan area, and thus have a slightly different composition than a Juneau chip might have, but the heat content would not be noticeably different):

Composite Pellet Properties		
net useable heat	8,128	BTU/lb at burn MC
density as pellets	23.535	lb/cf at burn MC
ash	0.0160	lb/wet lb at burn MC
ash volume	0.0025	cf/wet lb at burn MC

Wood for Chips		MC at	0.25	weight
		cut	burn	fraction
1	Cottonwood, logs			
2	Birch, logs			
3	Aspen, logs			
4	B Spruce, logs			
5	W Spruce, logs			
6	Western Hemlock	0.50	0.25	0.600
7	Douglas Fir	0.50	0.25	0.300
8	White Cedar	0.50	0.25	0.100
9				
10				

Composite Chip Properties		
net useable heat	5,711	BTU/lb at burn MC
weight at cut MC	1.500	lb/lb at burn MC
density as stacked logs	22.414	lb/cf at burn MC
density as chips	23.535	lb/cf at burn MC
combustion air req	5.423	lb/wet lb at burn MC
combustion air req	0.468	cf/wet lb at burn MC
CO2 formed	1.3741	lb/wet lb at burn MC
SOx formed	0.0011	lb/wet lb at burn MC
ash	0.0120	lb/wet lb at burn MC
ash volume	0.0019	cf/wet lb at burn MC

Figure 2.2

The most pertinent values in Figure 22 are the net useable heat contents, 8,162 BTU/lb and 5,711 BTU/lb, pellets and chips, respectively. Because of their low moisture content (4 percent), pellets are by far the most energy-dense form of wood fuel, and they generally cost more per BTU.

There are a number of manufacturers of pellet boilers; the basis of design (Base Case) boilers used in this study are the PES series of boilers made by Maine Energy Systems (MES). There are eight sizes in the PES series, ranging from 41 kBTU/h to 191 kBTU/h (output).

For the Base Case wood chip systems, the Basis of Design was the Pyrot line of boiler manufactured by Viessmann of Germany.

The basic pellet system components include:

- A pellet bin, which holds bulk amounts of wood pellets.
  - is kept filled by periodic deliveries to the Village by truck and ferry
  - allows a number of delivery and loading methods once within the Village
- A means of getting the pellets from the bin into the boiler (material handling)
  - a vacuum system; the bin may be up to 66 ft away from the boiler
- The boiler

  - uses onboard controls to modulate the firing rate to meet heating demand
  - will remain on and operating as long as the bin is kept filled, and no fuel fouling occurs
  - is a "hands-off" unit
- A vent or boiler stack
  - vents the products of combustion and boiler emissions into the air through an elevated stack or vent pipe
  - may or may not include additional emissions control equipment

The basic wood chips system components, which differ from pellet system components, include:

- Chip storage, which holds bulk amounts of wood chips.
  - a smaller amount is held on site, perhaps one week's worth, in a covered and (usually) heated area (a "day bin")
  - usually a larger chip storage area, covered, generally has no side and is not heated
  - chips bought by the ton, the large bulk storage is generally at the vendor's facility, and not part of the project
- A means of getting the chips from the day bin into the boiler (material handling)
  - usually an auger or drag chain
- A means of getting the bulk chips from the vendor into the day bin
  - generally owned and supplied by the chip vendor (when buying in bulk)

2.3 Proposed Conditions, Scenario 1

In Scenario 1, it was assumed that the new boiler and any chip or pellet storage would be in a new, dedicated building or container (pre-fabricated boiler plant) between the basement/mechanical room of the existing USFS office building and the smaller warehouse. The building would be as in Section 2.4. Since the existing boiler ties into the Warehouses through buried piping, only a single connection is required to connect all three buildings to a new wood fired boiler.

2.4 Scenarios 2 through 4

In Scenarios 2 through 4, a brand new boiler building is assumed. In the Base Case, this would be a pre-fabricated containerized Plant, built at the vendor's facility. Since the assumption is that existing used boilers are being used, it is also assumed a purpose-built Plant located at the intersection on site where all four access roads meet.

- The site is leveled, and any fill required is brought in for leveling and freeze protection.
- A new building, about 160 sf, is built on the slab.
- Water, power, sewer and storm drainage are extended to the building.
- The single biomass boiler is installed, and piped up.
- A thermal storage tank is included (see section 3).
- A heat exchanger is installed to separate the primary side (Plant) from the secondary side (distribution).
- Secondary pumps are installed.
- All required electrical work is installed.
- Automatic controls are installed to control and sequence the boilers.
- PEX piping is run to the USFS Office, NOAA, and the dorms.
- Interconnections are made to each building (Appendix 1).

