ENERGY AUDIT of
FULLY CONDENSING BOILER STACK ECONOMIZER

for:

CENTRAL WASHINGTON UNIVERSITY
Ellensburg, Washington

prepared by:

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SECTION I: EXECUTIVE SUMMARY

Central Washington University has been actively working to reduce energy consumption on campus for the past 15 years. Over that time period, the campus has grown by fifteen percent while the total energy use has fallen by ten percent. In addition to continuing to explore for more conservation, the University is now also committed to reducing their carbon footprint. This dual vision is what prompted the commissioning of this study to examine the feasibility of adding a fully condensing economizer to recover waste heat from the existing boiler stack gas and use that heat to offset new heating loads being planned at new buildings currently being designed (Science II, Samuelsen Communication and Technology Center, and Nutrition Exercise and Health Sciences).

The new buildings could easily consume all the waste heat that could be recovered from the boiler stacks. In fact, the New Science Building could consume most, if not all, of this heat. So, one way of thinking about this idea is that around 170,000 SF of new building could be heated with waste heat. This avoids the emission of 1,500 metric tons of carbon dioxide per year.

There are two different design concepts which could deliver the heat to the new buildings. One would be to use the existing chilled water loop which will be extended to all new buildings regardless of this heat recovery concept. The chilled water loop would be used as the heat source for new water-to-water heat pumps installed at the new buildings. Heat would be added to the loop at the boiler plant by the condensing economizer and then extracted at the buildings by the heat pumps. In the interim, or in the event the new buildings do not utilize the heat pump heating system, the waste heat will be utilized in existing building coils to preheat incoming air. The second approach would be to construct a new low temperature hot water loop to the new buildings and use the recovered heat directly. In either approach, all available waste heat can be utilized. However, the low temperature hot water loop can be in service year round whereas the chilled water loop cannot be used as a heat sink during the cooling season.

The direct use of low temperature hot water has a better payback (seven years) than the heat pump concept (10 year payback). It is simpler and requires less equipment space at the new building. However, the heat pump concept could readily be adapted to other free sources of heat like earth coupling and solar water heating which would not be practical with the direct water approach. This will become critical if the University is serious about becoming carbon neutral. Currently about 60 percent of the campus carbon footprint comes from fossil fuel combustion for building heat and hot water. Getting this to zero will certainly require conversions to renewable resources. The heat pumps would be a first step in that direction.

The required investment for implementing condensing stack heat recovery is $6.2M which includes about $3.0M for combined utility improvements that will support the new buildings in the Science Neighborhood but which will share the pathway created by the heat recovery project. The waste heat recovered is estimated to displace 300,000 therms of natural gas in the Central Heating Plant. The actual savings will be continuously metered and the Energy Service Company (ESCO) will guarantee a minimum level of savings of 264,000 therms per year. At current rates, this produces a cost savings of $206,000 per year.

Stack Heat Recovery Unit

SECTION II: CONDENSING STACK HEAT RECOVERY

The existing Central Heating Plant, has heat recovery in the form of stack economizers, or feedwater heaters. The leaving stack gas temperature controls associated with these units appear to be only partially effective, but it does appear to prevent the stack gas from getting much below 240 deg F. However, 240 deg F gas still contains a great deal of energy. A condensing heat recovery unit could be added to the Plant which would extract enough energy to fully condense the water vapor in the exhaust. By dropping the temperature enough to release latent heat, the unit recovers far more heat than the drop in gas temperature alone would imply. The condensation of water vapor occurs below 130 - 150 deg F, well below the acid dewpoint; to counteract the sulfuric acid formed, the unit is constructed of various grades of stainless steel.

In order to achieve leaving gas temperatures below 130 deg F, obviously, one must have a useful heat sink at a temperature lower than 130F. CWU in fact has three such potential sinks, which will be detailed below.

