Angoon Multifamily Apartments Biomass Pre-feasibility Report

Submitted to THRHA and AWEDTG

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1.0 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 THRHA supported the field study with information and assistance while in Angoon.

1.2 Objective:

The objective of this report is to document the results of a pre-feasibility study performed for the Tlingit Haida Regional Housing Authority (THRHA). The target buildings are 8 multi-plex residential buildings and a community center in Angoon, Alaska. Angoon is not on the road system, but it is accessible by ferry and float plane from Juneau.

In this report, we distinguish between a multi-plex (duplex, triplex, etc) and a residence – when we use the term "residence" we mean a distinct "home" within a multi-plex. A duplex has two residences, and so on. The buildings in the THRHA are currently heated with oil, one oil boiler per residence (and one for the community center). The primary subject of the study is the feasibility of constructing a wood-fired heating plant to serve all nine buildings in the THRHA complex.

A secondary objective is to evaluate the installation of a wood-fired boiler into a "typical" house. This is not part of the original scope for this work, but interest was found in the community for converting to pellet boilers if a supply of pellets were to exist in the community. Thus, the authors decided to give an example of costs and paybacks for a residence.

Because there are no wood chips available in the area, and the THRHA is not interested in stick-fired boiler, this study evaluates only pellet fired boilers.

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). 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 done to determine if it is worth the time and expense to initiate an L3 study. Level 3 studies are generally quite expensive, and thus not entered into lightly. The L2 study helps decision makers determine which aspects, if any, of a proposed project are worth the expense of an L3 study.

An L1 study can be done remotely; 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, although classified as pre-feasibility.

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. 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 Fairbanks Economic Development Corporation (FEDC). Data collected on site by SI include existing site conditions, equipment name plate data, current energy cost data, and, equally important, information gathered by talking to the local stakeholders in the Village.

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 completing multiple L2 and L3 wood-fired feasibility studies. Hourly weather data for the performance model was extracted from data collected and reported by the nearby Juneau Airport.

1.4 Scope

In Angoon, the scope of this report is limited to the THRHA complex and one typical house; currently, each residence within each multi-plex has its own boiler. The boilers feed two or more zones of heating within each residence, using hydronic baseboard heat.

Biomass heating systems can be 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. Significant parts of the cost of a district heating plant (DH Plant) are the interconnections to the individual boilers; in this case, the fact that each residence has a boiler (as opposed to one per multi-plex) potentially increases the capital costs of a project. Thus, more existing boilers means more interconnections and more cost, but no more additional savings. Interconnections are discussed in detail below.

For this report, we have modeled the performance on one DH Plant, and one individual building. The DH Plant contains all nine buildings; subsets of smaller groups of multi-plexes were not analyzed. Smaller DH Plants would have even less economy of scale, and the THRHA showed no interest in having two Plants rather than one. The individual building modeled is the "typical house" referred to above.

Although only one cluster of buildings for the DH Plant was evaluated, four different variations of that Plant (each variation is called a Scenario, abbreviated as Sc) were constructed. The performance is nearly identical between all four; the primary difference is the capital cost. This DH Plant has three disadvantages compared to many other DH Plants SI and efour have evaluated:

1. Not much economy of scale: The total oil consumption for the nine buildings is about 11,400 gallons per year. In many villages, a single building (usually the high school) uses two or more times as much oil as the entire THRHA complex.
2. High cost of wood: In most cases, we evaluate stick wood, and if feasible, wood chips. Both are less expensive on a BTU basis than wood pellets (although not nearly as convenient as pellets).
3. Many small buildings, each with multiple interconnections required. Each building is small (in terms of oil consumption), which makes it harder to pay for the cost of the piping required to get to the building, and the interconnections to the multiple boilers.

For these reasons, we looked at a number of ways to strip costs out of the DH Plant without materially affecting performance. One could say that the Scenario 1 DH Plant is the "Cadillac", and each successive DH Plant (Sc 2 through Sc 4) strips out equipment and features, which, while nice, may not be strictly required for the THRHA Plant. The differences between the Scenarios are detailed in Sections 2 and 3 below.

1.5 Resource Assumptions

As noted above, the only form of biomass modeled in this report is wood pellets. Wood chips are not available, and the THRHA was not interested in stick-fired boilers.

Figure 1.1 below shows the assumptions that have been made for the existing fuels in the Village (oil and electrical energy), in the units in which they are sold:

Village Energy Costs / Properties

description	value	units
No. 1 oil heat content	134.00	kBTU/gal
density	6.68	lb/gal
sulfur content	1,000	ppm
village cost, No. 1 oil	$5.40	per gal
electrical energy	$0.24	per kWh

Figure 1.1

Figure 1.2 shows the assumptions made for the cost of wood fuel, in various forms.

Wood Costs

description	value	units
wood chips, to DH		green ton
stick wood, split, to DH		cord
pellets, to DH	$300.00	ton
bricks, to DH		ton

Figure 1.2

Because each form of fuel has different heat content and is sold in differing units, direct comparisons of the data in Figures 1 and 2 are very difficult. To make the comparison simple, all these energy sources are converted to a common unit, one million BTU (1 mmBTU).

To make the comparison even more relevant, the conversion efficiency of each source has been factored in. In this case, the conversion efficiency is the boiler efficiency. It is different for each fuel – using drier wood results in better boiler efficiency, and the oil boilers have their own efficiencies as well. In Figure 1.3 below, therefore, the mmBTUs references are those coming out of the boiler into the space, not the gross heat content of the fuel going into the boiler.

Unit Energy Costs, comparison
(to village, boiler eff accounted for)

fuel	value	units
No. 1 oil	$47.97	per mmBTU
electrical energy	$70.34	per mmBTU
recovered heat		per mmBTU
pellets, at $360/ton	$24.50	per mmBTU
pellets, at $300/ton	$20.42	per mmBTU

Figure 1.3

As Fig 1.3 shows, electrical energy is about one half again as expensive as No.1 oil, which, in turn, is about two and quarter times more expensive than wood pellets. The wood pellets are assumed to contain 8,162 BTU/lb.

1.6 Summary of Findings

The following Figures summarize the performance and economic modeling that SI and efour performed. The model is based on a pellet cost of $300 per ton delivered to Angoon, but that may vary. The summary results are presented twice and include a graph, which shows the sensitivity of net simple payback to pellet cost.

Summary of Scenario Results
(Financial)

pellet price, per ton delivered	$300
client discount rate	4.00%
term for net present value calcs	20.0 yrs

	Sc 1	Sc 2	Sc 3	Sc 4
(1) project implementation cost	$399,092	$320,271	$292,728	$251,274
Base Fuel cost (oil only)	$61,544	$61,544	$61,544	$61,544
(2) Proposed Fuel costs (wood, oil, elec)	$33,060	$33,459	$33,459	$33,459
estimated annual savings	$28,484	$28,085	$28,085	$28,085
(3) Increased maintenance costs				
total savings	**$28,484**	**$28,085**	**$28,085**	**$28,085**
net simple payback	14.0 yrs	11.4 yrs	10.4 yrs	8.9 yrs
20 year sum of savings stream	$917,956	$907,773	$907,773	$907,773
net present value of savings stream	$532,153	$526,055	$526,055	$526,055
NPV of savings, including imp cost	$246,554	$312,559	$338,025	$376,351
Base oil displaced	0.9996	0.9996	0.9996	0.9996
benefit to cost ratio	**1.604**	**1.976**	**2.162**	**2.519**

(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 pumping energy
(3) see explanation below for maintenance costs

Figure 1.4 overall economic summaries with pellets at $300/ton.

Figure 1.5 shows the same metrics with pellets at $360/ton.