2.5 Energy Savings

As with the cash flows above, too many different tables would be required to represent the savings for every analysis performed. If the USFS selects exact configurations they might be interested in, savings summary for those configurations will be provided.

2.5 Cost Estimate

The construction cost estimate summaries are provided in Section 1 above. Once USFS determines which, if any, Scenario and fuel is worth further study, a detailed line item estimate for those Scenarios will be provided.

Appendix A. Interconnections

Interconnections and the Impact on Construction Cost

One of the most important features of a District Heating system is the interconnection between the DH system and the existing buildings systems. These interconnections can range from complex (and expensive), to very simple, often with one or more variations in between. The simpler the interconnections, the less expensive they are. However, even the least expensive connections constitute a significant amount of money. The goal, therefore, is to first minimize the number of connections, and then apply the lowest appropriate level of technology for each connection, minimizing overall construction cost.

All possible interconnections should have automated response so that, in the event that the DH Plant fails, or that the biomass boilers cannot meet the peak loads in very cold weather, operator intervention is not necessary. At the same time, in periods of the very high heating load, the system should ideally use 100 percent of the capacity from the biomass boilers first, and use the "back-up" oil only to cover the peaks.

The following is a summary of some of the things all interconnections should have in common (Note – these apply when connecting into a building that already uses hot water to distribute heat):

- In all systems, a heat exchanger is preferred between the distribution piping and the building piping. Many building systems use glycol, while the DH distribution systems use 100 percent water. The heat exchanger provides a physical barrier between the two systems to prevent cross-contamination, while allowing heat to cross over. A control valve is used on the distribution return line to control the return water temperature on the building side of the exchanger.
- Recommended interconnections heat the building hot water return before it gets to the building boiler(s). The basic premise is that the temperature setpoint for the building return water coming off the heat exchanger is 5 deg F (for example) hotter than the setpoint of the boiler itself. If the biomass system heats the building return water to a temperature at or above the boiler setpoint, the boiler will not come on, HOWEVER,
- If for any reason, the biomass system cannot heat the building return water all the way to boiler setpoint (failure or very cold weather), the return water temperature will begin to fall, and when it falls below the boiler setpoint, the boiler will automatically add enough heat to make its setpoint.
- This ensures that 100 percent of the available biomass heating capacity is utilized before any back-up fuel is used. Once the load drops to the point where the heat exchanger can heat the return water to above the boiler setpoint, the building boiler will stop firing.

Given the list above, for any given site, there can be many possible variations in the way buildings are connected. In general, the size of the DH Plant, the number and nature of the end-users, and the sophistication of the individual building controls also factor into the decisions on how to interconnect the buildings.

- For large DH Plants with extensive piping systems, the cost of the pumping energy required to distribute the heat through the pipes is significant. For that reason, variable speed secondary hot water pumps are recommended. At any load less than 100 percent, variable speed pumps cut the pumping energy by 1/4th to 1/8th of the energy of constant volume system at the same flow. In these situations, the preference is to use a good quality motor-actuated control valve to control the flow at each building (actually, at each connection – so there may be more than one per building).
- A motor-actuated valve generally pre-supposes that the building has a pneumatic or DDC control system to control all of the HVAC systems. Larger, more sophisticated buildings tend to have such control systems; smaller buildings use only local controls.
- For a DH Plant that serves multiple buildings with multiple owners, a metering system is installed. This allows the DH Plant to charge the end-users for the exact amount of heat they use.

Figure1 below shows a typical existing building configuration, with two oil boilers (one for back-up).

