Comprehensive Heating Plant Study

Volume 4 of 6

Madison, Wisconsin

SYSKA HENNESSY GROUP

LUTZ, DAILY & BRAIN, LLC

ENSR | AECOM

KEN SAIKI DESIGN INC

TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

List of Figures and Drawings

I. EXECUTIVE SUMMARY

Syska Hennessy Group (SHG) and its consultants were engaged by the Wisconsin Department of Administration (DOA) and the University of Wisconsin (UW) to prepare a Master Plan study with budget and concept report for the Walnut Street Heating Plant (WSHP) serving the University of Wisconsin (UW) – Madison campus.

A. Existing Conditions

All equipment with the exception of Boilers B-1 and B-2 are in fair operating condition but have some casing leaks that prohibit operation at peak rated capacity. These boilers should be replaced in the near future in order to keep the reliable dispatch of capacity for the campus.

B. Energy Needs

WSHP is an integral part of the current and future UW campus heating and cooling capacity. Two options are presented, but on their own, they do not solve the future needs of the campus and only replace the aging boilers on a capacity basis. In order to meet the future campus needs, both options would have to be implemented.

C. Discussion of Concepts, Economics and Score Card Results

The results of the life cycle cost (LCC) analyses are presented in the Table 1 below and the results of the more detailed LCC analysis results are located in Volume 1 after the Executive Summary. Option WSHP-1 adds (2) Gas Turbines with heat recovery steam generators and Option WSHP-2 replaces existing B-1 and B-2 with new 175,000 PPH boilers.

WALNUT STREET HEATING PLANT LCC OPTION RESULTS – TABLE 1							
Option	**First Cost**	**LCC Discounted First Cost**	**LCC Discounted Energy Cost**	**LCC Discounted CO_2 Cost**	**LCC Discounted O&M Cost**	**Total LCC Discounted Cost**	**Cost of Energy Provided ($/MMBtu)**
WSHP-1	$ 54,565,000	$45,955,000	$1,224,045,000	$224,652,300	$41,961,200	$1,526,747,000	**$ 12.08**
WSHP-2	$ 13,600,000	$11,455,000	$1,214,180,000	$290,829,500	($4,095,100)	$1,522,234,200	**$ 12.04**

Although the values in each cost criteria are different, they are extremely close in a 25 year analysis and could be deemed equivalent. The options were next quantitatively and qualitatively scored based on criteria found in Section VII and Table 2 below summarizes the scorecard results.

WALNUT STREET HEATING PLANT SCORECARD SUMMARY – TABLE 2				
Option Description	**Environmental Score**	**Reliability Score**	**Economic Score**	**Overall Score**
WSHP-1 (CT/HRSG)	**45.0**	**32.0**	**42.2**	**120.2**
WSHP-2 (Boilers)	**19.6**	**28.0**	**49.9**	**97.5**

D. Recommendations

This plant is not tied as tightly into the Amended Consent Decree as the coal burning plants and is analyzed mostly on an economic dispatch level. While cogeneration utilizing gas turbines was illustrated as being equal or better than traditional gas boilers, when compared to cogenerating using lower cost fuels such as coal or biomass, it is not as cost effective. The current spark spread difference between the current cost of electricity from the grid and natural gas is not great enough to justify natural gas based cogen at this time. Hence, the UW can find more attractive projects on campus such as at CSHP. If additional gas based cogeneration is desired by the UW, it may actually be more cost effective to purchase the power island at West Campus Cogeneration Facility (WCCF) in lieu of installing new gas turbine cogen at WSHP. This should be further discussed with the UW.

It should be noted that within the next 20 years, the existing gas fired Boilers B-1 and B-2 will need to be replaced. At that time, the UW should relook at the economics between gas cogeneration and larger gas-fired boilers as a replacement strategy and to bolster the firm capacity of the campus.

II. INTRODUCTION

A. Acknowledgements

SHG and its team of consultants (LD&B, ENSR and Ken Saiki Design Inc.) would like to thank the following personnel for their invaluable assistance in obtaining information for use in this report:

Alan Fish	Andrew Moyer	Jay Ehrfurth	Cari Anne Renlund	David Helbach
Craig Weiss	John Harrod	Dan Dudley	Faramarz Vakili	Rick Werre
Biren Patel	John Loescher	Gary Guitzkow	Greg Wanek	Don Peterson
Linda Barth	Bill McGaw	Rick Cibulka	Ralph Warner	Scott Neitzel

B. Background, Scope and Purpose

During August 2007, the Department of Administration (DOA) for the State of Wisconsin and the UW Madison campus contracted with Syska Hennessy Group (SHG) to prepare a Comprehensive Heating Plant Study (CHPS). This CHPS is to include the University of Wisconsin (UW) Charter Street Heating Plant (CSHP) and Walnut Street Heating Plant (WSHP), Capital Heat and Power Plant (CHPP) and a final plant scheme combining those two assets into a third new central plant. SHG retained the following team of consultants to assist them in the preparation of this Comprehensive Heating Plant Study:

1. Lutz, Daily & Brain, LLC (LD&B) Consulting Engineers, for their solid fuels expertise;
2. ENSR for their environmental consulting expertise and
3. Ken Saiki Design (KSD) for their expertise in organizing for public forums and other presentations.

Both CSHP and CHPP are reaching a period in their operational life where technological advancements need to be implemented in order to reduce emissions, incorporate alternate fuels and minimize operational/maintenance costs. Also, in the case of CSHP, UW will have need for additional steam resources within the next ten years. This study will address how the future configuration of these plants should be modified to best fulfill those needs. The basic intent of this study is to investigate, analyze and recommend on a plant-by-plant basis the optimum configuration of the central plants to serve their steam generation load base by addressing the following three key parameters:

- Environmental Concerns (carbon footprint, emissions, regulations, etc.)
- Reliability
- Economic Implications (construction costs, operation costs, energy costs, etc.)

A “scorecard” has been developed summarizing the quantitative and qualitative characteristics relating to the above parameters. The scorecard will be included in the executive summary of each report in tallying each option. The contents of the scorecard have evolved as the project has progressed towards completion of this study.

Various options will be analyzed on a 25-year life cycle cost (LCC) basis for each of the three plants. All technology options are to be compliant with current State of Wisconsin Executive Orders, Energy Policies and Statutory Requirements. Furthermore, as outlined in the scope of work overview below, the use of renewable and alternative energy sources will be investigated.

C. Scope of Work Overview

The major tasks to be performed in this Comprehensive Heating Plant Study for this plant are:

1. Review existing conditions at the WSHP.
2. Select options to be analyzed.
3. Make recommendations on how to optimize the heating plant for providing an economical, reliable and environmentally compliant program of improvements.
4. Perform economic analyses on various options for the heating plant.
5. Prepare a scorecard in order to compare the viability of each option within its specific plant based upon critical parameters with respect to meeting at least the minimum requirements for the environment, reliability and cost concerns.
6. Coordinate with and attend several progress meetings with all interested parties from DOA, UW, City of Madison, Dane County, Sierra Club and MG&E.
7. Issue final reports with findings after incorporating Owner comments.
8. Attend and actively participate in public meetings to present the project options and conclusions with the community.

III. EXISTING CONDITIONS

The Walnut Street Heating Plant (WSHP) is one of the three plants serving the campus with steam and chilled water. The plant was constructed in 1974 and utilizes natural gas as its primary fuel with fuel oil as a backup. There are three boilers that total 600,000 PPH of 175 PSIG steam, four chillers that total 18,000 tons of cooling and 1000 SCFM of compressed air that serve the campus distribution networks. No power is generated at this plant, but most of the chillers are steam driven (12,500 tons).

A. Existing Equipment

SHG personnel toured the plant and interviewed the operators in April 2008. The plant was initially in operation in late 1975 with an addition to the boiler house in 2000 for Boiler B-3 and was originally constructed to serve Phase 1 of the hospital complex and serve the growing west portion of campus. Boilers B-1 and B-2 are in fair to poor shape, Boiler B-3 is in very good shape and all plant auxiliaries are original. The plant has a firm capacity of 300,000 PPH and 600,000 PPH maximum installed capacity. Saturated steam is produced at 175 PSIG and routed to the high pressure distribution system as well as the turbine driven chillers.

Average steam temperature and pressure produced is 380°F and 210 PSIG. The plant typically peaks in the winter at around 450,000 PPH but exceeded that in 2001 at 557,000 PPH. The campus load growth is covered in Volume 6. The major heating plant equipment is summarized below.

WALNUT STREET HEATING PLANT EXISTING HEATING EQUIPMENT SUMMARY – TABLE 3							
Equip Tag	Age (yrs)	MFR.	Type Fuel/Drive	Rated Capacity	Temp Press	Condition[1]	Remaining Useful Life
B-1	1975/ 33	Trane Murray	Watertube Natural Gas / Fuel Oil	150,000 PPH	440°F 250 PSIG	1.5[2]	<5
B-2	1975/ 33	Trane Murray	Watertube Natural Gas / Fuel Oil	150,000 PPH	440°F 250 PSIG	1.5[3]	<5
B-3	2001/ 7	Indeck - Volcano	Watertube Natural Gas / Fuel Oil	300,000 PPH	440°F 250 PSIG	5[4]	33
BFWP-1	8	Ingersoll Dresser 4LLR-11A	Electric/150 HP	600 GPM 590 ft	244°F 280 PSIG	4	17
BFWP-2	8	Ingersoll Dresser 4LLR-11A	Electric/150 HP	600 GPM 590 ft	244°F 280 PSIG	4	17

1 Condition rated on a scale of 1 - 5 (where 1 = poor and 5 = excellent).
2 B-1 needs retubing work. The casing leaks and front wall seals and back wall must be replaced. Burner modifications are also required.
3 B-2 needs retubing work. The front wall seals and back wall must be replaced. Burner modifications are also required.
4 Boiler B-3 has some vibration issues with the burner that is currently being addressed.

WALNUT STREET HEATING PLANT EXISTING HEATING EQUIPMENT SUMMARY – TABLE 3							
Equip Tag	Age (yrs)	MFR.	Type Fuel/Drive	Rated Capacity	Temp Press	Condition[1]	Remaining Useful Life
BFWP-3	26	Flow Serve GT	Steam Turbine	300 GPM 590 ft	244°F 280 PSIG	3[5]	4
BFWP-4	24	Lincoln LincGuard 365TS	Electric/100 HP	330 GPM 600 ft	244°F 280 PSIG	2	<3
CP-1	8	Ingersoll Dresser	Electric/40 HP	600 GPM 150 ft	244°F 280 PSIG	4	17
CP-2	8	Ingersoll Dresser	Electric/20 HP	300 GPM 150 ft	244°F 280 PSIG	4	17
CP-3	26	Worthington	Steam/22 HP	150 GPM 115 ft	244°F 280 PSIG	1[6]	<5
CP-4	8	Ingersoll Dresser	Electric/40 HP	600 GPM 150 ft	244°F 280 PSIG	4	17
DA Heater Storage	34	Chicago Heater	15000 Gallon 0.2 hr residence time	1200 GPM	245°F 12 PSIG	2	6
DA Spray Tank	8	Kansas City DA	Tray Type/72,000	300 GPM	300°F 12 PSIG	4[7]	32
Plant Surge Tank	34	Felker Bros. MFG	22,000 Gallon Interior coated tank 0.3 hr residence time		250°F Atmos.	2	6

Fuels: Natural gas is the predominant fuel used. The plant also has (4) 30,000 gallon underground fuel oil tanks.

