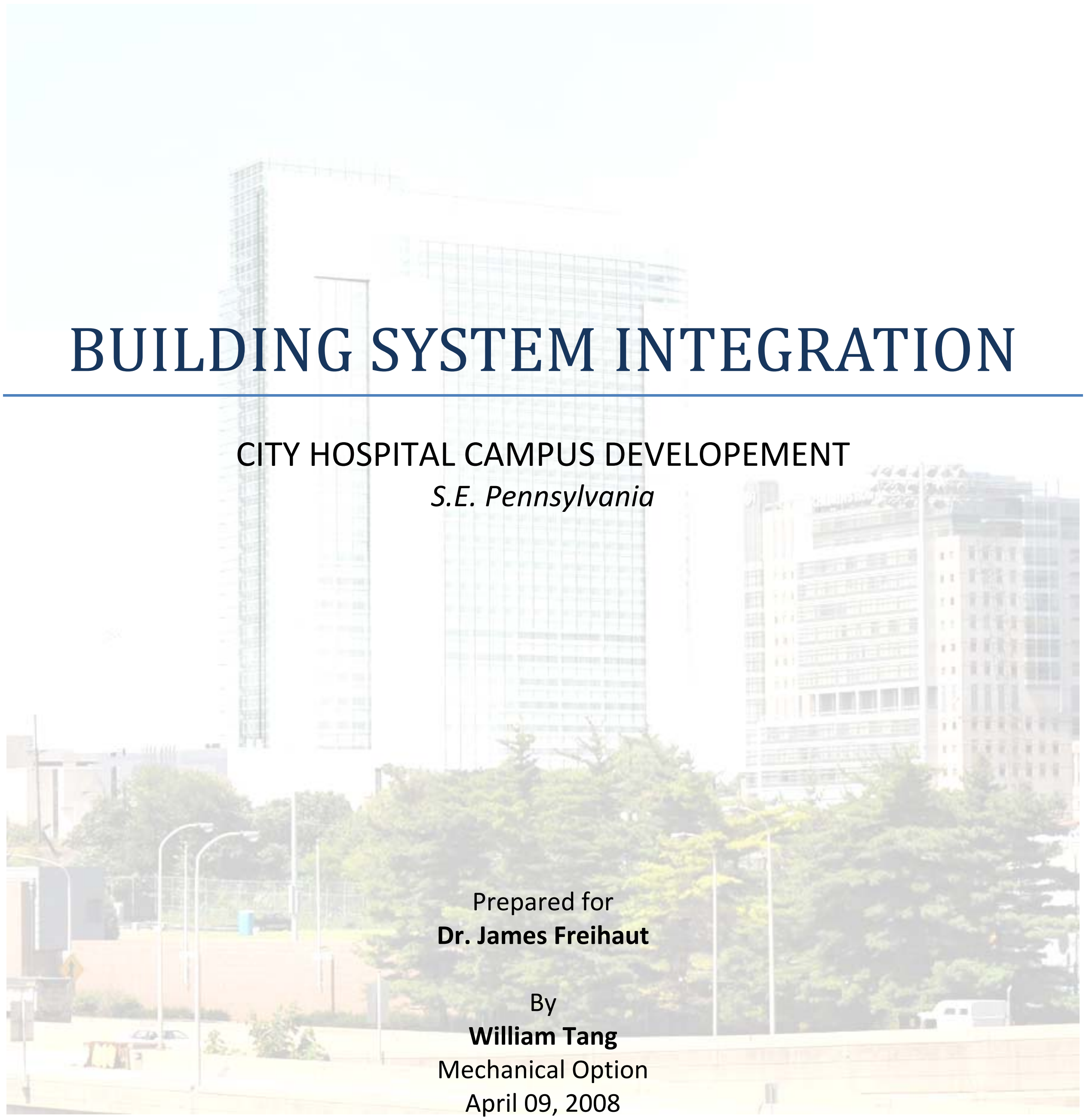

BUILDING SYSTEM INTEGRATION

CITY HOSPITAL CAMPUS DEVELOPEMENT

S.E. Pennsylvania

Prepared for

Dr. James Freihaut

By

William Tang

Mechanical Option

April 09, 2008

The Pennsylvania State University | Department of Architectural Engineering

CITY HOSPITAL – CAMPUS DEVELOPMENT

S.E. Pennsylvania

Project Team

Owner: City Hospital

Construction Manager: Turner Construction

Architect: Ballinger

Civil Engineer: Pennoni Assiciates

Structural Engineers: LeMessurier Consultants

MEP Engineers: BR+A Consulting Engineers

Master Plan

30-year development plan

- 1 million SF Research Spaces
- 1 million SF Ambulatory Care & Clinical Office Spaces
- 1 million SF Parking & Support Services Spaces

Structural System

Shallow Spread Footing Foundations

Steel Frame with Concrete Shear Walls

Integrated Foundation Wall & Structural Frame System

Composite Construction Floor System

Electrical System

(2) 13.2 kV Primary Service Feeds

(3) 5,000 kVA Substations w. Tie-Breakers

(2) 2 MW Emergency Diesel Generators

4160 Electric Chiller Distribution Voltage

480/277 & 208/120 Secondary Distribution Voltages

Mechanical System

Air Side — Phase 1

(6) 100k CFM 100% OA AHU with VSDs

(3) 120k CFM EAHU with VSDs & Heat Recovery

Air Side — Phase 2

(1) 100k CFM 100% OA AHU with VSDs

(4) 50k CFM 100% OA AHU with VSDs

(4) 50k CFM AHU with VSDs

(3) 100k CFM EAHU with VSDs & Heat Recovery

Central Plant

(1) 2,000 Ton Steam Turbine Chiller

1) 2,000 Ton Electrical Centrifugal Chiller

(4) 1,000 Ton Cooling Towers with VSD Fans

(4) 800 Bhp Dual Fuel Boiler with VSD Blowers

William K. Tang

Mechanical Option

http://www.arche.psu.edu/thesis/portfolios/2008/kzd108

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Executive Summary

City Hospital campus of southeast Pennsylvania has a 30-year development master plan which included approximately one million square feet of research space, one million square feet of ambulatory care and clinical office space, and one million square feet of parking and support services. Laboratory and hospital environments such as the one developed by City Hospital in southeast Pennsylvania will have a much higher energy intensity than a typical building. City Hospital campus will have an estimated annual utility bill of $21.3 million upon completion, a direct result of the size of the building as well as the building type.

Due to the nature of activities performed in these spaces, stringent indoor air qualities are required to protect its occupants, and various methods engineered to control energy consumption on the air side are already in place, central plant is the focus of alternative building system design. The primary goal of the alternate building system modification is to further curtail energy usage and annual utility cost. It is also important to maintain occupant health and thermal comfort, system reliability in certain foreseeable events, the ability to expand as the campus grows.

Trace energy model indicated that heating, cooling, and electric load profile of City Hospital Phase 1 and Phase 2 is an excellent candidate for cogeneration where electricity and useful heat is produced simultaneously. Phase 1 and 2 can save $ 250,000 in energy cost by installing a cogeneration plant that produces enough electricity meet building's base demand without excess. Besides the fact that cogeneration can save annual energy cost, it's environmental benefits are significant. Carbon dioxide, nitrous oxide, and sulfur dioxide emission are reduced by 78% when compared to the existing building system.

The alternate system which included turbine driven electric generator is an additional source of noise on site, and the noise cause annoyance when transmitted to occupied spaces nearby. Acoustic properties of the building and generator are analyzed to engineer methods to reduce noise level and ensure occupant comfort. The study found that noise transmitted through existing room construction is acceptable, and acoustic remediation is unnecessary.

The Addition of cogeneration plant also has an impact of the electrical system. Additional electrical equipment such as paralleling-switchgear and feeders need to be sized and incorporated with the existing system.

Phase 1 and 2 is part of a 30-year development. Thus, the alternate system designed for the central plant must work well for Phase 1 and 2 and the completed campus. Two equipment staging and four life cycle cost scenarios are evaluated to find the most beneficial combination. It is concluded that cogeneration plant of larger capacity should be install at a later construction phase to increase annual savings and decrease payback period of the alternate system.

Project Background

City Hospital campus of southeast Pennsylvania has a 30-year development master plan which included approximately one (1) million square feet of research space, one (1) million square feet of ambulatory care and clinical office space, and one (1) million square feet of parking and support services.

City Hospital campus development Phase 1 (P1) is the first phase of this multiphase campus development, and it was completed in March, 2008. P1 in essence consisted of three individual buildings, a three-level sub grade vivarium, a three-level sub grade Central Utility Plant (CUP), and a Support Services on street level. The vivarium contained 176,300 square feet of laboratory spaces and animal suites to promote advancement in medical research. The three-level, 59,500 square feet CUP is constructed adjacent to the vivarium, contained mechanical, electrical, and plumbing (MEP) infrastructures to support P1 and future phases. Future phases will be constructed above and adjacent to P1.

Phase 2 (P2) will be constructed above P1 vivarium. P2 contained 249,500 square feet of laboratory spaces and research offices on seven (7) levels. Future phases will be constructed above P2 and adjacent to P1.

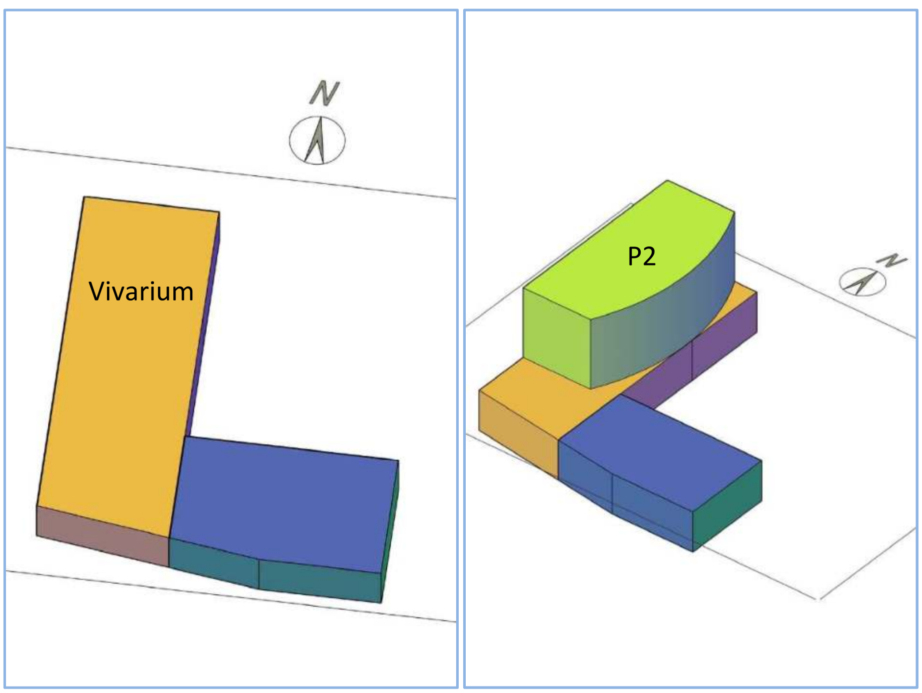

Figure 1: P 1&2 Conceptual

Note: Previous reports prepared for this thesis was written on Phase 1 only since it was the only information available at the time. Phase 2 information was included as it become available to increase accuracy. This thesis will suggest alternate solutions(s) to the building system design of City Hospital campus. Modifications and changes are for academic purposes, and do not imply errors or flaws in original design.

Existing Mechanical System

Air System

The ventilation system for P1 - vivarium comprised of six (6) 100,000 CFM custom air handling units (AHU) equipped with variable speed drives (VSD). All six (6) AHUs are demand based, and supply airflow can be reduced to 50% of the design airflow. Each AHU draws outdoor air (OA) from the OA intake plenum. OA then pass through 30% and 95% efficient pre-filter, heat recovery coil, direct injection steam humidifier, chilled water coil bank, a set of sound attenuators before and after the supply fans, and final filter of 99.9% efficient.

Two (2) AHUs are grouped together to deliver 100% outdoor air to each level by the means of variable air volume (VAV) system. Ductworks reach individual zone by ganged/manifold distribution concept through a mechanical distribution corridor on each floor.

Three (3) 120,000 CFM exhaust air handlers (EAHU) with sensible heat recovery remove majority of the indoor air, and preheat OA that become the supply air (SA). Other exhaust systems compensate for the remaining indoor air removal. The Vivarium Air Flow Diagram showed relation of AHUs, EAHUs, and exhaust fans to each space.

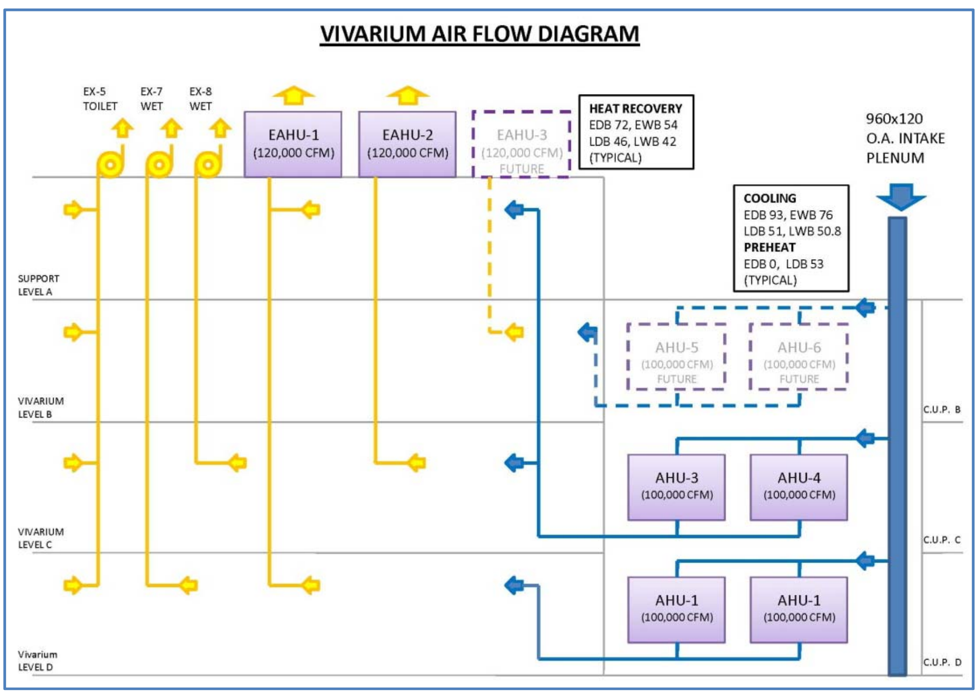

Figure 2: P1 Air Flow Diagram

The ventilation system for P2, eight (8) 50,000 CFM and one (1) 100,000 CMF custom AHU similar to AHU specified for P1, are located on seventh (7^{th}) floor. On the nine (9) AHU, four (4) 50,000 CMF and one (1) 100,000 CFM AHU supply 100% OA to laboratory spaces on floor third (3^{rd}) to sixth (6^{th}). Two (2) 50,000 CFM AHU with minimum 25,000 CFM of OA serve offices on floor second (2^{nd}) to sixth (6^{th}). The remaining two (2) 50,000 CFM AHU with minimum 25,000 CFM of OA serve office and conference rooms on level A and first (1^{st}) floor.

Three (3) 100,000 CFM EAHU with sensible heat recovery similar to EAHU specified for P1 are located on the eighth (8^{th}) floor, currently the roof. These EAHU remove indoor air from laboratory spaces on floor third (3^{rd}) through sixth (6^{th}) to maintain 100% OA.

Heat Recovery & Pre-heat System

The exhaust air heat recovery system employed a runaround glycol loop, which has an effectiveness of 74%, to recover heat from exhaust air. The heat recovery loop is interconnected with the low pressure steam system through steam-water heat exchangers to pre-heat OA air to 53°F in winter months.

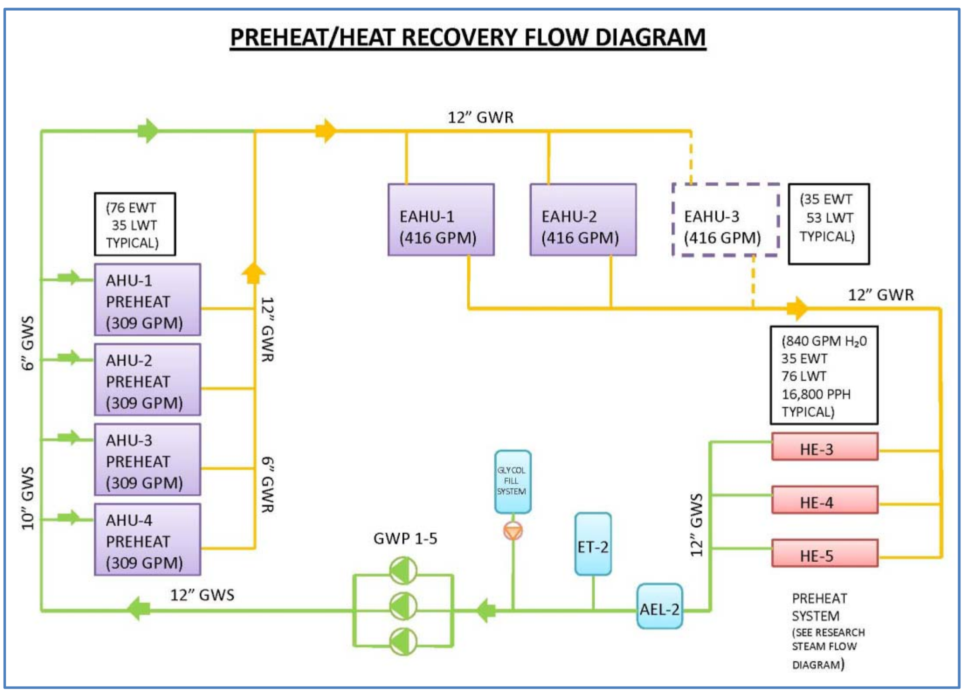

Figure 3: P1 Heat Recovery Diagram

Steam System

The boiler plant for Phase 1 and Phase 2 (P 1&2) are located on CUP level C. It included four (4) 800 boiler horse power (bhp) (27,600 lb/hr of steam each) dual fuel steam boilers with VSD blowers and stack economizer (BSE). Boiler stack economizer pre-heat boiler feed water by recovering heat. Each BSE has the capacity to increase boiler efficiency by 3.2%.

The boiler plant produce high pressure steam at 125 psig for high efficiency distribution, and drive steam turbine chiller(s) which operate at 120 psig. High pressure steam is reduced to 70 psig medium pressure steam for domestic hot water heating and laboratory process equipments. Steam pressure is further reduced to 2 psig low pressure steam for humidification and building hot water loop re-heat. Additional boilers will be added in future phases to increase steam capacity as construction continues.