Before discussing the heat sinks, a description of the heat recovery equipment is useful. It is basically like a larger stack economizer, with water in tubes heated by hot stack gas passing around the tubes, all enclosed in an airtight housing. However, because the design must accommodate acid in the condensate stream, the unit is expensive, so it is important to keep the utilization rate up. For that reason, generally only one economizer is installed for the entire plant rather than one on each boiler. It is configured to have the ability to extract stack gas from any operating boiler. It uses ductwork, dampers, and a dedicated induced draft (ID) fan with VFD. The economizer also has its own discharge stack.

Generally, a “tee” is cut into each boiler stack, just above the roof penetration. Horizontal ducts from the stem of the four tees would then be combined into a single, larger duct. Prior to the branches coming together, however, installed in each branch line would be a modulating damper and a manual damper (for maintenance isolation). Using the HR unit controls, the condensing heat recovery unit can now draw gas from any operating boiler, and isolate the boilers not operating using dampers. Because the gas is ducted to the unit, it can be located remotely from the roof-top stacks – even down at grade outside the Plant.

The ID fan VFD modulates to maintain the unit entering gas temperature about 5 deg F below the stack gas temperature – this ensures that the unit is capturing all the available stack gas at all times (the 5 deg F drop comes because a small fraction of fresh air is actually being drawn back down the active stacks).

The existing boiler stacks have no obstructions installed. Thus, on a failure of the HR unit ID fan (or when the HR unit is down), the stack gas from each boiler simply goes up its own stack as it does now. There is no failure mode that can block the existing stack.

As noted, the unit is expensive, so sizing it correctly is an issue. Even though it would be connected to four boilers (at CWU), it is not sized to handle the gas from all four at once. It is not even normally sized for the peak expected gas flow – because that peak simply does not happen enough hours in a year to justify sizing the unit for that flow.

The best tool for the sizing the unit is a load frequency profile. This can be done a number of ways, but a bar chart can be an especially effective means of visualizing the steam load. Figure 1 below shows the load frequency generated from the 2009 steam load data:

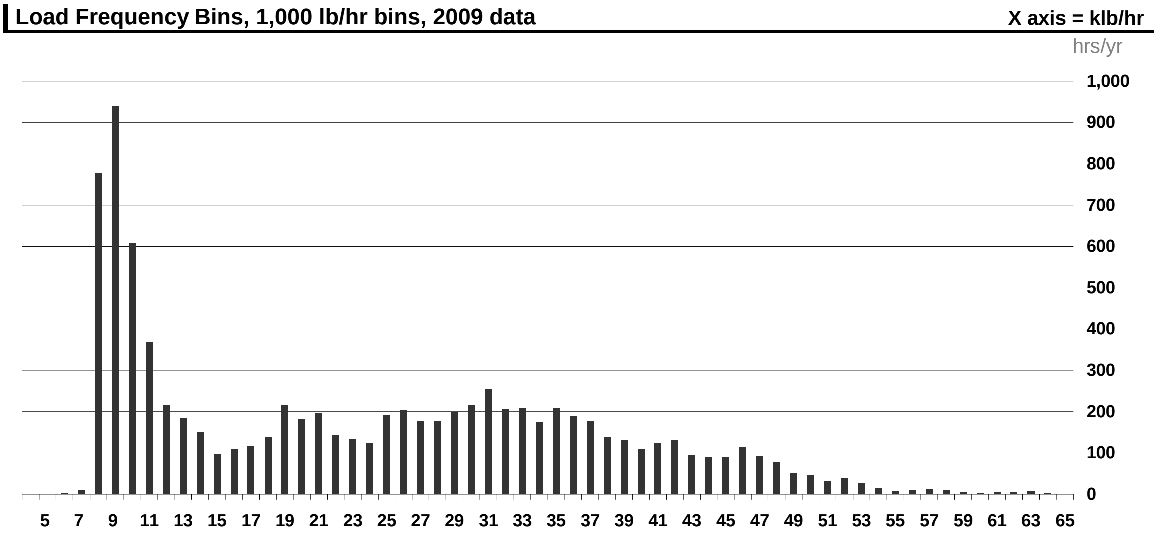

Figure 1, Load Frequency bins, 2009

Looking at the data, one can see a drop in frequency (hours per year at that load) at about 36,000 lb/hr, and another at about 48,000 lb/hr. Below those two flow rates the returns on a bigger unit are definitely diminishing. Because the campus steam load is expected to increase in the near future, and to maximize recovery, a “48,000 lb/hr” unit was analyzed for this report. In fact, the unit is limited not by the steam output, but by how much stack gas it can handle. However, it is more convenient and familiar to refer to the unit capacity by the associated steam flow, or 48,000 lb/hr.