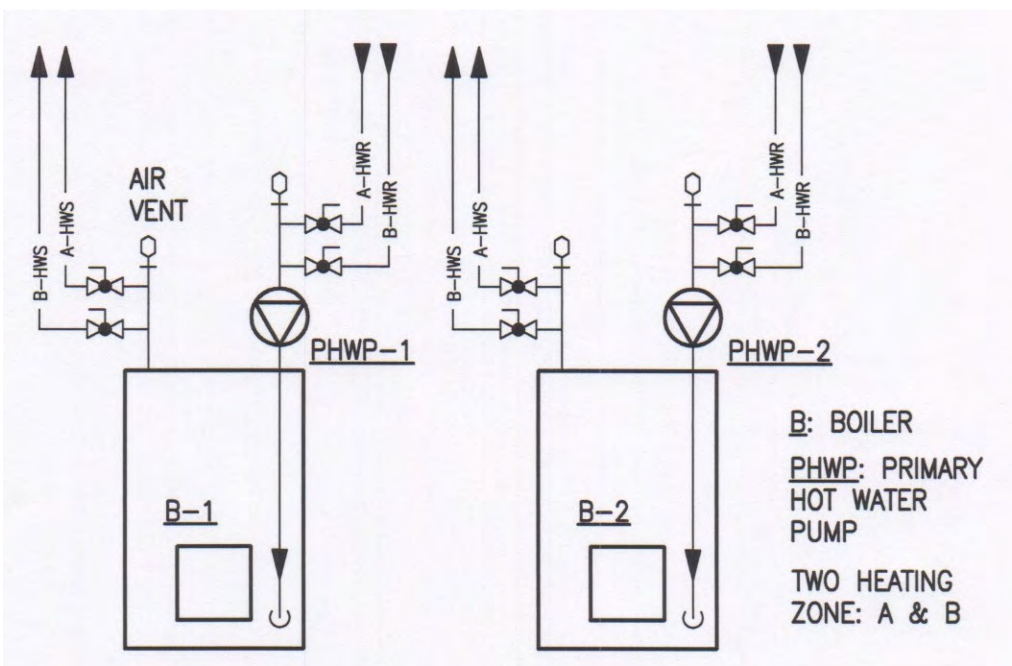


Figure A-1

In a large DH Plant with multiple building owners, one must meter the heat extracted by each building in order to charge the owner for the heat delivered. Figure A-2 below shows a typical installation for such a DH Plant. Note however, that Figure A-2 shows a separate HX and meter for each boiler within the room, that would only be done if each boiler served a separate building tenant. If both boilers served the building as a whole, then only one set of HXs and meters would be needed.

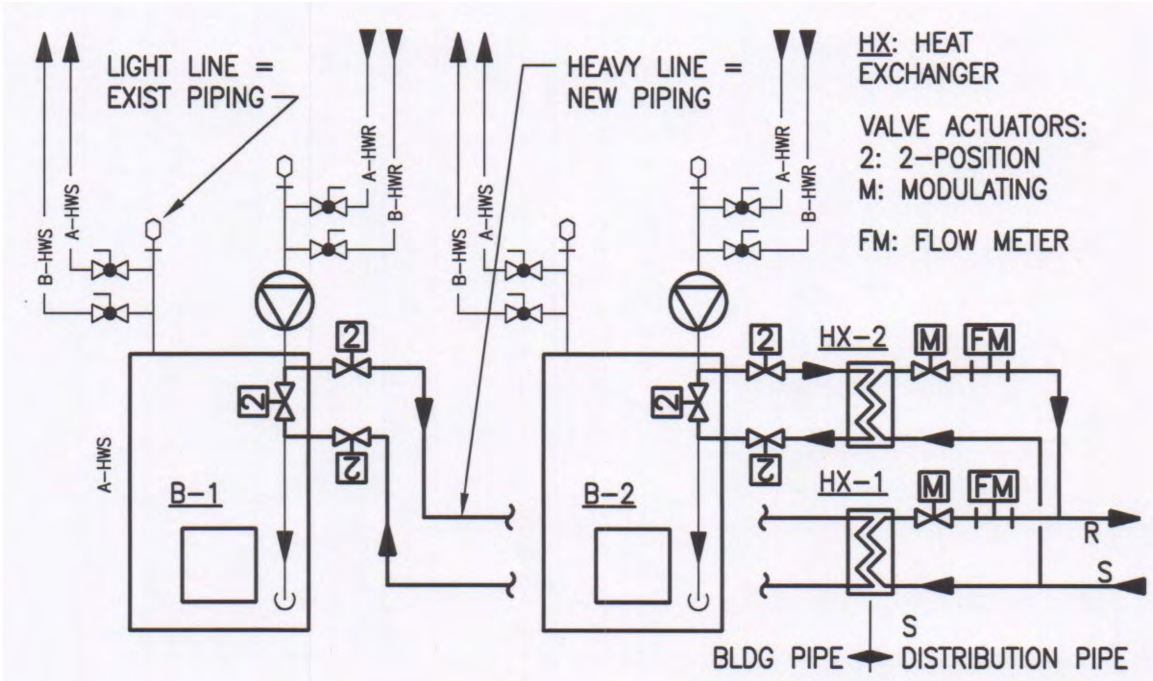


Figure A-2

Figure A-2 above shows the most expensive means of interconnecting.