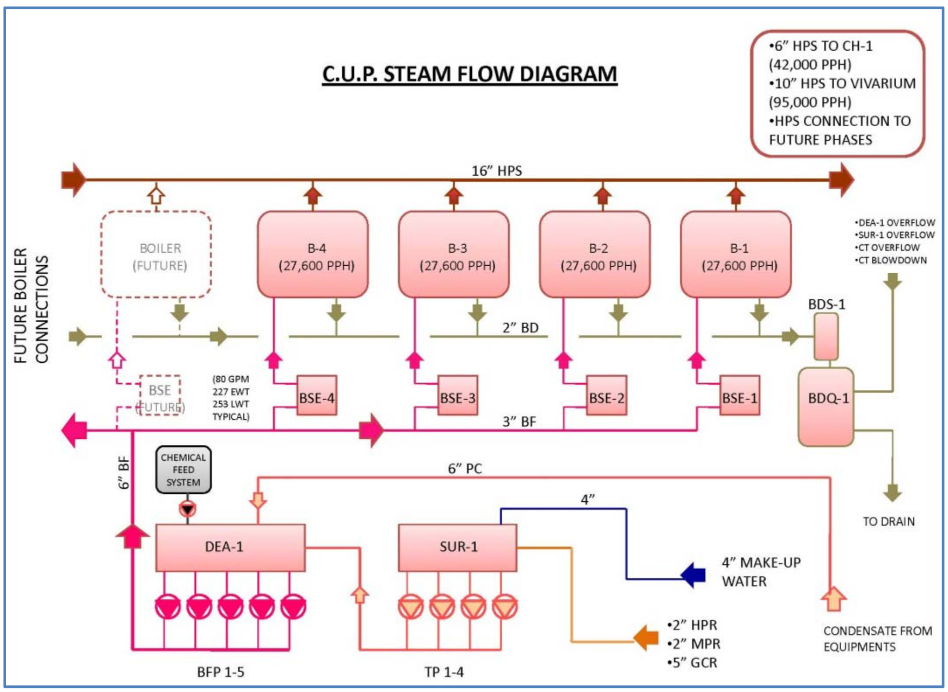

Figure 4: CUP Steam Flow Diagram

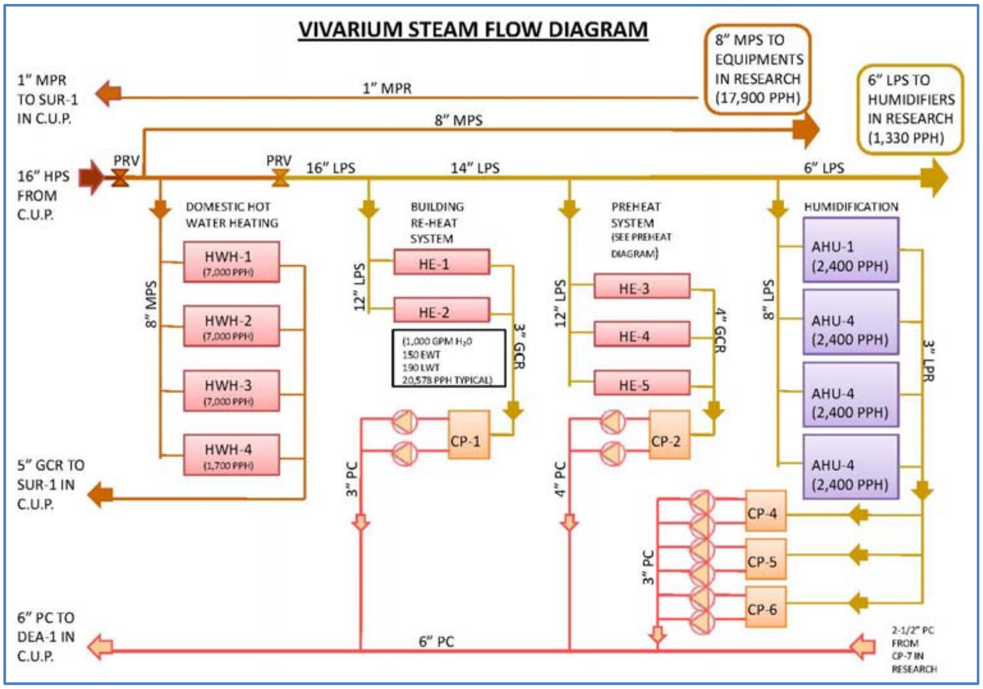

Figure 5: P1_Vivarium Steam Flow Diagram

Chilled Water System

The chiller plant for P1 and P2 consisted of one (1) 2,000 ton steam turbine chiller and one (1) 2,000 ton electric centrifugal chiller that produce 42°F chilled water. These chillers provide chilled water to the AHUs, as well as process chilled water (PCHW) loads. Chilled water is distributed to loads with two (2) variable speeds secondary chilled water pumps on a primary/secondary loop. Eight (8) or more 2,000 ton chillers will be added in future phases to meet capacity requirement.

Chillers reject heat via a condenser water system which included four (4) 1,000 ton cooling towers with VSD fans. These cooling towers serve both chillers and produce process chilled water in winter months. Additional cooling towers will be added in future phases to accommodate future chillers' heat rejection requirement.

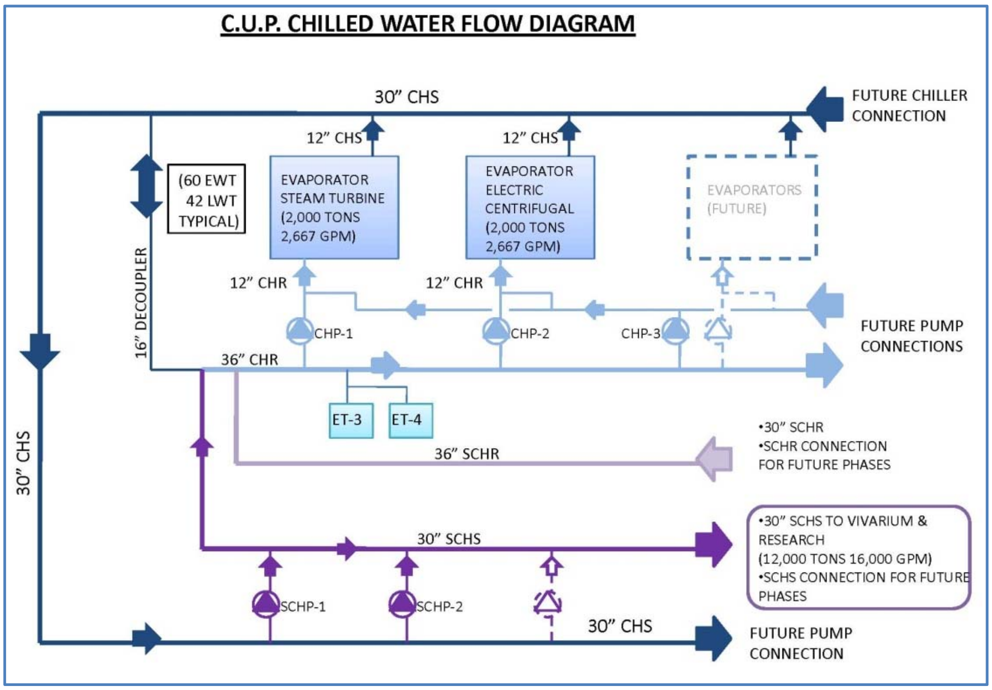

Figure 6: CUP Chilled Water Flow Diagram

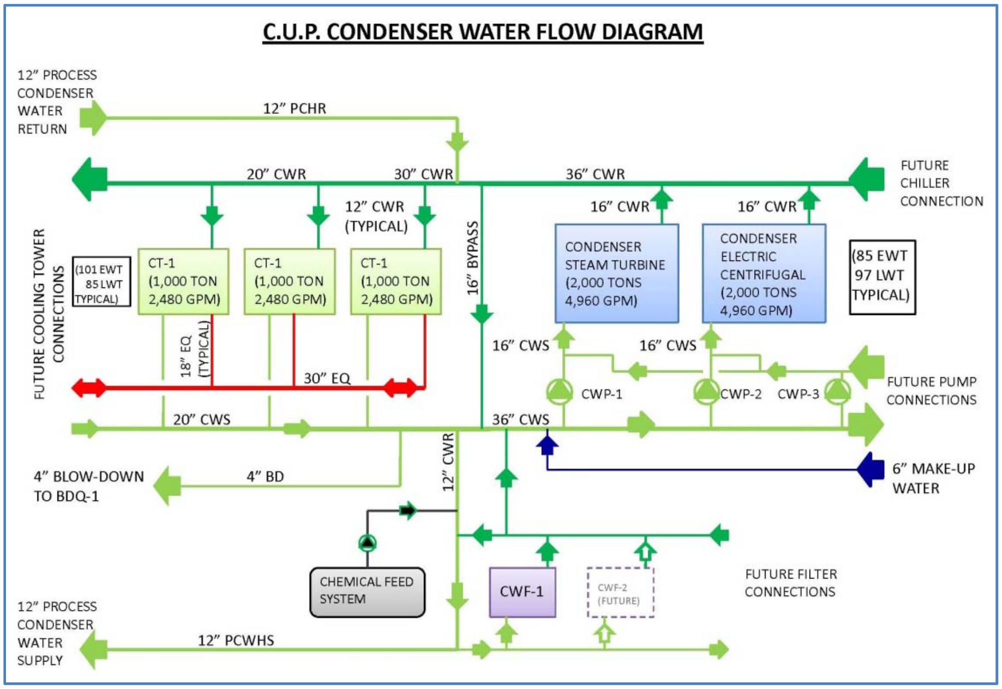

Figure 7: Condenser Water Flow Diagram

Existing Electrical System

Electrical power is supplied by an electric company in Pennsylvania on two 13.2KV service feeders via underground duct bank. The 15 KV duel line switchgear with bus tie breaker, rated at 2,000 A delivers electricity to three substations by means of secondary selective for improved reliability. Two 2,500 KVA double ended substations with tie breaker, step 13.2 KV to 480/277 V, 3ϕ, 4 wires, and distribute services to P 1&2, and future phases. A 5,000 KVA substation steps 13.2 KV to 4160 V, 3ϕ, 4 wires for a 2,000 ton electric centrifugal chiller. Emergency/life safety demand is supported by two 2 MW diesel powered generators. Additional switchgear and substation will be added to the CUP as part of future phases.

Existing Structural System

The structural system for Phase I consisted of steel frame with concrete shear walls on shallow foundation system with spread footings. Foundation walls are integrated with structural frame via steel shear plates. Each 24 inches thick shear wall has two curtains, vertical and horizontal reinforcement varies with height, and steel columns implanted for extra stiffness. The shear wall system, running from Level D to Level A, is sized to resist lateral forces transferred from future phases above. The composite floor system consisted of 4,000psi concrete on composite steel deck with shear studs. Steel beams ranged from W12 – W24 for the research facility, W8 – W30 for CUP, and bay width varies from 24' to 33'.

Mechanical System Design Alternates

Laboratory and hospital environments such as the one developed by City Hospital in southeast Pennsylvania will have a much higher energy intensity than a standard commercial building. City Hospital campus has an estimated annual utility bill of $20.5 million upon completion. This is a direct result of the size of the building as well as the building type. Laboratory spaces have requirements that will directly increase the cost of operation. Air cannot be recalculated and therefore all of the air in the labs must be exhaust out of the building. Providing 100% OA to all laboratory spaces will increase fan energy and equipment energy because such large amount of the air must be conditioned and moved throughout the building.

As found in Technical reports One and Two, City Hospital P1 meets ventilation requirements outlined in ASHRAE 62.1, and complies with equipment power allowance and building envelope outlined in ASHRAE Standard 90.1. Due to the nature of activities performed in these spaces, stringent indoor air qualities are required to protect its occupants. In addition, the existing air side system already employed runaround glycol loop exhaust heat recovery and variable air volume fume hood exhausts to control energy consumption. Thus, the central plant is the focus of alternative building system design.

The primary goal of the alternate building system modification is to further reduce energy consumption and annual utility cost. As energy consumption is reduced, emissions will decrease as well. It is also important to maintain occupant health and thermal comfort, system reliability in certain foreseeable events, the ability to expand as the campus grows. Furthermore, the alternate design should have a reasonable payback period to justify its application.

Existing Load Calculation

The first step in the designing an alternate mechanical system for City Hospital Campus is to model the existing laboratory and office spaces with an energy analysis program as accurately as possible. Information for load calculation was obtained from the master drawings and specifications provided by construction manager Turner Construction Company, and MEP design engineer Bard, Rao, and Athanas Consulting Engineers, LLC.

Space	Ventilation Rate		Occupant Density	Lighting Density	Equipment Load
	ACH	CFM/occ.	ft^2/occ.	w/ ft^2	w/ ft^2
Lab	10.0	-	40	1.5	4.0
Office	-	20.0	200	1.5	0.5
Other	4.0	-	0	1.0	0.0
	Design Temp.		RH		
	DB °F	WB °F	%		
Winter	0	-	-		
Summer	95	78	-		
Indoor	72	-	40		

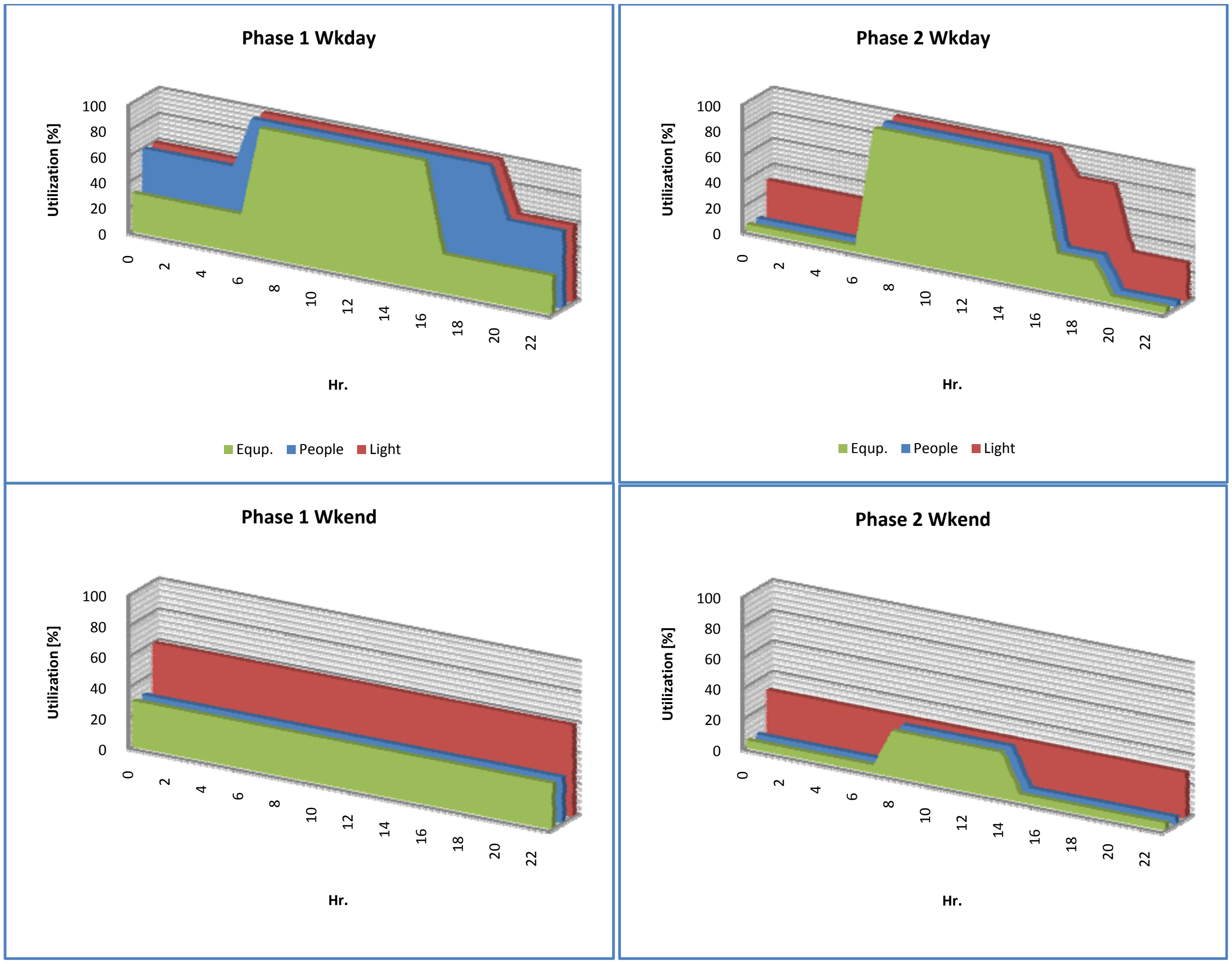

Figure 8: Assumed Occupant, Lighting, and Lab Equipment Schedule

Trane Trace was used to stimulate load calculation based on design criteria, assumed schedules, and construction documents such as:

- Room dimensions and orientations
- Wall, ceiling, and floor assemblies
- Window and roof characteristics
- Air system type and equipments specifications
- Plant characteristics and configurations

Results from the Trace model provided electric and thermal demand of the existing system, and serve as a benchmark which alternate designs are compared and analyzed.