Based on conversations with CWU, two heat recovery scenarios were considered. The first Scenario, shortened to Sc 1 in the model, involves using the existing chilled water piping and water as a heat source for building-scale water source heat pumps or directly as preheat in existing chilled water coils. A more traditional ground source heat pump loop would be limited to the ground temperature, about 50 deg F for CWU. This is an acceptable heat source temperature for the heat pumps, but a higher temperature does two things: 1) increases the heating capacity of a given heat pump, and 2) increases the coefficient of performance (COP). The effect is very significant, as the shows.

The second Scenario is more straightforward – it assumes CWU would create a new low temperature hot water loop to feed buildings close to the Plant. The HR unit would heat this water directly, and if the recovered heat was not enough, steam at the building would make up the difference. In this Scenario (Sc 2), the option of a second stage of recovery was analyzed – this second stage would preheat boiler make-up water, an even lower temperature heat sink.

There are several key assumptions in the spreadsheet model:

- In both Scenarios, the hot water supply temperature to the buildings is low (120 deg F). No buildings currently on campus (Hogue renovation excepted) can utilized such low temperature water. However, it is critical to both Scenarios, so essentially the model is assuming future buildings.
- In Sc 1, the model assumes that three new buildings are being planned simultaneously, and they are intended to be heated by heat pumps. In the absence of an HR unit, the heat source water temperature into the heat pump units would be 50 deg F, leaving at 30 deg F (the water is then heated back up to ground temperature in wells drilled for that purpose). With an HR unit in place, the chilled water is heated 25 deg F to 75 deg F, the temperature entering the heat pumps. It then leaves the heat pumps at 55 deg F. Other Sc 1 assumptions:
    - At some outside air temperature (OAT), the chilled water loop would be required for cooling, which would mean the heat pumps would no longer use it as a heat source. The details of this switchover, and what other equipment might be involved, have not been resolved, thus the need for more study on this concept. To get around that, the model assumes a "lockout" OAT of 55 deg F (adjustable) – above that, no heating with heat pumps occurs, and the model ignores this condition.
    - The financial section of the model deals only with this heating mode. All first costs and operating costs are strictly for this period below the lock-out OAT.
    - The financial model assumes it all happens at once – that CWU has designed these four buildings to built at one time using low temperature hot water, and is evaluating the best way to heat them.
    - The model evaluates four heating modes, and compares them to the base case (which is to simply heat them with steam as is done now). Again,