The system is configured to heat the building hot water return before it gets to the boiler. The 2-position valve directly below the pump would be closed, and the other two 2-position valves open; building hot water return flows to the heat exchanger. The building HWR would be heated, and return to the boiler loop just above the point it enters the boiler. Because the HWR is now hotter than the setpoint for the boiler, the boiler never fires. The modulating valves at the HX control the building HWR temperature, and the flow meters at each HX allow the DH Plant operator to measure the exact amount of heat consumed by end-user.

For purposes of the USFS, the complexity of Figure A-2 may be inappropriate. An interconnect that resembles Figure A-3 below is recommended.

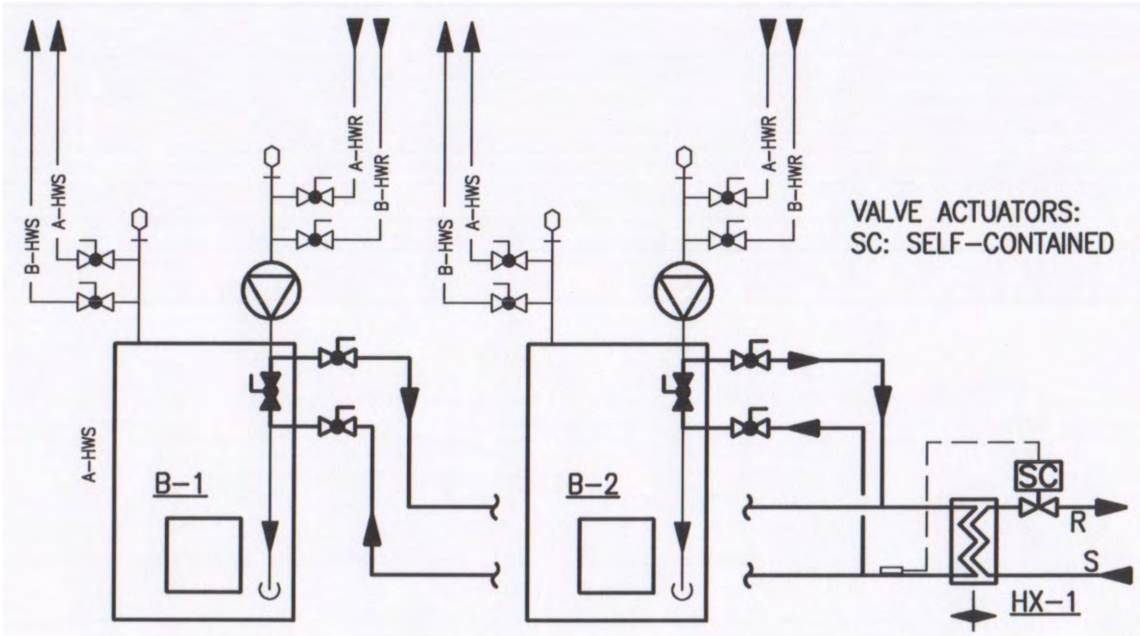


Figure A-3

In Figure A-3, all of the actuated valves have been replaced, except that the building HWR temperature is still controlled by what we have labeled as a self-controlled valve. This valve is controlled by the expansion and contraction of a fluid within a "sensing bulb" strapped to the pipe and a fluid-filled line from the bulb to the actuator itself (light dashed line). The hotter the building HWR gets, the more the fluid expands; the resulting pressure moves the actuator in the valve to modulate and control the HWR temperature – no external power source or controller is required. The level of precision is not as high, but is more than enough for the application.

Figures A-1, A-2 and A-3 apply to connecting into an existing hydronic system, which occurs only at the USFS Office. NOAA and the dorms are heated electrically.

In the NOAA building, much the same principle of control is used. New HW coils would be installed upstream of the electric coils, in the main air handling equipment. The HW coils would have a higher setpoint than the electric coils, so that if the HW coils hit their setpoints, the electric coils never come on. If the HW system fails for any reason, the electric coils will simply work exactly as they do now.

In the dorms, installation of new hydronic (HW) baseboard heating is recommended in the living spaces of each of the 14 units. Ideally, the electric baseboard units would be left in place as back up (and controlled exactly as the electric coils would be at NOAA). This would have to be determined in further Level 3 studies of this site.

The added expense of the HW / electrical connections, plus the fact that all of the electric heat cannot be displaced in either building, the economics of Scenarios 2, 3, and 4 are much less attractive than those of Scenario 1.