Controls. There are some PCC-II digital loop controllers by Preferred Utilities Manufacturing Corporation, but the majority of the controls are outdated and need to be upgraded.

Water Treatment. System is sized for 305 GPM make-up. There are (3) dealkalizers at 90 GPM each. Similar to the Charter Street Plant, an RO system is desired and there is a proposed project to reduce the TDS and boiler blowdown with the installation of an RO system.

Condensate System. The DA spray chamber was installed with Boiler B-3 in 1995 but the DA tank, surge tank and pumps are original. There are five 300 gallon condensate polishers, but they are not heavily used due to the quality of the condensate coming back being good.

5 Turbine was rerated at 100 Hp in 1997 and a new pump casing and impellor installed in 2004.
6 Operates below rated power and speed with maximum pressure of 50 PSID dead head.
7 Rebuilt spray pipe to address water hammer

***Figure 1** – Steam flow diagram for Walnut Street Heating Plant (Courtesy of Innovative Business Engineering, LLC)*

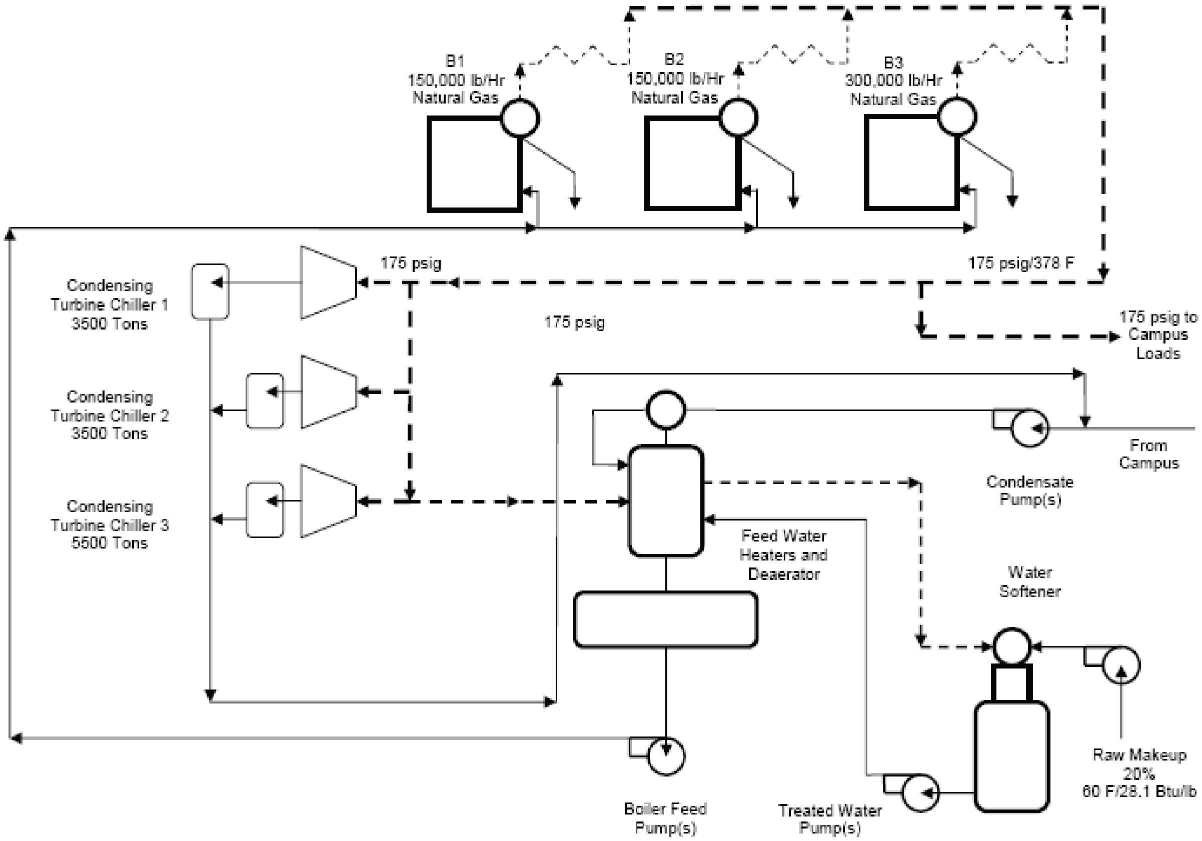


Figure 1 – Steam Flow Diagram (Courtesy of Innovative Business Engineering, LLC)

Emergency Generator. A diesel engine generator installed in 2003 has enough capacity to start the plant for a black startup. This unit has synchronizing gear and could be used for peak shaving of Electrical usage.

Electrical Distribution System. The WSHP has both a 480V 3-phase, 4-wire and 4160V 3-phase electrical power to serve auxiliary loads. The WSHP receives utility power at the 13.8KV level from the adjacent utility substation yard which also contains the primary distribution substation. The primary distribution substation serves much of the university campus. The 480V system is supplied through two 2000 KVA, 13.8KV-480Y/277V, dry type transformers, each feeding a 2500A fusible switchboard in a main-tie-main configuration. The switchboards then supply motor control centers for control and overcurrent protection of various motor and other auxiliary loads. A 4160V system was added in the early 1990's to support the chilled water pump and cooling tower additions. These individual motor loads are in excess of 500Hp each. The 4160V system is supplied through a 15/20MVA, 13.8KV-4.16KV, outdoor oil filled substation transformer which supplies a 3000A 4160V bus consisting of fused interrupter switchgear.

B. Site Conditions and Constraints

There are few opportunities for growth at the site without major building demolition and acquisition of adjacent properties. The figure below illustrates that the site is bounded by the West Campus Cogeneration Facility (WCCF) to the north, Walnut Street to the west, the USDA Malt and Barley Lab building to the south and the west campus electrical substation. The UW is currently in negotiations to “reacquire” the Malt and Barley lab back from the USDA. It is under this assumption that all major plant expansion would occur (dashed area in figure below).

IV. EXISTING PLANT ENERGY USAGE

As can be seen from the table below, during the past 9 years (1999 to 2007) the plant averaged 19,941 MMBtu/year with the high occurring in 2003 at 33,212 MMBtu/yr. The West Campus Cogeneration Facility (WCCF) initially went on line in early 2006 and impacts how WSHP boilers are economically dispatched. From the table it is also apparent that Charter Street Heating Plant (CSHP) is the base loaded plant providing the majority of the steam production for the campus. Also, from annual logs there are times when boilers at the WSHP are not operating at all.

CAMPUS HEATING PLANT ENERGY OUTPUT SUMMARY – TABLE 4

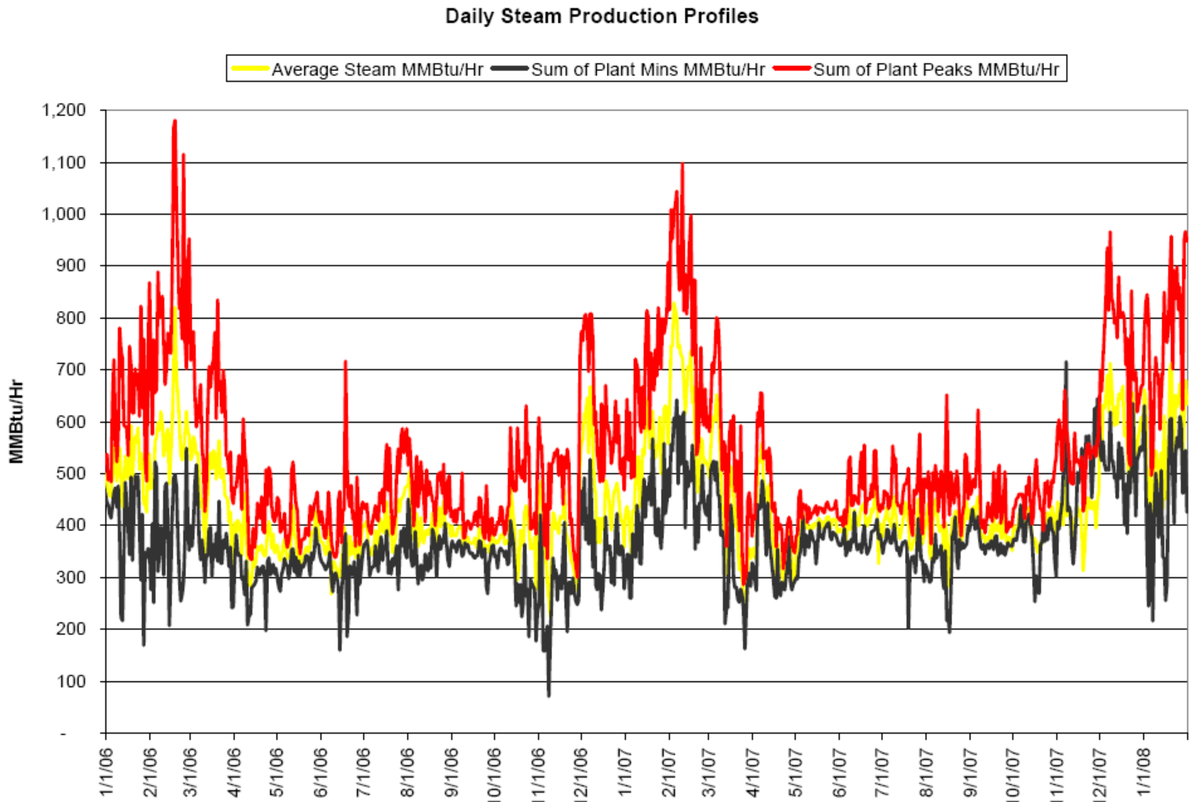
Year	CSHP Annual Steam Output (MMBtu/yr)	WSHP Annual Steam Output (MMBtu/yr)	WCCF Annual Steam Output (MMBtu/yr)	Total Annual Campus Output (MMBtu/yr)	CSHP Output % of Total	WSHP Output % of Total	WCCF Output % of Total
2007	143,295	15,787	5,382	164,464	87.1%	9.6%	3.3%
2006	119,894	26,737	6,896	153,527	78.1%	17.4%	4.5%
2005	140,508	29,381	-	169,889	82.7%	17.3%	0.0%
2004	148,731	15,483	-	164,214	90.6%	9.4%	0.0%
2003	134,212	33,212	-	167,424	80.2%	19.8%	0.0%
2002	136,353	27,016	-	163,369	83.5%	16.5%	0.0%
2001	140,106	16,599	-	156,706	89.4%	10.6%	0.0%
2000	148,055	5,628	-	153,683	96.3%	3.7%	0.0%
1999	135,114	9,622	-	144,736	93.4%	6.6%	0.0%
Low	**119,894**	**5,628**	**-**	**153,527**	**78.1%**	**3.7%**	**0.0%**
Avg	**138,474**	**19,941**	**1,364**	**159,779**	**86.8%**	**12.3%**	**0.9%**
Max	**148,731**	**33,212**	**6,896**	**169,889**	**96.3%**	**19.8%**	**4.5%**

The campus currently does not have hourly peak load data trended over a period of time. Several graphs have been developed by consultants to the UW that estimate the hourly use by fitting the known daily output to typical weather data for Madison. The following graph is courtesy of Innovative Business Engineering, LLC and illustrates this estimated approach to the 2005 peak load and it has been used for the energy analysis portion of this study.