    however, only the annual hours at or below the lock-out OAT are included in the analysis.
  - The four options for heating are: 1) water source heat pumps with HR providing heat to the loop, 2) true ground source heat pumps, extracting heat from a well, 3) water source heat pumps with condensing boilers at the Plant providing heat to the loop, and 4) condensing boilers at each building, heating them directly (no heat pumps).
  - In each option, it is important to note that the amount of heat provided to the building is the same for all four options. In essence, the amount of heat that the basis of design (BOD) heat pumps could put out under the HR option was calculated and used as the “Design Heat Load”. All other options were assumed to provide the exact same magnitude of end-use heat.
  - Note that for heat pumps, the output heat to the buildings is greater than the recovered heat input into the loop – this is because the heat of compression generated within the heat pumps goes into the building heating water. This is 1.2 to 1.25 times the input water heat. Thus the heat pump leverages the recovered heat.
- In Sc 2, the model assumes that the heat is used in a single new building (Science II was used for estimating the length of piping required). It is assumed that the building actually requires more heat than the HR unit can supply, and so all the HR heat is used by the building. The HWS temperature was assumed to be 120 deg F, the HWR temperature 95 deg F (thus the HR unit sees a 95 deg F heat sink).
  - In this case, the HR unit is supplying heating hot water directly – there is no leveraging effect as with heat pumps.
  - As with SC 1, the HR heating is compared to the base case (steam heat). In this Scenario, however, there is only one other option examined, providing the same amount of heat using condensing boilers at the building.
- As noted above, a second stage of heat recovery was analyzed. This would use the (now much cooler) stack gas leaving the first (heating hot water) stage of the HR unit to heat the boiler make-up. This is much less effective than the first stage because:
  - Much of the heat content of the stack gas has already been extracted in the first stage,
  - The make-up water is intermittent. The Plant operators found that when the make-up trickled continuously through the softeners, the water traveled only through the center of the softening media; a very ineffective mode of operation. So now they introduce large amounts of make-up at intervals, generally about 6 – 7 intervals per day of about 30 minutes each. This makes the softening more effective, but lowers the utilization rate of a second stage. Obviously, when no make-up is passing through the HR unit 2nd stage, no heat is being recovered. (The stack gas at this point is well below 212 deg F, so there is no danger of overheating the stagnant water in the coils between intervals.)
  - The steam being displaced is DA steam. DA steam comes straight from the header, and thus experiences none of the losses that distribution steam experiences.

  - The model analyzes stage 2 first as a marginal adder. In other words, it assumes stage 1 is already there; the model looks at how much more it would cost to add stage 2, and this marginal cost is evaluated against the marginal heat recovery attributed to stage 2.
- Finally, the Sc 2 model looks at stages 1 and 2 combined vs the base case of steam heat.

In terms of heat recovery, Sc 1 is almost ideal. The heat sink (chilled water loop) is both very large and very cold. The term “large” here denotes that the ability of the chilled water loop to absorb heat far exceeds the available stack heat to be recovered – in effect it is an “infinite heat sink”. Very cold here means 50 deg F. The result is that at peak steam load (~70,000 lb/hr), the HR unit can recover 11.55 mmBTU/h – 13.9 percent of the input gas heat. In essence, this would raise the Plant boiler efficiency from about 83 percent to 96.9 percent. The leaving stack gas temperature under this condition would be an amazing 66 deg F.

As noted above, this recovered heat is leveraged by the heat pumps; the final heat rate to the buildings at peak load was calculated to be 13,861 mmBTU/h. This was the amount of end-use heat that each option had to provide. Because the chilled water loop is only a degree or two warmer than the boiler make-up water, there is no point in using second stage for this Scenario.

The advantage a higher heat source temperature provides to a heat pump is shown in Figure 2 below – these are the heating characteristics of the basis of design heat pumps:

Basis of Design
Multistack MS070XN with R410-A

		deg F design HWS temp		120
LWT, source temp deg F	input power kW	heat output kBTU/h	heating COP	1.20 heat from source kBTU/h
30	66.8	711.2	3.12	592.7
35	67.1	770.2	3.36	641.8
40	67.4	833.5	3.62	694.6
45	67.8	901.8	3.90	751.5
50	68.3	974.9	4.18	812.4
55	68.9	1,053.2	4.48	877.7
60	69.6	1,136.0	4.79	946.7
65	70.3	1,223.7	5.12	1,019.8

Figure 2, Multistack 75 ton HP data

Note that the first column is heat source *leaving* water temperature, not entering water temperature. So the comparison is between 30 deg F (ground source option, 50 > 30 deg F) versus 55 deg F (HR water source, 75 > 55 deg F). In the HR option, the unit provides 1053.2 kBTU/h of 120 deg F water, at a COP of 4.48. Dividing 1,053,200 BTU / 4.48 / 3412 BTU/kW equals 68.9 kW of input power. In the ground source application, the unit can only produce 711.2 kBTU/h, and uses 66.8 kW to do it, a COP of 3.12.