Thermal Storage

The used ACT boilers available are all actually larger than the application requires. This normally means the boilers will cycle on and off significantly more than a boiler that is well matched to heating demand. Thermal storage provides a number of benefits, and has been included in these proposed projects. This subsection reviews the utility and benefits of thermal storage.

When referring to a hot water heating system, thermal storage simply refers to a hot water tank, which stores hot water (thermal storage). The importance of using thermal storage in a biomass-fired heating plant varies depending on the form of the wood and type/size of the boiler.

Stick fired boilers are batch fed, with an operator adding batches of fuel as needed. In this case, thermal storage is a requirement, because once the fuel starts burning, it is impossible to modulate the rate of burn to match the heat load. Instead, the amount of fuel added is sized to heat the thermal storage, while the pumping/piping system extracts heat from the thermal storage as needed to match the load. The thermal storage "de-couples" the rate of burn from the variations in heating load.

Chip fired boilers are automatically fed, and can modulate to meet load. It would seem then that they would not need thermal storage, and in fact many chip systems are installed without storage. Where storage really provides value in a chip system is when the heating load varies over a very large range, as they do in Alaska, or when the boiler is significantly oversized, as at the USFS. The boiler can only turn down to about 25 percent of full load capacity; below that heating demand, the boiler will cycle off until hot water temperature drops a set amount, and then restart. A good chip boiler will auto-restart, but they still will not cycle On and Off like an oil boiler, for instance. Once the fuel is in a solid fuel burner, it will burn whether the heat is needed or not. They take a long time to cool down, and an equally long time to heat back up. Finally, if the fuel is very wet, the auto-start may take a long time, or in extreme cases, fail. A thermal storage tank helps limit the cycling, the boiler now modulates to keep the tank at setpoint, and as above, the system extracts heat from the tank as needed. The thermal storage can keep the boiler running at very low levels rather than cycling.

The performance of pellet boilers is as close to an oil-fired boiler as is possible with wood. The fuel is very dry, and easy to re-start. The boilers are generally much smaller than chip boilers, so there is not much fuel in the unit at any given time. They are not as heavy, so they heat up much quicker. While a thermal storage tank would again limit cycling at low loads, pellet boilers do not strictly require a tank to modulate and follow loads (although, as noted above, AWEA prefers to utilize them, and the performance as modeled (and priced) does include thermal storage). However, all good pellet boilers have an auto-cleaning feature, where they clean the tubes, generally once a day. Many models cannot do this while the boiler is actually running, so they shut down. Such boilers generally use thermal storage to "bridge over" the time they are off.

Caveat Regarding the Re-use of Existing Boilers

NOTE THAT SI AND EFOUR have never seen the used ACT Bioenergy boilers and associated thermal storage tanks that are being proposed for this project. We have assumed, for convenience, that they have the stated capacities we were supplied with, that they are in good working order, and that they can operate efficiently with pellets or chips. SI and efour provide no assurances, nor do we warrant that these assumptions are valid.

Appendix B. Photos and Site Maps for Mendenhall Glacier Visitor Center

The Mendenhall Glacier Visitor Center is a special site in that the foundation is placed on bed rock and there is an interest in keeping the site as natural looking as possible. There is not space in the boiler room for a pellet boiler and external installation is unacceptable. The site below is a shop built into the rock with a wooden roof, which can be removed for installation of a boiler. Note that the roof is an observation deck for the glacier. (Figure B-1)

Figure B-1. Mendenhall workshop location for a pellet boiler

Figure B-2. Mendenhall entrance where pipe will enter the building and then up a chase to boiler room.

There is an utilidor under the walkway.

Figure B-3. Boiler room in the interior of the visitor center building.