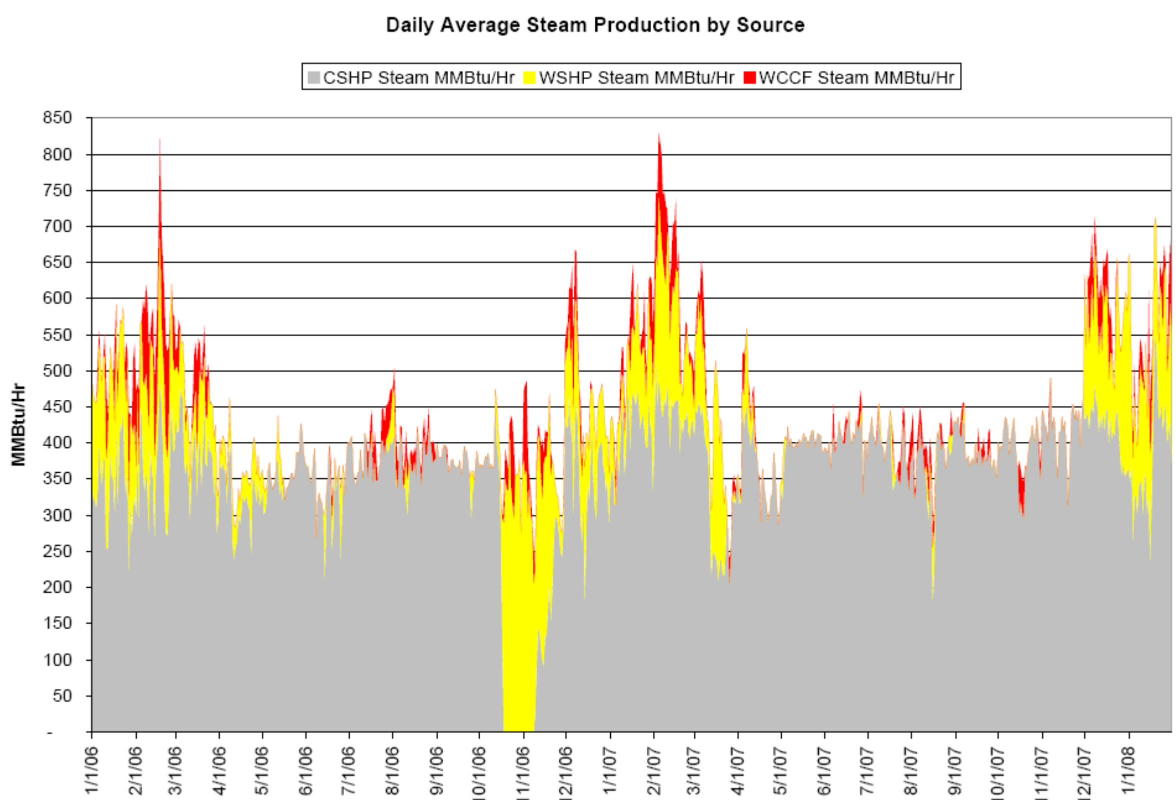
The following table displays the current 12 month energy inputs and outputs for the plant. The Table shows that the plant is primarily fueled by gas to generate steam that not only serves the campus, but also the steam turbine driven equipment within the plant.

WALNUT STREET HEATING PLANT ENERGY INPUT, ENERGY OUTPUT AND COST SUMMARY TABLE

	2005 Totals	May 2007	June 2007	July 2007	Aug 2007	Sept 2007	Oct 2007	Nov 2007	Dec 2007	Jan 2008	Feb 2008	Mar 2008	April 2008	Past 12 Month Total
AVERAGE STEAM PRESSURE PSIA	195	195	195	195	195	195	195	195	195	195	195	195	195	195
AVERAGE STEAM TEMPERATURE F	380	380	380	380	380	380	380	380	380	380	380	380	380	380
AVERAGE FEEDWATER TEMPERAT	242	242	242	242	242	242	242	242	242	242	242	242	242	242
AVERAGE FEEDWATER PRESSURE	292	292	292	292	292	292	292	292	292	292	292	292	292	292
AVERAGE DAILY MAKEUP M-GALLO	226	47	0	0	95	2	0	270	335	227	317	307	10	134
STEAM USE PLANT M-Lbs	31,553	-36,822	-49,723	-48,032	-20,094	-18,253	-8,926	41,609	110,828	111,668	101,291	115,245	94,295	32,757
ENTHALPY STEAM Btu/lb	1,198	1,198	1,198	1,198	1,198	1,198	1,198	1,198	1,198	1,198	1,198	1,198	1,198	1,198
ENTHALPY FEEDWATER Btu/lb	210	210	210	210	210	210	210	210	210	210	210	210	210	210
NET STEAM ENTHALPY Btu/lb	988	988	988	988	988	988	988	988	988	988	988	988	988	988
AVG DAILY MAKEUP M-GALLONS	569	4	0	0	3	0	0	93	89	43	18	27	1	23
M-LBS STEAM (GAS/#2OIL) Total	713,716	2,200	723	3,505	7,222	872	131	44,761	115,549	115,554	104,637	122,783	98,054	615,990
GAS CONSUMED (MCF)	815,360	2,801	1,043	4,199	12,764	1,236	437	52,890	134,473	134,497	121,974	144,305	115,052	725,671
#2 OIL CONSUMED (GAL)	179,136	-	-	-	-	-	-	-	-	-	-	-	-	-
GAS CONSUMED (MCF) MMBtu	820,150	2,874	1,066	4,283	13,109	1,269	446	54,054	137,431	137,187	124,170	147,624	116,663	740,175
#2 OIL CONSUMED (GAL) MMBtu	24,777	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Heat Input MMBtu	844,925	2,874	1,066	4,283	13,109	1,269	446	54,054	137,431	137,187	124,170	147,624	116,663	740,175
MAX STM LOAD M-LBS/HR	2,339	62	-	72	201	81	-	264	348	393	439	295	252	2,407
MIN. STM LOAD M-LBS/HR	383	-	-	20	16	20	-	16	18	60	65	51	23	
HOURS BOILER ON LINE	6,201	70	18	50	129	15	-	306	634	744	696	744	552	3,958
HEAT OUTPUT BY GAS MMBtu	684,688	2,174	714	3,463	7,136	861	130	44,224	114,162	114,167	103,381	121,309	96,877	608,598
HEAT OUTPUT TOTAL MMBtu	**705,149**	**2,174**	**714**	**3,463**	**7,136**	**861**	**130**	**44,224**	**114,162**	**114,167**	**103,381**	**121,309**	**96,877**	**608,598**
FUEL (GAS) COSTS	$ 7,537,281	$ 22,876	$ 16,767	$ 32,422	$ 94,382	$ 7,718	$ 3,190	$ 430,266	$ 1,165,418	$ 1,042,621	$ 1,049,233	$ 1,248,899	$ 1,129,295	$ 6,243,088
FUEL (#2 OIL) COSTS	$ 325,971	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
FUEL TOTAL COSTS	$ 7,863,253	$ 22,876	$ 16,767	$ 32,422	$ 94,382	$ 7,718	$ 3,190	$ 430,266	$ 1,165,418	$ 1,042,621	$ 1,049,233	$ 1,248,899	$ 1,129,295	$ 6,243,088
LABOR COSTS	$ 536,775	$ 47,014	$ 73,288	$ 48,913	$ 45,377	$ 41,147	$ 39,968	$ 62,060	$ -	$ 44,095	$ 40,355	$ 41,203	$ 41,949	$ 525,369
OPERATIONS / MAINTENANCE COS	$ 257,359	$ 43,670	$ 52,934	$ 112	$ 20,317	$ 6,690	$ 110,578	$ 35,450	$ -	$ 59,129	$ 6,697	$ 26,853	$ 22,681	$ 385,111
BOILER ELECTRICAL COST	$ 406,073	$ 12,285	$ 48,114	$ 36,910	$ 46,059	$ 24,697	$ 18,129	$ 110,095	$ 224,528	$ 54,491	$ 65,683	$ 42,183	$ 49,925	$ 733,098
CHILLER ELECTRICAL COST	$ 1,984,128	$ 65,037	$ 139,770	$ 103,219	$ 215,762	$ 79,023	$ 40,240	$ 110,095	$ 20,842	$ 19,553	$ 20,863	$ 18,076	$ 15,881	$ 848,361
BOILER TEATMENT COST*	$ 8,982	$ 284	$ 1,213	$ 1,213	$ 1,213	$ 1,213	$ 1,213	$ 1,213	$ 1,213	$ 284	$ 1,213	$ 1,213	$ 1,213	$ 12,698
CHILLER TREATMENT COST*	$ 51,948	$ 3,368	$ 5,290	$ 5,290	$ 5,290	$ 5,290	$ 5,209	$ 5,290	$ 5,292	$ 3,368	$ 5,290	$ 5,290	$ 5,290	$ 59,557
TOTAL PRODUCTION COSTS	$ 11,047,588	$ 190,881	$ 330,873	$ 221,576	$ 421,896	$ 159,275	$ 212,106	$ 747,966	$ 1,410,788	$ 1,219,889	$ 1,182,831	$ 1,377,215	$ 1,259,732	$ 8,735,027
ELECTRIC POWER SOLD COST	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
STEAM SOLD COST	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
TOTAL PLANT OPERATING COSTS	**$ 11,047,588**	**$ 190,881**	**$ 330,873**	**$ 221,576**	**$ 421,896**	**$ 159,275**	**$ 212,106**	**$ 747,966**	**$ 1,410,788**	**$ 1,219,889**	**$ 1,182,831**	**$ 1,377,215**	**$ 1,259,732**	**$ 8,735,027**
CHILLER STEAM $/TonHr	$ 0.07	$ 0.10	$ -	$ 0.10	$ 0.08	$ 0.09	$ 0.23	$ 0.12	$ 0.12	$ 0.10	$ 0.11	$ 0.07	$ 0.10	$ 0.10
CHILLER ELECTRICAL $/TonHr	$ 0.03	$ 0.02	$ 0.03	$ 0.02	$ 0.05	$ 0.04	$ 0.04	$ 0.44	$ 0.05	$ 0.05	$ 0.07	$ 0.04	$ 0.04	$ 0.07
CHILLER CHEMICALS $/TonHr	$ -	$ -	$ -	$ -	$ 0.00	$ 0.00	$ 0.01	$ 0.02	$ 0.01	$ 0.01	$ 0.02	$ -	$ -	$ 0.01
GAS FUEL $/MMBtu	$ 9.19	$ 7.96	$ 9.90	$ 7.57	$ 7.20	$ 6.08	$ 7.15	$ 7.96	$ 8.48	$ 7.60	$ 8.45	$ 8.46	$ 9.68	$ 8.04
#2 OIL FUEL COST $/MMBtu	$ 13.16	$ -	$ -	$ -	$ 9.43	$ 11.90	$ 18.39	$ 19.30	$ 19.40	$ 19.10	$ 13.78	$ -	$ -	$ 9.28
GAS/#2 OIL $/MMBtu Steam	$ 11.15	$ 10.52	$ 23.48	$ 9.36	$ 13.23	$ 8.96	$ 24.63	$ 9.73	$ 10.21	$ 9.13	$ 10.15	$ 8.97	$ 11.66	$ 12.50
ALL FUELS $/MMBtu Steam	$ 11.15	$ 10.52	$ -	$ 9.36	$ 13.23	$ 8.96	$ 24.63	$ 9.73	$ 10.21	$ 9.13	$ 10.15	$ 8.97	$ 11.66	$ 10.55
LABOR * $/MMBtu Steam	$ 0.76	$ 21.63	$ 102.61	$ 14.13	$ 6.36	$ 47.77	$ 308.57	$ 1.40	$ -	$ 0.39	$ 0.39	$ 0.30	$ 0.43	$ 42.00
O&M * $/MMBtu Steam	$ 0.36	$ 20.09	$ 74.11	$ 0.03	$ 2.85	$ 7.77	$ 853.71	$ 0.80	$ -	$ 0.52	$ 0.06	$ 0.19	$ 0.23	$ 80.03
CHEMICALS $/MMBtu Steam	$ 0.01	$ 0.13	$ 1.70	$ 0.35	$ 0.17	$ 1.41	$ 9.36	$ 0.03	$ 0.01	$ 0.00	$ 0.01	$ 0.01	$ 0.01	$ 1.10
ELECTRICAL $/MMBtu Steam	$ 0.58	$ 5.65	$ 67.36	$ 10.66	$ 6.45	$ 28.67	$ 139.97	$ 2.49	$ 1.97	$ 0.48	$ 0.64	$ 0.35	$ 0.52	$ 22.10
OVERALL COST $/MMBtu Steam	**$ 15.67**	**$ 56.34**	**$ 260.16**	**$ 32.65**	**$ 28.15**	**$ 87.03**	**$ 1,286.66**	**$ 14.30**	**$ 12.13**	**$ 10.48**	**$ 11.19**	**$ 11.16**	**$ 12.78**	**$ 12.86**
ENERGY CONS BOILERS (KWH)	6,018,400	211,800	614,400	460,800	564,000	301,200	195,000	292,800	643,200	593,000	852,000	415,200	521,400	5,664,800
ENERGY CONS CHILLERS (KWH)	29,577,200	955,200	1,853,400	1,224,600	2,583,000	532,200	273,000	292,800	299,400	252,000	280,200	238,800	194,400	8,979,000
ENERGY COST ($/KW)	$ 0.045	$ 0.040	$ 0.054	$ 0.054	$ 0.055	$ 0.052	$ 0.050	$ 0.052	$ 0.051	$ 0.055	$ 0.055	$ 0.055	$ 0.055	$ 0.05
ENERGY COST ($)	$ 1,615,428	$ 46,762	$ 134,446	$ 91,180	$ 172,959	$ 43,387	$ 23,288	$ 30,416	$ 48,242	$ 46,644	$ 62,747	$ 35,911	$ 39,698	$ 775,679
PEAK BOILER LOAD (KW)	2,657	384	1,325	1,050	1,320	816	852	9,915	19,374	2,082	1,890	1,855	2,078	19,374
PEAK CHILLER LOAD (KW)	9,099	2,706	3,511	3,240	6,468	4,644	2,695	9,915	558	540	546	475	504	9,915
DEMAND RATE ($/kw)	$ 9.09	$ 9.89	$ 11.05	$ 11.41	$ 11.41	$ 11.05	$ 9.89	$ 9.57	$ 9.89	$ 10.45	$ 9.77	$ 10.45	$ 10.11	$ 10.41
DEMAND COST ($)	$ 774,774	$ 30,560	$ 53,438	$ 48,949	$ 88,861	$ 60,333	$ 35,082	$ 189,773	$ 197,127	$ 27,400	$ 23,800	$ 24,349	$ 26,108	$ 805,779
ENERGY ($) + DEMAND ($)	**$ 2,390,202**	**$ 77,322**	**$ 187,884**	**$ 140,129**	**$ 261,820**	**$ 103,720**	**$ 58,369**	**$ 220,189**	**$ 245,370**	**$ 74,044**	**$ 86,546**	**$ 60,260**	**$ 65,806**	**$ 1,581,459**