Summary of Scenario Results (Financial)			pellet price, per ton delivered	$360
			client discount rate	4.00%
			term for net present value calcs	20.0 yrs
	Sc 1	**Sc 2**	**Sc 3**	**Sc 4**
(1) project implementation cost	**$399,092**	**$320,271**	**$292,728**	**$251,274**
Base Fuel cost (oil only)	$61,544	$61,544	$61,544	$61,544
(2) Proposed Fuel costs (wood, oil, elec)	$39,232	$39,631	$39,631	$39,631
estimated annual savings	$22,312	$21,913	$21,913	$21,913
(3) Increased maintenance costs				
total savings	**$22,312**	**$21,913**	**$21,913**	**$21,913**
net simple payback	17.9 yrs	14.6 yrs	13.4 yrs	11.5 yrs
20 year sum of savings stream	$782,061	$771,878	$771,878	$771,878
net present value of savings stream	$448,815	$442,717	$442,717	$442,717
NPV of savings, including imp cost	$154,482	$220,487	$245,952	$284,279
Base oil displaced	0.9996	0.9996	0.9996	0.9996
benefit to cost ratio	**1.364**	**1.678**	**1.835**	**2.138**

Figure 1.5

As footnote (3) indicates, we have not estimated any increase in annual maintenance with the installation of the pellet-fired boiler. This is because the fuel consistency is so high, the material handling so smooth, and the pellet boilers so reliable that in essence it is as close to being as automatic as an oil fired boiler as a wood fired boiler can get. We would expect that whoever currently cares for the oil boilers will also take care of the pellet boilers, and that no significant additional time or parts expenses will be incurred. Experience has shown that pellet boilers are reliable enough to be used in residences; this would not be the case if there were significant maintenance and expense required.

The net present value and benefit to cost calculation assume a 20 year project life; during that period, costs must be assumed to escalate. Figure 1.6 below shows the proposed escalation factors.

Escalation Factors	client discount rate	**0.040**
variable	rate	
oil	0.030	per year
electrical energy	0.025	per year
recovered heat	0.030	per year
wood chips	0.010	per year
stick wood	0.010	per year
wood pellets, bricks	0.010	per year
maintenance, labor	0.030	per year

Figure 1.6

Using these factors results in the following 20 year cash flows:

Cash Flows pellet price, per ton delivered **$300**

	Sc 1			Sc 2		
yr	existing cists	existing cists	**savings**	existing cists	existing cists	**savings**
1	61,544	33,060	**28,484**	61,544	33,459	**28,085**
2	63,390	33,424	**29,966**	63,390	33,832	**29,558**
3	65,292	33,792	**31,500**	65,292	34,211	**31,081**
4	67,251	34,165	**33,086**	67,251	34,594	**32,656**
5	69,268	34,542	**34,726**	69,268	34,982	**34,286**
6	71,346	34,924	**36,422**	71,346	35,375	**35,971**
7	73,487	35,311	**38,175**	73,487	35,773	**37,713**
8	75,691	35,703	**39,988**	75,691	36,176	**39,515**
9	77,962	36,099	**41,863**	77,962	36,585	**41,377**
10	80,301	36,501	**43,800**	80,301	36,998	**43,302**
11	82,710	36,907	**45,803**	82,710	37,417	**45,292**
12	85,191	37,318	**47,873**	85,191	37,842	**47,349**
13	87,747	37,735	**50,012**	87,747	38,271	**49,475**
14	90,379	38,157	**52,222**	90,379	38,707	**51,672**
15	93,091	38,584	**54,506**	93,091	39,148	**53,943**
16	95,883	39,017	**56,866**	95,883	39,595	**56,289**
17	98,760	39,455	**59,304**	98,760	40,047	**58,712**
18	101,723	39,899	**61,823**	101,723	40,506	**61,217**
19	104,774	40,349	**64,425**	104,774	40,971	**63,804**
20	107,917	40,804	**67,113**	107,917	41,441	**66,476**
sum	1,653,705	735,749	**917,956**	1,653,705	745,932	**907,773**

Cash Flows (continured) pellet price, per ton delivered **$300**

	Sc 3			Sc 4		
yr	existing cists	existing cists	**savings**	existing cists	existing cists	**savings**
1	61,544	33,459	**28,085**	61,544	33,459	**28,085**
2	63,390	33,832	**29,558**	63,390	33,832	**29,558**
3	65,292	34,211	**31,081**	65,292	34,211	**31,081**
4	67,251	34,594	**32,656**	67,251	34,594	**32,656**
5	69,268	34,982	**34,286**	69,268	34,982	**34,286**
6	71,346	35,375	**35,971**	71,346	35,375	**35,971**
7	73,487	35,773	**37,713**	73,487	35,773	**37,713**
8	75,691	36,176	**39,515**	75,691	36,176	**39,515**
9	77,962	36,585	**41,377**	77,962	36,585	**41,377**
10	80,301	36,998	**43,302**	80,301	36,998	**43,302**
11	82,710	37,417	**45,292**	82,710	37,417	**45,292**
12	85,191	37,842	**47,349**	85,191	37,842	**47,349**
13	87,747	38,271	**49,475**	87,747	38,271	**49,475**
14	90,379	38,707	**51,672**	90,379	38,707	**51,672**
15	93,091	39,148	**53,943**	93,091	39,148	**53,943**
16	95,883	39,595	**56,289**	95,883	39,595	**56,289**
17	98,760	40,047	**58,712**	98,760	40,047	**58,712**
18	101,723	40,506	**61,217**	101,723	40,506	**61,217**
19	104,774	40,971	**63,804**	104,774	40,971	**63,804**
20	107,917	41,441	**66,476**	107,917	41,441	**66,476**
sum	1,653,705	745,932	**907,773**	1,653,705	745,932	**907,773**

Figure 1.7

With these escalation factors, the savings increase by a factor of 2.4 over 20 years.

Of course, a primary variable in the financial analysis is the cost of pellets. For that reason, as noted above, we include a graph that shows the effect of pellet cost on net simple payback:

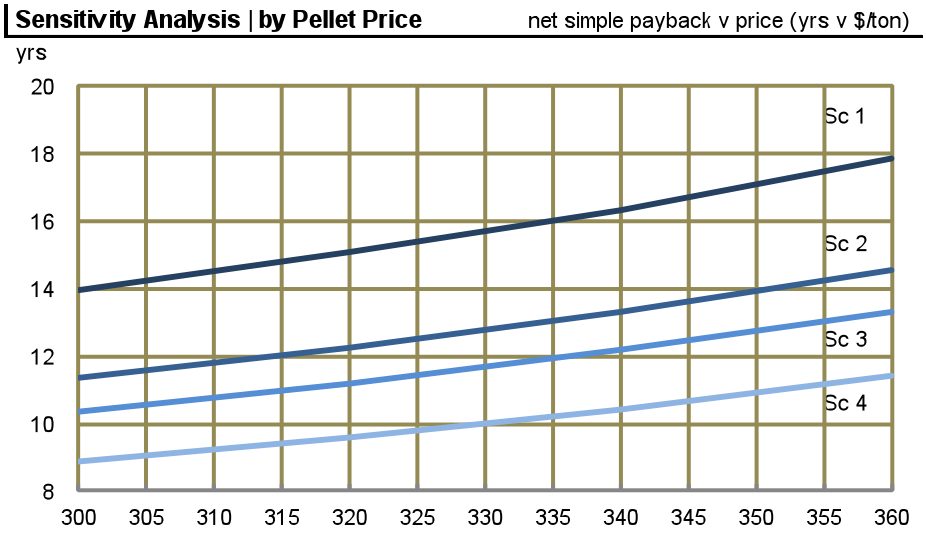


Figure 1.8

Figure 1.9 below is a summary of the cost estimate. The complete construction estimate is contained in Section 2:

Cost Estimate Summary

		Sc 1	Sc 2	Sc 3	Sc 4
total construction		**$323,898**	**$256,242**	**$257,788**	**$221,103**
(see section 2 for construction cost est)					
(1) final design/study	0.070	$22,673	$17,937	$9,534	$7,562
bid assistance	0.005	$1,619	$1,281	$1,289	$1,106
engineer const admin	0.005	$1,619	$1,281	$1,289	$1,106
(2) site construction admin		$16,000	$16,000		
Cx/start up	0.010	$3,239	$2,562	$2,578	$2,211
(3) contingency	0.075	$24,292	$19,218	$14,501	$12,437
subtotal, soft costs		$69,443	$58,280	$29,190	$24,421
fraction of construction cost		0.214	0.227	0.113	0.110
interior storage, at peak permits		$5,000	$5,000	$5,000	$5,000
estimated review cost		$750	$750	$750	$750
subtotal, fees/permits		$5,750	$5,750	$5,750	$5,750
estimated total implementation		**$399,092**	**$320,271**	**$292,728**	**$251,274**

Figure 1.9

There are three notes that must be amended to Figure 1.9:

1. In order to reduce costs, Sc 3 and Sc 4 assume that no final study is done (or a minimal update of this study), for these Scenarios, this line item is cut by 50%, from 7.0 percent to 3.5 percent.
2. Sc 1 and Sc 2 assume an outside construction manager/administrator is living and working in the Village during construction, actively managing the project. However, in talking to THRHA, they indicate they may have the capacity to take on these tasks. Therefore, in Sc 3 and 4, the on-site construction management is eliminated. There is still money for an engineer / manager to answer site questions, review submittals, etc.
3. In order to minimize soft costs, for Sc 3 and Sc 4, the contingency was cut by 25 percent (therefore, it is 0.75 * 0.75 = 0.56 of construction cost).

Finally, Figure 1.10 shows a financial / performance summary for a typical house in Angoon. This is based on a number of assumptions as we were not able to get an amount of oil used annually for a large house. When individual buildings are evaluated, the same cost factors are used, but with a different reporting format, because many elements that go into a DH Plant do not apply when looking at a single boiler / single boiler configuration. In addition, because this is a strictly residential application, many soft costs are not applied. There is no external construction administration, for example, and no design/study costs (the contractor is assumed to be competent to design/execute the interconnection). The boiler is assumed to be in the residence, which eliminates site pipe, etc. Figure 1.10 shows the typical house results at $300 per ton:

1	**Pellet-Fired Boiler**			MES 12	boiler 1	9
in No.					boiler 2	
B14	**House, int Boiler**				boiler 3	
current oil	780 gal	chips req	6 tons	boiler(s)		
unit price	$5.400	unit price	$300	building		
annual cost	$4,212	annual cost	$1,702	mechanical		
				electrical		
proposed oil		electrical	2,838 kWh	controls		
unit price		unit price	$0.240	project costs		
annual cost		annual cost	$681	total cost	$17,386	
oil displaced	780 gal			ann savings	$1,828	
fraction disp	1.000			**NSP**	**9.5 yrs**	
NPV benefit	**$34,735**			**B / C ratio**	**3.039**	

Figure 1.10

Project Performance

Both the DH Plant (Scenario 4) and the typical house have a net simple payback of about nine years. For a Housing Authority looking to control energy costs, budget for the future, and create an alternative to oil, this is likely a reasonable payback – renewable energy projects often have benefits that extend beyond the merely financial. For a home owner, a nine year payback may be harder to swallow. In both cases, however, the benefit to cost ratio is well over 1.0, the minimum standard (2.5 and 3.0, respectively).

Although financial forecasts cannot be made on "maybes", there is also possibility that as wood pellets become more common in SE Alaska, there will be more suppliers and more economy of scale, causing unit prices to drop below $300 per ton.

1.7 Next steps

THRHA must evaluate these results using their own investment metrics and criteria. However, it appears, based on the findings of this report, that if THRHA can form a team of the right professionals and contractors, and design a lean delivery method that maximizes the assets of the Authority, this is certainly a viable project, financially.

The next step, therefore, is to work with the Authority to determine what elements are required for a project that they consider a "success", and figure out to deliver those elements within a cost and performance structure appropriate for the community.

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

- Use of renewable resources
- Reliance on local, 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 local economy

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 for the THRHA and other stakeholders to make these decisions. The authors believe that the project is strong enough financially and with VBECS to immediately apply to the AEA Renewable Energy Fund for a grant to support this project.

2.0 TECHNICAL SUMMARY

2.1 Existing Conditions:

The following statistics in Figure 2.1 summarize the existing conditions in the THRHA complex:

Existing Conditions		
No. buildings	9	
year constructed	1997	
age	17	yrs
residential	**8**	
duplexes	4	
triplexes	2	
quadplexes	2	
non-residential	**1**	
community center	1	
total area	21,772	sf
occupied		daily
heating type	hot water baseboard	
domestic water	off main boiler	
age of boilers	17	yrs
mfg of boilers		Burnham
condition		med to bad
No of boilers	23	(1 per res)
est total oil consumption	11,400	gal per yr

Figure 2.1

The proposed pellet-fired DH Plant would displace over 99 percent of the current fuel consumption; however, the existing boilers would remain in place as back up in all Scenarios. In some Scenarios, they would be the only back-up. This is explained in more detail in subsection 2.4.

2.2 Wood Fuels / Wood Fired Heating Equipment

Figure 2.2 below shows the properties of the pellets that were used in this study:

Composite Pellet Properties

net useable heat	8,162	BTU/lb at burn MC
density as pellets	22.168	lb/cf at burn MC
SOx formed	0.0000	lb/wet lb at burn MC
ash	0.0142	lb/wet lb at burn MC
ash volume	0.0022	cf/wet lb at burn MC

Figure 2.2

The most pertinent value in the Figure is the net useable heat content, 8,162 BTU/lb. Because of the low moisture content (4 percent), pellets are by far the most energy-dense form of wood fuel.

There are a number of manufacturers of pellet boilers; the basis of design 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).

The basic system components include:

- A pellet bin, which holds bulk amounts of wood pellets.
  - This bin is kept filled by periodic deliveries to the Village by truck and ferry
  - There are 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)
  - For MES, this is a vacuum system; the bin may be up to 66 ft away from the boiler
- 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
  - This 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

Examples of the MES boilers and accessories are included in Appendix A

2.3 Proposed Conditions, Sc 1

As noted above, the thermal performance of all four Scenarios is about the same. What changes from Scenario to Scenario is the implementation cost, the level of complexity and sophistication, and the level of involvement of THRHA. Subsection 2.3 outlines the configuration of Scenario 1, while subsection 2.4 details how each subsequent Scenario deviates from Sc 1. Some of the features of Scenario 1:

- A new 8 x 34 containerized pellet boiler plant, piped and wired at the manufacturer, and delivered to the site
- The container includes primary piping, two boilers, expansion tanks, ash container, controls as specified, lights, and all electrical lighting and wiring – plus room for variable speed secondary pumps, secondary pumps and a secondary heat exchanger and expansion tank

- An oil-fired boiler is included in the new DH plant to cover failures and high peak load periods.
- A new slab constructed to house the container, with pipe and wiring routed to slab
- Distribution piping from the slab to each building
- Connection from the distribution piping to each of the 23 boilers
- One control valve, HX and flow meter per interconnection (see Section 3)
- DDC controls as required to control the Plant and interconnections
- The new piping will be tied into the existing systems in such a way that will always take the "wood heat" before taking oil/propane heat (Figure 3.2 below)
- However, if for any reason the wood fired system cannot meet load, the existing boilers will automatically start and fire as required to meet load
- Full design and construction administration/management services, with 7.5 percent contingency

Figure 3.1 in the section below shows the "Scenario 1" configuration, as it applies to building interconnections. The means of interconnection is one of the primary differences between the Scenarios.