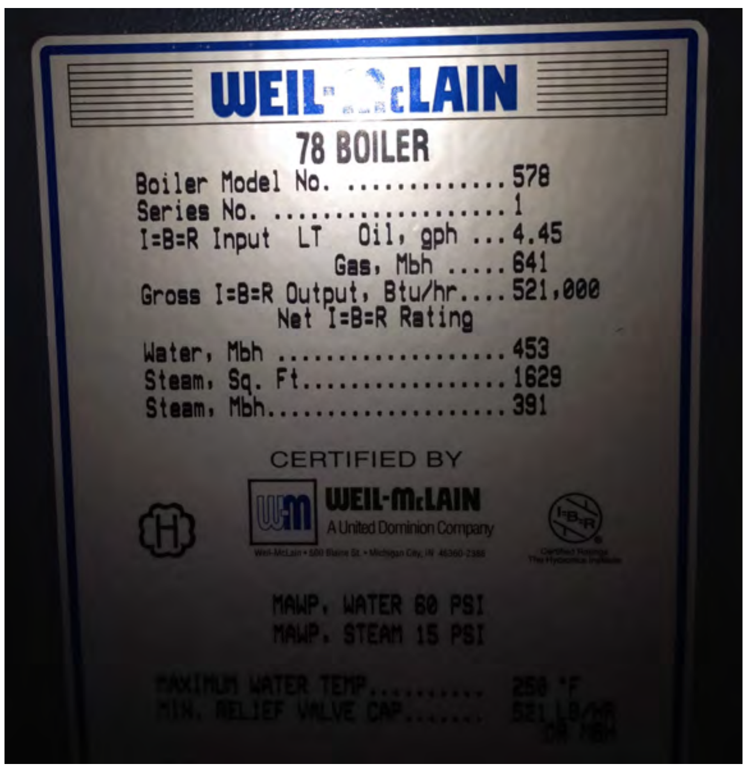


Figure B-4. Boiler Label.

Figure B-5. Site map for Visitor Center showing shop location, access for pellet delivery to an inside bin with a shoot leading into it and distance from building.

Appendix C. Photos and Site Map for Ranger Station Complex

The ranger station complex is made up of three buildings connected together as on heating system with one boiler that heats all located in the office building. The other two buildings are two warehouses. On site there are three other buildings, two dorms considered one building in the analysis and a NOAA building. Both are heated with electricity.

Figure C-1. USFS Ranger Station boiler room. This boiler heats three buildings.

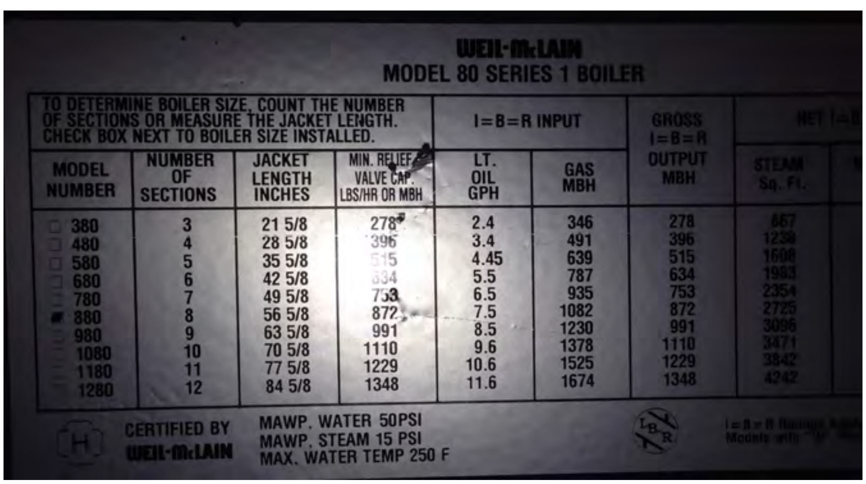


Figure C-2. Boiler Label

Figure C-3. Domestic Hot Water System

Figure C-4. Ranger Station Office Building

Figure C-5. Two warehouse shop buildings heated from office building.

Figure C-6. NOAA office building heated with electricity.

Figure C-7. Two dorms heated with electricity.