The most obvious implication of this is that in the ground source option, one needs several more units to produce the same heat (and each unit costs the same no matter how it is used). In fact, in the model, the HR option requires 13 heat pumps; the ground source option requires 19 units – a significant first cost difference. Due to the lower COP, the 19 units would consume significantly more power as well, as the model shows.

In Sc 2, stage 1, the heat sink is also large, but at 95 deg F, much warmer. Thus the peak recovery rate is 5.979 mmBTU/hr, just over half that of Sc 2. However, unlike Sc 1, there is no “lock-out” OAT – the HR unit would run 8,760 hours, thus the total annual heat recovery is more balanced (28,872 mmBTU for Sc 1 v 23,124 mmBTU for Sc 2 stage 1). The Science building would need reheat even in summer, so the unit is assumed to run continuously.

The second stage of Sc 2 is less effective for the reasons noted above, and unless CWU expects make-up rates to increase significantly in the near term, does not appear cost effective.

CWU is encouraged to use the model and see the results – it is not possible to summarize them all here – there are too many variables. Figure 3 below shows the amount of heat that would be recovered at the two likely operating conditions, either using the chilled water loop or using a dedicated low temperature hot water loop.

			ground source scenario, unlimited mass rate at EWT shown					**hydronic heating, unlimited mass rate, 95 deg F EWT**			
			mmBTU	35,454	heat recovered			mmBTU	23,124	heat recovered	
	8,760.0										
OAT deg F	total hrs		OAT deg F	load lb/hr	HR kBTU/h	EWT deg F		OAT deg F	load lb/hr	HR kBTU/h	EWT deg F
107	0.3		107	8,176	1,196	66.2		107	8,176	859	95.0
106	0.5		106	8,214	1,202	66.1		106	8,214	863	95.0
105	1.5		105	8,252	1,208	65.9		105	8,252	868	95.0
104	1.5		104	8,290	1,215	65.8		104	8,290	873	95.0
103	4.3		103	8,327	1,221	65.6		103	8,327	878	95.0
102	2.5		102	8,365	1,228	65.5		102	8,365	883	95.0
101	4.0		101	8,403	1,234	65.3		101	8,403	887	95.0
100	5.5		100	8,441	1,241	65.2		100	8,441	892	95.0
99	7.3		99	8,478	1,247	65.0		99	8,478	897	95.0
98	7.5		98	8,516	1,253	64.8		98	8,516	902	95.0
97	11.8		97	8,554	1,260	64.7		97	8,554	907	95.0
96	14.0		96	8,592	1,266	64.5		96	8,592	911	95.0
95	16.3		95	8,630	1,273	64.4		95	8,630	916	95.0
94	20.0		94	8,667	1,279	64.2		94	8,667	921	95.0
93	17.0		93	8,705	1,286	64.1		93	8,705	926	95.0
92	22.5		92	8,743	1,292	63.9		92	8,743	930	95.0
91	20.8		91	8,781	1,298	63.8		91	8,781	935	95.0
90	27.0		90	8,818	1,305	63.6		90	8,818	940	95.0
89	30.5		89	8,856	1,311	63.5		89	8,856	945	95.0
88	30.0		88	8,894	1,318	63.3		88	8,894	949	95.0
87	35.5		87	8,932	1,324	63.2		87	8,932	954	95.0
86	32.8		86	8,969	1,331	63.0		86	8,969	959	95.0
85	41.3		85	9,007	1,337	62.9		85	9,007	964	95.0
84	33.3		84	9,045	1,343	62.7		84	9,045	969	95.0
83	50.5		83	9,083	1,350	62.6		83	9,083	973	95.0
82	49.0		82	9,120	1,356	62.4		82	9,120	978	95.0
81	55.0		81	9,158	1,363	62.3		81	9,158	983	95.0
80	57.8		80	9,196	1,369	62.1		80	9,196	988	95.0
79	59.5		79	9,234	1,376	62.0		79	9,234	992	95.0
78	62.0		78	9,272	1,382	61.8		78	9,272	997	95.0
77	61.0		77	9,309	1,388	61.7		77	9,309	1,002	95.0
76	67.3		76	9,347	1,395	61.5		76	9,347	1,006	95.0
75	77.0		75	9,385	1,401	61.4		75	9,385	1,011	95.0
74	77.0		74	9,423	1,408	61.2		74	9,423	1,016	95.0
73	85.3		73	9,460	1,414	61.1		73	9,460	1,021	95.0
72	79.0		72	9,498	1,420	60.9		72	9,498	1,025	95.0
71	95.5		71	9,536	1,427	60.8		71	9,536	1,030	95.0
70	101.5		70	9,574	1,433	60.6		70	9,574	1,035	95.0