2.4 Scenarios 2 through 4

Scenarios 2 through 4 differ from Scenario 1 in the following ways:

Scenario 2

- The oil fired back-up boiler at the DH Plant is eliminated, and the existing boilers are assumed to provide back-up
- The interconnection to each boiler is revised from Figure 3.2 to Figure 3.3 – a much less complex and expensive configuration
- The controls are all assumed to be local, with no DDC control
- The secondary pumps are assumed to be constant speed (they are so small, there is little energy penalty)
- In Sc 2, we eliminated some manufacturer's boiler controls, and some features in an attempt to lower costs, but it did not get the financials to a viable point, and it eliminated some desirable features, so these options were added back in in Sc 3 and 4 (thus the container costs are slightly higher)

Scenario 3

All of the Sc 2 modification, plus

- The interconnection detail remains Figure 3.3 – with 23 total connections
- This simplifies the connections and eliminates the need for DDC controls; however, there are still 23 connections required
- Final study and design fees are cut in half; this assumes that THRHA can allocate some resources to the project
- External construction management is handled by THRHA
- This local control allows the contingency to be decreased by 25 percent.

Scenario 4

All of the Sc 3 modification, plus

- The interconnection detail becomes Figure 3.4 or Figure 3.5 (depending on Village needs) – cutting the total connections to 11.

2.5 Energy Savings

Figure 2.3 below summarizes the energy consumption, existing and proposed, on a monthly basis:

Scenario 1: Base Inputs and Costs														
		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	total
total oil	gal	1,389	1,160	1,288	996	755	541	498	522	662	937	1,228	1,420	11,397
existing cost	$5.40	**$7,502**	**$6,266**	**$6,956**	**$5,381**	**$4,075**	**$2,919**	**$2,687**	**$2,821**	**$3,577**	**$5,060**	**$6,634**	**$7,666**	**$61,544**
total oil	gal	4	0	0									0	5
biomass	tons	12	10	11	9	7	5	5	5	6	8	11	12	103
electrical	kWh	906	788	870	764	694	634	654	654	644	728	837	894	9,068
oil cost	$5.40	$21	$1	$1									$1	$25
biomass cost	$300.00	$3,650	$3,064	$3,400	$2,670	$2,095	$1,577	$1,486	$1,545	$1,865	$2,530	$3,245	$3,733	
electrical cost	$0.24	$218	$189	$209	$183	$167	$152	$157	$157	$155	$175	$201	$215	
proposed cost		**$3,888**	**$3,254**	**$3,610**	**$2,854**	**$2,262**	**$1,729**	**$1,643**	**$1,701**	**$2,019**	**$2,705**	**$3,446**	**$3,949**	**$33,060**
	savings	**$3,614**	**$3,012**	**$3,345**	**$2,527**	**$1,814**	**$1,190**	**$1,044**	**$1,120**	**$1,558**	**$2,355**	**$3,188**	**$3,717**	**$28,484**

Figure 2.3

Figure 2.4 shows the same data for Sc 2 through Sc 4 (the savings for these Scenarios does not change, only the implementation cost):

Scenario 2 through 4: Base Inputs and Costs														
		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	total
total oil	gal	1,389	1,160	1,288	996	755	541	498	522	662	937	1,228	1,420	11,397
existing cost	$5.40	**$7,502**	**$6,266**	**$6,956**	**$5,381**	**$4,075**	**$2,919**	**$2,687**	**$2,821**	**$3,577**	**$5,060**	**$6,634**	**$7,666**	**$61,544**
total oil	gal	4	0	0									0	5
biomass	tons	12	10	11	9	7	5	5	5	6	8	11	12	103
electrical	kWh	994	893	987	903	856	799	825	825	806	881	954	995	10,719
oil cost	$5.40	$23	$2	$2									$1	$28
biomass cost	$300.00	$3,650	$3,064	$3,400	$2,670	$2,095	$1,577	$1,486	$1,545	$1,865	$2,530	$3,245	$3,733	$30,859
electrical cost	$0.24	$239	$214	$237	$217	$206	$192	$198	$198	$194	$211	$229	$239	$2,572
proposed cost		**$3,911**	**$3,279**	**$3,639**	**$2,887**	**$2,301**	**$1,769**	**$1,684**	**$1,743**	**$2,058**	**$2,742**	**$3,474**	**$3,973**	**$33,459**
	savings	**$3,591**	**$2,987**	**$3,317**	**$2,494**	**$1,775**	**$1,151**	**$1,003**	**$1,078**	**$1,519**	**$2,318**	**$3,160**	**$3,693**	**$28,085**

Figure 2.4

2.6 Cost Estimate:

The construction cost estimate is provided below in Figure 2.5. These are commonly referred to as the "hard costs". The remaining soft costs, fees, permits, etc, are detailed in Section 1.

Construction Cost Estimate

tag	description		Sc 1	Sc 2	Sc 3	Sc 4
1	boilers		$43,110	$43,110	$43,110	$43,110
2	frieght					
3	install					
4	containerization		$32,000	$30,685	$32,000	$32,000
5	container freight		$8,500	$8,500	$8,500	$8,500
6	boiler stack		$4,500	$4,500	$4,500	$4,500
7						
8	back-up oil boiler		$11,420			
9	oil boiler piping		$750			
10	stack		$900			
11						
12	pumps/VFDs		$7,583	$4,103	$4,103	$4,103
13	secondary piping/HX		$8,132	$3,904	$3,904	$3,904
14						
15	distribution piping (PEX)		$28,464	$28,464	$28,464	$28,464
16	insulation boards		$2,752	$2,752	$2,752	$2,752
17						
18	building interconnects		$59,686	$59,254	$59,254	$28,654
19	slab for container		$12,500	$12,500	$12,500	$12,500
20	gravel fill for slab		$3,000	$3,000	$3,000	$3,000
21						
22	control points		$34,500	$9,000	$9,000	$9,000
23	DDC contol panels, HMI		$11,400	$5,700	$5,700	$5,700
24	prgramming		$1,172	$348	$348	$348
25	wire, conduit for bldg control		$3,408			
26						
27			**Sc 1**	**Sc 2**	**Sc 3**	**Sc 4**
28	**mechanical subtotal**		**$116,895**	**$94,801**	**$96,116**	**$96,116**
29	general conditions	0.020	$2,338	$1,896	$1,922	$1,922
30	equip rental, tools	0.015	$1,753	$1,422	$1,442	$1,442
31	margin	0.120	$16,498	$13,380	$13,566	$13,566
32	**total mechanical**		**$137,485**	**$111,499**	**$113,046**	**$113,046**
33						
34			**Sc 1**	**Sc 2**	**Sc 3**	**Sc 4**
35	**Sitework subtotal**		**$105,970**	**$105,970**	**$105,970**	**$75,370**
36	general conditions	0.025	$2,649	$2,649	$2,649	$1,884
37	equip rental, tools	0.030	$3,179	$3,179	$3,179	$2,261
38	margin	0.120	$15,245	$15,245	$15,245	$10,843
39	**total site**		**$127,043**	**$127,043**	**$127,043**	**$90,358**
40						
41			**Sc 1**	**Sc 2**	**Sc 3**	**Sc 4**
42	**Controls subtotal**		**$50,479**	**$15,048**	**$15,048**	**$15,048**
43	general conditions	0.025	$1,262	$376	$376	$376
44	equip rental, tools	0.010	$505	$150	$150	$150
45	margin	0.120	$7,124	$2,124	$2,124	$2,124
46	**total controls**		**$59,370**	**$17,699**	**$17,699**	**$17,699**
47						
48						
49	**total construction cost**		**$323,898**	**$256,242**	**$257,788**	**$221,103**

Figure 2.5

3.0 INTERCONNECTIONS and Thermal Storage

3.1 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 get, the less they cost. 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.