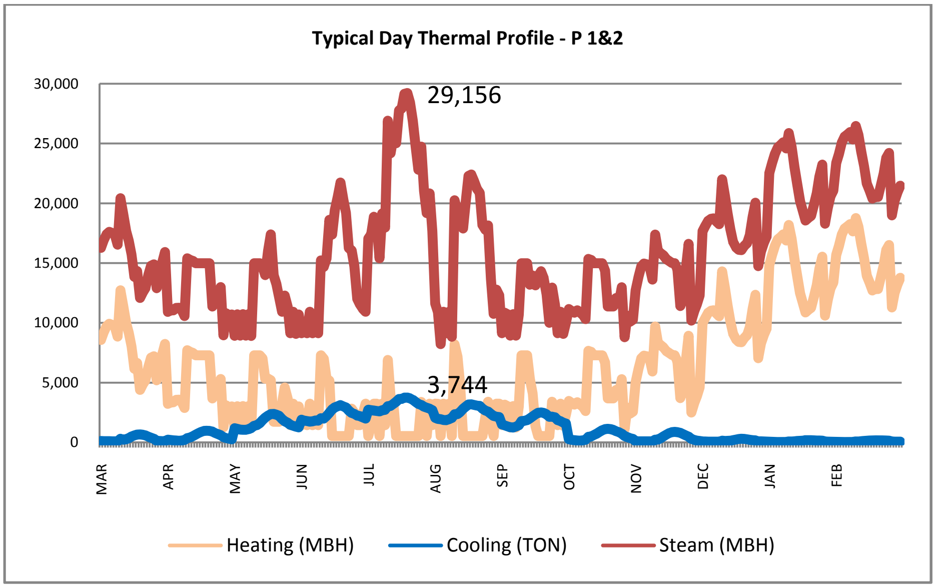

Figure 9: P 1&2 Thermal Profile

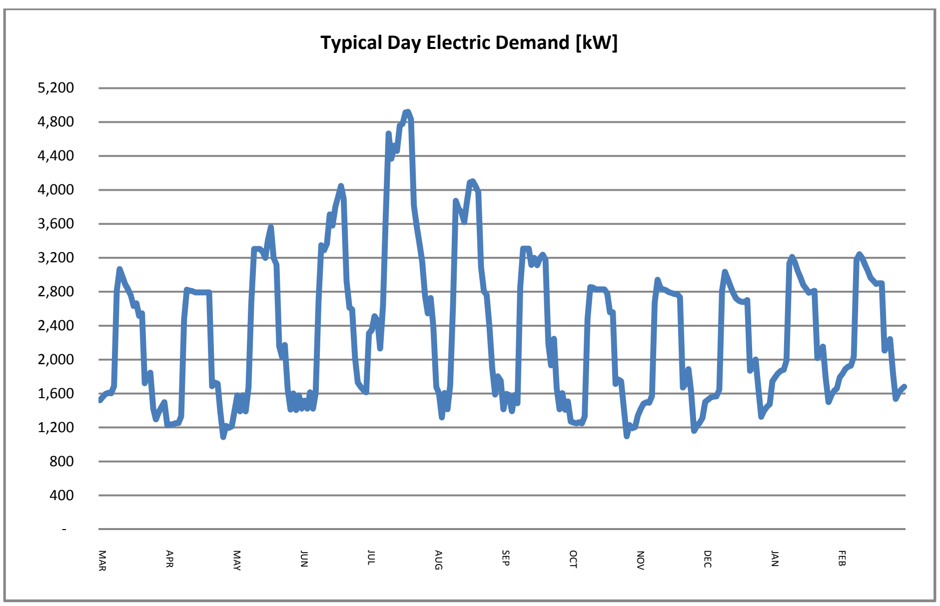

Figure 10: P 1&2 Electric Demand Profile

Design Alternate 1: All Electric Centrifugal Chiller Plant

The existing mechanical system is designed to use steam generated by boilers to meet building thermal load, process equipment load, and drive steam turbine chiller(s). Trace assumed steam turbine chiller to provide primary chilled water production, and electric centrifugal chiller(s) compensate remaining chilled water load. Actual sequence of operation may vary. Steam turbine chiller(s) specified for the project consume 11.2 pound of steam per hour-ton, an efficiency equivalent of 13,365 Btu/hr-ton (340°F, 120 psig). Electric centrifugal chiller(s), rated 0.598 kW/ton, have efficiency equivalent of 2,041 Btu/hr-ton. Therefore, electric centrifugal chiller is 84.7% more efficient than steam turbine chiller. An all electric centrifugal chiller plant will have a much higher efficiency than the current steam turbine/electric chiller plant, operation cost and maintenance cost will be lower. Capital cost for an all electric centrifugal chiller plant will be less than the current configuration as well.

Energy usage of the existing system and an all electric centrifugal chiller plant is converted into common unit of million British thermal units (MMBtu) for comparison. The existing system consumes 172,983 MMBtu of natural gas and 78,194 MMBtu of electricity annually. An all electric chiller plant uses 87,325 MMBtu of natural gas and 85,662 MMBtu of electricity. Even though natural gas does not have a demand charge like electricity, and relatively less expansive per MMBtu, annual utility cost of an all electric centrifugal chiller plant cost $4.07 million (*Appendix ii*) compared to $4.33 million of the existing design (*Appendix i*) in energy expenditure. An all electric centrifugal chiller plant can save City Hospital Phase 1&2 $274,000 annually in energy cost by increasing efficiency.

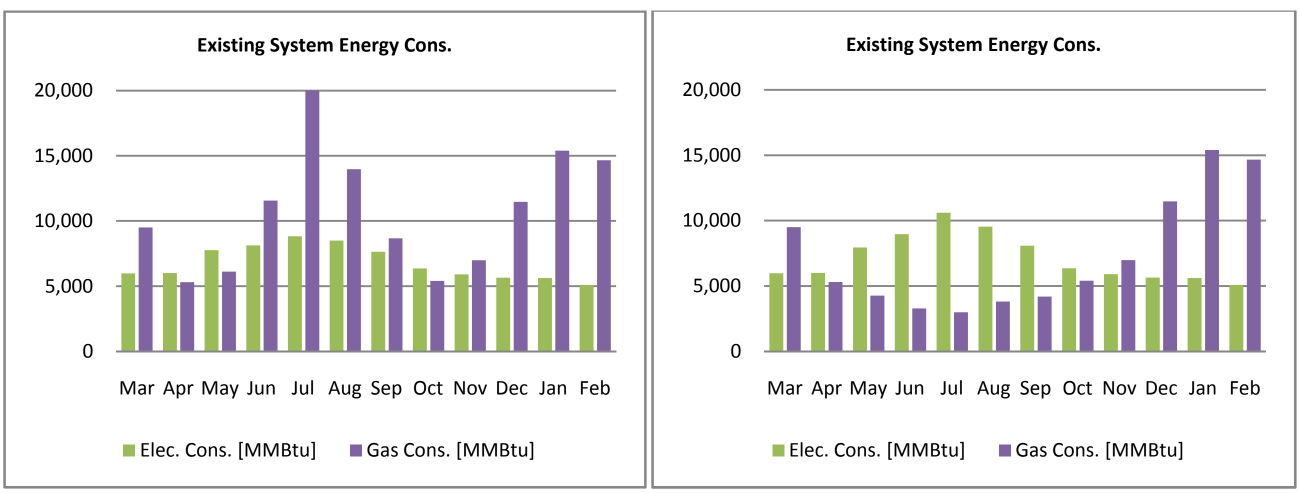

Figure 11: Energy Usage of Existing Chiller Plant and All Electric Centrifugal Chiller Plant

All though an electric centrifugal chiller is much more efficient than a steam turbine chiller, there are disadvantages to such efficiency. Current chiller plant configuration considered to be fail-safe due to chiller plant's flexible energy source, steam or electricity. Flexibility is essential to critical environments such as vivarium and laboratory spaces on the campus. Thus, an all electric centrifugal chiller plant will not be considered further as an alternate mechanical design.

Design Alternate 2: Cogeneration

Cogeneration, also known as combined heat and power (CHP), simultaneously generate both electricity and useful heat. Conventional power plants emit the heat created as a byproduct of electricity generation into the atmosphere as flue gas. CHP captures the byproduct heat for domestic heating purposes. According to Dr. Joseph A. Orlando, P.E., director of Mid-Atlantic CHP Application Center, cogeneration has an overall efficiency of 68.9% and source energy reduction of 35%, while conventional electrical system has an overall efficiency of 44.5%. Higher efficiency translated to lower energy consumption, fewer emissions, and lower operating cost.

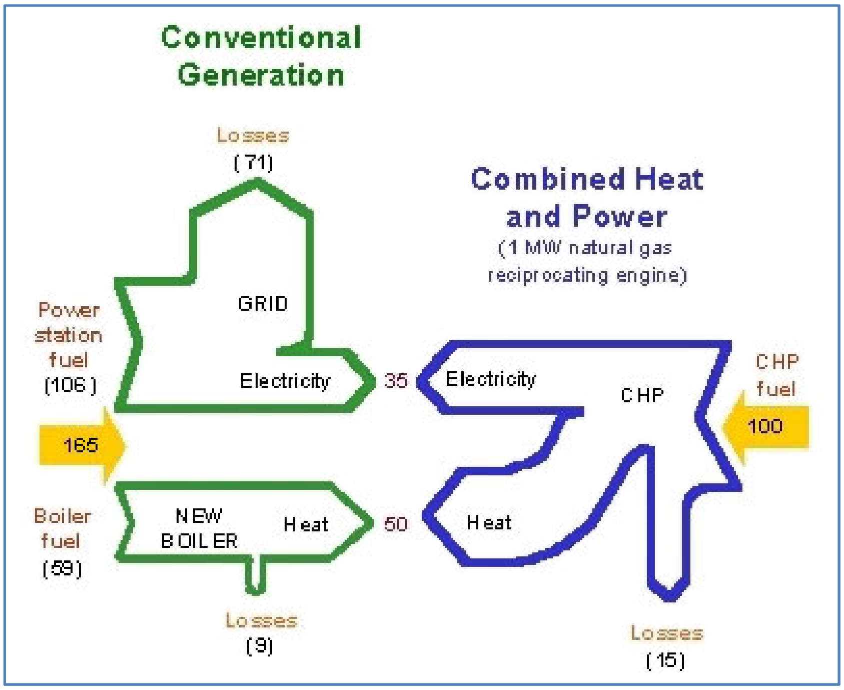

Figure 12: Separated vs. Combined Heat and Power (Source: DOE)

Energy analysis from Trace model showed that P 1&2 of City Hospital campus development required significant amount electricity (22.9 GWh), and steam (233.9 MMBtu) annually for indoor environmental control and laboratory equipment process. Other than a need for process heat, Laboratories for the 21st Century: On-Site Power System for Laboratories (Lab21) also suggests that CHP system is most practical and cost-effective when:

- A central or district heating and/or cooling system is already in place
- Electricity are high or when most of facility's energy cost go to demand charges
- When ratio of average electric load to peak load is greater than 0.7
- The "Spark spread" is greater than $12/MMBtu

Electrical Feasibility of CHP

To test feasibility of CHP for City Hospital, annual electricity and natural gas consumption from Trace model are used to calculate energy expenditure based on the tariff structure of City Hospital's utility provider. The 'Existing System Annual Electricity Cost' and 'Existing System Annual Natural Gas Cost' (*Appendix i*) shown that electricity cost $3.0 million for 22.9 MWh, an average of $0.11/kWh or $32.92/MMBtu, and natural gas cost $2.2 million for 1.67 million therms, an average of $1.34/therm or $13.42/MMBtu. The 'Spark spread' for City Hospital is $19.50, higher than the 'Spark spread' suggested by Lab21. Demand charge accounted for one third (1/3rd) of the electricity cost, but the average electric load to peak load ration is 0.52. Since City Hospital only satisfied four out of five recommendations suggested by Lab21, CHP may or may not be cost-effective.

CHP Selection

HVAC System and Equipment Handbook published by ASHRAE, stated basic components for a cogeneration plant are:

- Prime mover and its fuel system
- Generator
- Waste heat recovery system
- Control system
- Electrical and thermal transmission and distribution system
- Connection to building mechanical and electrical services

From U.S. Environmental Protection Agency (EPA), Catalog of CHP Technology, there are five (5) commercially available CHP prime movers. Due to the constrain of steam turbine chiller which operate with 120 psig of steam, the CHP prime mover must be able to produce 125 psig of steam to work with the existing steam distribution system. Of the five (5) commercially available CHP prime movers, gas turbine and fuel cell technology has the capability to produce high pressure steam.

Typical Cost and Performance of Gas Turbine and Fuel Cell		
Technology	Gas Turbine	Fuel Cell
Power efficiency	22 - 36 %	30 - 63 %
Overall efficiency	70 - 75 %	65 - 80 %
Typical Capacity (MW)	1 - 500	0.01 - 2
Typical power to heat ratio	0.5 - 2	2-Jan
Part-load	poor	good
CHP Installed cost ($/kW)	800 - 1,800	2,700 - 5,300
O&M cost ($/kW)	0.003 - 0.0096	0.005 - 0.04
Hours to overhauls	30,000 - 50,000	10,000 - 40,000
Start-up time	10 min - 1 hr	3 hr - 2 days
Fuels	natural gas bio gas propane, oil	Hydrogen bio gas propane, Methanol
Noise	moderate	low

From the 'Summary Table', gas turbine technology is a better candidate than fuel cell for City Hospital. Gas turbine has lower initial cost, lower operating and maintenance (O&M) cost, and longer hours between overhauls. In addition, it can use both natural gas or fuel oil which is readily available since the existing design specified dual fuel boilers that use both natural gas and fuel oil.

Since gas turbine has a poor part load performance, thus the prime mover is more efficient when operated continuously at peak load. In addition, CHP capacity will be selected meet either electric demand without excess because excess electric power sold at wholesale rate cannot recover cost of on-site generation. In order to operate at full capacity without excess electric power or steam at all time, CHP's capacity shall be less than 1.2 MW and 10 MMBtu/hr.

One (1) Saturn 20 duel fuel (natural gas as primary, fuel oil as backup) gas turbine electric generator set by Solar Turbines with Maxfire heat recovery steam generator (HRSG) by C-B Energy Recovery is selected for the City Hospital P 1&2 alternate design. This CHP system can produce 1.21 MW, 4.1 MMBtu/hr equivalent of electricity and 9.6 MMBtu/hr of steam. At 16.8 MMBtu/hr of heat input, this CHP system can achieve 81.6% efficiency of source energy.

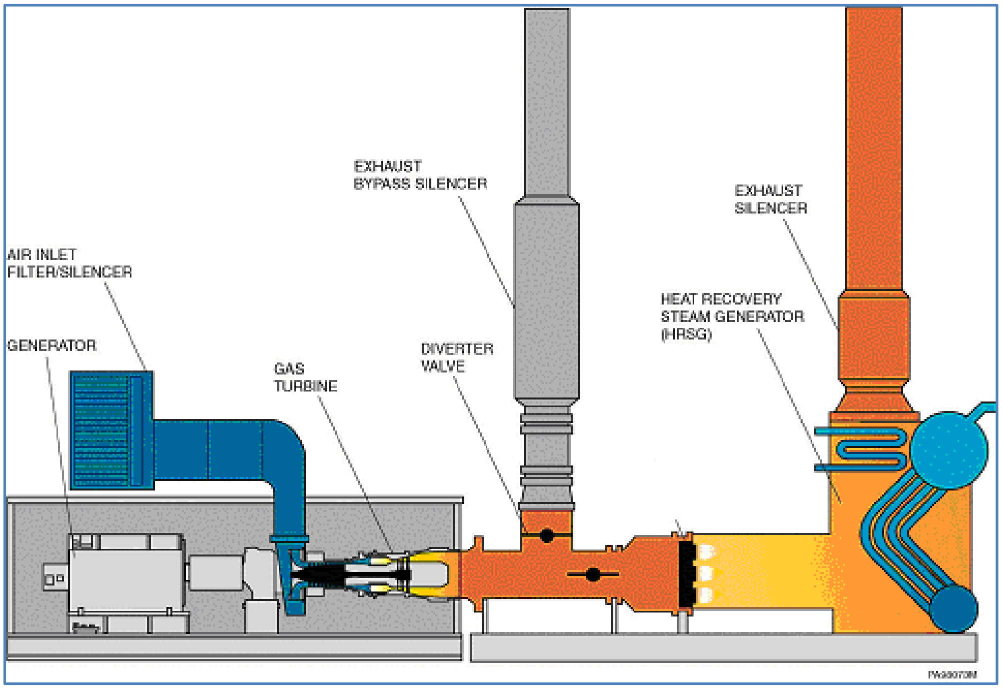

Figure 13: Typical CHP Layout (Source: Solar Turbine)

The CHP system will be place in the boiler room in CUP C Level and its breaching and stack shall follow design method for boilers of the existing design, see 'Alternate Design Boiler Room Layout' (*Appendix xix*).

Alternate Design Energy Cost

The CHP system selected for City Hospital P 1& 2 has the capability to produce 1.21 MW of electricity and 9.6 MMBtu/hr of Steam. With 8,520 operating hours per year, the prime mover consumes 781.4 lbm/hr of natural gas, or 1.34 million therms of natural gas per year. At the same time, it reduces boiler steam production by 9.6 MMBtu/hr, or 1.02 million therms of natural gas per year. As a result, the natural gas consumption of the alternate design will be $2.29 million per year, $576,000 more than the existing design (*Appendix i and iii*).

Calculating electricity cost for the alternate design are bit more challenging. City Hospital's electricity provider does not have a "standby" rate for on-site generation. Instead, it impose a "Customer Transition Charge" depended on the percentage of hours which the generator goes off-line in the previous fiscal year. As a result, "standby" electric tariff from two (2) nearby electricity providers are studied.

PECO, provide electric distribution service in southeast Pennsylvania. It imposed a demand charge of $3.22/kW in addition to base rate. Therefore, the cost of electricity of the alternate design for City Hospital P 1&2 would be $1.80 million ($0.133/kWh), an annual saving of $826,000 (*Appendix iii*).

Bucknell University, located at central Pennsylvania has a similar CHP design in placed. Bucknell pays its utility provider 80% of their demand without CHP in addition to the actual usage. With a 1.21 MW generator in place, and at the rate of $13.52/kW, it would cost City Hospital $157,000 annually on "standby" charge. Even so, the electricity cost of alternate design would be $1.82 million ($0.134/kWh), an annual saving of $809,000 (*Appendix iii*). Bucknell's "standby" rate is 1% higher than the PECO's "standby" rate. Hence, the difference is relatively insignificant.

The alternate design would cost City Hospital $576,000 more for natural gas. Since natural gas cost $19.50 less per MMBtu than electricity, the alternate design would save City hospital $250,000 annually in energy cost for P_1&2 alone.

Future References

MEP infrastructures in the CUP are intended to serve the entire City Hospital campus. The alternate design must perform well for P 1&2, and the completed campus. Since P 1&2 information are the only information available at the moment for City Hospital campus development, it is chosen as basis of analysis. To ensure accuracy of the Trace model, steam and electrical demand from P 1&2 are compared along with steam and electrical demand of similar spaces.

Name	Whitehead Biomedical Research Center	Fred Hutchinson Cancer research Center	Louis Stoke Laboratories, NIH	Research Laboratories University of California	City Hospital Campus Development
Location	Atlanta, GA	Seattle, WA	Bethesda, MD	CA	S.E. PA
Elec. Intensity (kWh/ft²-yr)	63.3	77.0	67.5	79	56.8
Steam Intensity (kBtu/sf²-yr)	210	-	-	559	372

City Hospital's electricity consumption intensity is on the lower range contributed by City Hospital's chiller plant configuration which the steam turbine chiller(s) give flexibility to the plant as well as lowering its electricity consumption. Overall, the Trace model of City Hospital P 1&2 is within the range of electric and steam intensity of spaces with similar functions. Electricity and steam consumption and demand are compiled and extrapolated to mimic the state of City Hospital campus upon completion.