Figure 3, continued on next page.

			ground source scenario, unlimited mass rate at EWT shown					hydronic heating, unlimited mass rate, 95 deg F EWT			
			mmBTU	35,454	heat recovered			mmBTU	23,124	heat recovered	
	8,760.0										
OAT	total		OAT	load	HR	EWT		OAT	load	HR	EWT
deg F	hrs		deg F	lb/hr	kBTU/h	deg F		deg F	lb/hr	kBTU/h	deg F
69	98.5		69	9,611	1,440	60.5		69	9,611	1,040	95.0
68	100.0		68	9,649	1,446	60.3		68	9,649	1,044	95.0
67	111.0		67	9,687	1,453	60.2		67	9,687	1,049	95.0
66	119.5		66	9,725	1,459	60.0		66	9,725	1,054	95.0
65	117.5		65	9,968	1,500	59.8		65	9,968	1,084	95.0
64	136.3		64	10,825	1,646	59.7		64	10,825	1,190	95.0
63	149.8		63	11,683	1,792	59.5		63	11,683	1,295	95.0
62	130.0		62	12,541	1,938	59.4		62	12,541	1,399	95.0
61	138.8		61	13,398	2,084	59.2		61	13,398	1,502	95.0
60	153.0		60	14,256	2,230	59.1		60	14,256	1,603	95.0
59	150.8		59	15,113	2,376	58.9		59	15,113	1,703	95.0
58	156.0		58	15,971	2,522	58.8		58	15,971	1,803	95.0
57	173.3		57	16,828	2,668	58.6		57	16,828	1,901	95.0
56	168.0		56	17,686	2,813	58.5		56	17,686	1,997	95.0
55	135.3		55	18,543	2,959	58.3		55	18,543	2,093	95.0
54	167.8		54	19,401	3,105	58.2		54	19,401	2,187	95.0
53	157.3		53	20,258	3,251	58.0		53	20,258	2,281	95.0
52	152.3		52	21,116	3,397	57.9		52	21,116	2,373	95.0
51	151.5		51	21,973	3,543	57.7		51	21,973	2,464	95.0
50	190.3		50	22,831	3,689	57.6		50	22,831	2,554	95.0
49	163.0		49	23,689	3,835	57.4		49	23,689	2,642	95.0
48	167.5		48	24,546	3,981	57.3		48	24,546	2,730	95.0
47	176.8		47	25,404	4,126	57.1		47	25,404	2,816	95.0
46	162.8		46	26,261	4,272	57.0		46	26,261	2,901	95.0
45	160.5		45	27,119	4,418	56.8		45	27,119	2,985	95.0
44	150.3		44	27,976	4,564	56.7		44	27,976	3,068	95.0
43	159.0		43	28,834	4,710	56.5		43	28,834	3,150	95.0
42	167.5		42	29,691	4,856	56.4		42	29,691	3,230	95.0
41	170.5		41	30,549	5,002	56.2		41	30,549	3,310	95.0
40	178.0		40	31,406	5,148	56.1		40	31,406	3,388	95.0
39	176.8		39	32,264	5,294	55.9		39	32,264	3,465	95.0
38	188.3		38	33,121	5,439	55.8		38	33,121	3,541	95.0
37	210.3		37	33,979	5,585	55.6		37	33,979	3,616	95.0
36	223.0		36	34,836	5,731	55.5		36	34,836	3,689	95.0
35	188.3		35	35,694	5,877	55.3		35	35,694	3,761	95.0
34	185.8		34	36,552	6,023	55.2		34	36,552	3,833	95.0
33	148.0		33	37,409	6,169	55.0		33	37,409	3,903	95.0
32	152.3		32	38,267	6,315	54.8		32	38,267	3,971	95.0
31	126.5		31	39,124	6,461	54.7		31	39,124	4,039	95.0
30	155.5		30	39,982	6,607	54.5		30	39,982	4,106	95.0