One thing that all possible interconnections should have in common is that no operator intervention should be required in the event that the DH Plant fails, or that the biomass boilers cannot meet the peak loads in very cold weather. 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:

- In all systems, it is preferred that a heat exchanger is installed 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 hot water return water temperature on the building side of the exchanger.
- Interconnect in such a way that the building hot water return is heated 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. The result is simple; if the biomass system heats the building return water to a temperature at or above that of 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 used. 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 the use.

In Angoon, the existing boiler system configurations present a number of challenges for keeping the interconnection costs as low as possible. The overall housing complex consists of duplexes, triplexes, and quadplexes, as well as the community center. In the multi-plexes, there is one boiler per residence, and each boiler can serve only the residence it was meant to serve. This means that instead of nine connections (the number of buildings), the current configuration requires 23 connections:

- (4) duplexes * 2 connection = 8 connections
- (2) triplexes * 3 connections = 6 connections
- (2) quadplexes * 4 connections = 8 connections
- (1) community center * 1 connection = 1 connection

The total from above is 23 connections. Even if we reduce the unit cost to as low a value as possible, 23 connections represent a large sum of money. For Angoon, therefore, four Scenarios were modeled. Sc 1 was the "base case", which represents the configuration of a large, complex, multi-user system with above average sophistication.

For Scenario 2, some of the sophistication was reduced, some of the equipment, and thus some of the money. In Scenario 3, there is more reduction, and In Scenario 4; the assumption is that some level of re-piping has been done in each building, such that a single point of connection can be made (instead of 2 – 4 per building). The exception is the two north-most duplexes. The individual boilers in these buildings are not in the same room, so they will always have two connections. Figures 3.1 through 3.5 below show some of the interconnection options for Angoon.

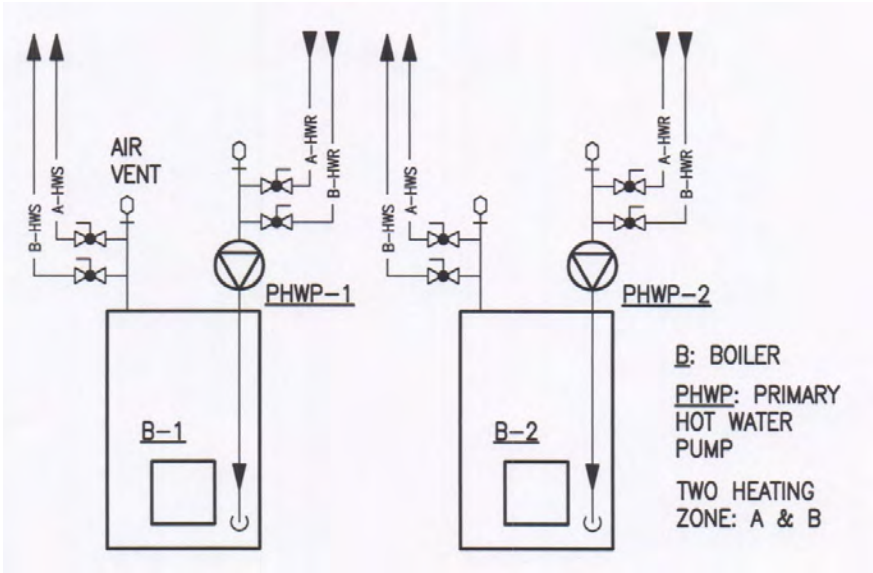


Figure 3.1

Figure 3.1 shows a typical Angoon duplex arrangement. Each boiler can serve only one residence, and there are two zones for each residence, A & B. The boilers cannot cross over and serve the other residence in the event of a failure. There is, as noted above, one boiler per residence.

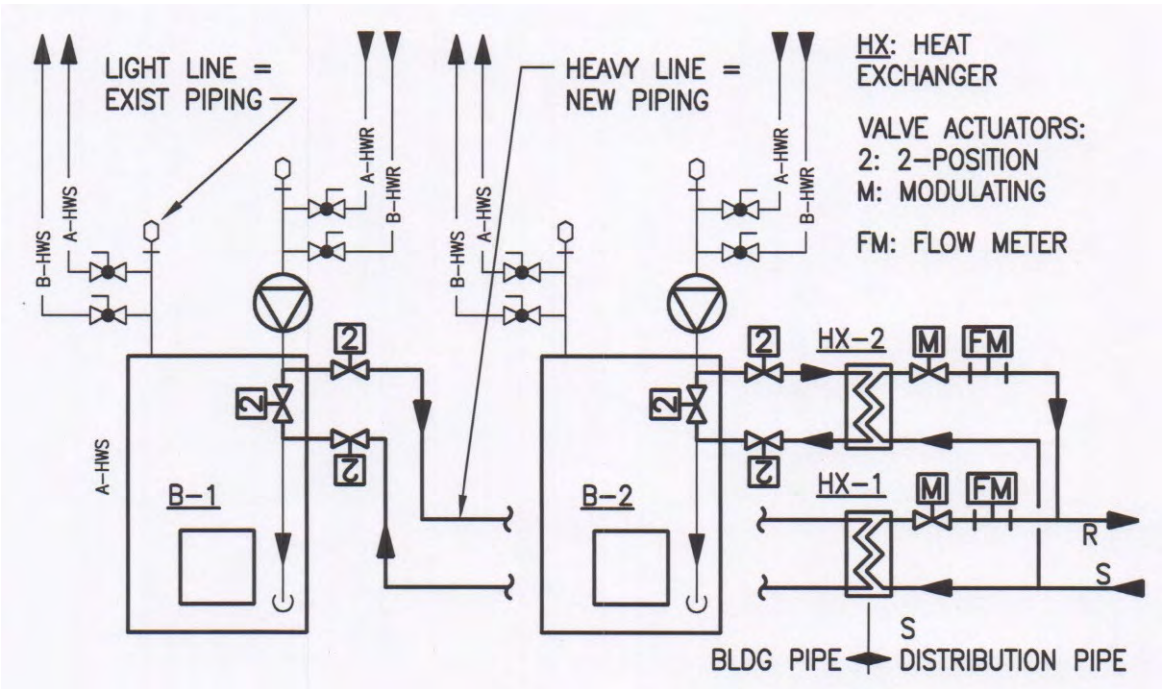


Figure 3.2

Figure 3.2 above shows the most expensive means of interconnecting; this would correspond to the pricing assumptions made in Scenario 1. This assumes that 1) each boiler must be connected separately, 2) that each end-user must be sub-metered, 3) an external control system exists in each building, and 4) the secondary pumping is variable speed.

As noted above, 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 returned 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 each residence within the multi-plex.

This is clearly over-kill for the situation in Angoon. First, the amount of flow in the system is so small that the secondary pumps are less than one horsepower. Thus, while electricity is still expensive, there is no need to use expensive control valves at each HX, and no need to make the secondary pumps variable speed. Second, there are no building control systems to control all the valves shown above. Third, there appears to be no reason to individually meter the heat to each residence.

Item 3.2 above means that a single heat exchanger can be used for each multi-plex – however, we do still have to hook up to each boiler individually. There are still 23 separate connections, although each one is significantly less complex and less expensive than the interconnections priced out in Scenario 1.

This is the basic configuration assumed in Scenarios 2 and 3 (there are other differences between 2 and 3 that affect price; these are detailed elsewhere in this report).