Basis for Extrapolation			
Peak Electric Intensity	11		W/ft²
Base Electric Intensity	3		W/ft²
Peak Steam Intensity	75		btuh/ft²
	Existing Design	Alternate Design	
Elec. Cons. Intensity	57		kWh/ft²-yr
NG Cons. Intensity	3.0	3.53 - 3.97	therm/ft²-yr
Cost of elec./ft²	6.27	2.36 - 4.10	$/ft²
Cost of Natural Gas /ft²	4.08	5.08 - 5.40	$/ft²
CO_2 emission	17.9	3.2 - 7.2	ton/ft²-yr
No_x emission	15.0	2.7 - 6.1	lbm/ft²-yr
SO_2 emission	0.7	0.1 - 0.4	lbm/ft²-yr

City Hospital P1 was completed in March, 2008. However, though completion dates of future constructions remained unknown. Since laboratory and office spaces are the dominant load and energy consumer, they are the prime focus of the analysis. Therefore, three (3) artificial construction milestones are created to evaluate three equipment staging scenarios, and approximately one (1) million square feet of support service spaces, such as mechanical room, loading dock, and parking space are excluded.

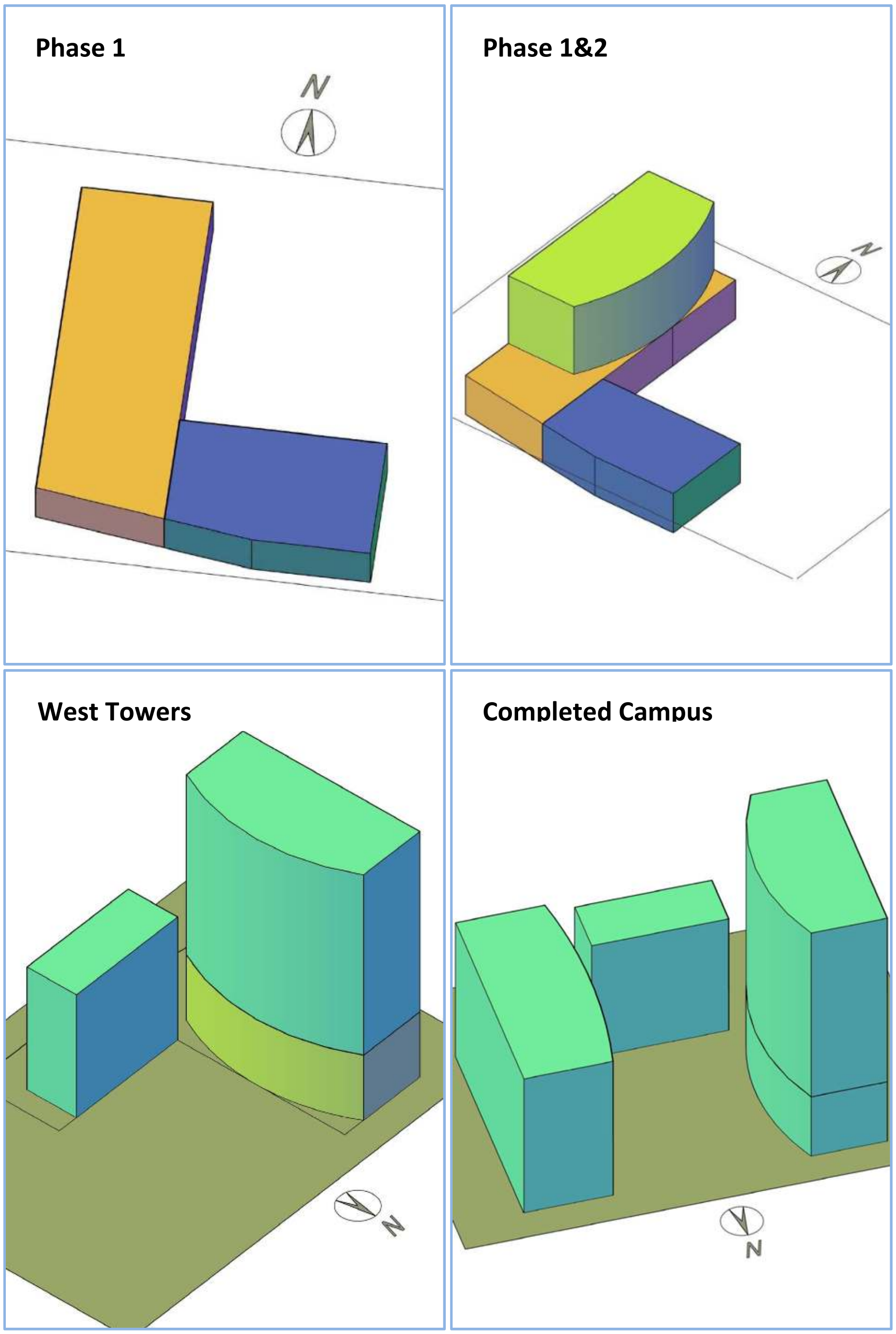

Figure 14: Campus Development Conceptual

Steam and Electricity Demand			
Construction Milestones	Phase 1&2	West Tower	Completed Campus
Square Footage (ft²)	420,000	1,150,000	2,000,000
Peak Steam Demand (MMBtu/hr)	31.4	85.9	149.4
Natural Gas Consumption (million therm/yr)	1.25	3.42	5.95
Peak Elec. Demand (kW)	4,805	13,157	22,881
Base Elec. Demand (kW)	1,345	3,684	6,407
Electricity Consumption (MWh/yr)	28,647	78,439	136,415

Mechanical Equipment Staging

Bases on the 'Steam and Electricity Demand Table', the existing mechanical system would need two (2), four (4), and six (6) 800 bhp, 32 MMBtuh for construction milestone Phase 1&2, West Tower, and the Completed Campus respectively due to "N+1" design practice for laboratory spaces such as City Hospital.

Equipment Staging						
	Scenario 1			Scenario 2		
Construction Milestones	Phase 1&2	West Tower	Completed Campus	Phase 1&2	West Tower	Completed Campus
1.2 MW Generator	1	2	2			
3.5 MW Generator			1		1	2
HRSG	1	2	3		1	2
800 BHP Boiler	1	2	1	1	2	1
2000 BHP Boiler			1			1
Backup 800 BHP Boiler	1	1	2	1	1	2
Total MW	1.2	2.4	5.9	0.0	3.5	7.0
CHP MMBtuh	9.6	19.2	42.1	0.0	22.9	45.8
Boiler MMBtuh	32.3	64.5	114.7	32.3	64.5	114.7
Available MMBtuh	41.9	83.7	156.8	32.3	87.4	160.5
Backup Boiler MMBtuh	32.3	32.3	64.5	32.3	32.3	64.5
Boiler MMBtuh	64.5	96.8	179.3	64.5	96.8	179.3
Total MMBtuh	74.1	116.0	378.2	64.5	119.7	385.6
Number of Boilers	2	3	4	2	3	4
Number of Equipments	4	7	10	2	5	8

From the 'Equipment Staging of Alternate Design', Scenario 1 would save the most energy. It reduce electricity demand and cost early in the early phase of campus development, and the combination of smaller boilers offers maximum amount of time of high efficiency operation. However, Scenario 3 equipment staging is recommended.

Equipment staging Scenario 2 uses the less number of equipments of the two (2) equipment staging scenarios which minimized capital cost and "lost rentable space". The boiler room of P1 CUP is designed to accommodate six (6) 800 bhp fire tube steam boilers size equipments. It is intended to locate additional boilers in mechanical space which will be part of the CUP extension when construction for East Tower construction begins. Thus, it is best to group all six (6) fire tube steam boilers together in Phase 1 boiler room, and purchase CHP units of higher capacity (3.5 MW, 22.9 MMBtuh steam) at later phase when additional mechanical spaces are built and the demands are high.

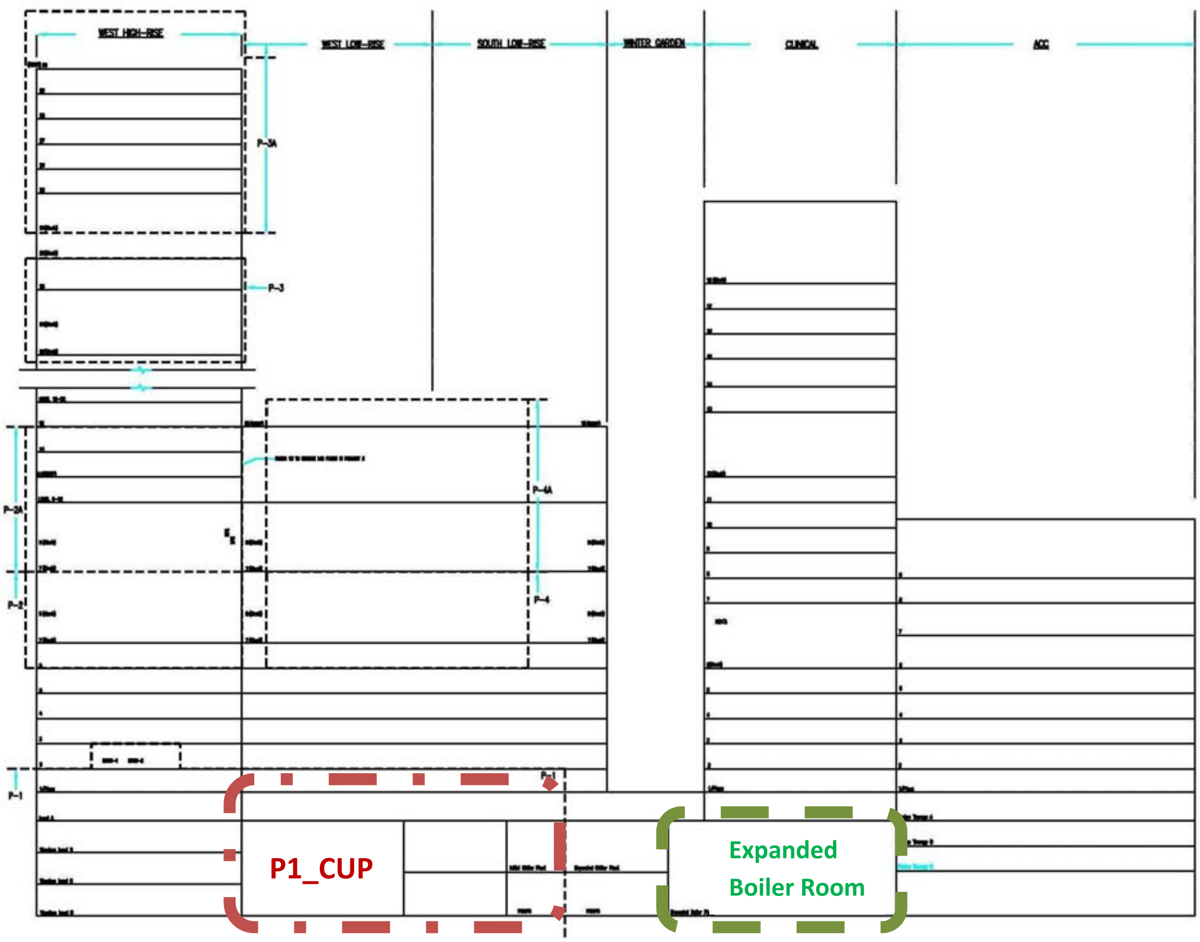

Figure 15: Mechanical Equipment Room Location (For Reference Only)

Alternate Design Saving						
Construction Milestones	West Tower			Completed Campus		
	Exist. Design	Alt. Design	Savings	Exist. Design	Alt. Design	Savings
NG Consumption (therm/yr)	3,420,463	4,057,494		5,948,632	7,935,101	
Electric Cost ($mil/yr)	7.61	4.71		13.23	4.72	
Natural Gas Cost ($mil/yr)	4.65	5.52	2.03	8.09	10.79	5.82
Saving ($mil/yr)			17%			27%
CO_2 emission (1000 ton/yr)	20,570	8,295	12,276	35,775	8,853	26,922
			60%			75%
No_x emission (ton/yr)	8,625	3,486	5,139	15,000	3,724	11,276
			60%			75%
SO_2 emission (ton/yr)	471	216	255	820	210	610
			54%			74%
Car Removed (millions)			**0.54**			**1.18**

As City Hospital campus expands, energy usage escalates linearly with its square footage. When West Tower completes, City hospital would consume 23,872 MWh of electricity and 1.25 million therms of natural gas annually. When City Hospital campus is completed, two (2) million square feet of laboratory and office space, its energy usage would be five (5) time of P 1&2, with 136.5 GWh of electricity and 6.0 million therms of natural gas annually (*Appendix v and vi*).

Small conservation can translate into substantial savings for large development such as City Hospital campus. By incorporating a CHP technology, City Hospital would save $5.82 millions in energy annually when the campus is completed. Likewise, it will have a significant effect on the environment. EPA estimated that an average passenger car emits 11,450 pound of carbon dioxide per year. By generating electricity on-site, it reduced 26.9 million tons of carbon dioxide annually, an equivalent of removing 1.2 million passenger cars off the road. City of Philadelphia only has a population of 1.5 million in 2005.

Electrical Breadth

The alternate mechanical design included addition of gas turbine generator(s) for electricity generation to reduce demand and usage purchased from local grid. Equipments for distributing electricity must be integrated as part of the new system.

The existing electrical system included two (2) 13.2 KV service feeders from electricity company, two (2) 2,500 KVA double ended substations with tie breaker to step 13.2 KV to 480/277 V, and a 5,000 KVA substation to steps 13.2 KV to 4160 V for a 2,000 ton electric centrifugal chiller. The gas turbine generator manufacturer for the alternate system offered standard and custom voltage options. Selecting 13,200 V electric output allowed the alternate system to connect to the existing substations to provide power to different loads, and use smaller distribution equipment.

Feeders Selection

Voltage	13.2 kV				
Generator	Amp/Conductor	Required Conductor Capacity	Conductor	Actual Conductor Capacity	Conduit
(kW)	(Amp)	(Amp)		(Amp)	
1210	53	66	(4) #6 AWG THHW	75	(1) 1"
3515	154	192	(4) 2/0 AWG THHW	195	(1) 2"

Equipment Staging Scenario 1:

(2) 1.2 MW turbine generators
(1) 3.5 MW turbine generator
(2) sets of (4) #6 AWG THHW with (2) 1 inch conduit
(1) 2/0 AWG THHW with (1) 2 inch conduit

Equipment Staging Scenario 2:

(2) 3.5 MW turbine generators
(2) sets of (4) 2/0 AWG THHW with two (2) 2 inch conduit

Paralleling Switchgear

The alternate design included two (2) or more generator sets for City Hospital campus. The purposes of a paralleling-switchgear are initiate multiple generator sets start up, synchronize electric output, and transfer power to loads. To select paralleling-switch gear for City Hospital alternate building system design, largest possible generation capacity (7.0 MW) is analyzed to select distribution equipment. At 7,030 kW and 13.2 kV, generator sets have combined amperage of 530. ASCO 4000 Series paralleling-switchgear, with 600 amp rating, is selected to parallel multiple generator set for the alternate building system design.

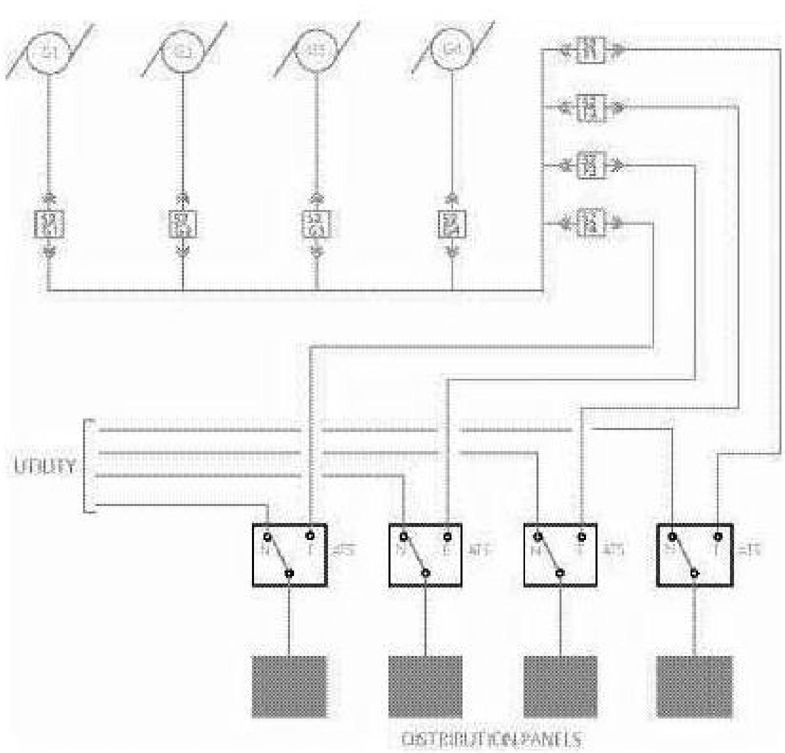

Figure 16: One-line Schematic of Typical (4) Engine-generator paralleling-switchgear configuration. Source: ASCO

Acoustic Breadth

Gas turbine electric generator for cogeneration has moderate noise level, and should be place outdoor when possible. City Hospital campus is located in a dense urban area. Due to limitation of available outdoor space and future construction above "roof" of P 1&2, location of CHP generator(s) are limited to the boiler room. Noise generated by gas turbine generator(s) may transmit to occupied spaces near the boiler room. Noise criteria are evaluated to ensure occupant comfort.

Sound level from each third (3^{rd}) bandwidth was obtain by measuring a 4.8 MW gas turbine generator set, similar to the one suggested for the alternate design, at Bucknell University. The gas turbine generator itself has an overall noise level of 96 dBA. However, the package included a weatherproof acoustic enclosure which reduced the overall noise level to 81 dBA. OSHA permits exposure up to 90 dBA for an (8) eight-hour work day without personal protection equipment. Optional equipments included inlet and exhaust silencers which reduced noise level below ambient outdoor noise level. Thus, sound created by the turbine generator would not be a concern at the property line.

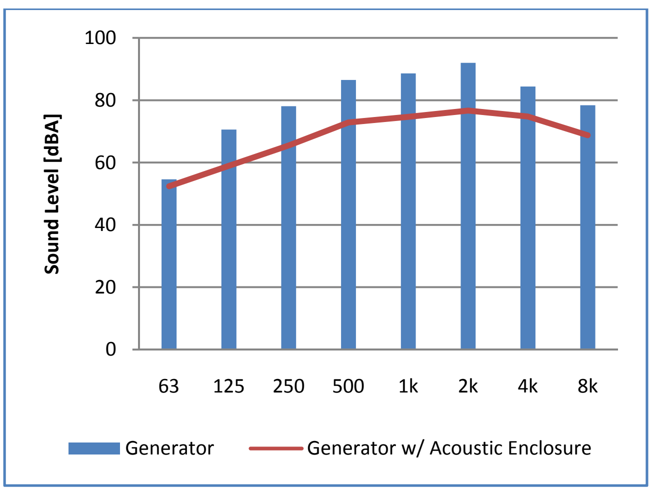

Figure 17: 4.8 MW Gas Turbine Generator Acoustic Properties

Designer of P1 CUP took acoustic design into consideration by placing equipments (chillers) with highest noise level farthest away from occupied area. P1 Boiler room, where the CHP for the alternate building system design is located, is surrounded by buffer zones. It is connected to the chiller room to the east, AHU room to the west, electrical room to the north separated by a corridor, and loading dock above.