Daily Steam Production Profiles
Average Steam MMBtu/Hr
Sum of Plant Mins MMBtu/Hr
Sum of Plant Peaks MMBtu/Hr
MMBtu/Hr
1,200
1,100
1,000
900
800
700
600
500
400
300
200
100
-
1/1/06
2/1/06
3/1/06
4/1/06
5/1/06
6/1/06
7/1/06
8/1/06
9/1/06
10/1/06
11/1/06
12/1/06
1/1/07
2/1/07
3/1/07
4/1/07
5/1/07
6/1/07
7/1/07
8/1/07
9/1/07
10/1/07
11/1/07
12/1/07
1/1/08



Daily Average Steam Production by Source
CSHP Steam MMBtu/Hr
WSHP Steam MMBtu/Hr
WCCF Steam MMBtu/Hr
MMBtu/Hr
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
-
1/1/06
2/1/06
3/1/06
4/1/06
5/1/06
6/1/06
7/1/06
8/1/06
9/1/06
10/1/06
11/1/06
12/1/06
1/1/07
2/1/07
3/1/07
4/1/07
5/1/07
6/1/07
7/1/07
8/1/07
9/1/07
10/1/07
11/1/07
12/1/07
1/1/08

V. DESCRIPTION OF SYSTEM OPTIONS

Existing Boilers B-1 and B-2 need major repairs that are costly. Previous reports prepared by other consultants have recommended that the boilers not be operated at full capacity due to possible leakage of boiler gases from the boiler refractory and casing. This is not only an efficiency issue, but also a safety concern. Repairs can exceed $600,000 for boilers that are approaching the end of their useful life. Also repairs to these boilers were delayed due to the generating capacity available at WCCF that may be dispatched. Hence, two replacement options were investigated – adding combustion turbines (CT) with heat recovery steam generators (HRSG) and replacing with new larger boilers.

A. Summary of Options Investigated

1. WSHP Option 1 – Replace existing 150,000 PPH Boilers B-1 and B-2 with combined heat and power cogeneration using CT/HRSGs.

2. WSHP Option 2 –Replace existing 150,000 PPH Boilers B-1 & B-2 with “in kind” newer water tube gas/oil fired boilers. The largest sized boiler that will feasibly fit will be investigated as a replacement.

B. Environmental Analysis Inputs

1. WSHP Option 1 – BACT for these options is the same for each unit. Review of the USEPA RACT/BACT/LAER Clearinghouse and existing air pollution control permits shows that BACT for these units is likely to be the following:

   - Sulfur Dioxide (SO_2) Control – Low Sulfur Fuels, 0.0047 lb/MMBtu
   - Nitrogen Oxide (NOx) control – Selective Catalytic Reduction (SCR), 0.01 lb/MMBtu
   - Particulate Matter Less than 10 μm – None control, 0.013 lb/MMBtu
   - Mercury – None, with an assumed emission rate of 2.5 X10-7 lb/MMBtu

2. WSHP Option 2 – BACT for these options is the same for each unit. Review of the USEPA RACT/BACT/LAER Clearinghouse and existing air pollution control permits shows that BACT for these units is likely to be the following:

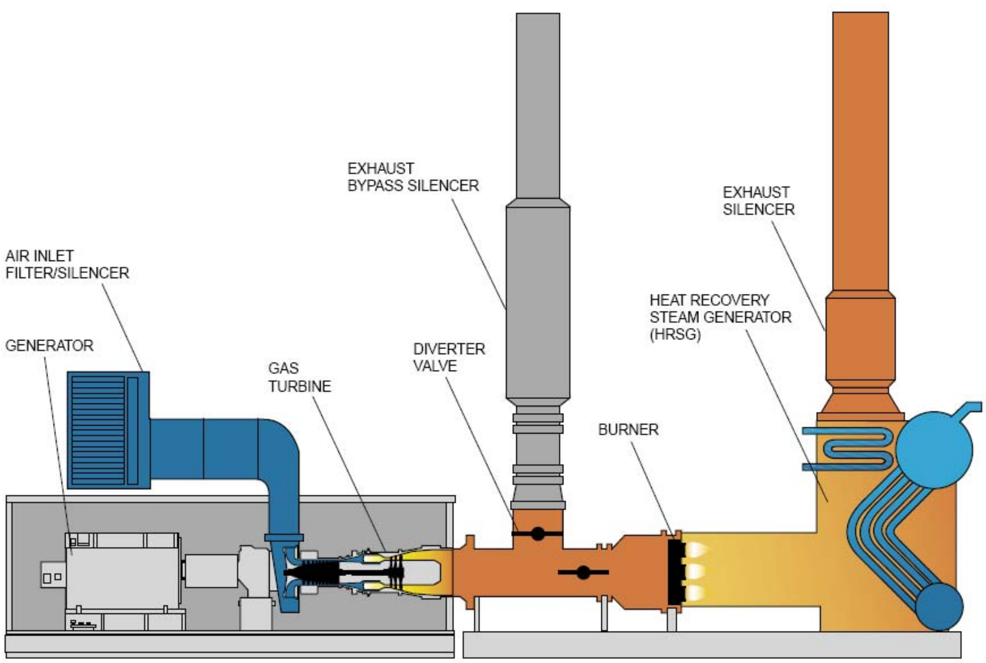
   - Sulfur Dioxide (SO_2) Control – None, 0.0006 lb/MMBtu
   - Nitrogen Oxide (NOx) control – Low NOx Burners (LNB), 0.039 lb/MMBtu
   - Particulate Matter Less than 10 μm (PM10) – Combustion Control, 0.013 lb/MMBtu
   - Mercury – None, with an assumed emission rate of 2.5 X10-7 lb/MMBtu

C. Option 1 Discussion

CT/HRSGs have been used at a number of college campuses around the country for not only producing heating, but also to generate electrical power in cogeneration or combined heat and power (CHP) configurations. Typical power plants have thermal efficiencies of only about 35% which means 65% of the heat output is exhausted up the boiler stack. Cogeneration reverses these efficiencies by being able to size the unit closer to balancing thermal and electrical needs and typically the overall system efficiency exceeds 70%. Units typically come with a HRSG that acts like a boiler for steam generation. The HRSG may be un-fired or cut-fired for additional capacity and increased efficiencies.

CTs typically only have a turn-down of 2:1. Therefore, they should be sized to be base loaded thermally. However, with duct-firing they can achieve 10:1 turndowns. CTs and duct-fired HRSGs may be single fuel with natural gas or dual fuel with No. 2 fuel oil. Typically, the fuel oil is only used in emergency and backup scenarios because the emissions are not as clean and foul the HRSG and pollution control surfaces rapidly. Dual fuels make both the CT and the HRSG more expensive. Duct fired HRSGs are available in a fresh air fired mode to be used if the CT is unavailable, steam can still be generated for thermal use without the power being generated. CTs typically require gas compressors for increasing the gas pressure to operate.

CTs are reliable with a typical time-to-overhaul intervals of 25,000 to 50,000 hours. The power output of the turbine increases below International Standards Organization (ISO) conditions of 59°F and sea level, but decreases when temperatures exceed this level. Hence, the inlet air is cooled to keep the efficiency of the turbine high. The diagram below is a generic layout of the CHP process that would be used with the exception of the by-pass stack.