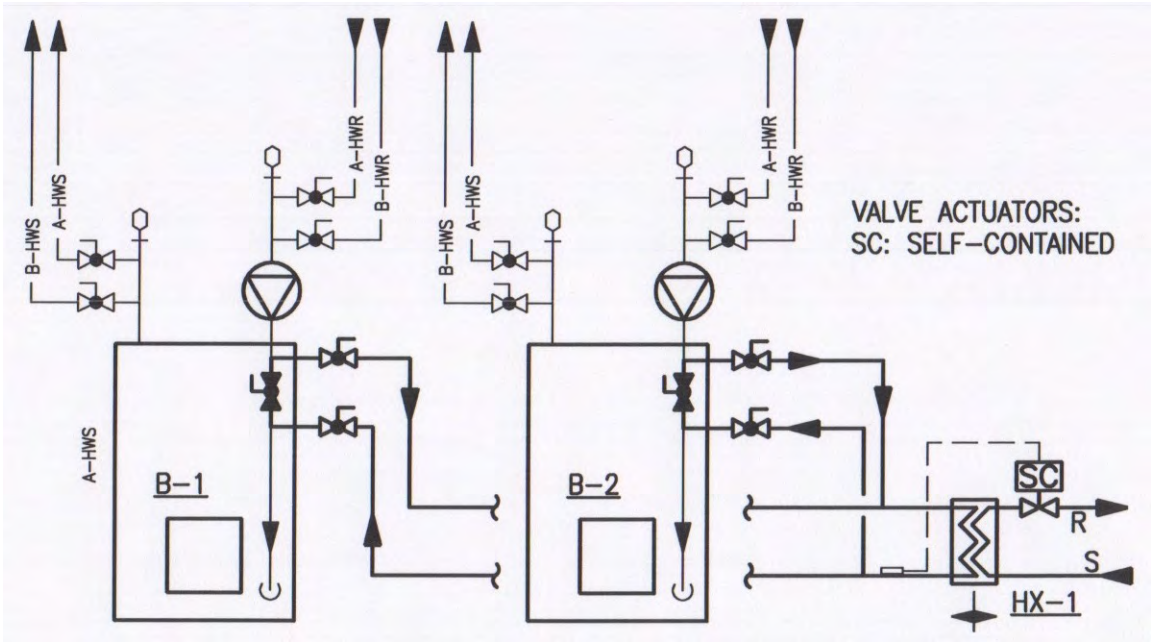


Figure 3.3

In Figure 3.3, all of the actuated valves have been replaced, except that the building HWR temperature is still controlled by what we have labelled 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 to 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.

The 2-position valves are replaced with manual valves. They would normally be left as shown (the two horizontal valves are open, the vertical valve is closed). These valve positions would only be reversed if, for some reason, a resident wished to isolate their boiler from the DH Plant.

A single HX is used for the multi-plex, although as noted above, there are still two connections required, and the boilers cannot back one another up (each boiler can still only serve its original residence).

In talking to the Villagers, we learned that there was some thought of converting the multi-plexes such that each one had only one boiler, regardless of the number of residences. This would obviously make the DH Plant much less expensive; in addition to using the much less expensive interconnections, the number on interconnections decreases from 23 to 11 (the two northernmost duplexes cannot easily be converted to one boiler, so 7 buildings * 1 connection + 2 buildings * 2 connections = 11 connections).

No indication was given on the potential timing of such a measure, but the model shows the effect that such a re-configuration of the existing systems would have. Although Sc 2 and Sc 3 have been reduced, the combination of 1) a small overall amount of "base" oil consumption, 2) a long distance

between the buildings (thus lots of buried pipe), and 3) a very large number of interconnections was making Scenarios 1, 2, and 3 appear unattractive, financially.

A final model was run, assuming only 11 interconnects. Rather than assume that the existing boilers had been removed, and a single new boiler added, two ways were presented to reduce the number of connections to one per building while leaving the existing boilers in place. Figures 3.4 and 3.5 show the basic piping schematics.

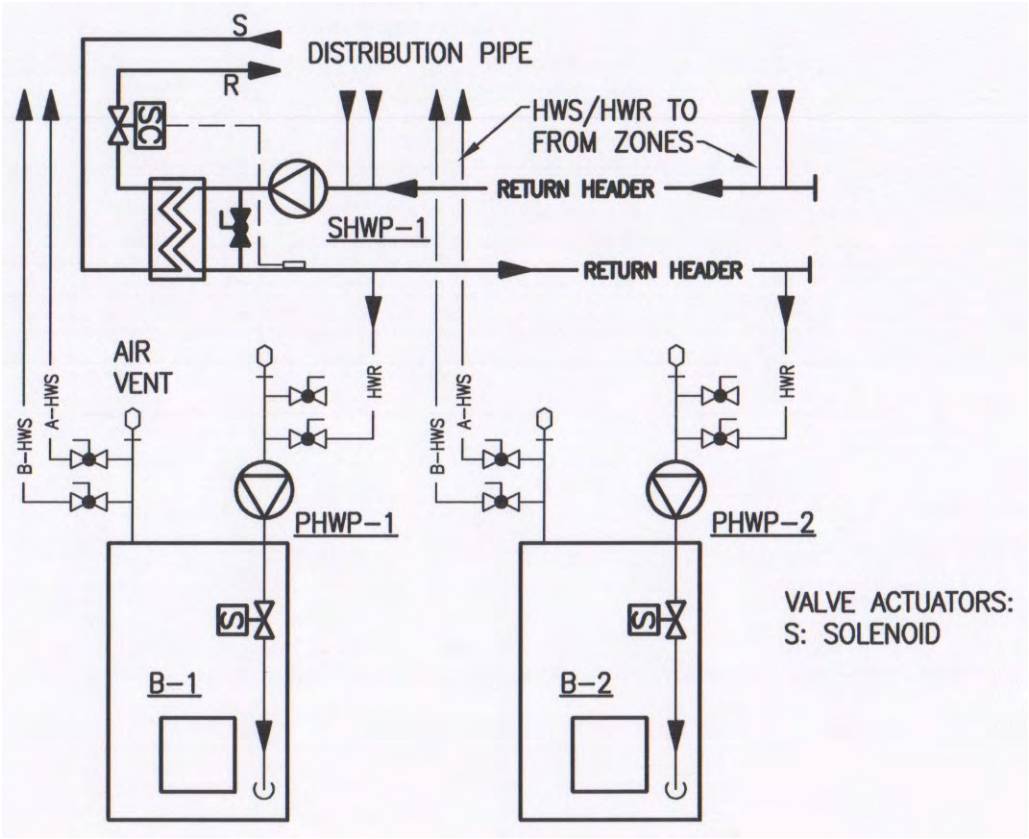


Figure 3.4

In this configuration, a new building return water (HWR) header is installed. All four HWR lines tie into the header. A new secondary building pump is shown, but may not be needed (more field work would be required to determine this). The single heat exchanger can now heat all of the hot water for the whole building with one connection to the new header.

At each boiler, a solenoid valve is added – the valve would be open whenever the associated PHWP was operating. Thus if Residence 2 did not need heat, PHWP-2 would be off. The associated solenoid would close, preventing water that should be flowing only to Residence 1 from flowing through B-2.

Since all of the return lines flow into a common header, there is no need for two HWR lines to each boiler, so one line is removed. This assumes the remaining line can handle the entire HWR flow. ,A subject for future field work.

This configuration represents the aim of reducing the number of connections to one. However, each boiler can still only serve the original residence it "belonged to" – the supply lines off each boiler are still separate and dedicated.

Figure 3.5, therefore, shows an added building hot water supply header as well. In this configuration, there is a single point connection, and any boiler can serve any load in the building.