(1) Vivarium
(2) AHU equipment room
(3) Boiler room
(4) Chiller room
(5) Electrical room

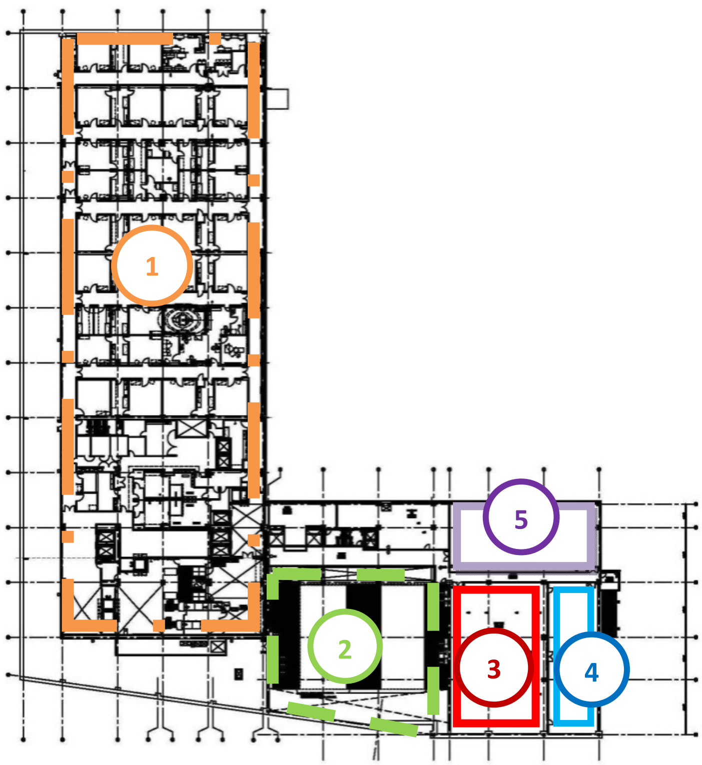

Figure 18: P1 Level C Plan

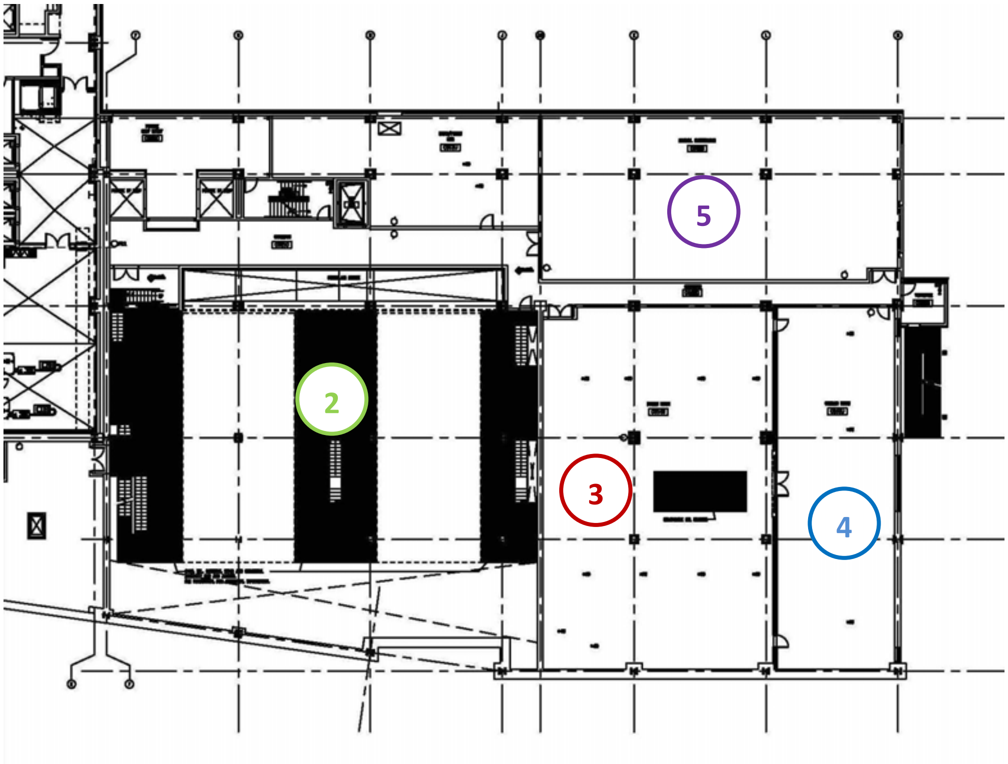

Figure 19: P1 CUP Plan

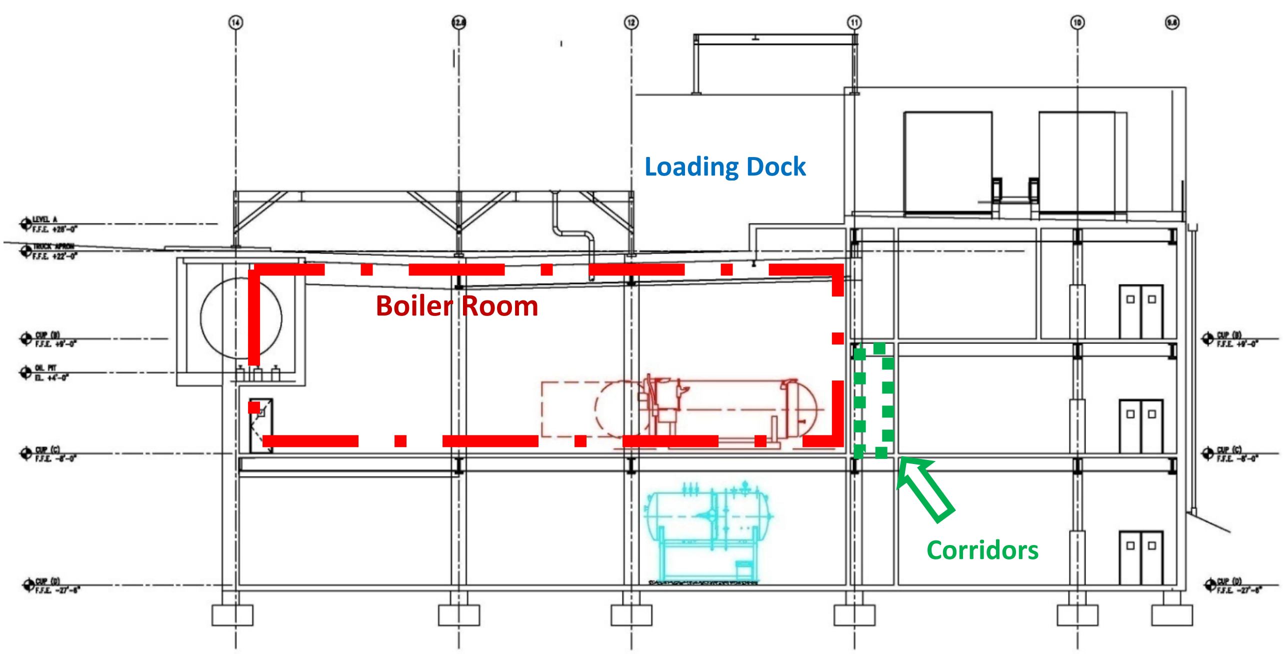

Figure 20: CUP Section Looking West

The AHU room is separated from the boiler room by an eighteen (18) inches thick concrete shear wall. Sound transmission through this wall would be minimal. The corridor is focus of the sound transmission analysis because it is connected to other spaces on the floor.

The corridor is separated from the boiler by an eight (8) inch concrete masonry unit (CMU) partition with a six (6) by seven (7) hollow core metal door. Three (3) equations are used to calculate sound transmission through the assembly:

Equation 1: $$TL_{ov} = 10\log\frac{\sum A}{\sum {A_i}^{-0.1TL_i}}$$

A_i = Area of an element
TL_i = Transmission loss of an element

Equation 2: $$NR = TL + 10log\frac{\sum A}{S}$$

A = Total absorption in the receiving room
S = Surface area of the barrier

Equation 3: $L_2 = L_1 - NR$

L_1 = Noise level of source
L_2 = Noise level of receiver room

Noise reduction (NR) of this partition assembly calculated to be 34 dBA, and the noise level in the corridor would be 47 dBA (*Appendix iv*). It would not be a source disturbance even if the corridor is connected to a laboratory space that has a recommended noise criteria (NC) level of 45 -55 (53 – 58 dBA).

Structural Assessment

To evaluate whether the alternate mechanical system can be support by the existing structural system of P1 CUP, a simple comparison method is used. The existing structural system is designed to support 800 bhp which weighs 75,150 lbm with water over a foot print of 110 square feet, or 685lbm/ft^2. The 3.5 MW generator has an approximate weight of 57,350 lbm over 256 square feet (225 lbm/ft^2). The generatorexert one third (1/3) the pressure of the 800 bhp boiler on the boiler room floor. Therefore, the existing floor system can support the alternate building system design.

Life Cycle Cost Analysis

Previous analysis has successfully proven cogeneration can save City Hospital 17 – 27 % in energy cost annually. Besides energy and energy cost saving, the alternate building system should have a reasonable payback period to justify its application. To analysis economic viability of the cogeneration, life cycle cost (LCC) analysis is performed for both existing and alternate system with two (2) equipment staging scenarios.

A period of twenty (20) years is chosen for LCC analysis since most boilers has an average lifetime of twenty (20) years. Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis-2007 is used to obtain "Fuel Escalation Rates" and "Real Discount Rate" of 3% for investments with 11 – 30 years period.

Other perimeters for LCC analysis included equipment capital cost, annual energy cost, and operating and maintenance (O&M) cost in 2007 dollars. Annual energy cost, operating and maintenance cost for the alternate system has taken into considerations that the CHP will be taking off-line between 4 - 5 days semiannually for maintenance, and overhaul every 30,000 – 50,000 hours suggested by James Knight, Associate Director for Utilities and Co-generation at Bucknell University.

Item	Installed Cost	O&M Cost
800 bhp Boiler	$ 379,907	$ 3,559
2000 bhp Boiler	$ 1,122,116	$ 9,095
1.2 MW CHP	$ 2,067,032	$ 94,044
3.5 MW CHP	$ 4,245,927	$ 209,431

Another perimeter that is taken into consideration for LCC analysis is the effect of utility deregulation. Deregulation of electric utility should foster competition in the provision of electricity. However, Baltimore, Maryland where deregulation has already occurred, consumer experience a dramatic 75% increase in electricity costs, contrary to the intentions of deregulation. With Pennsylvania' electric utilities fully deregulated by December 30, 2010, how electric rate change remained uncertain. As a result, four (4) LCC scenarios will be analysis for P 1&2, West Tower, and the completed campus.

(1) Normal Fuel Price escalation
(2) 75% increase in electricity cost by 2011, natural gas cost remain normal
(3) 15% increase in electricity cost by 2011, natural gas cost remain normal
(4) 15% increase in natural gas cost by 2009, electricity cost remain normal

Scenario 1_Annual Saving and Payback Period for 20 Year LCC (2007 Dollars)						
Construction Milestones	Phase 1 & 2		West Tower		Completed Campus	
	Energy Cost Savings	Discounted Payback Period	Energy Cost Savings	Discounted Payback Period	Energy Cost Savings	Discounted Payback Period
Scenarios	($ mil)	(Yr)	($ mil)	(Yr)	($ mil)	(Yr)
Normal Fuel Escalation	0.01	**155.1**	1.20	0.8	2.86	1.6
75% Increase in Elec. (2011)	0.34	6.1	2.35	0.4	5.42	0.8
15% Increase in Elec. (2011)	0.09	23.1	1.46	0.6	4.16	1.1
15% Increase in NG (2009)	(0.04)	**(56.3)**	1.12	0.8	2.32	2.0

Scenario 3_Annual Saving and Payback Period for 20 Year LCC (2007 Dollars)						
Construction Milestones	Phase 1 & 2		West Tower		Completed Campus	
	Energy Cost Savings	Discounted Payback Period	Energy Cost Savings	Discounted Payback Period	Energy Cost Savings	Discounted Payback Period
Scenarios	($ mil)	(Yr)	($ mil)	(Yr)	($ mil)	(Yr)
Normal Fuel Escalation	-	-	1.68	1.9	3.42	1.3
75% Increase in Elec. (2011)	-	-	3.38	0.9	6.80	0.7
15% Increase in Elec. (2011)	-	-	2.07	1.5	4.20	1.1
15% Increase in NG (2009)	-	-	1.56	2.0	3.18	1.4

The 20 Year LCC for the alternate system has shown that equipment staging Scenario 2 is superior to Scenario 1. Scenario 1 would have too long of a payback period to be economic viable for many owners. The alternate system may cost more if price of natural gas is higher than normal prediction. Other than minimized capital cost and “lost rentable space”, equipment staging Scenario 2 has larger annual saving and shorter payback period than Scenario 1 in all fuel price escalation scenarios (*Appendix vii – xix*).

Conclusions

Economic

At first glance, City Hospital campus is a great candidate for CHP application. It has a central heating and cooling system, and there is a need for process heat. On top of that, the “spark spread” is much higher than the minimum recommended. As a matter of fact, cogeneration with base demand to reduce electric usage from local grid has a decent annual energy cost saving. However, after a closer examination with life cycle cost analysis which included discount rate, operating and maintenance cost, and a large capital cost for the system, the alternate design has a payback period that is too long to be economic feasible for City Hospital P 1&2 with a 1.2 MW turbine generator CHP. Equipment staging Scenario 2 has shown that CHP has a reasonable payback period if it is installed when West tower is completed.

Environment

Other than concrete costs from LCC analysis, CHP for large development such as City Hospital campus has proven its environmental benefit to be phenomenal and should not be ignored. Compared the existing building system design, CHP can reduces 54% – 82% of carbon dioxide, nitrous oxide, and sulfur dioxide emissions. According to Forbes magazine, people are increasingly invested in companies that have shown social responsibility as consciousness of the environment takes hold. By reducing energy consumption and emissions, City Hospital can establish more than just a health care provider and advance medical research, but a leader in social responsibility. Such marketing strategy is extremely invaluable. In addition, if “Emission Capped and Trade” falls in place, CHP can become an additional source of cost saving.

Recommendations

City Hospital campus development plan spans three (3) decades, it is recommended to install CHP with larger capacity at a later construction phase. It will allow MEP engineers to usage actual electricity and steam usage from occupied laboratory and office spaces whether than depend on estimated energy model to design CHP for City Hospital. Effect of the fully deregulated utility should be more apparent and easier for owner and designers to make decision.

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Appendix

Electric Tariff (HT Rate)				
MONTHLY SERVICE	$			291.43
	$/kW	First 150 hr	Next 150 hr	Additional
		¢/kWh		
DISTRIBUTION SERVICE	$ 1.68	$ 0.0091	$ 0.0054	$ 0.0018
COMPETITIVE TRANSITION	$ 4.68	$ 0.0251	$ 0.0149	$ 0.0048
ENERGY & CAPACITY	$ 7.16	$ 0.0549	$ 0.0391	$ 0.0237
	$ 13.52	$ 0.0891	$ 0.0594	$ 0.0303
(Jun ~ Sep) On-Peak		$ 0.0949	$ 0.0652	$ 0.0361
(Oct ~ May) On-Peak		$ 0.0913	$ 0.0616	$ 0.0325
Off-Peak		$ 0.0870	$ 0.0573	$ 0.0282

Existing System Annual Electricity Cost

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total / Max			
Demand (On)	3,395	3,402	3,650	3,718	4,253	4,477	4,804	4,502	4,345	3,887	3,776	3,459	4,804	kW		
Demand (Off)	3,271	3,270	3,319	3,379	3,906	4,079	4,429	4,181	4,168	3,430	3,297	3,274	4,429	kW		
Consumption	1,646,806	1,491,331	1,751,842	1,759,718	2,275,200	2,380,283	2,586,079	2,490,348	2,236,568	1,864,235	1,729,381	1,655,306	23,867,097	kWh		
Cons. (On-Peak)	874,932	791,999	1,004,531	927,943	1,233,650	1,304,325	1,258,740	1,369,759	1,130,798	1,040,415	950,845	836,454	12,724,391	kWh		
Cons. (Off-Peak)	771,874	699,332	747,311	831,775	1,041,550	1,075,958	1,327,339	1,120,589	1,105,770	823,820	778,536	818,852	11,142,706	kWh		
													Ratchet Chg			
Demand Charge	$ 45,900	$ 45,995	$ 49,348	$ 50,267	$ 57,501	$ 60,529	$ 64,950	$ 60,867	$ 58,744	$ 52,552	$ 51,052	$ 46,766	$ 64,950		$ 779,401	29.6%
First 150 Hr. (On)	$ 46,495	$ 25,719	$ 49,987	$ 50,918	$ 58,245	$ 63,730	$ 68,385	$ 64,086	$ 59,505	$ 53,232	$ 51,712	$ 47,371			$ 639,385	24.3%
Next 150 Hr.(On)	$ 22,526	$ 17,353	$ 33,726	$ 22,807	$ 36,695	$ 41,257	$ 35,087	$ 44,030	$ 31,234	$ 28,174	$ 23,682	$ 19,564			$ 356,134	13.5%
Additional kWh (On)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 692	$ -	$ -	$ -	$ -			$ 692	0.0%
First 150 Hr. (Off)	$ 42,687	$ 60,842	$ 43,313	$ 44,096	$ 50,973	$ 53,231	$ 57,798	$ 54,562	$ 54,392	$ 44,762	$ 43,026	$ 42,726			$ 592,408	22.5%
Next 150 Hr.(Off)	$ 16,114	$ 11,966	$ 14,294	$ 18,618	$ 26,109	$ 26,593	$ 37,989	$ 28,274	$ 27,537	$ 17,724	$ 16,272	$ 18,780			$ 260,271	9.9%
Additional kWh (Off)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -			$ -	0.0%
													Annual Total			
Monthly Total	$ 193,063	$ 181,121	$ 206,561	$ 201,681	$ 237,264	$ 250,053	$ 264,501	$ 256,885	$ 237,909	$ 209,133	$ 199,934	$ 193,683	$ 2,631,787			

Existing System Annual Natural Gas Cost

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
Consumption	148,990	141,844	91,914	51,366	59,172	111,877	193,951	135,189	83,851	52,262	67,590	110,939	1,248,945	therm
$/Mcf	$ 16.20	$ 15.45	$ 14.85	$ 14.12	$ 14.05	$ 13.57	$ 13.63	$ 13.52	$ 13.21	$ 12.25	$ 12.92	$ 13.01	$ 13.90	Yr 06
													Annual	
Mo. Total	$ 235,093	$ 213,463	$ 132,979	$ 70,697	$ 81,026	$ 147,901	$ 257,480	$ 178,045	$ 107,930	$ 62,413	$ 85,105	$ 140,612	$ 1,712,745	