Figure 3, continued on next page.

			ground source scenario, unlimited mass rate at EWT shown					**hydronic heating, unlimited mass rate, 95 deg F EWT**			
			mmBTU	35,454	heat recovered			mmBTU	23,124	heat recovered	
	8,760.0										
OAT deg F	total hrs		OAT deg F	load lb/hr	HR kBTU/h	EWT deg F		OAT deg F	load lb/hr	HR kBTU/h	EWT deg F
29	128.3		29	40,839	6,752	54.4		29	40,839	4,171	95.0
28	111.3		28	41,697	6,898	54.2		28	41,697	4,235	95.0
27	119.3		27	42,554	7,044	54.1		27	42,554	4,298	95.0
26	96.5		26	43,412	7,190	53.9		26	43,412	4,360	95.0
25	93.5		25	44,269	7,336	53.8		25	44,269	4,421	95.0
24	72.8		24	45,127	7,482	53.6		24	45,127	4,480	95.0
23	54.3		23	45,984	7,628	53.5		23	45,984	4,539	95.0
22	50.0		22	46,842	7,774	53.3		22	46,842	4,596	95.0
21	39.0		21	47,700	7,920	53.2		21	47,700	4,652	95.0
20	41.0		20	48,557	8,030	53.0		20	48,557	4,687	95.0
19	26.0		19	49,415	8,148	52.9		19	49,415	4,730	95.0
18	30.8		18	50,272	8,268	52.7		18	50,272	4,774	95.0
17	36.8		17	51,130	8,390	52.6		17	51,130	4,819	95.0
16	28.5		16	51,987	8,514	52.4		16	51,987	4,865	95.0
15	22.5		15	52,845	8,640	52.3		15	52,845	4,911	95.0
14	23.8		14	53,702	8,767	52.1		14	53,702	4,958	95.0
13	22.5		13	54,560	8,897	52.0		13	54,560	5,005	95.0
12	15.3		12	55,417	9,028	51.8		12	55,417	5,053	95.0
11	16.8		11	56,275	9,162	51.7		11	56,275	5,102	95.0
10	12.8		10	57,132	9,297	51.5		10	57,132	5,152	95.0
9	13.8		9	57,990	9,434	51.4		9	57,990	5,202	95.0
8	9.3		8	58,848	9,573	51.2		8	58,848	5,253	95.0
7	16.5		7	59,705	9,713	51.1		7	59,705	5,305	95.0
6	10.3		6	60,563	9,856	50.9		6	60,563	5,357	95.0
5	9.8		5	61,420	10,001	50.8		5	61,420	5,410	95.0
4	6.5		4	62,278	10,147	50.6		4	62,278	5,464	95.0
3	6.3		3	63,135	10,296	50.5		3	63,135	5,519	95.0
2	5.5		2	63,993	10,446	50.3		2	63,993	5,574	95.0
1	4.3		1	64,850	10,598	50.2		1	64,850	5,630	95.0
0	2.5		0	65,708	10,752	50.0		0	65,708	5,686	95.0
(1)	1.3		(1)	66,565	10,908	49.8		(1)	66,565	5,743	95.0
(2)	1.0		(2)	67,423	11,066	49.7		(2)	67,423	5,801	95.0
(3)	0.3		(3)	68,280	11,225	49.5		(3)	68,280	5,860	95.0
(4)	0.0		(4)	69,138	11,387	49.4		(4)	69,138	5,919	95.0
(5)	0.5		(5)	69,996	11,550	49.2		(5)	69,996	5,979	95.0

Figure 3, Heat Recovery from Boiler Stack.