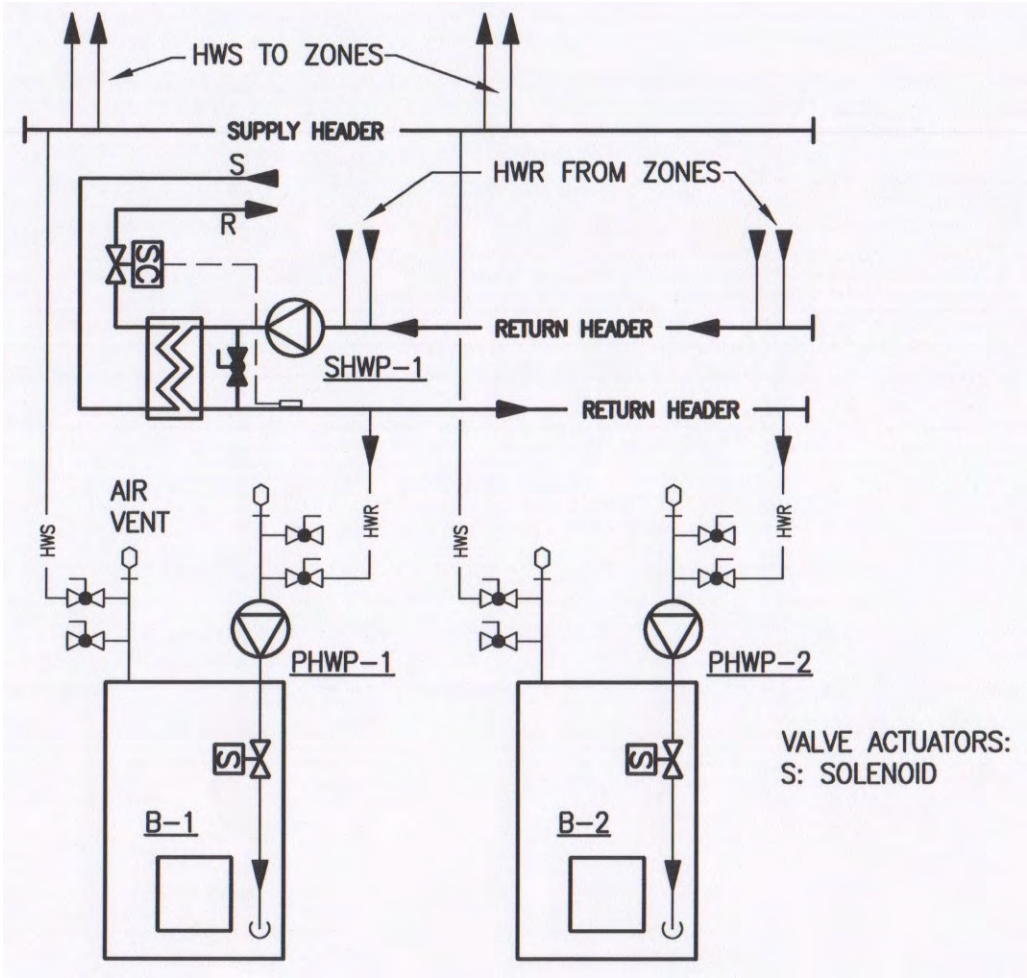


Figure 3.5

NOTE *that while Scenario 4 takes credit for the cost savings associated with reducing the number of connections from 23 to 11, it* ***DOES NOT*** *include the costs associated with adding the header or headers (depending on final configuration). Since THRHA was considering something similar, the change was modeled to show how it would affect the economics of the DH Plant.*

3.2 Thermal Storage

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

Stick fired boilers are batch fed, with an operator adding batches of fuel as needed. In this case, thermal storage is almost a requirement. This is 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. 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 storage tank can help 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 as heavy, so they heat up much quicker. While a thermal storage tank would, again, limit cycling at low loads, pellet boilers generally do not need a tank to modulate and follow loads. 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. The Okofen boilers sold by Maine Energy Systems do not shut down while cleaning, and so while thermal storage can be added to the MES boilers, a determination must be made for storage based on the application, need and cost.

In a district heating application, one is likely to have two, or even three boilers. If each boiler has a 4:1 turndown, then a plant with two boilers can turn down 8:1, and a three-boiler plant can turn down 12:1. The buried piping provides a small but constant load, and even on warm days in AK, nights can be cold. So, in these DH situations, thermal storage is not added, the combined turndown of the boilers is sufficient to minimize cycling.

In a small single building or residential application, a small (50 – 90 gallon) tank may be added, even for an MES boiler, space and money permitting.