All Electric Chiller Plant Annual Electricity Cost

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total / Max			
Demand (On)	3,395	3,402	3,650	3,718	4,735	5,194	5,788	5,238	4,856	3,887	3,776	3,459	5,788	kW		
Demand (Off)	3,271	3,270	3,319	3,379	3,906	4,512	5,153	4,700	4,186	3,430	3,297	3,274	5,153	kW		
Consumption	1,646,806	1,491,331	1,751,842	1,759,718	2,328,662	2,627,657	3,107,930	2,795,619	2,367,442	1,864,235	1,729,381	1,655,306	25,125,929	kWh		
Cons. (On-Peak)	874,932	791,999	1,004,531	927,943	1,283,118	1,478,388	1,507,720	1,590,386	1,227,943	1,040,415	950,845	836,454	13,514,674	kWh		
Cons. (Off-Peak)	771,874	699,332	747,311	831,775	1,045,544	1,149,269	1,600,210	1,205,233	1,139,499	823,820	778,536	818,852	11,611,255	kWh		
													Ratchet Chg			
Demand Charge	$ 45,900	$ 45,995	$ 49,348	$ 50,267	$ 64,017	$ 70,223	$ 78,254	$ 70,818	$ 65,653	$ 52,552	$ 51,052	$ 46,766	$ 78,254		$ 939,045	32.5%
First 150 Hr. (On)	$ 46,495	$ 25,719	$ 49,987	$ 50,918	$ 64,846	$ 73,937	$ 82,392	$ 74,563	$ 66,503	$ 53,232	$ 51,712	$ 47,371			$ 687,675	23.8%
Next 150 Hr.(On)	$ 22,526	$ 17,353	$ 33,726	$ 22,807	$ 35,289	$ 45,594	$ 41,697	$ 51,228	$ 32,570	$ 28,174	$ 23,682	$ 19,564			$ 374,208	12.9%
Additional kWh (On)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 685	$ -	$ -	$ -	$ -			$ 685	0.0%
First 150 Hr. (Off)	$ 42,687	$ 60,842	$ 43,313	$ 44,096	$ 50,973	$ 58,882	$ 67,247	$ 61,335	$ 54,627	$ 44,762	$ 43,026	$ 42,726			$ 614,514	21.2%
Next 150 Hr.(Off)	$ 16,114	$ 11,966	$ 14,294	$ 18,618	$ 26,338	$ 27,072	$ 47,402	$ 28,663	$ 29,315	$ 17,724	$ 16,272	$ 18,780			$ 272,559	9.4%
Additional kWh (Off)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -			$ -	0.0%
													Annual Total			
Monthly Total	$ 206,366	$ 194,425	$ 219,865	$ 214,984	$ 255,991	$ 284,029	$ 317,283	$ 295,020	$ 261,560	$ 222,437	$ 213,238	$ 206,986	$ 2,892,184			

All Electric Chiller Plant Annual Natural Gas Cost

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
Consumption	148,990	141,844	91,914	51,366	41,259	31,871	29,031	36,921	40,547	52,262	67,590	110,939	844,534	therm
$/Mcf	$ 16.20	$ 15.45	$ 14.85	$ 14.12	$ 14.05	$ 13.57	$ 13.63	$ 13.52	$ 13.21	$ 12.25	$ 12.92	$ 13.01	$ 13.90	Yr 06
													Annual	
Mo. Total	$ 235,093	$ 213,463	$ 132,979	$ 70,697	$ 56,520	$ 42,187	$ 38,604	$ 48,680	$ 52,229	$ 62,413	$ 85,105	$ 140,612	$ 1,178,582	

CHP Annual Electricity Cost (w/ PECO Rate)																
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total / Max			
Demand (On)	2,185	2,192	2,440	2,508	3,043	3,267	3,594	3,292	3,135	2,677	2,566	2,249	3,594	kW		
Demand (Off)	2,061	2,060	2,109	2,169	2,696	2,869	3,219	2,971	2,958	2,220	2,087	2,064	3,219	kW		
Consumption	787,706	632,231	892,742	900,618	1,416,100	1,521,183	1,726,979	1,631,248	1,377,468	1,005,135	870,281	796,206	13,557,897	kWh		
Cons. (On-Peak)	445,382	362,449	574,981	498,393	804,100	874,775	829,190	940,209	701,248	610,865	521,295	406,904	7,569,791	kWh		
Cons. (Off-Peak)	342,324	269,782	317,761	402,225	612,000	646,408	897,789	691,039	676,220	394,270	348,986	389,302	5,988,106	kWh		
													Ratchet Chg			
Demand Charge	$ 36,577	$ 36,694	$ 40,846	$ 41,984	$ 50,940	$ 54,690	$ 60,164	$ 55,108	$ 52,480	$ 44,813	$ 42,955	$ 37,648	$ 60,164		$ 721,963	40.0%
First 150 Hr. (On)	$ 29,924	$ 3,072	$ 33,416	$ 34,347	$ 41,674	$ 46,506	$ 51,161	$ 46,862	$ 42,934	$ 36,662	$ 35,141	$ 30,800			$ 432,497	24.0%
Next 150 Hr.(On)	$ 7,246	$ 2,073	$ 22,546	$ 7,527	$ 21,415	$ 25,084	$ 18,914	$ 29,106	$ 15,061	$ 12,894	$ 8,402	$ 4,285			$ 174,552	9.7%
Additional kWh (On)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -			$ -	0.0%
First 150 Hr. (Off)	$ 26,896	$ 23,471	$ 27,522	$ 28,305	$ 35,183	$ 37,440	$ 42,008	$ 38,772	$ 38,602	$ 28,971	$ 27,235	$ 26,935			$ 381,341	21.1%
Next 150 Hr.(Off)	$ 1,901	$ -	$ 81	$ 4,405	$ 11,895	$ 12,380	$ 23,776	$ 14,061	$ 13,323	$ 3,511	$ 2,059	$ 4,567			$ 91,959	5.1%
Additional kWh (Off)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -			$ -	0.0%
													Annual Total			
Monthly Total	$ 126,422	$ 89,071	$ 144,020	$ 135,040	$ 170,622	$ 181,865	$ 196,313	$ 189,255	$ 170,375	$ 142,492	$ 133,293	$ 127,042	$ 1,805,810			

CHP Annual Electricity Cost (w/ Bucknell Rate)																
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total / Max**			
Demand (On)	2,185	2,192	2,440	2,508	3,043	3,267	3,594	3,292	3,135	2,677	2,566	2,249	3,594	kW		
Demand (Off)	2,061	2,060	2,109	2,169	2,696	2,869	3,219	2,971	2,958	2,220	2,087	2,064	3,219	kW		
Consumption	787,706	632,231	892,742	900,618	1,416,100	1,521,183	1,726,979	1,631,248	1,377,468	1,005,135	870,281	796,206	13,557,897	kWh		
Cons. (On-Peak)	445,382	362,449	574,981	498,393	804,100	874,775	829,190	940,209	701,248	610,865	521,295	406,904	7,569,791	kWh		
Cons. (Off-Peak)	342,324	269,782	317,761	402,225	612,000	646,408	897,789	691,039	676,220	394,270	348,986	389,302	5,988,106	kWh		
													Ratchet Chg			
Demand Charge	$ 29,541	$ 29,636	$ 32,989	$ 33,908	$ 41,141	$ 44,170	$ 48,591	$ 44,508	$ 42,385	$ 36,193	$ 34,692	$ 30,406	$ 48,591		$ 583,091	32.0%
First 150 Hr. (On)	$ 29,924	$ 3,072	$ 33,416	$ 34,347	$ 41,674	$ 46,506	$ 51,161	$ 46,862	$ 42,934	$ 36,662	$ 35,141	$ 30,800			$ 432,497	23.7%
Next 150 Hr.(On)	$ 7,246	$ 2,073	$ 22,546	$ 7,527	$ 21,415	$ 25,084	$ 18,914	$ 32,196	$ 15,061	$ 12,894	$ 8,402	$ 4,285			$ 177,642	9.7%
Additional kWh (On)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ (1,711)	$ -	$ -	$ -	$ -			$ -	0.0%
First 150 Hr. (Off)	$ 26,896	$ 23,471	$ 27,522	$ 28,305	$ 35,183	$ 37,440	$ 42,008	$ 38,772	$ 38,602	$ 28,971	$ 27,235	$ 26,935			$ 381,341	20.9%
Next 150 Hr.(Off)	$ 1,901	$ (2,247)	$ 81	$ 4,405	$ 11,895	$ 12,380	$ 23,776	$ 14,061	$ 13,323	$ 3,511	$ 2,059	$ 4,567			$ 89,712	4.9%
Additional kWh (Off)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -			$ -	0.0%
													Annual Total			
Monthly Total	$ 127,936	$ 88,338	$ 145,534	$ 136,554	$ 172,137	$ 183,380	$ 197,828	$ 193,859	$ 171,890	$ 144,007	$ 134,807	$ 128,556	$ 1,824,828			

CHP Annual Natural Gas Cost														
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
Consumption	175,533	168,387	118,457	111,743	111,743	138,420	220,494	161,732	111,743	111,743	111,743	137,482	1,679,220	therm
$/Mcf	$ 16.20	$ 15.45	$ 14.85	$ 14.12	$ 14.05	$ 13.57	$ 13.63	$ 13.52	$ 13.21	$ 12.25	$ 12.92	$ 13.01	$ 13.90	Yr 06
													Annual	
Mo. Total	$ 276,962	$ 253,393	$ 171,359	$ 153,708	$ 152,946	$ 182,973	$ 292,707	$ 212,988	$ 143,807	$ 133,361	$ 140,651	$ 174,237	$ 2,289,093	

Transmission Lost Calculation									
	Hz	125	250	500	1000	2000	4000		Area
1-3/4" Steel Door	TL	23	28	36	41	39	44		42
8" CMU (painted)	TL	38	38	45	50	52	55		991
Composite Wall	TL_{ov}	32	dBA						1033

Noise Reduction Calculation									
	Hz	125	250	500	1000	2000	4000		Area
8" CMU (painted)	α	0.1	0.05	0.06	0.07	0.09	0.08		954
	A	95	48	57	67	86	76		429
8" Conc. Floor Slab	α	0.01	0.01	0.01	0.02	0.02	0.02		681
	A	7	7	7	14	14	14		61
Openings	α	1.0	1.0	1.0	1.0	1.0	1.0		180
	A	180	180	180	180	180	180		1078
Composite Wall	NR	34	dBA						1569
L2		47	dBA						

Energy Usage & Cost Estimate

		P1&2		West Tower			Completed Campus		
			1.2MW		2.4 MW	3.5 MW		5.9 MW	7.5 MW
Jun-Sep	Demand (On)	4,533	3,323	12,412	9,992	8,897	21,586	15,651	14,556
Oct-May	Demand (On)	3,696	2,486	10,121	7,701	6,606	17,601	11,666	10,571
	Demand (Off)	3,668	2,458	10,043	7,623	6,528	17,465	11,530	10,435
Jun-Sep	Cons. (On)	1,266,177	407,077	3,466,913	1,748,713	971,263	6,029,413	1,815,563	1,038,113
Oct-May	Cons. (On)	954,796	95,696	2,614,322	896,122	118,672	4,546,647	332,797	-
	Cons. (Off)	1,328,682	469,582	3,638,057	1,919,857	1,142,407	6,327,056	2,113,206	1,335,756
	Cons. (kWh)	28,647,254	8,028,854	78,438,910	37,202,110	18,543,310	136,415,495	35,283,095	20,181,523
	Service $	$ 3,497	$ 3,497	$ 3,497	$ 3,497	$ 3,497	$ 3,497	$ 3,497	$ 3,497
	Demand $	$ 735,429	$ 667,518	$ 2,013,675	$ 2,007,134	$ 1,787,171	$ 3,502,044	$ 3,143,888	$ 2,923,924
Jun-Sep	Cons. (On) 150hr $	$ 258,107	$ 154,526	$ 706,723	$ 568,928	$ 368,691	$ 1,229,083	$ 689,188	$ 394,068
	Cons. (On) 300hr $	$ 152,889	$ -	$ 418,625	$ 65,189	$ -	$ 728,043	$ -	$ -
	Cons. (On) add. $	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Oct-May	Cons. (On) 150hr $	$ 404,962	$ 36,326	$ 1,108,825	$ 340,168	$ 45,048	$ 1,928,391	$ 126,330	$ -
	Cons. (On) 300hr $	$ 197,296	$ -	$ 540,215	$ -	$ -	$ 939,504	$ -	$ -
	Cons. (On) add. $	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Cons. (Off) 150 $	$ 574,362	$ 384,876	$ 1,572,658	$ 1,193,686	$ 1,022,209	$ 2,735,058	$ 1,805,637	$ 1,394,529
	Cons. (Off) 300 $	$ 378,287	$ 69,397	$ 1,035,785	$ 533,907	$ 112,271	$ 1,801,366	$ 263,810	$ -
	Cons. (Off) add. $	$ 77,281	$ -	$ 211,602	$ -	$ -	$ 368,003	$ -	$ -
	Total $	$ 2,782,111	$ 1,316,141	$ 7,611,606	$ 4,712,509	$ 3,338,887	$ 13,234,990	$ 6,032,350	$ 4,716,019
	$/kWh	$ 0.10	$ 0.16	$ 0.10	$ 0.13	$ 0.18	$ 0.10	$ 0.17	$ 0.23
	$Elec./SF	$ 6.62	$ 3.13		$ 4.10	$ 2.90		$ 3.02	$ 2.36
lbm/hr	CHP		781.4		1562.8	2000.0		3562.8	4000.0
therm			1,340,916		2,681,831	3,432,085		6,113,916	6,864,170
MMBtu	HRSG		81,792		163,584	195,108		358,692	390,216
therm			1,022,400		2,044,800	2,438,850		4,483,650	4,877,700
therm	NG	1,249,213	1,567,728	3,420,463	4,057,494	4,413,698	5,948,632	7,578,898	7,935,101
	therm/SF	2.97	3.73		3.53	3.84		3.79	3.97
	Service $	$ 900	$ 900	$ 900	$ 900	$ 900	$ 900	$ 900	$ 900
	Cons $	$ 1,699,829	$ 2,133,010	$ 4,652,730	$ 5,519,092	$ 6,003,529	$ 8,091,039	$ 10,308,201	$ 10,792,638
	$therm/SF	$ 4.05	$ 5.08		$ 4.80	$ 5.22		$ 5.15	$ 5.40

Emissions Estimate									
		P 1&2		West Tower			Completed Campus		
Elec.	CO_2	34,835,061	9,763,086	95,381,714	45,237,765	22,548,665	165,881,242	42,904,244	24,540,732
Boiler		14,990,552,261	2,721,752,261	41,045,559,763	16,507,959,763	11,779,359,763	71,383,582,196	17,579,782,196	12,851,182,196
CHP		-	18,309,480	-	36,616,186	93,720,000	-	83,476,186	93,720,000
Total		7,512,694	1,374,912	20,570,471	8,294,907	5,947,814	35,774,732	8,853,081	6,484,721
Elec.	No_x	54,143	15,175	148,250	70,312	35,047	257,825	66,685	38,143
Boiler		6,246,063	1,134,063	17,102,317	6,878,317	4,908,067	29,743,159	7,324,909	5,354,659
CHP		-	11,715	-	23,184	67,250	-	56,809	67,250
Total		3,150	580	8,625	3,486	2,505	15,000	3,724	2,730
Elec.	SO_2	269,370	75,495	737,561	349,811	174,363	1,282,715	331,767	189,767
Boiler		74,953	13,609	205,228	82,540	58,897	356,918	87,899	64,256
CHP		-	0	-	0	1	-	1	1
Total		172	45	471	216	117	820	210	127

P 1&2 LCC w/ Normal Fuel Escalation

		Existing Design LCC					Alternate Design LCC w/ Scenario 1				
Capital Cost		$ 759,814					$ 2,826,847				
Ann. Elec. Cost		$ 2,631,787					$ 1,805,810				
Ann. NG Cost		$ 1,712,745					$ 2,289,093				
Real Discount rate		3%					3%				
		O&M	Natural Gas		Electricity		O&M	Natural Gas		Electricity	
Date	Year	Boiler	UPV	Cost	UPV	Cost	Boiler & CHP	UPV	Cost	UPV	Cost
2008	1	$3,559	0.96	$1,644,235	0.97	$2,552,834	$97,603	0.96	$2,197,529	0.97	$1,751,635
2009	2	$3,559	0.92	$1,575,725	0.94	$2,473,880	$97,603	0.92	$2,105,965	0.94	$1,697,461
2010	3	$3,559	0.89	$1,524,343	0.90	$2,368,608	$97,603	0.89	$2,037,293	0.90	$1,625,229
2011	4	$3,559	0.85	$1,455,833	0.87	$2,289,655	$97,603	0.85	$1,945,729	0.87	$1,571,054
2012	5	$3,559	0.83	$1,421,578	0.86	$2,263,337	$97,603	0.83	$1,899,947	0.86	$1,552,996
2013	6	$3,559	0.81	$1,387,323	0.87	$2,289,655	$97,603	0.81	$1,854,165	0.87	$1,571,054
2014	7	$3,559	0.80	$1,370,196	0.86	$2,263,337	$97,603	0.80	$1,831,274	0.86	$1,552,996
2015	8	$3,559	0.80	$1,370,196	0.87	$2,289,655	$97,603	0.80	$1,831,274	0.87	$1,571,054
2016	9	$3,559	0.80	$1,370,196	0.87	$2,289,655	$97,603	0.80	$1,831,274	0.87	$1,571,054
2017	10	$3,559	0.82	$1,404,451	0.87	$2,289,655	$97,603	0.82	$1,877,056	0.87	$1,571,054
2018	11	$3,559	0.82	$1,404,451	0.89	$2,342,291	$97,603	0.82	$1,877,056	0.89	$1,607,170
2019	12	$3,559	0.81	$1,387,323	0.89	$2,342,291	$97,603	0.81	$1,854,165	0.89	$1,607,170
2020	13	$3,559	0.82	$1,404,451	0.89	$2,342,291	$97,603	0.82	$1,877,056	0.89	$1,607,170
2021	14	$3,559	0.81	$1,387,323	0.89	$2,342,291	$97,603	0.81	$1,854,165	0.89	$1,607,170
2022	15	$3,559	0.82	$1,404,451	0.89	$2,342,291	$97,603	0.82	$1,877,056	0.89	$1,607,170
2023	16	$3,559	0.83	$1,421,578	0.89	$2,342,291	$97,603	0.83	$1,899,947	0.89	$1,607,170
2024	17	$3,559	0.84	$1,438,705	0.89	$2,342,291	$97,603	0.84	$1,922,838	0.89	$1,607,170
2025	18	$3,559	0.84	$1,438,705	0.90	$2,368,608	$97,603	0.84	$1,922,838	0.90	$1,625,229
2026	19	$3,559	0.84	$1,438,705	0.89	$2,342,291	$97,603	0.84	$1,922,838	0.89	$1,607,170
2027	20	$3,559	0.84	$1,438,705	0.89	$2,342,291	$97,603	0.84	$1,922,838	0.89	$1,607,170
Column NPV		$52,950		$21,430,259		$34,871,151	$1,452,082		$28,641,663		$23,926,956
Total NPV						$57,114,175					$56,847,547
Total Saving (20 yr)							$ 266,627				
Saving / yr							$ 13,331				
							yr.	mo.			
Payback Period (yr)							155	-			