Because the installation at WSHP would most likely replace any coal boiler equipment at CSHP, it is assumed that they will be base loaded. Therefore a suitably sized unit was selected to satisfy a base thermal and electrical campus load. Refer to Drawing WSHP-OPT1 for a layout of this option. The major elements of the new CHP system are discussed in the following pages.

1. CHP Plant
    a. Natural Gas Service
    b. Electrical Switchgear
    c. Gas Compressors
    d. New building housing the gas turbines, gas compressors and HRSG

2. Solar Titan 130 Gas Turbine Generator Set
    a. Low NOx natural gas fuel system
    b. Speed reducing gearbox
    c. Electric starting system
    d. Lube oil system
    e. Control system
    f. Self cleaning intake air system with two-stage filter
    g. Water wash system
    h. Fire and gas detection systems
    i. Sound attenuated enclosure

3. Heat Recovery Steam Generator
    a. Supplemental firing dual fuel burners (natural gas & fuel oil)
    b. Heat recovery steam generator feedwater system
    c. Transition for selective catalytic reduction (SCR) section
    d. SCR section with catalyst system
    e. CO Catalyst
    f. Economizer
    g. Exhaust gas insulated ductwork to existing stack

4. Natural Gas Compression System
    a. Duplex natural gas two-stage centrifugal compressor
    b. Lube oil system
    c. Lube oil cooling system
    d. GC controls and safety system

5. CHP System Control Package
    a. Gas turbine generator control system
    b. Heat recovery steam generator controls and safety system
    c. Utility switchgear
    d. Balance-of-plant control system

The CHP facility would be based on two new Solar Titan 130 gas turbine generator sets as the prime mover. The units would be capable of operating on natural gas and fuel oil (diesel). Each generator is rated at 13,800 Volts, 0.8 power factor, 3-phase, 60 hertz. The units would operate in parallel with the campus electric utility grid. The Solar Titan 130 is rated at 15,000 Kilowatts at ISO conditions.

Heat from the gas turbine's exhaust would be recovered and used to produce 175 PSIG/378ºF steam. A single heat recovery steam generator would produce a maximum steam quantity of approximately 63,000 PPH unfired and 150,000 PPH fired.[8] The HRSG would be connected to the steam plant's existing steam header via a steam pipe line between the satellite plant and the existing central utility plant.

The HRSG will also have the capability to fresh air fire in the event the gas turbine is out of service. In this mode the HRSG will act like a conventional boiler requiring combustion in order to support steam production. The burner will have dual fuel capability allowing full steam production up to 150,000 PPH during times when the Gas turbine is out of service.

CHP Plant Layout & Description: The proposed location for the new recommended CHP configuration will be adjacent to the existing service building boiler plant. The major equipment within the building would be set on isolated reinforced concrete pads, and smaller equipment would be on housekeeping pads. The gas compressor would be housed in an indoor location as part of the new CHP building. A natural gas line would be installed to the new gas compressor building with service being provided by the local gas utility.

The new 13.8 kV utility interfacing and metering electrical switchgear, generator current limiting reactor (CLR) or transformer (to limit short circuit impact on utility system) and CHP auxiliary power transformer would be located in the new CHP building. The output from the CLR/primary side of the transformers will run underground via a concrete duct bank to the existing 13.8 kV switchgear line up for interconnection with the utility.

Gas Turbine Generator Set: The turbine generator package consists of turbine engine, gearbox and generator, all mounted on a rigid steel base and enclosed in a waterproof acoustical enclosure. The enclosure is designed for a weighted average noise level of 85 dBa three feet from the enclosure in a free field. Dry low NOx combustors would be provided to suppress the oxides of nitrogen (NOx) when operating on natural gas fuel. These combustors reduce NOx levels by introducing large volumes of air to reduce the flame temperature. This system has been designed to provide NOx emissions limits of 10 parts per million operating at full power levels and can be effective down to 50% total power output.

The Titan 130 is a single shaft turbine capable of generating approximately 15 Megawatt at the generator terminals for continuous duty at standard conditions. The enclosure includes the following features:

8 A water wall designed HRSG capable of 250,000 PPH is available at a premium of $1,500,000 million.

1. **Fuel System.** The turbine generator can be powered by either natural gas or diesel fuel. The gas compressor will deliver natural gas at 350 to 450 PSIG. The natural gas fuel system is mounted on the gas turbine-generator set skid and mainly includes: strainer assembly, stop valve assemblies, gas regulating valve, gas vent solenoid valve, gas pressure switch, gas temperature thermo element and gas distribution manifold.

2. **Electric Variable Frequency Drive (VFD) Start System.** The turbine generator starting system utilizes a VFD to allow start-up without a substantial electric inrush. Power from the electric utility will be utilized for start-up of the turbine.

3. **Lubrication Oil Systems.** The lube oil system is designed to provide clean and cool lubricating oil to the power turbine and electric generator. It will be a self-contained closed loop system including storage, shaft driven main lube oil pump, AC pre/post lube oil pump, DC pre/post lube oil pump, filtration, lube oil demister, skid mounted duplex lube oil heat exchangers, stainless steel piping, instrumentation and automatic temperature control. The existing plant condenser water system will be the water supply for the lube oil cooling.

4. **Intake Air System.** The inlet air filtration system will include both combustion air filtration to the turbine compartment as well as general ventilation to all sub compartments. All air used within the turbine generator enclosure will be filtered. Combustion air will be drawn through a separate high efficiency two-pass inlet air filtration system. The combustion air filter housing will be free standing and located adjacent to the gas turbine compartment. The combustion air filtration system includes silencers within the ductwork to the combustion turbine compartment.

   General compartment ventilation will include redundant ventilation fans, inlet and exhaust silencers, and the air inlet module includes a silencer and ductwork, all located within weatherproof hoods.

5. **Water Wash System.** The turbine will be equipped with a mounted water wash system, which includes a stainless steel reservoir, associated stainless steel piping, valves and control. The water wash system is designed to have on-line capabilities and off-line water wash during crank speed. This system will be designed to wash the associated turbine compressor sections to maintain turbine efficiency

6. **Fire and Gas Detection/Suppression System.** A fire and gas detection/suppression system will be provided with the turbine and generator compartments. The system utilizes CO_2 for fire suppression and consists of a combustible gas monitor, gas monitor, back panel mounted fire system control panel, unit mounted thermal and ultraviolet fire sensors, gas detectors, and the CO_2 cylinders.

CHP System Auxiliary Systems: The gas turbine generator set requires several auxiliaries to support its operation and to generate steam from its exhaust gases. The following is a brief description of those systems:

1. **DLE Fuel Injection System.** The gas turbine is equipped with the latest dry low emissions (DLE) fuel injection system designed to reduce the oxides of nitrogen (NOx) in the engine exhaust gases by introducing staged ignition and over fired combustion air.

2. **CO Catalyst and SCR Section**. A transition section will be provided between the turbine outlet and heat recovery steam generator for the installation of a CO catalyst and SCR system. This SCR section if installed can further reduce the emissions of the combustion turbine generator to today's Lowest Achievable Emission Rate standards set by the EPA. Other SCR components would include the ammonia catalyst system and consist of a transfer/storage system, a mixing station, and the ammonia injection pumps/piping and controls.

3. **Heat Recovery Steam Generator (HRSG).** The heat recovery steam generator will be used to recover heat from the turbine exhaust gas and generate steam at 175 PSIG at 378ºF for campus use. The heat recovery steam generator will be designed to generate approximately 63,000 PPH of steam from the recoverable heat from the turbine at ISO conditions, and 150,000 PPH steam with supplemental and fresh air firing.

   The heat recovery steam generator includes a dual fuel supplemental and fresh air firing burner, a slant water tube evaporator section, economizer section and associated boiler control systems. Deaerated water (from the existing boiler plant deaerator) is delivered to the economizer section of the boiler where it is pre-heated prior to delivery to the steam drum, where it is heated to the boiling point (about 353°F) and vaporized. A boiler control module is located on the heat recovery steam generator to monitor water level and steam pressure, and can be controlled and monitored remotely at the CHP control area.

4. **Boiler Feedwater System.** The CHP system will use the existing feedwater system for the existing Walnut Street boiler plant.

5. **CHP System Control Package.** The CHP system will have an integrated monitoring and control system for the turbine generator set, heat recovery steam generator system, gas compressor system, turbine generator control and utility interconnect.

6. **Turbine Generator Control System.** The turbine generator set control console will be free-standing and will include gas turbine control, gas turbine protection and generator protection. The system is fully electronic and includes sequencing, alarm, and shutdown communication, and readout of critical parameters. A 24V DC lead calcium battery package and charger are provided.

7. **Heat Recovery Steam Generator Control and Safety System.** The heat recovery steam generator control and safety system will include a local control panel at the boiler plus remote monitoring/control within the control room area. The control and safety system is designed with a control logic relay system which coordinates boiler steam pressure and gas turbine shutdown. The safety system is tied into boiler controls and monitors steam pressure, boiler water level and feedwater pressure.

8. **Electric Switchgear.** Electric switchgear includes generator neutral ground resistor; generator current limiting reactor/output transformer 13.8 kV – 480/277V auxiliary power transformer, a 13.8 kV generator breaker, power metering, synchronization and protection equipment. The output of the gas turbine electric generator will tie into the existing electrical 13.8 kV Campus Switchgear. The CHP auxiliary power system, the CLR and auxiliary power transformer will be located indoors on grade in the new CHP building.

CHP System Cooling System: A steam condenser will be required to condense any steam that is produced by the heat recovery steam generator but is not utilized by the existing steam users. It is sized to condense 100 percent of the heat recovery steam generator capacity to avoid the need to install a bypass stack.

Piping connected to the existing WSHP condenser water system (cooling towers as the heat sink) will be used as the condenser water source for the lube oil cooler and steam condensers. Required new components will include a new duplex circulating water pumping system, distribution piping and control valves.

Emergency Black Start Capability- CHP Island Mode Operation: Two additional features which can be considered for the proposed CHP installation are:

- The ability to generate independent from the electric grid as an island, and
- The ability to restart and connect the turbine generator without the presence of normal utility supply in a “black-start” mode.

The island mode of operation requires one of two conditions to exist in order to be truly feasible. The first is the size of the CHP to be equal to – though ideally slightly larger than – the available campus load. If this condition existed, UW could elect to separate from the grid and generate power independently. If the CHP rating is less than the connected campus load – which is the case in this study’s proposed system configuration – the second condition to make the option feasible would be to have automated means to immediately shed excess campus load to prevent the overloading of the turbine generator. This second method would result in the reduction in the ability of UW to meet its mission since normal campus operations would cease to the extent imposed by the load shedding program.

The ability to restart the turbine generator and power a reduced level of the campus load in the absence of normal utility power supply is known as “black-start”. Several items are required in order to achieve this operational capability in the proposed CHP configuration. First, the ability to reduce connected campus load to equal or be less than the turbine generator rating is required. In this instance, unlike the island mode discussion above, the timing of load isolation does not need to be an immediately executed event, but rather must be completed before the turbine generator is brought on line. This can be accomplished as a manual isolation procedure, but needs to be fully developed by UW as an official procedure well in advance of its need and should include the necessary safeguards (similar to a lockout/tagout) to make sure that disconnected loads are not repowered until the normal utility supply has returned to the campus. The other item that is required is a black-start engine generator set, fueled by either diesel or natural gas (rich burn), with a close-transition transfer switch to connect the turbine generator auxiliary MCC to either the normal power supply point or the black start generator set. The transfer switch would be allowed to operate in closed transition only as long as the campus is not powered by the utility and the normal source of power supply would need to be among the first loads connected to the turbine generator. The ability to have this mode of operation would also require synchronization controls across the incoming utility main circuit breakers in the existing switchgear if it were desired to return to normal utility supply without a second outage of the loads powered, the provision of additional building space near the CHP unit for the generator set and its fuel supply, and the obtaining of the additional emission permits of the generator set.