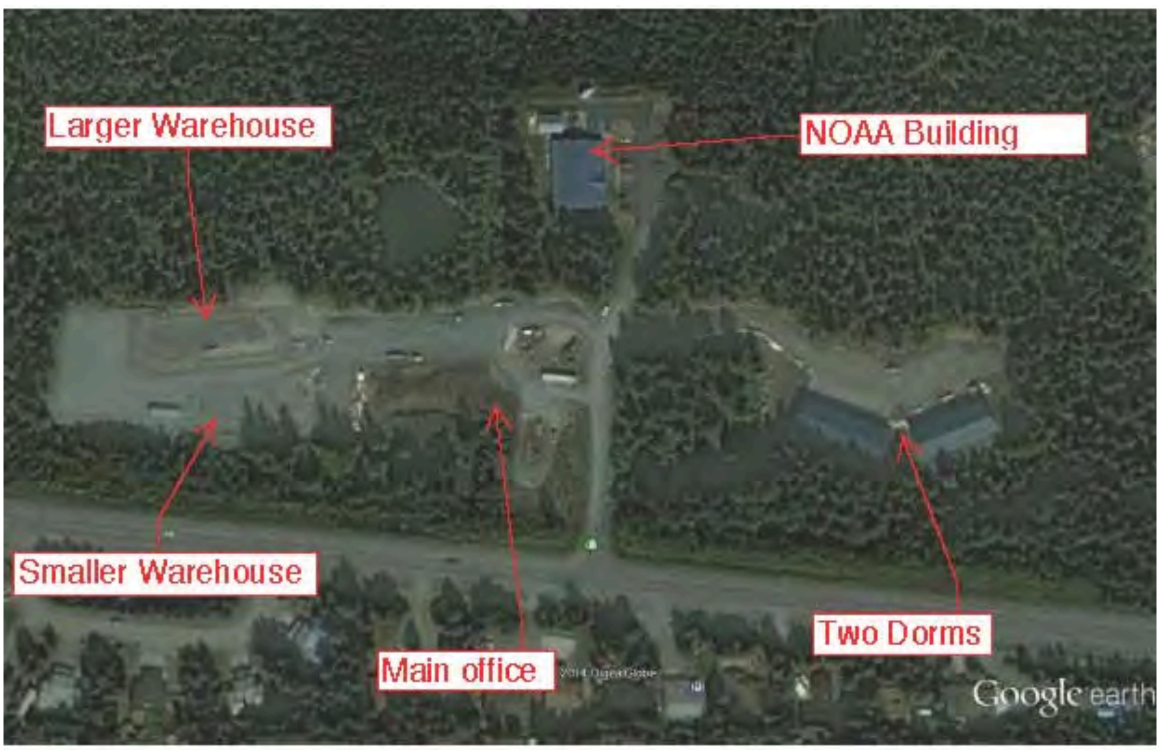
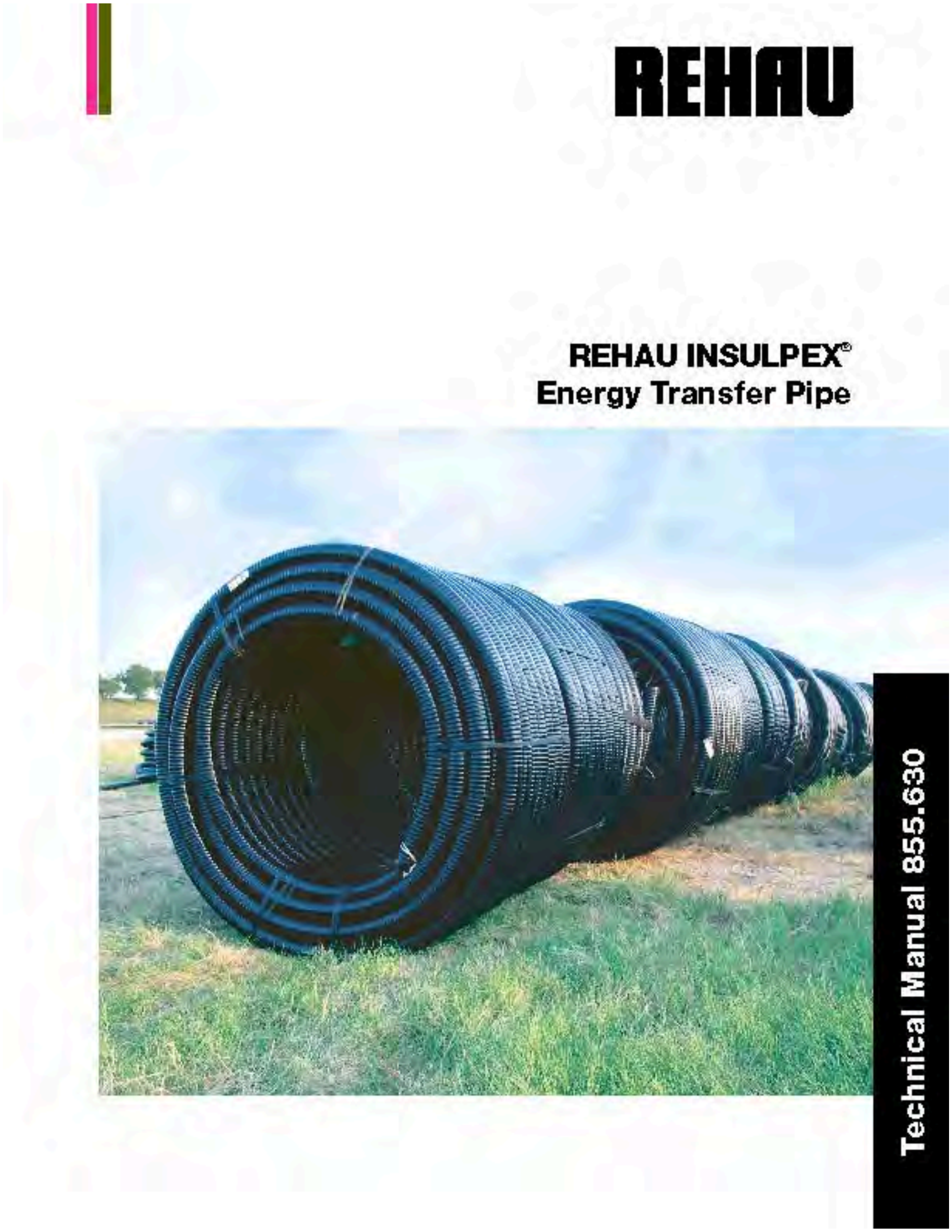