P 1&2 LCC w/ 75% increase in elec. cost by 2011												
		Existing Design						Alternate Design LCC w/ Scenario 1				
Capital Cost		$ 759,814						$ 2,826,847				
Ann. Elec. Cost		$ 2,631,787						$ 1,805,810				
Ann. NG Cost		$ 1,712,745						$ 2,289,093				
Real Discount rate		3%						3%				
		O&M	Natural Gas		Electricity			O&M	Natural Gas		Electricity	
Date	Year	Boiler	Esc.	Cost	Esc.	Cost		Boiler & CHP	Esc.	Cost	Esc.	Cost
2008	1	$3,559	0.96	$1,644,235	0.97	$2,552,834		$97,603	0.96	$2,197,529	0.97	$1,751,635
2009	2	$3,559	0.92	$1,575,725	0.94	$2,473,880		$97,603	0.92	$2,105,965	0.94	$1,697,461
2010	3	$3,559	0.89	$1,524,343	0.90	$2,368,608		$97,603	0.89	$2,037,293	0.90	$1,625,229
2011	4	$3,559	0.85	$1,455,833	1.52	$4,006,896		$97,603	0.85	$1,945,729	1.52	$2,749,345
2012	5	$3,559	0.83	$1,421,578	1.51	$3,960,840		$97,603	0.83	$1,899,947	1.51	$2,717,743
2013	6	$3,559	0.81	$1,387,323	1.52	$4,006,896		$97,603	0.81	$1,854,165	1.52	$2,749,345
2014	7	$3,559	0.80	$1,370,196	1.51	$3,960,840		$97,603	0.80	$1,831,274	1.51	$2,717,743
2015	8	$3,559	0.80	$1,370,196	1.52	$4,006,896		$97,603	0.80	$1,831,274	1.52	$2,749,345
2016	9	$3,559	0.80	$1,370,196	1.52	$4,006,896		$97,603	0.80	$1,831,274	1.52	$2,749,345
2017	10	$3,559	0.82	$1,404,451	1.52	$4,006,896		$97,603	0.82	$1,877,056	1.52	$2,749,345
2018	11	$3,559	0.82	$1,404,451	1.56	$4,099,009		$97,603	0.82	$1,877,056	1.56	$2,812,548
2019	12	$3,559	0.81	$1,387,323	1.56	$4,099,009		$97,603	0.81	$1,854,165	1.56	$2,812,548
2020	13	$3,559	0.82	$1,404,451	1.56	$4,099,009		$97,603	0.82	$1,877,056	1.56	$2,812,548
2021	14	$3,559	0.81	$1,387,323	1.56	$4,099,009		$97,603	0.81	$1,854,165	1.56	$2,812,548
2022	15	$3,559	0.82	$1,404,451	1.56	$4,099,009		$97,603	0.82	$1,877,056	1.56	$2,812,548
2023	16	$3,559	0.83	$1,421,578	1.56	$4,099,009		$97,603	0.83	$1,899,947	1.56	$2,812,548
2024	17	$3,559	0.84	$1,438,705	1.56	$4,099,009		$97,603	0.84	$1,922,838	1.56	$2,812,548
2025	18	$3,559	0.84	$1,438,705	1.58	$4,145,065		$97,603	0.84	$1,922,838	1.58	$2,844,150
2026	19	$3,559	0.84	$1,438,705	1.56	$4,099,009		$97,603	0.84	$1,922,838	1.56	$2,812,548
2027	20	$3,559	0.84	$1,438,705	1.56	$4,099,009		$97,603	0.84	$1,922,838	1.56	$2,812,548
Column NPV		$52,950		$21,430,259		$55,791,043		$1,452,082		$28,641,663		$38,281,210
Total NPV						$78,034,067						$71,201,801
Total Saving (30 yr)								$ 6,832,266				
Saving / yr								$ 341,613				
								yr.	mo.			
Payback Period (yr)								6	-			

P 1&2 LCC w/ 15% increase in elec. cost by 2011												
		Existing Design LCC						Alternate Design LCC w/ Scenario 1				
Capital Cost		$ 759,814						$ 2,826,847				
Ann. Elec. Cost		$ 2,631,787						$ 1,805,810				
Ann. NG Cost		$ 1,712,745						$ 2,289,093				
Real Discount rate		3%						3%				
		O&M	Natural Gas		Electricity			O&M	Natural Gas		Electricity	
Date	Year	Boiler	Esc.	Cost	Esc.	Cost		Boiler & CHP	Esc.	Cost	Esc.	Cost
2008	1	$3,559	0.96	$1,644,235	0.97	$2,552,834		$97,603	0.96	$2,197,529	0.97	$1,751,635
2009	2	$3,559	0.92	$1,575,725	1.08	$2,844,962		$97,603	0.92	$2,105,965	1.08	$1,952,080
2010	3	$3,559	0.89	$1,524,343	1.04	$2,723,900		$97,603	0.89	$2,037,293	1.04	$1,869,013
2011	4	$3,559	0.85	$1,455,833	1.00	$2,633,103		$97,603	0.85	$1,945,729	1.00	$1,806,712
2012	5	$3,559	0.83	$1,421,578	0.99	$2,602,838		$97,603	0.83	$1,899,947	0.99	$1,785,946
2013	6	$3,559	0.81	$1,387,323	1.00	$2,633,103		$97,603	0.81	$1,854,165	1.00	$1,806,712
2014	7	$3,559	0.80	$1,370,196	0.99	$2,602,838		$97,603	0.80	$1,831,274	0.99	$1,785,946
2015	8	$3,559	0.80	$1,370,196	1.00	$2,633,103		$97,603	0.80	$1,831,274	1.00	$1,806,712
2016	9	$3,559	0.80	$1,370,196	1.00	$2,633,103		$97,603	0.80	$1,831,274	1.00	$1,806,712
2017	10	$3,559	0.82	$1,404,451	1.00	$2,633,103		$97,603	0.82	$1,877,056	1.00	$1,806,712
2018	11	$3,559	0.82	$1,404,451	1.02	$2,693,634		$97,603	0.82	$1,877,056	1.02	$1,848,246
2019	12	$3,559	0.81	$1,387,323	1.02	$2,693,634		$97,603	0.81	$1,854,165	1.02	$1,848,246
2020	13	$3,559	0.82	$1,404,451	1.02	$2,693,634		$97,603	0.82	$1,877,056	1.02	$1,848,246
2021	14	$3,559	0.81	$1,387,323	1.02	$2,693,634		$97,603	0.81	$1,854,165	1.02	$1,848,246
2022	15	$3,559	0.82	$1,404,451	1.02	$2,693,634		$97,603	0.82	$1,877,056	1.02	$1,848,246
2023	16	$3,559	0.83	$1,421,578	1.02	$2,693,634		$97,603	0.83	$1,899,947	1.02	$1,848,246
2024	17	$3,559	0.84	$1,438,705	1.02	$2,693,634		$97,603	0.84	$1,922,838	1.02	$1,848,246
2025	18	$3,559	0.84	$1,438,705	1.04	$2,723,900		$97,603	0.84	$1,922,838	1.04	$1,869,013
2026	19	$3,559	0.84	$1,438,705	1.02	$2,693,634		$97,603	0.84	$1,922,838	1.02	$1,848,246
2027	20	$3,559	0.84	$1,438,705	1.02	$2,693,634		$97,603	0.84	$1,922,838	1.02	$1,848,246
Column NPV		$52,950		$21,430,259		$39,730,052		$1,452,082		$28,641,663		$27,260,907
Total NPV						$61,973,075						$60,181,498
Total Saving (30 yr)								$ 1,791,577				
Saving / yr								$ 89,579				
								yr.	mo.			
Payback Period (yr)								23	-			

P 1&2 LCC w/ 15% increase in NG cost by 2009

		Existing Design LCC						Alternate Design LCC w/ Scenario 1				
Capital Cost		$ 759,814						$ 2,826,847				
Ann. Elec. Cost		$ 2,631,787						$ 1,805,810				
Ann. NG Cost		$ 1,712,745						$ 2,289,093				
Real Discount rate		3%						3%				
		O&M	Natural Gas		Electricity			O&M	Natural Gas		Electricity	
Date	Year	Boiler	Esc.	Cost	Esc.	Cost		Boiler & CHP	Esc.	Cost	Esc.	Cost
2008	1	$3,559	0.96	$1,644,235	0.97	$2,552,834		$97,603	0.96	$2,197,529	0.97	$1,751,635
2009	2	$3,559	1.06	$1,812,084	0.94	$2,473,880		$97,603	1.06	$2,421,860	0.94	$1,697,461
2010	3	$3,559	1.02	$1,752,994	0.90	$2,368,608		$97,603	1.02	$2,342,887	0.90	$1,625,229
2011	4	$3,559	0.98	$1,674,208	0.87	$2,289,655		$97,603	0.98	$2,237,588	0.87	$1,571,054
2012	5	$3,559	0.95	$1,634,815	0.86	$2,263,337		$97,603	0.95	$2,184,939	0.86	$1,552,996
2013	6	$3,559	0.93	$1,595,422	0.87	$2,289,655		$97,603	0.93	$2,132,290	0.87	$1,571,054
2014	7	$3,559	0.92	$1,575,725	0.86	$2,263,337		$97,603	0.92	$2,105,965	0.86	$1,552,996
2015	8	$3,559	0.92	$1,575,725	0.87	$2,289,655		$97,603	0.92	$2,105,965	0.87	$1,571,054
2016	9	$3,559	0.92	$1,575,725	0.87	$2,289,655		$97,603	0.92	$2,105,965	0.87	$1,571,054
2017	10	$3,559	0.94	$1,615,118	0.87	$2,289,655		$97,603	0.94	$2,158,615	0.87	$1,571,054
2018	11	$3,559	0.94	$1,615,118	0.89	$2,342,291		$97,603	0.94	$2,158,615	0.89	$1,607,170
2019	12	$3,559	0.93	$1,595,422	0.89	$2,342,291		$97,603	0.93	$2,132,290	0.89	$1,607,170
2020	13	$3,559	0.94	$1,615,118	0.89	$2,342,291		$97,603	0.94	$2,158,615	0.89	$1,607,170
2021	14	$3,559	0.93	$1,595,422	0.89	$2,342,291		$97,603	0.93	$2,132,290	0.89	$1,607,170
2022	15	$3,559	0.94	$1,615,118	0.89	$2,342,291		$97,603	0.94	$2,158,615	0.89	$1,607,170
2023	16	$3,559	0.95	$1,634,815	0.89	$2,342,291		$97,603	0.95	$2,184,939	0.89	$1,607,170
2024	17	$3,559	0.97	$1,654,511	0.89	$2,342,291		$97,603	0.97	$2,211,264	0.89	$1,607,170
2025	18	$3,559	0.97	$1,654,511	0.90	$2,368,608		$97,603	0.97	$2,211,264	0.90	$1,625,229
2026	19	$3,559	0.97	$1,654,511	0.89	$2,342,291		$97,603	0.97	$2,211,264	0.89	$1,607,170
2027	20	$3,559	0.97	$1,654,511	0.89	$2,342,291		$97,603	0.97	$2,211,264	0.89	$1,607,170
Column NPV		$52,950		$24,405,346		$34,871,151		$1,452,082		$32,617,884		$23,926,956
Total NPV						$60,089,262						$60,823,768
Total Saving (30 yr)								$ (734,507)				
Saving / yr								$ (36,725)				
								yr.	mo.			
Payback Period (yr)								(56)	(3)			

West Tower LCC w/ Normal Fuel Escalation

		Existing Design					Alternate Design LCC w/ Scenario 1					Alternate Design LCC w/ Scenario 2				
Capital Cost		$ 1,519,629					$ 2,446,940					$ 4,625,834				
Ann. Elec. Cost		$ 7,611,606					$ 4,712,509					$ 3,338,887				
Ann. NG Cost		$ 4,652,730					$ 5,519,092					$ 6,003,529				
Real Discount rate		3%					3%					3%				
		O&M	Natural Gas		Electricity		O&M	Natural Gas		Electricity		O&M	Natural Gas		Electricity	
Date	Year	Boiler	UPV	Cost	UPV	Cost	Boiler & CHP	UPV	Cost	UPV	Cost	Boiler & CHP	UPV	Cost	UPV	Cost
2008	1	$10,677	0.96	$4,466,621	0.97	$7,383,258	$195,205	0.96	$5,298,329	0.97	$4,571,134	$216,550	0.96	$5,763,388	0.97	$3,238,720
2009	2	$10,677	0.92	$4,280,512	0.94	$7,154,909	$195,205	0.92	$5,077,565	0.94	$4,429,759	$216,550	0.92	$5,523,247	0.94	$3,138,554
2010	3	$10,677	0.89	$4,140,930	0.90	$6,850,445	$195,205	0.89	$4,911,992	0.90	$4,241,258	$216,550	0.89	$5,343,141	0.90	$3,004,998
2011	4	$10,677	0.85	$3,954,821	0.87	$6,622,097	$195,205	0.85	$4,691,229	0.87	$4,099,883	$216,550	0.85	$5,103,000	0.87	$2,904,832
2012	5	$10,677	0.83	$3,861,766	0.86	$6,545,981	$195,205	0.83	$4,580,847	0.86	$4,052,758	$216,550	0.83	$4,982,929	0.86	$2,871,443
2013	6	$10,677	0.81	$3,768,711	0.87	$6,622,097	$195,205	0.81	$4,470,465	0.87	$4,099,883	$216,550	0.81	$4,862,859	0.87	$2,904,832
2014	7	$10,677	0.80	$3,722,184	0.86	$6,545,981	$195,205	0.80	$4,415,274	0.86	$4,052,758	$216,550	0.80	$4,802,824	0.86	$2,871,443
2015	8	$10,677	0.80	$3,722,184	0.87	$6,622,097	$195,205	0.80	$4,415,274	0.87	$4,099,883	$216,550	0.80	$4,802,824	0.87	$2,904,832
2016	9	$10,677	0.80	$3,722,184	0.87	$6,622,097	$195,205	0.80	$4,415,274	0.87	$4,099,883	$216,550	0.80	$4,802,824	0.87	$2,904,832
2017	10	$10,677	0.82	$3,815,239	0.87	$6,622,097	$195,205	0.82	$4,525,656	0.87	$4,099,883	$216,550	0.82	$4,922,894	0.87	$2,904,832
2018	11	$10,677	0.82	$3,815,239	0.89	$6,774,329	$195,205	0.82	$4,525,656	0.89	$4,194,133	$216,550	0.82	$4,922,894	0.89	$2,971,610
2019	12	$10,677	0.81	$3,768,711	0.89	$6,774,329	$195,205	0.81	$4,470,465	0.89	$4,194,133	$216,550	0.81	$4,862,859	0.89	$2,971,610
2020	13	$10,677	0.82	$3,815,239	0.89	$6,774,329	$195,205	0.82	$4,525,656	0.89	$4,194,133	$216,550	0.82	$4,922,894	0.89	$2,971,610
2021	14	$10,677	0.81	$3,768,711	0.89	$6,774,329	$195,205	0.81	$4,470,465	0.89	$4,194,133	$216,550	0.81	$4,862,859	0.89	$2,971,610
2022	15	$10,677	0.82	$3,815,239	0.89	$6,774,329	$195,205	0.82	$4,525,656	0.89	$4,194,133	$216,550	0.82	$4,922,894	0.89	$2,971,610
2023	16	$10,677	0.83	$3,861,766	0.89	$6,774,329	$195,205	0.83	$4,580,847	0.89	$4,194,133	$216,550	0.83	$4,982,929	0.89	$2,971,610
2024	17	$10,677	0.84	$3,908,293	0.89	$6,774,329	$195,205	0.84	$4,636,038	0.89	$4,194,133	$216,550	0.84	$5,042,965	0.89	$2,971,610
2025	18	$10,677	0.84	$3,908,293	0.90	$6,850,445	$195,205	0.84	$4,636,038	0.90	$4,241,258	$216,550	0.84	$5,042,965	0.90	$3,004,998
2026	19	$10,677	0.84	$3,908,293	0.89	$6,774,329	$195,205	0.84	$4,636,038	0.89	$4,194,133	$216,550	0.84	$5,042,965	0.89	$2,971,610
2027	20	$10,677	0.84	$3,908,293	0.89	$6,774,329	$195,205	0.84	$4,636,038	0.89	$4,194,133	$216,550	0.84	$5,042,965	0.89	$2,971,610
Column NPV		$158,851		$58,216,043		$100,853,691	$2,904,164		$69,056,169		$62,440,695	$3,221,711		$75,117,558		$44,240,217
Total NPV						$160,748,213					$136,847,967					$127,205,321
Total Saving (20 yr)							$ 23,900,245					$ 33,542,892				
Saving / yr							$ 1,195,012					$ 1,677,145				
							yr.	mo.				yr.	mo.			
Payback Period (yr)							-	9				1	10			