Proposed Mode of System Operation: During normal operations, the CHP system will operate at its rated 100% capacity (30 Megawatts) to satisfy a portion of UW electrical demand throughout the year. UW would continue to purchase the surplus power requirements, plus the overall demand during turbine plant outages, from the electric utility (or other electric service provider).

Steam will be generated using the CHP unit, with the existing boiler plant providing supplemental capacity when needed. When on line, each of the two heat recovery steam generators will be capable of generating up to approximately 63,000 PPH of steam via the waste heat from the turbine's combustion gases and 150,000 PPH with supplemental firing. The HRSG will provide the steam when any of the turbines are shutdown via fresh air firing. The operations should be based on the following practices:

- Waste heat steam should be the primary base steam load for the campus steam system.
- Steam production should be via HRSG as the primary source.
- Waste heat utilization should be maximized as it improves the overall system efficiency (does not require additional fuel to achieve the steam generation).
- During periods of turbine shutdown, UW would need to procure replacement electricity and generate steam via the fresh air firing of the HRSG.
- The CHP plant equipment may be considered a source of power to support UW's campus in the event of a loss of utility power.

1. Advantages and Disadvantages:

    a. Advantages:

        - Very efficient means of providing heat and power on campus
        - Provides electric power to the grid and offsets coal usage
        - Generator output voltage can be selected to match the WSHP distribution voltage and can easily be connected via the main distribution switchgear at the WSHP substation
        - More efficiently uses resources compared to traditional boilers
        - Good turn down – while CT is only 2:1 (or 32,000 PPH), duct fired HRSG is 10:1
        - Scalable to most load ranges and profiles
        - Improves energy security and reliability

- Can be phased easily
- Easier to permit
- A maximum 250,000 PPH is available for each HRSG at a cost premium of ~$1,500,000, but has longer lead time and increased difficulty of shipping and more field fabrication.
- Lowers the emissions

b. Disadvantages:

- Not very fuel flexible - can only burn two fuel types (gas/oil)
- Higher fuel costs since uses gas as base fuel
- Higher first cost
- Higher O&M costs
- Requires more space than available from removal of existing boilers and will not fit in existing boiler house
- SCR requires special shipping equipment and has long lead time
- Questionable reliability. May experience unexpected and prolonged outages

2. Required Modifications: Will not physically fit inside the existing boiler house, therefore, a separate structure needs to be constructed on the parking lot to the east of the CHPP building site.

3. Alternative Energy Use: limited uses with the exception of syngas and bio diesel.

D. Option 2 Discussion

The existing boilers are water tube “D” style and the replacement boilers investigated are of the same type. After obtaining existing drawings of the building, computer aided drafting was utilized to determine if a larger boiler could be accommodated. The largest boiler size that would fit was a 175,000 PPH boiler, which would be an increase of 25,000 PPH from the original installed capacity. With this nominal increase, that the steam header and ancillary equipment (surge tank, deaerator, chemical treatment and water softeners, etc.) would not have to be replaced, but could be reused. Refer to drawing WSHP-OPT2 for a layout of this option.

1. Advantages and Disadvantages:

a. Advantages:

- Highly reliable source of heating
- Has several vendors to offer competition and fair pricing
- Less space required than CT/HSRG option
- SCRs are available for Low NOx, but will not physically fit in the existing boiler house
- Ease of permitting

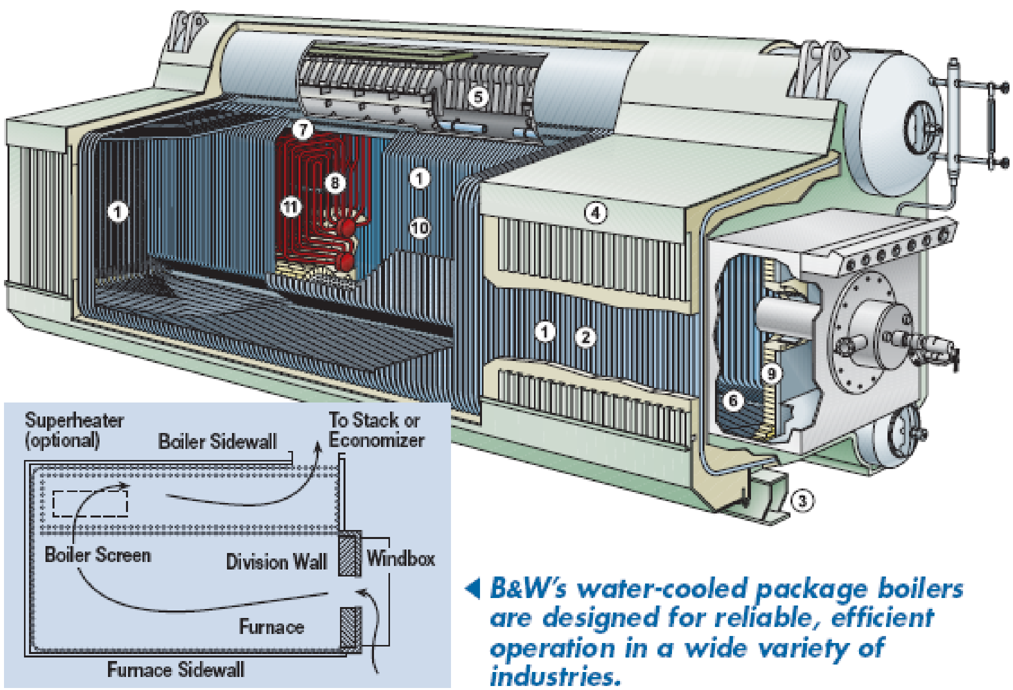
b. Disadvantages:

- Not very fuel flexible - can only burn two fuel types (gas/oil)
- Uses natural gas as primary fuel source which recently has high cost and is volatile
- More difficult to phase due to removal of existing boilers

2. Alternative Energy Use: Should be able to use bio-diesel or syngas without any modifications.

3. Required Modifications: minimal modification required to the existing plant and systems. Burner and combustion air fans are larger than the existing so the electrical systems must be checked for expansion capabilities

4. Stand-Alone and Black Start Capability: In order for the boiler to have black start capability, it must have the burner, combustion air fan and feed water pumps on emergency power.



B&W's water-cooled package boilers are designed for reliable, efficient operation in a wide variety of industries.

VI. COST DISCUSSION

A. General

The economic evaluation included estimates of probable cost, energy usage and operations data. All of this data was input into a spreadsheet for present value evaluation of life cycle costs. It should be noted that the 25 year analysis assumes that the building will be completed in 2009. While incorrect in premise, it should not affect the outcome of the analysis.

B. Estimates of Probable Costs

The construction cost estimates have been developed using data from similar projects, from current manufacturers' estimated costs, from area contractors who regularly perform this type of work and from various cost estimating guides. Construction cost estimates which are shown on the following Table are based on a June 2008 cost level. Escalation factors may be used to arrive at a total installed cost during the first year of commercial operation. Actual cost data from similar projects have been adjusted for inflation, location of the project, and for variation in design capacity and operating features of the equipment. The remainder of the estimate used a material and labor approach based on costs obtained in 2008 MEANS MECHANICAL COST DATA and costs were adjusted per the City Index factors for material and labor cost in Madison. At this phase of the project, the costs are very preliminary and accuracy of the estimates should be ±25%.

Common assumptions to the cost estimates are:

- Estimated cost of each option was assumed to use traditional design-bid-build delivery method
- Allowance for control system.
- Allowance for extending sewer, water and electrical power to new building.
- Commissioning of plant.
- A blended sales tax rate of 5.5% on materials only (Does not apply to State owned projects).
- While projects would be phased in reality, the cost estimates did not reflect this for the sake of simplicity.
- 25% construction contingency.
- Permits and fees at between ~1.5% of construction costs.
- Estimate of design fees compensating for complexity of project, number of design packages and duration of project.
- No standby or emergency power was assumed.
- Distribution steam piping is constructed in a concrete box conduit buried 6 feet deep to the top of the concrete box.
- The cost of new construction for buildings were burdened for each option.

WSHP COST SUMMARY – TABLE 6					
		QTY	Unit	OPTION 1 New CT/HRSG	OPTION 2 New Boilers
A. SITE PREPARATION WORK					
1	Site Work including demolition			$ 500,000	$ 0
2	Mech Tie-ins – UG/AG Steam Piping	200	FT	$ 265,000	$ 25,000
3	Mech Tie-ins – UG/AG FW Piping	500	FT	$ 75,000	$ 10,000
4	Mech Tie-ins – UG/AG FO Piping	200	FT	$ 27,000	$ 20,000
5	Elec Tie-ins – UG/AG Ductbank	200	FT	$ 105,000	$ 25,000
	SUB-TOTAL SITE PREPARATION			**$ 972,000**	**$ 80,000**
B. STRUCTURES/BUILDING WORK					
1	Cogen/CT Bldg (struct, HVAC, plbg, Fire Prot, etc)	18000	SF	$ 4,500,000	$ 25,000
2	Turbine Foundations		LS	$ 55,000	$ 0
3	HRSG/Boiler Foundations		LS	$ 75,000	$ 20,000
4	Gas Compressor Foundations		LS	$ 25,000	$ 0
5	Elec. Switchgear Extension Pads		LS	$ 10,000	$ 7,000
6	Stack Foundations		LS	$ 20,000	$ 0
7	Emerg. Black Start Gen. Foundation		LS	$ 10,000	$ 0
8	Fuel Oil Tanks		LS	$ 0	$ 0
9	Equipment Pads		LS	$ 10,000	$ 10,000
10	Ladders/Catwalks		LS	$ 35,000	$ 50,000
11	Demolition & removal of existing boilers			$ 0	$ 125,000
	SUB-TOTAL STRUCTURES			**$ 4,740,000**	**$ 237,000**
C. MECHANICAL WORK					
1	(2) 15 Mw Solar Titan 130 Gas Turbines		LS	$ 14,500,000	$ 0
2	(2) 150,000 PPH HRSG's w/sup. firing & dual fuel[9]		LS	$ 6,500,000	$ 0
3	(2) Gas Compressors		LS	$ 1,750,000	$ 0
4	750 kW Black Start Generator		LS	$ 300,000	$ 0
5	175,000 PPH Boilers		LS	$ 0	$ 7,000,000
6	Steam/Cond Piping, Valves, Insulation, Jacketing		LS	$ 2,500,000	$ 600,000
7	Water Treatment		LS	$ 75,000	$10,000
8	Misc Work for Auxiliary Equipment			$ 200,000	$100,000
9	Rigging and Installation of Mechanical Equipment		LS	$ 700,000	$150,000
10	Testing and Balancing		LS	$ 100,000	$50,000
	SUB-TOTAL MECHANICAL			**$ 26,625,000**	**$ 7,910,000**
D. ELECTRICAL WORK					
1	(2) Breakers w/protective relaying		LS	$ 350,000	$ 0
2	4.16V/480V transformer		LS	$ 150,000	$ 125,000
3	480 V load center		LS	$ 80,000	$ 50,000

9 A standard 150,000 PPH HRSG is included, a water wall designed HRSG capable of 250,000 PPH is available at a premium of $750,000 each.