Figure C-8. Site map for USFS Ranger District Complex.

Appendix D. Portion of Tech Brochure for Pex Piping


REHAU

REHAU INSULPEX®
Energy Transfer Pipe

Technical Manual 855.630

1. Introduction

The objective of this technical manual is to provide a fundamental understanding of the features of REHAU's INSULPEX piping system and to assist in the design and specification of these systems. For a list of products, refer to the *INSULPEX Product Catalog*. Installers should consult the *INSULPEX Installation Guide*.

Additional assistance and information and updates (Technical Bulletins) are always available online at www.REHAU-NA.com or by contacting your regional REHAU representative.

1.1 Description

INSULPEX is specially designed for the efficient transfer of hot or chilled water through buried pipelines. A flexible alternative to rigid piping systems, INSULPEX offers ease of installation, combined with the long-term performance of PEX pipe.

INSULPEX consists of RAUPEX® pipe surrounded by a solid layer of CFC-free polyurethane foam insulation. The smooth interior wall of RAUPEX provides superior flow and consistent water pressure, and resists mineral build-up and bacterial growth. INSULPEX is available in one- and two-pipe configurations. The two-pipe configuration combines supply and return pipes, streamlining the installation process.

Connections are made with REHAU's EVERLOC® fitting system, providing reliable joints that allow for immediate pressure testing, and are safe to bury.

INSULPEX is lighter than rigid piping systems and is available in continuous coils of various lengths that reduce the need for joints in the pipeline—features that greatly reduce the costs and time associated with installation. The continuous single layer of insulation minimizes heat loss and water permeability, while the outer LDPE casing offers protection from abrasion.

Fig. 1.1: INSULPEX pipe

INSULPEX is offered with three different RAUPEX carrier pipes:

- RAUPEX O_2 Barrier, ASTM (copper tube size) pipes in sizes 1", 1 1/4", 1 1/2" and 2"
- RAUPEX Non-barrier, ASTM (copper tube size) pipes in sizes 1", 1 1/4", 1 1/2" and 2"
- RAUPEX O_2 Barrier, Metric pipes in sizes 63, 75, 90 and 110 mm outside diameter

To assist with identification, both ASTM and metric RAUPEX O_2 Barrier pipes are red in color. RAUPEX Non-barrier pipes are natural in color.

The INSULPEX system consists of INSULPEX pipe, fittings, tools, and installation accessories designed for optimal performance and ease of installation.

1.2 Application

INSULPEX is intended for the transfer of water-based heated/chilled fluids. INSULPEX can be buried, or installed above ground indoors or outdoors provided it is sheltered completely from UV light and/or sunlight. The following are possible applications:

- District heating supply
- Energy transfer
- Snow and ice melting supply
- Chilled water
- Process piping
- Hydronic piping
- Potable water

The following should be considered when designing an INSULPEX system:

- RAUPEX O_2 Barrier pipes cannot be used for potable water systems.
- INSULPEX must be permanently and completely sheltered from UV exposure (sunlight).
- INSULPEX may ot be used for permanent, unsheltered outdoor exposure.

1.2.1 Chlorinated Potable Water

RAUPEX Non-barrier pipes can be used for chlorinated potable water subject to the following conditions:

- The pH of the water is 7.0 or higher
- The concentration of free chlorine is 4.0 parts per million (ppm) or lower
- Water temperature is 140°F (60°C) or lower
- Water pressure is 80 psi (550 kPa) or lower

Contact your regional REHAU representative to discuss any chlorinated potable water system with a temperature and/or pressure beyond those listed above.

1.2.2 Non-Chlorinated Potable Water

RAUPEX Non-barrier pipes can be used for non-chlorinated potable water subject to the pressure and temperature limits as found in Tables 2.1 and 2.2.

REHAU® 1