Appendix 1. Photos and site map

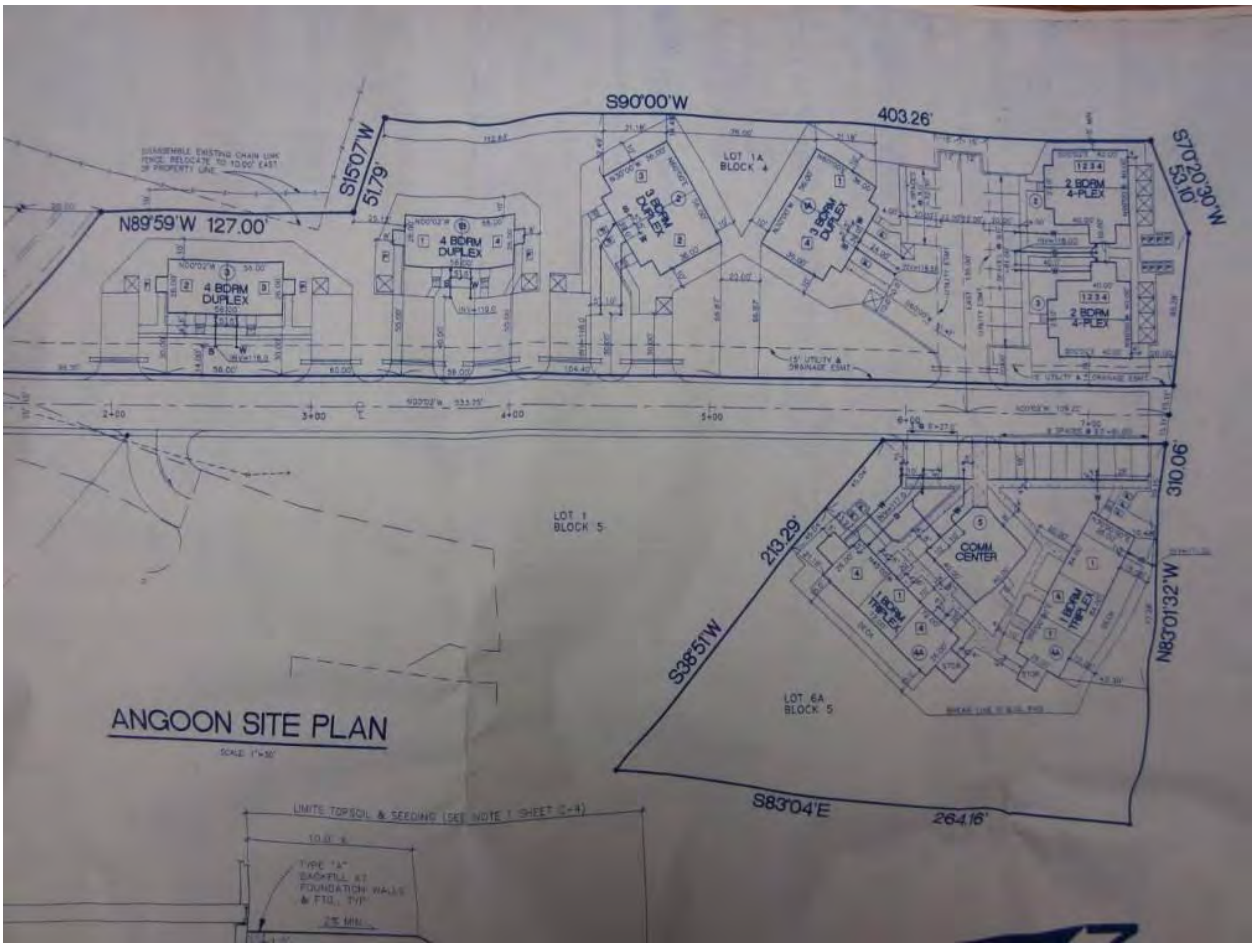


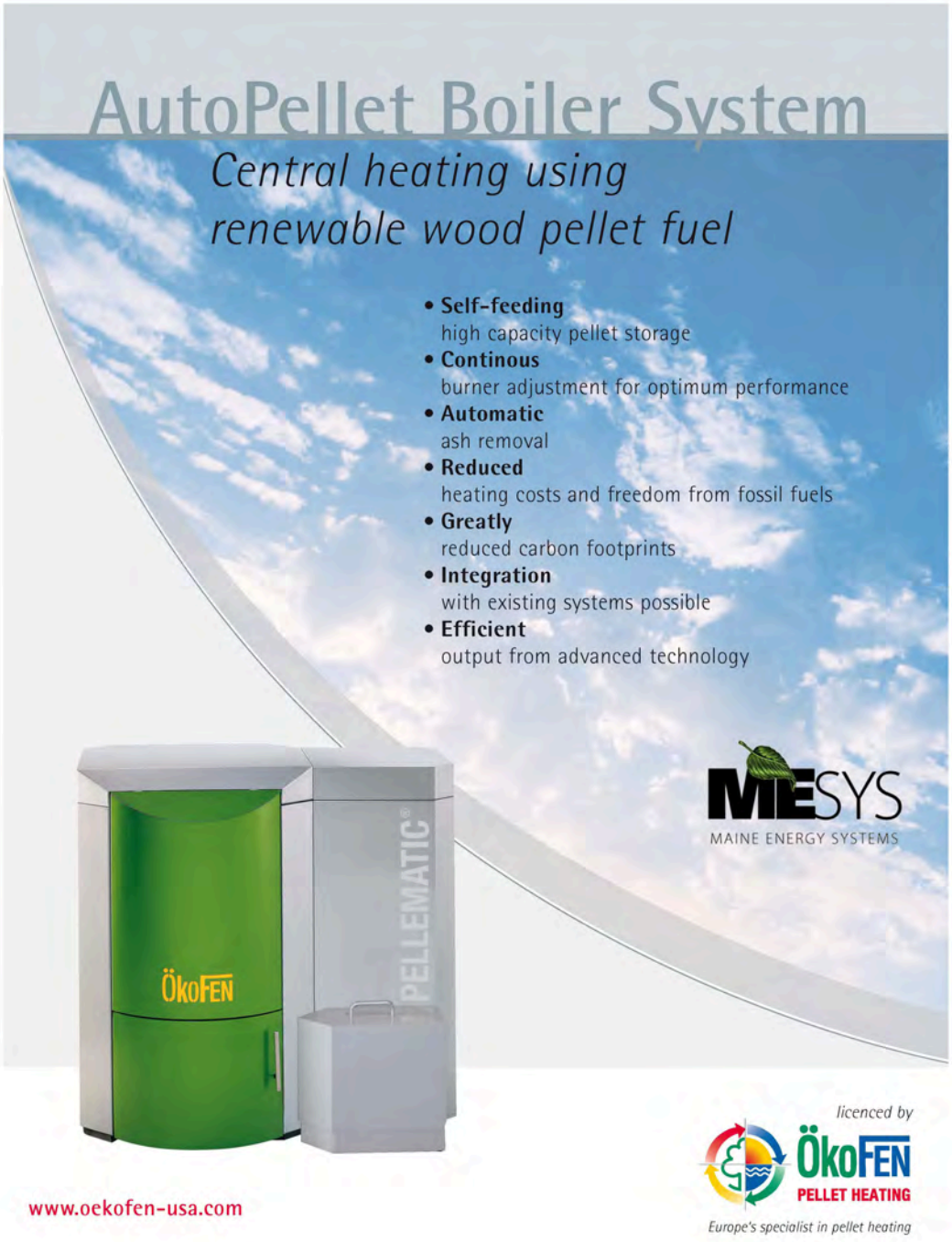
Figure 1. Site plan with potential location of the Pellet District Heat Plant.

Figure 2. Each building has as many boilers as there are apartments in the building.

Figure 3. Example of a duplex with two boilers, two oil tanks and two stacks on top of the building.

Figure 4. Example of a four plex. See the 4 stacks on right from adjacent 4-plex and the boiler room for the building.

Appendix 2. Brochure for MES OkFen Pellet Boilers



AutoPellet Boiler System

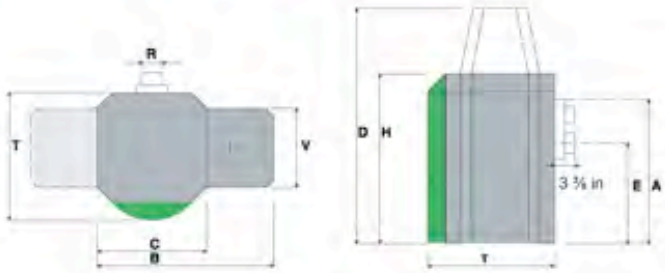
The AutoPellet boiler systems are UL approved for use with premium grade pellets. Suitable for direct replacement of an existing oil/gas boiler, or as the main heat source while maintaining the existing oil/gas boiler. An AutoPellet system is the ideal solution for decreasing our dependence on fossil fuels in times of unpredictable energy prices without reducing the level of convenience.
Each AutoPellet boiler system comes standard with either an auger or vacuum pellet feed system and automatic ash removal equipment.

Venting and Installation Requirements:
The boiler must have its own chimney/flue chase approved for solid fuel firing. Use a black smoke pipe for boiler breeching to the chimney. Install a furnished barometric in vertical direction. Slope flue pipe to chimney at least 1/4" per foot upward to the chimney. Ensure adequate combustion air at all times. Extend chimney at least 3 ft above roof penetration and at least 2 ft above any part of the roof within a radius of 10 ft. Follow Table below for minimum chimney heights. Maintain at least 4 ft lateral clearance between pellet boiler and pellet fuel storage.

Boiler - Type			PE(S)12	PE(S)16	PE(S)20	PE(S)25	PE(S)32	PES36	PES49	PES56
Boiler rated power		BTU/hr	41,000	51,000	68,300	85,300	109,500	123,000	164,000	191,000
Width - total	B	Inch	44 ½	44 ½	44 ½	46 ¾	46 ¾	51	51	51
Width - boiler	C	Inch	27 ½	27 ½	27 ½	29 ¾	29 ¾	34	34	34
Height - boiler	H	Inch	43	43	43	50 ¾	50 ¾	61 ¾	61 ¾	61 ¾
Height - vacuum suction system	D	Inch	60	60	60	67 ¼	67 ¼	73	73	73
Depth - boiler	T	Inch	32	32	32	34 ¼	34 ¼	39	39	39
Depth - casing	V	Inch	20	20	20	20	20	20	20	20
Water supply/return - dimensions		Inch	1	1	1	5/4	5/4	2	2	2
Water supply/return - height of connection	A	Inch	35 ¾	35 ¾	35 ¾	43 ¾	43 ¾	52	52	52
Flue size - diameter	R	Inch	5	5	5	6	6	7	7	7
Flue - height of connection	E	Inch	25 ½	25 ½	25 ½	33 ¾	33 ¾	41	41	41
Overall Weight		lb	534	542	551	697	705	1,327	1,336	1,345
Water capacity		Gal	15.0	15.0	15.0	23.6	23.6	30.6	30.6	30.6

Chimney Size	Min. Height
6" x 6"	12 ft
7" x 7"	16 ft
8" x 8"	16 ft
6" round	19 ft
7" round	17 ft

The AutoPellet system must be installed by a trained service technician. The boiler will require cleaning and brushing of the boiler heating surfaces **once a year**.



MESys Certified Contractor

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Figure 1. Two page Brochure.

Appendix 3. 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.

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