WSHP COST SUMMARY – TABLE 6					
		QTY	Unit	OPTION 1 New CT/HRSG	OPTION 2 New Boilers
4	Distributed Control System		LS	$ 500,000	$ 200,000
5	CEMS System		LS	$ 925,000	$ 430,000
6	Electrical and Instrumentation Material & Installation		LS	$ 2,200,000	$ 300,000
	SUB-TOTAL ELECTRICAL			**$ 4,205,000**	**$ 1,105,000**
E.	**TOTAL CONSTRUCTION**			**$ 36,540,000**	**$ 9,230,000**
F.	**MISCELLANEOUS WORK**				
1	Startup/Commissioning		LS	$ 450,000	$ 125,000
	Engineering Design Fees		12%	$ 4,400,000	$ 1,100,000
	Permits and Fees		2%	$ 600,000	$185,000
	SUB-TOTAL MISCELLANEOUS			**$ 5,450,000**	**$ 1,410,000**
	TOTAL CONSTRUCTION COSTS			**$ 41,985,000**	**$ 10,540,000**
	DSF FEES		4%	**$ 1,650,000**	**$ 410,000**
	CONTINGENCY & TAXES (IF ANY)		25%	**$ 10,530,000**	**$ 2,650,000**
	GRAND TOTAL			**$ 54,165,000**	**$ 13,600,000**

C. Life Cycle Costing Assumptions

- 25 year analysis study period.
- Life of water tube boilers, buried piping systems and major components were assumed to be greater than 30 years, hence replacement costs are not included.
- Annual maintenance and major overhaul expenses and other routine maintenance contracts. O&M for gas turbines assumed $0.01/kWh.
- Operational staff salaries.
- No property or real estate taxes were included for State owned options.
- The analysis was run assuming the project was 100% financed at 4.0% bonding.
- Chemical usage based on existing plant data.
- Nominal discount rate of 7.12%
- Inflation rate of 3% per year.
- Escalation rate of 2.8% per year for all utilities.
- Applicable blended gas and electric rates. Estimated cost of alternative fuels delivered to site including transportation costs and hauling of any ash/products of combustion. Sensitivity analyses were also conducted. Gas and electric rates used were:
  - $11/MMBtu for interruptible gas
  - $0.08/kWh for electricity
- Carbon Offsets used $25/ton escalated at 5% per year on actual direct emitted values plus the indirect values of the prevailing power generation emissions based on the percent power purchased from the grid compared to power cogenerated on site.

D. Life Cycle Cost Analysis Results

WALNUT STREET HEATING PLANT LCC OPTION RESULTS – TABLE 7							
Option	First Cost	LCC Discounted First Cost	LCC Discounted Energy Cost	LCC Discounted CO_2 Cost	LCC Discounted O&M Cost	Total LCC Discounted Cost	Cost of Energy Provided ($/MMBtu)
WSHP-1	$ 54,165,000	$45,955,000	$1,224,045,000	$224,652,300	$41,961,200	$1,526,747,000	**$ 12.08**
WSHP-2	$ 13,600,000	$11,455,000	$1,214,180,000	$290,829,500	($4,095,100)	$1,522,234,200	**$ 12.04**

As can be seen from Table 7 above, the 25 year LCC values are extremely close. The discounted energy costs are the largest single contributor amounting to around 80% of the total discounted life cycle costs depending on the option and fuel used. Furthermore, it is apparent that the operations and maintenance costs of the CT/HRSG options are a great deal higher than the gas boiler option. First cost was only a small impact on the total LCC. Once again, the cost of carbon allowances had an impact costs (about 14 to 19% of total LCC). The results of sensitivity analyses for the above criteria are explained further in Volume 1 especially the roll the cost of carbon plays.

The cogenerated power not only offsets purchased electricity for WSHP-1, but also offsets the difference between the onsite direct emission and the indirect emissions of the electric utility based on fuel source highlighting once again the impact that the cost of carbon cost plays in the analysis. But it was not enough to makeup for the O&M or first cost differential. Even though there are more logical heating plant options at CSHP, if a selection between these two options must be made based on how they satisfy the State Statues,**WSHP-1** would be preferred only due to the fact that it does cogenerate power and it has similar economics to WSHP-2 and can be deemed the cost effective option based on a life cycle cost analysis.

VII. SCORE CARD METHODOLOGY AND RESULTS

A. Discussion

The scoring of each option was based on the three main guidepost categories established early on in the study – environmental qualities, reliability and economic implications. Each category topic was worth 10 points and each guidepost category was equally weighted as one-third of the grade.

The Environmental Qualities portion is scored on each option's calculated emissions based on the fuel(s) that were combusted on a per unit of heat output basis (lb./MMBtu). Most of the subtopics within the guidepost categories are quantifiable therefore their comparative rank between all four plant's options was used – a total of 13 options. Hence the highest rank achievable was 13 and the lowest was a 1. Actual point values were obtained by using a ratio of the results to a 1 to 10 scale. Hence, a rank of 13 received 10 points (13/13 times 10 = 10 points) and a rank of 1 received 0.8 points (1/13 times 10 = 0.8 points).

Other topics were more qualitative and the options were graded subjectively on comparing their effects amongst the alternative options. The topics/emissions scored were:

- CO_2 – Carbon Dioxide, a green house gas contributor
- CO – Carbon Monoxide
- NO_x – Nitrogen Oxide
- SO_2 – Sulfur Dioxide.
- Particulate Matter (PM)
- Heavy Metals (i.e., mercury – Hg)
- Health Care Impacts of emissions. This topic was graded by taking the average of the PM and Hg emissions per unit of heat output of the heating plant (lb/MMBtu).

Reliability was scored subjectively by comparing each option qualitatively. The topics scored were:

- Fuel Source Availability. Consideration was given to whether a fuel source was readily available and reliable, impact of seasonal availability or whether long term contracts were currently available.
- Fuel Flexibility. A low score was applied to a technology that only could burn a limited number of fuels (i.e., gas/oil) and a higher score for a technology that could burn multiple fuels.
- Reduced Maintenance Requirements. How each system compares to existing staffing requirements and whether it would increase or decrease staff.
- Equivalent Availability. Comparing each option on how frequent unscheduled outages occur and how easily the technology could recover, outage durations and potential plant capacity derate if a fuel source was lost.

- Ease of Phasing. Plant additions that were new buildings and were not relying on existing plant demolitions, etc. that would affect construction phasing or constructability.

Economic implications are broken down into several topics that are components to the life cycle cost analysis. Most of the topics are actually quantifiable therefore their comparative rank between options was used as their score. The topics scored included:

- Initial First Costs
- Operations and Maintenance
- Fuel costs. Cost of harvesting, processing transporting and delivering fuels to the plant plus removal of any ash, etc.
- Electric Offsets or how much power is produced via cogeneration
- Carbon Costs assuming $25/ton of green house gas allowance or tax
- Cost and ease of Permitting the project
- Fuel Volatility. Gas is extremely volatile fuel and therefore scored low.

B. Point Scores

Due to the difficulty of subjectively scoring an option to indicate higher and lower performances, only raw scores were used without grading on a curve. Unfortunately, the scoring methodology used in this report does not easily highlight what option is best for each plant in a succinct manner nor does it allow for easy comparisons. The basis of this phenomenon is that each option is scored against all thirteen options from all four plants and thus its individual plant impact is diluted. Since WSHP only has two options, the comparison is easier than with the other plants, especially when the fuel sources are both natural gas. The table below summarizes the scores. The table below summarizes the scores. Refer to Volume 1 of this study for the actual point tallies for each sub-topic within the categories.

WALNUT STREET HEATING PLANT SCORECARD SUMMARY – TABLE 8				
Option Description	**Environmental Score**	**Reliability Score**	**Economic Score**	**Overall Score**
WSHP-1 (CT/HRSG)	**45.0**	**32.0**	**42.2**	**120.2**
WSHP-2 (Boilers)	**19.6**	**28.0**	**49.9**	**97.5**

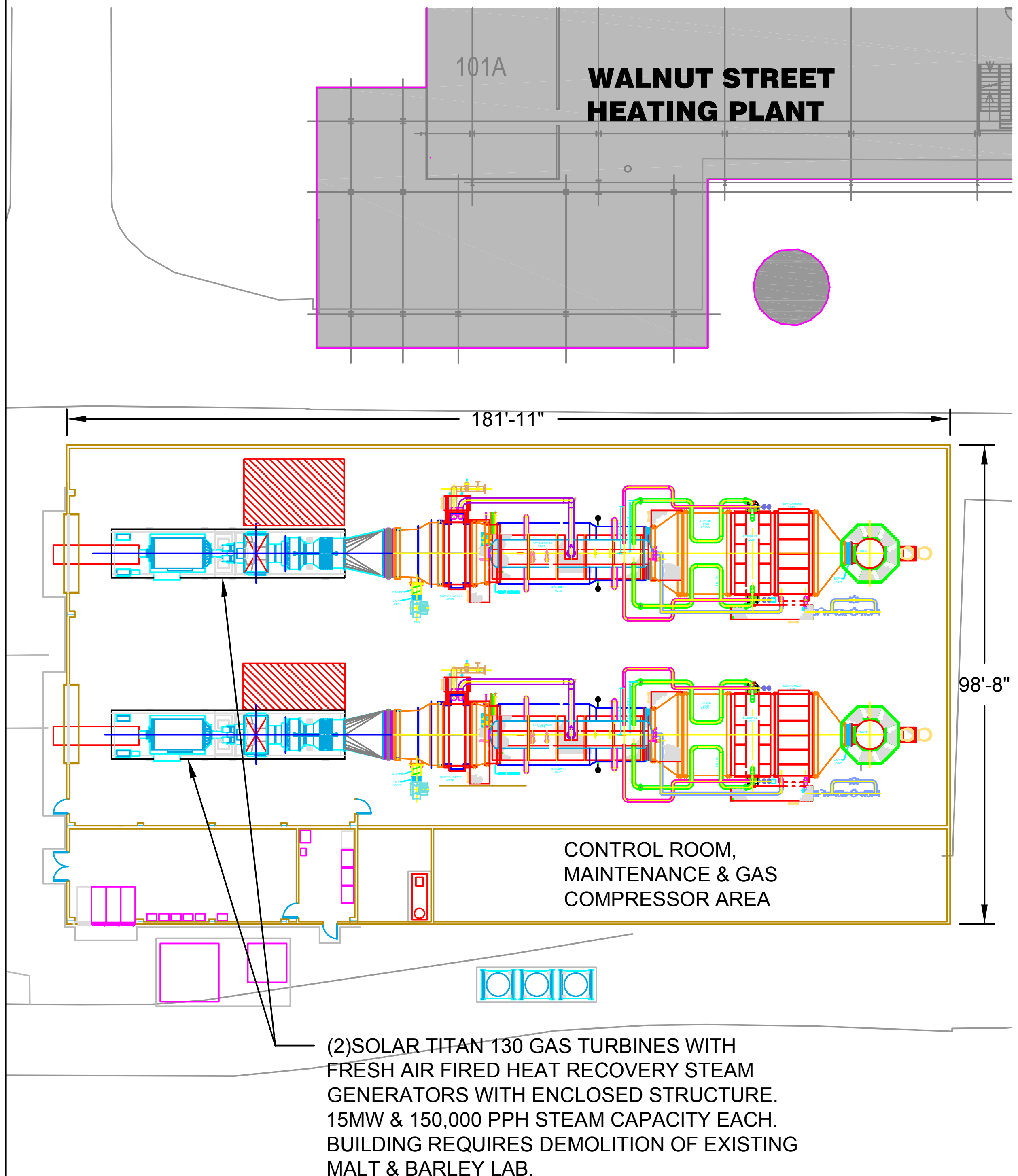
As can be seen from Table 8, **WSHP-1** has higher scores in all categories except economics due to a higher first cost and O&M cost. Combining this with the results from Table 7 where the economics were almost equal WSHP-1 would be the option of choice for Walnut Street Heating Plant. Furthermore, the CT/HRSG option scored better in the environmental area than the gas boilers due to the fact that they offset more indirect emissions from regional power plants due to having electrical cogeneration installed.