SECTION III: PROJECT FEASIBILITY

It is likely CWU will execute a sequence that uses both the chilled water heat sink and the low temperature hot water loop. Thus, it is reasonable to estimate the energy savings will be near the upper end of those estimated in Figure 3. As part of an ESCO project, the guaranteed savings would be 264,000 therms of natural gas (about 80% of the estimated savings).

At $0.78 per therm, this produces an annual energy cost savings of $206,000.

The project has two major components. The first is to construct the stack heat recovery system and modify the existing building chilled water systems to accept its heat during the non-cooling season. The second is to construct the combined utilities that will make the waste heat useable at the new buildings in the Science Neighborhood - Science II, Samuelsen Communication and Technology Center, and Nutrition Exercise and Health Sciences (and into the future grow the low temperature hot water loop to more of the campus). These costs are summarized below in Figure 4.

	No.		unit cost	est install	cost per unit	total
Base Stack HR (Reject Heat Into CHW Loop and Use at Existing CHW Coils)						
heat recovery unit	1	ea	$350,000	$350,000	$700,000	$700,000
structrual mods	1	ls			$100,000	$100,000
pumping and piping	1	ls	$75,000		$75,000	$75,000
modifications at existing HX	1	ls	$10,000	$20,000	$30,000	$30,000
add coil pumps and control changes at each building	26	ea	10000	10000	$20,000	$520,000
controls integration, boiler plant	1	ls			$25,000	$25,000
electrical	1	ls	$10,000	$20,000	$30,000	$30,000
comissioning	1	ls		$40,000	$40,000	$40,000
Sub-Total Base Stack HR						$1,520,000
Soft Costs						$680,000
TOTAL BASE STACK HR						$2,200,000
Combined Utilities to Extend HR to Science Neighborhood						
	No.		unit cost	est install	cost per unit	total
New CHW from Plant to east of D Street	900	lf			$500	$450,000
LTHW to Neighborhood	900	lf			$500	$450,000
Incorporate dual mode into Stack HR (to CHW and LTHW)	1	ls			$100,000	$100,000
Emergency Power Ductbank	900	lf			$300	$270,000
Increase CHW Capacity at Plant	1	ls			$1,200,000	$1,200,000
Add primary and secondary CHW pump capacity	1	ls			$100,000	$100,000
Add 480 V Capacity at Plant to Meet New Loads	1	ls			$50,000	$50,000
Add 4160 V Capacity at Plant for New Loads	1	ls			$50,000	$50,000
Add Emergency Power Capacity at Plant	1	ls			$100,000	$100,000
Sub-Total Combined Utiities						$2,770,000
Soft Costs						$1,230,000
TOTAL BASE STACK HR						$4,000,000
TOTAL PROJECT						$6,200,000

Figure 4 – Project Cost Estimate

The payback on the total project at 30 years is not that compelling. However, it must be considered that about $3.2M of the project cost would have to be spent in the construction of the new Science Neighborhood buildings if this project were not constructed. The payback on the net $3.0M cost of the stack heat recovery system is 16 years which makes economic sense for a system that is expected to remain in service for 30 years. Furthermore, if CWU is awarded a grant under the Department of Commerce 2012 Energy Efficiency Grants for Higher Education and local Governments, then the net cost to CWU for the heat recovery would be reduced to $1.35M (grant request is $1.85M). The payback on this net cost is only seven years.

In addition to the energy savings, this project produces significant environmental benefits. The recovered heat is enough to heat 170,000 square feet of new buildings and avoids the emission of 1,500 metric tons of CO2 per year. Co-locating the emergency power generators at the Plant ,rather than distributing them at each new building, allows the critical power needs to be met with existing emergency generators avoiding the permitting of an additional 1,000 horsepower of diesel engines.