APPENDICES

I. DRAWINGS

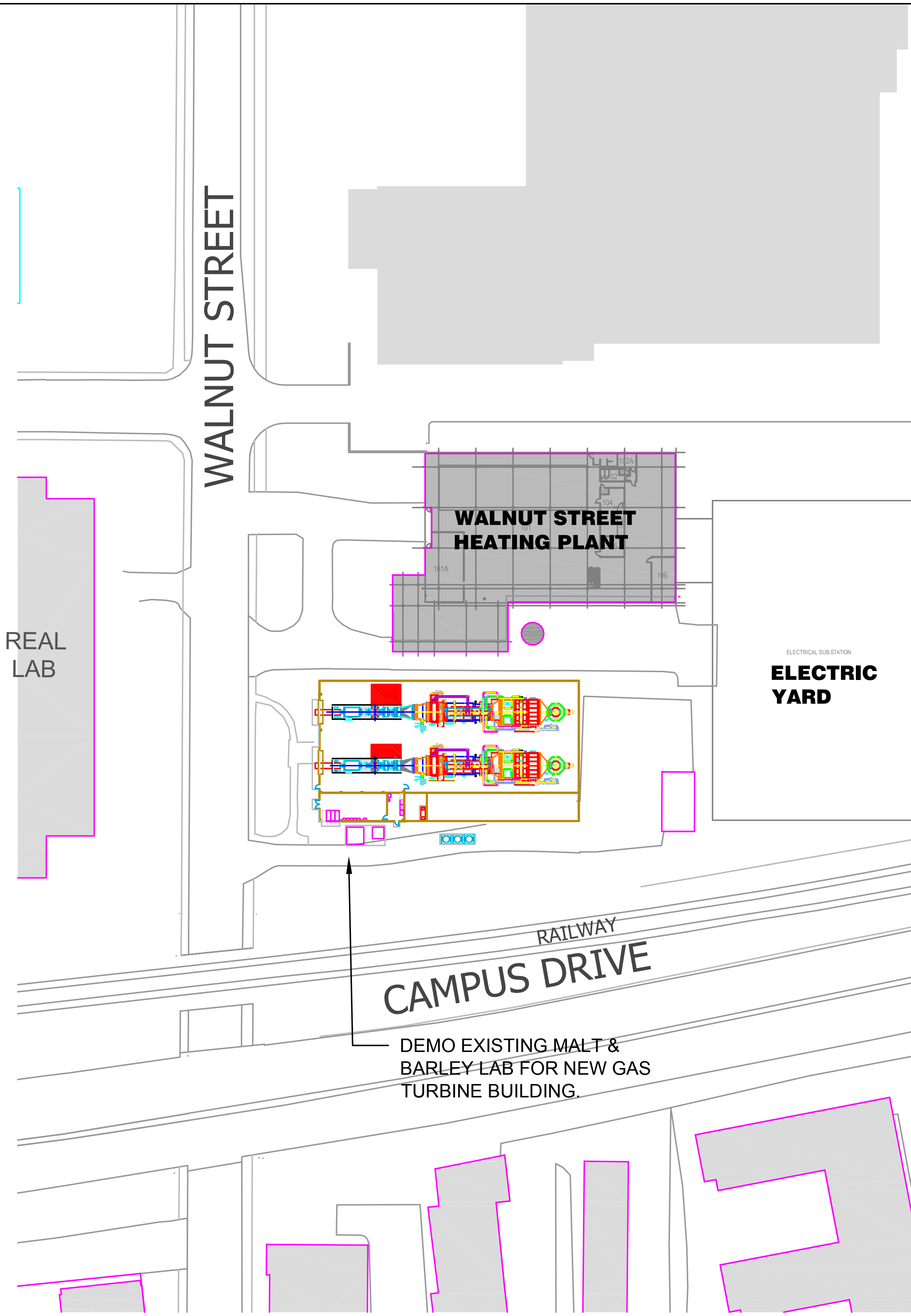
WSHP-OPT1 – WSHP CT/HSRG OPTION 1 PLANS

WSHP-OPT2 – WSHP CT/HSRG OPTION 2 PLANS



2 WSHP CT/HRSG GROUND FLOOR PLAN
SCALE: 1/16"=1'-0"

North



1 WSHP SITE PLAN
SCALE: 1"=100'-0"

North

SYSKA HENNESSY GROUP

Syska Hennessy Group, Inc.
429 Gammon Place
Suite 200
Madison, WI 53719
Tel: 608.826.9400
Fax: 608.826.9401
www.syska.com

PROJECT

STATE OF WISCONSIN
COMPREHENSIVE HEATING
PLANT STUDY

2	7-31-08	FINAL ISSUE
1	6-10-08	INITIAL DRAFT
MARK	DATE	DESCRIPTION

ISSUE:

PROJECT No: UWI01000

CAD DWG FILE:

DRAWN BY:

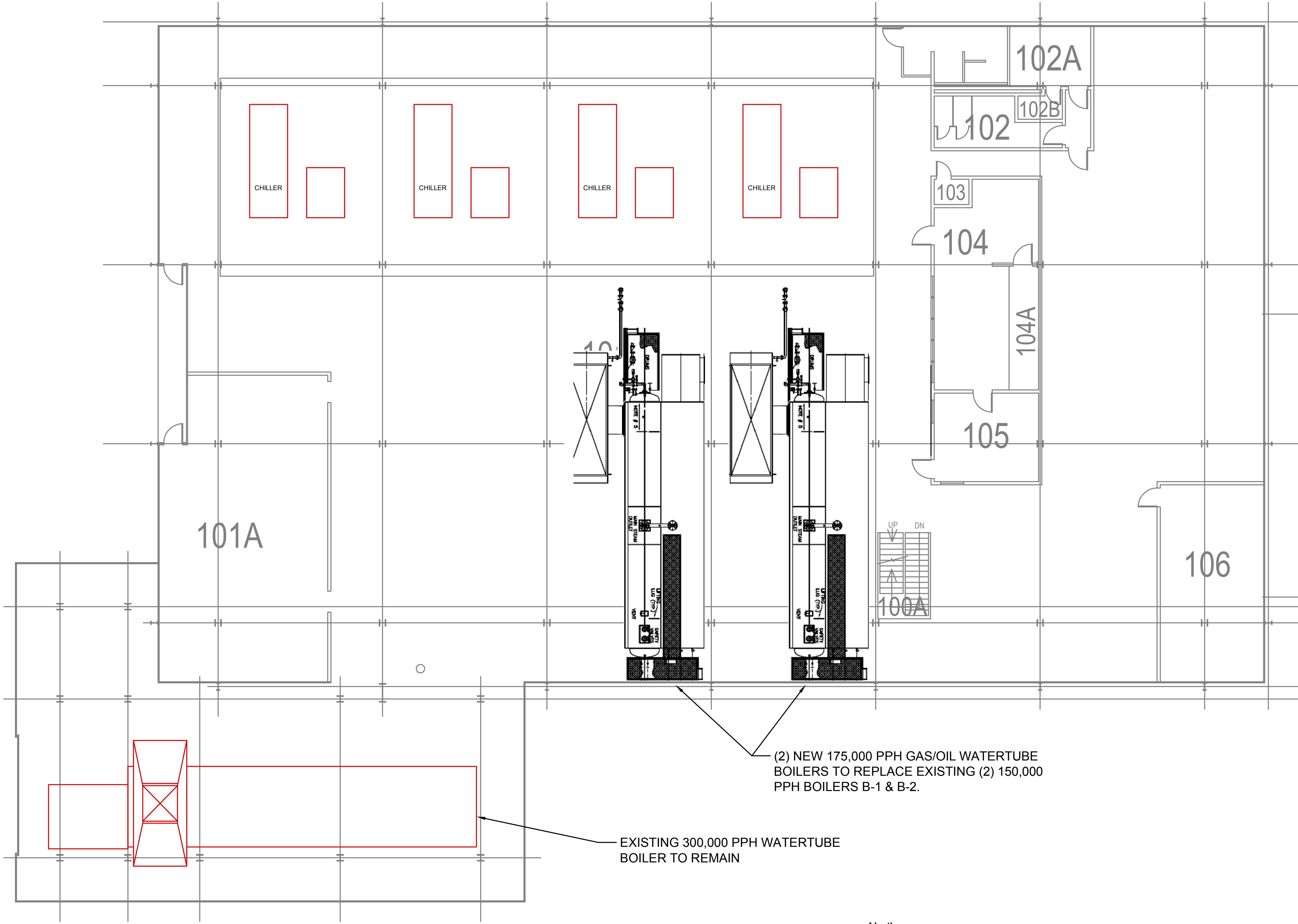
COPYRIGHT:
SYSKA HENNESSY GROUP

SHEET TITLE

WSHP CT/HRSG OPTION 1 PLANS

WSHP-OPT1

Jul 29, 2008 - 8:35PM - P:_PROJECTS\UWI01001 WI HEATING PLANTS\DRAWINGS\MECH\WSHP CT-HRSG OPTION 1 PLANS.DWG



1 BOILER OPERATING LEVEL PLAN
SCALE: 1/16"=1'-0"

Jul 29, 2008 - 8:15PM - P:_PROJECTS\UWI01001 WI HEATING PLANTS\DRAWINGS\MECH\WSHP 175,000 PPH BOILER OPT 2 PLANS.DWG

SYSKA HENNESSY GROUP

Syska Hennessy Group, Inc.
429 Gammon Place
Suite 200
Madison, WI 53719
Tel: 608.826.9400
Fax: 608.826.9401
www.syska.com

PROJECT

STATE OF WISCONSIN
COMPREHENSIVE HEATING PLANT STUDY

MARK	DATE	DESCRIPTION
2	7-31-08	FINAL ISSUE
1	6-10-08	INITIAL DRAFT

ISSUE:

PROJECT No:	UWI01000
CAD DWG FILE:	
DRAWN BY:	

COPYRIGHT:
SYSKA HENNESSY GROUP

SHEET TITLE

WSHP 175,000 PPH BOILER OPTION 2 PLANS

WSHP-OPT2