West Tower LCC w/ 75% increase in elec. cost by 2011

		Existing Design LCC					Alternate Design LCC w/ Scenario 1					Alternate Design LCC w/ Scenario 2				
Capital Cost		$ 1,519,629					$ 2,446,940					$ 4,625,834				
Ann. Elec. Cost		$ 7,611,606					$ 4,712,509					$ 3,338,887				
Ann. NG Cost		$ 4,652,730					$ 5,519,092					$ 6,003,529				
Real Discount rate		3%					3%					3%				
		O&M	Natural Gas		Electricity		O&M	Natural Gas		Electricity		O&M	Natural Gas		Electricity	
Date	Year	Boiler	Esc.	Cost	Esc.	Cost	Boiler & CHP	Esc.	Cost	Esc.	Cost	Boiler & CHP	Esc.	Cost	Esc.	Cost
2008	1	$10,677	0.96	$4,466,621	0.97	$7,383,258	$195,205	0.96	$5,298,329	0.97	$4,571,134	$216,550	0.96	$5,763,388	0.97	$3,238,720
2009	2	$10,677	0.92	$4,280,512	0.94	$7,154,909	$195,205	0.92	$5,077,565	0.94	$4,429,759	$216,550	0.92	$5,523,247	0.94	$3,138,554
2010	3	$10,677	0.89	$4,140,930	0.90	$6,850,445	$195,205	0.89	$4,911,992	0.90	$4,241,258	$216,550	0.89	$5,343,141	0.90	$3,004,998
2011	4	$10,677	0.85	$3,954,821	1.52	$11,588,670	$195,205	0.85	$4,691,229	1.52	$7,174,795	$216,550	0.85	$5,103,000	1.52	$5,083,456
2012	5	$10,677	0.83	$3,861,766	1.51	$11,455,467	$195,205	0.83	$4,580,847	1.51	$7,092,326	$216,550	0.83	$4,982,929	1.51	$5,025,025
2013	6	$10,677	0.81	$3,768,711	1.52	$11,588,670	$195,205	0.81	$4,470,465	1.52	$7,174,795	$216,550	0.81	$4,862,859	1.52	$5,083,456
2014	7	$10,677	0.80	$3,722,184	1.51	$11,455,467	$195,205	0.80	$4,415,274	1.51	$7,092,326	$216,550	0.80	$4,802,824	1.51	$5,025,025
2015	8	$10,677	0.80	$3,722,184	1.52	$11,588,670	$195,205	0.80	$4,415,274	1.52	$7,174,795	$216,550	0.80	$4,802,824	1.52	$5,083,456
2016	9	$10,677	0.80	$3,722,184	1.52	$11,588,670	$195,205	0.80	$4,415,274	1.52	$7,174,795	$216,550	0.80	$4,802,824	1.52	$5,083,456
2017	10	$10,677	0.82	$3,815,239	1.52	$11,588,670	$195,205	0.82	$4,525,656	1.52	$7,174,795	$216,550	0.82	$4,922,894	1.52	$5,083,456
2018	11	$10,677	0.82	$3,815,239	1.56	$11,855,076	$195,205	0.82	$4,525,656	1.56	$7,339,733	$216,550	0.82	$4,922,894	1.56	$5,200,317
2019	12	$10,677	0.81	$3,768,711	1.56	$11,855,076	$195,205	0.81	$4,470,465	1.56	$7,339,733	$216,550	0.81	$4,862,859	1.56	$5,200,317
2020	13	$10,677	0.82	$3,815,239	1.56	$11,855,076	$195,205	0.82	$4,525,656	1.56	$7,339,733	$216,550	0.82	$4,922,894	1.56	$5,200,317
2021	14	$10,677	0.81	$3,768,711	1.56	$11,855,076	$195,205	0.81	$4,470,465	1.56	$7,339,733	$216,550	0.81	$4,862,859	1.56	$5,200,317
2022	15	$10,677	0.82	$3,815,239	1.56	$11,855,076	$195,205	0.82	$4,525,656	1.56	$7,339,733	$216,550	0.82	$4,922,894	1.56	$5,200,317
2023	16	$10,677	0.83	$3,861,766	1.56	$11,855,076	$195,205	0.83	$4,580,847	1.56	$7,339,733	$216,550	0.83	$4,982,929	1.56	$5,200,317
2024	17	$10,677	0.84	$3,908,293	1.56	$11,855,076	$195,205	0.84	$4,636,038	1.56	$7,339,733	$216,550	0.84	$5,042,965	1.56	$5,200,317
2025	18	$10,677	0.84	$3,908,293	1.58	$11,988,279	$195,205	0.84	$4,636,038	1.58	$7,422,202	$216,550	0.84	$5,042,965	1.58	$5,258,747
2026	19	$10,677	0.84	$3,908,293	1.56	$11,855,076	$195,205	0.84	$4,636,038	1.56	$7,339,733	$216,550	0.84	$5,042,965	1.56	$5,200,317
2027	20	$10,677	0.84	$3,908,293	1.56	$11,855,076	$195,205	0.84	$4,636,038	1.56	$7,339,733	$216,550	0.84	$5,042,965	1.56	$5,200,317
Column NPV		$158,851		$58,216,043		$161,357,813	$2,904,164		$69,056,169		$99,900,102	$3,221,711		$75,117,558		$70,780,798
Total NPV						$221,252,335					$174,307,374					$153,745,901
Total Saving (30 yr)							$ 46,944,961					$ 67,506,434				
Saving / yr							$ 2,347,248					$ 3,375,322				
							yr.	mo.				yr.	mo.			
Payback Period (yr)							-	4				-	11			

West Tower LCC w/ 15% increase in elec. cost by 2011

		Existing Design				
Capital Cost		$ 1,519,629				
Ann. Elec. Cost		$ 7,611,606				
Ann. NG Cost		$ 4,652,730				
Real Discount rate		3%				
		O&M	Natural Gas		Electricity	
Date	Year	Boiler	Esc.	Cost	Esc.	Cost
2008	1	$10,677	0.96	$4,466,621	0.97	$7,383,258
2009	2	$10,677	0.92	$4,280,512	1.08	$8,228,146
2010	3	$10,677	0.89	$4,140,930	1.04	$7,878,012
2011	4	$10,677	0.85	$3,954,821	1.00	$7,615,411
2012	5	$10,677	0.83	$3,861,766	0.99	$7,527,878
2013	6	$10,677	0.81	$3,768,711	1.00	$7,615,411
2014	7	$10,677	0.80	$3,722,184	0.99	$7,527,878
2015	8	$10,677	0.80	$3,722,184	1.00	$7,615,411
2016	9	$10,677	0.80	$3,722,184	1.00	$7,615,411
2017	10	$10,677	0.82	$3,815,239	1.00	$7,615,411
2018	11	$10,677	0.82	$3,815,239	1.02	$7,790,478
2019	12	$10,677	0.81	$3,768,711	1.02	$7,790,478
2020	13	$10,677	0.82	$3,815,239	1.02	$7,790,478
2021	14	$10,677	0.81	$3,768,711	1.02	$7,790,478
2022	15	$10,677	0.82	$3,815,239	1.02	$7,790,478
2023	16	$10,677	0.83	$3,861,766	1.02	$7,790,478
2024	17	$10,677	0.84	$3,908,293	1.02	$7,790,478
2025	18	$10,677	0.84	$3,908,293	1.04	$7,878,012
2026	19	$10,677	0.84	$3,908,293	1.02	$7,790,478
2027	20	$10,677	0.84	$3,908,293	1.02	$7,790,478
Column NPV		$158,851		$58,216,043		$114,906,512
Total NPV						$174,801,034
Total Saving (30 yr)						
Saving / yr						
Payback Period (yr)						

	Alternate Design LCC w/ Scenario 1				
Capital Cost	$ 2,446,940				
Ann. Elec. Cost	$ 4,712,509				
Ann. NG Cost	$ 5,519,092				
Real Discount rate	3%				
	O&M	Natural Gas		Electricity	
Date	Boiler & CHP	Esc.	Cost	Esc.	Cost
2008	$195,205	0.96	$5,298,329	0.97	$4,571,134
2009	$195,205	0.92	$5,077,565	1.08	$5,094,222
2010	$195,205	0.89	$4,911,992	1.04	$4,877,447
2011	$195,205	0.85	$4,691,229	1.00	$4,714,865
2012	$195,205	0.83	$4,580,847	0.99	$4,660,672
2013	$195,205	0.81	$4,470,465	1.00	$4,714,865
2014	$195,205	0.80	$4,415,274	0.99	$4,660,672
2015	$195,205	0.80	$4,415,274	1.00	$4,714,865
2016	$195,205	0.80	$4,415,274	1.00	$4,714,865
2017	$195,205	0.82	$4,525,656	1.00	$4,714,865
2018	$195,205	0.82	$4,525,656	1.02	$4,823,253
2019	$195,205	0.81	$4,470,465	1.02	$4,823,253
2020	$195,205	0.82	$4,525,656	1.02	$4,823,253
2021	$195,205	0.81	$4,470,465	1.02	$4,823,253
2022	$195,205	0.82	$4,525,656	1.02	$4,823,253
2023	$195,205	0.83	$4,580,847	1.02	$4,823,253
2024	$195,205	0.84	$4,636,038	1.02	$4,823,253
2025	$195,205	0.84	$4,636,038	1.04	$4,877,447
2026	$195,205	0.84	$4,636,038	1.02	$4,823,253
2027	$195,205	0.84	$4,636,038	1.02	$4,823,253
Column NPV	$2,904,164		$69,056,169		$71,141,100
Total NPV					$145,548,372
Total Saving (30 yr)	$ 29,252,662				
Saving / yr	$ 1,462,633				
	yr.	mo.			
Payback Period (yr)	-	7			

	Alternate Design LCC w/ Scenario 2				
Capital Cost	$ 4,625,834				
Ann. Elec. Cost	$ 3,338,887				
Ann. NG Cost	$ 6,003,529				
Real Discount rate	3%				
	O&M	Natural Gas		Electricity	
Date	Boiler & CHP	Esc.	Cost	Esc.	Cost
2008	$216,550	0.96	$5,763,388	0.97	$3,238,720
2009	$216,550	0.92	$5,523,247	1.08	$3,609,337
2010	$216,550	0.89	$5,343,141	1.04	$3,455,748
2011	$216,550	0.85	$5,103,000	1.00	$3,340,557
2012	$216,550	0.83	$4,982,929	0.99	$3,302,159
2013	$216,550	0.81	$4,862,859	1.00	$3,340,557
2014	$216,550	0.80	$4,802,824	0.99	$3,302,159
2015	$216,550	0.80	$4,802,824	1.00	$3,340,557
2016	$216,550	0.80	$4,802,824	1.00	$3,340,557
2017	$216,550	0.82	$4,922,894	1.00	$3,340,557
2018	$216,550	0.82	$4,922,894	1.02	$3,417,351
2019	$216,550	0.81	$4,862,859	1.02	$3,417,351
2020	$216,550	0.82	$4,922,894	1.02	$3,417,351
2021	$216,550	0.81	$4,862,859	1.02	$3,417,351
2022	$216,550	0.82	$4,922,894	1.02	$3,417,351
2023	$216,550	0.83	$4,982,929	1.02	$3,417,351
2024	$216,550	0.84	$5,042,965	1.02	$3,417,351
2025	$216,550	0.84	$5,042,965	1.04	$3,455,748
2026	$216,550	0.84	$5,042,965	1.02	$3,417,351
2027	$216,550	0.84	$5,042,965	1.02	$3,417,351
Column NPV	$3,221,711		$75,117,558		$50,404,591
Total NPV					$133,369,695
Total Saving (30 yr)	$ 41,431,340				
Saving / yr	$ 2,071,567				
	yr.	mo.			
Payback Period (yr)	1	5			

West Tower LCC w/15% increase in NG cost by 2009																
		Existing Design LCC					Alternate Design LCC w/ Scenario 1					Alternate Design LCC w/ Scenario 2				
Capital Cost		$ 1,519,629					$ 2,446,940					$ 4,625,834				
Ann. Elec. Cost		$ 7,611,606					$ 4,712,509					$ 3,338,887				
Ann. NG Cost		$ 4,652,730					$ 5,519,092					$ 6,003,529				
Real Discount rate		3%					3%					3%				
		O&M	Natural Gas		Electricity		O&M	Natural Gas		Electricity		O&M	Natural Gas		Electricity	
Date	Year	Boiler	Esc.	Cost	Esc.	Cost	Boiler & CHP	Esc.	Cost	Esc.	Cost	Boiler & CHP	Esc.	Cost	Esc.	Cost
2008	1	$10,677	0.96	$4,466,621	0.97	$7,383,258	$195,205	0.96	$5,298,329	0.97	$4,571,134	$216,550	0.96	$5,763,388	0.97	$3,238,720
2009	2	$10,677	1.06	$4,922,588	0.94	$7,154,909	$195,205	1.06	$5,839,200	0.94	$4,429,759	$216,550	1.06	$6,351,734	0.94	$3,138,554
2010	3	$10,677	1.02	$4,762,069	0.90	$6,850,445	$195,205	1.02	$5,648,791	0.90	$4,241,258	$216,550	1.02	$6,144,612	0.90	$3,004,998
2011	4	$10,677	0.98	$4,548,044	0.87	$6,622,097	$195,205	0.98	$5,394,913	0.87	$4,099,883	$216,550	0.98	$5,868,450	0.87	$2,904,832
2012	5	$10,677	0.95	$4,441,031	0.86	$6,545,981	$195,205	0.95	$5,267,974	0.86	$4,052,758	$216,550	0.95	$5,730,369	0.86	$2,871,443
2013	6	$10,677	0.93	$4,334,018	0.87	$6,622,097	$195,205	0.93	$5,141,035	0.87	$4,099,883	$216,550	0.93	$5,592,288	0.87	$2,904,832
2014	7	$10,677	0.92	$4,280,512	0.86	$6,545,981	$195,205	0.92	$5,077,565	0.86	$4,052,758	$216,550	0.92	$5,523,247	0.86	$2,871,443
2015	8	$10,677	0.92	$4,280,512	0.87	$6,622,097	$195,205	0.92	$5,077,565	0.87	$4,099,883	$216,550	0.92	$5,523,247	0.87	$2,904,832
2016	9	$10,677	0.92	$4,280,512	0.87	$6,622,097	$195,205	0.92	$5,077,565	0.87	$4,099,883	$216,550	0.92	$5,523,247	0.87	$2,904,832
2017	10	$10,677	0.94	$4,387,524	0.87	$6,622,097	$195,205	0.94	$5,204,504	0.87	$4,099,883	$216,550	0.94	$5,661,328	0.87	$2,904,832
2018	11	$10,677	0.94	$4,387,524	0.89	$6,774,329	$195,205	0.94	$5,204,504	0.89	$4,194,133	$216,550	0.94	$5,661,328	0.89	$2,971,610
2019	12	$10,677	0.93	$4,334,018	0.89	$6,774,329	$195,205	0.93	$5,141,035	0.89	$4,194,133	$216,550	0.93	$5,592,288	0.89	$2,971,610
2020	13	$10,677	0.94	$4,387,524	0.89	$6,774,329	$195,205	0.94	$5,204,504	0.89	$4,194,133	$216,550	0.94	$5,661,328	0.89	$2,971,610
2021	14	$10,677	0.93	$4,334,018	0.89	$6,774,329	$195,205	0.93	$5,141,035	0.89	$4,194,133	$216,550	0.93	$5,592,288	0.89	$2,971,610
2022	15	$10,677	0.94	$4,387,524	0.89	$6,774,329	$195,205	0.94	$5,204,504	0.89	$4,194,133	$216,550	0.94	$5,661,328	0.89	$2,971,610
2023	16	$10,677	0.95	$4,441,031	0.89	$6,774,329	$195,205	0.95	$5,267,974	0.89	$4,194,133	$216,550	0.95	$5,730,369	0.89	$2,971,610
2024	17	$10,677	0.97	$4,494,537	0.89	$6,774,329	$195,205	0.97	$5,331,443	0.89	$4,194,133	$216,550	0.97	$5,799,409	0.89	$2,971,610
2025	18	$10,677	0.97	$4,494,537	0.90	$6,850,445	$195,205	0.97	$5,331,443	0.90	$4,241,258	$216,550	0.97	$5,799,409	0.90	$3,004,998
2026	19	$10,677	0.97	$4,494,537	0.89	$6,774,329	$195,205	0.97	$5,331,443	0.89	$4,194,133	$216,550	0.97	$5,799,409	0.89	$2,971,610
2027	20	$10,677	0.97	$4,494,537	0.89	$6,774,329	$195,205	0.97	$5,331,443	0.89	$4,194,133	$216,550	0.97	$5,799,409	0.89	$2,971,610
Column NPV		$158,851		$66,297,970		$100,853,691	$2,904,164		$78,642,993		$62,440,695	$3,221,711		$85,545,864		$44,240,217
Total NPV						$168,830,140					$146,434,791					$137,633,626
Total Saving (30 yr)							$ 22,395,349					$ 31,196,514				
Saving / yr							$ 1,119,767					$ 1,559,826				
							yr.	mo.				yr.	mo.			
Payback Period (yr)							-	9				1	11			

Completed Campus LCC w/ Normal Fuel escalation

		Existing Design LCC					Alternate Design LCC w/ Scenario 1					Alternate Design LCC w/ Scenario 2				
Capital Cost		$ 759,814					$ 5,368,043					$ 5,368,043				
Ann. Elec. Cost		$ 13,234,990					$ 6,032,350					$ 4,716,019				
Ann. NG Cost		$ 8,091,039					$ 10,308,201					$ 10,792,638				
Real Discount rate		3%					3%					3%				
		O&M	Natural Gas		Electricity		O&M	Natural Gas		Electricity		O&M	Natural Gas		Electricity	
Date	Year	Boiler	UPV	Cost	UPV	Cost	Boiler & CHP	UPV	Cost	UPV	Cost	Boiler & CHP	UPV	Cost	UPV	Cost
2008	1	$17,795	0.96	$7,767,398	0.97	$12,837,941	$410,173	0.96	$9,895,873	0.97	$5,851,380	$431,517	0.96	$10,360,932	0.97	$4,574,538
2009	2	$17,795	0.92	$7,443,756	0.94	$12,440,891	$410,173	0.92	$9,483,545	0.94	$5,670,409	$431,517	0.92	$9,929,227	0.94	$4,433,057
2010	3	$17,795	0.89	$7,201,025	0.90	$11,911,491	$410,173	0.89	$9,174,299	0.90	$5,429,115	$431,517	0.89	$9,605,448	0.90	$4,244,417
2011	4	$17,795	0.85	$6,877,383	0.87	$11,514,442	$410,173	0.85	$8,761,971	0.87	$5,248,145	$431,517	0.85	$9,173,742	0.87	$4,102,936
2012	5	$17,795	0.83	$6,715,563	0.86	$11,382,092	$410,173	0.83	$8,555,807	0.86	$5,187,821	$431,517	0.83	$8,957,890	0.86	$4,055,776
2013	6	$17,795	0.81	$6,553,742	0.87	$11,514,442	$410,173	0.81	$8,349,643	0.87	$5,248,145	$431,517	0.81	$8,742,037	0.87	$4,102,936
2014	7	$17,795	0.80	$6,472,831	0.86	$11,382,092	$410,173	0.80	$8,246,561	0.86	$5,187,821	$431,517	0.80	$8,634,110	0.86	$4,055,776
2015	8	$17,795	0.80	$6,472,831	0.87	$11,514,442	$410,173	0.80	$8,246,561	0.87	$5,248,145	$431,517	0.80	$8,634,110	0.87	$4,102,936
2016	9	$17,795	0.80	$6,472,831	0.87	$11,514,442	$410,173	0.80	$8,246,561	0.87	$5,248,145	$431,517	0.80	$8,634,110	0.87	$4,102,936
2017	10	$17,795	0.82	$6,634,652	0.87	$11,514,442	$410,173	0.82	$8,452,725	0.87	$5,248,145	$431,517	0.82	$8,849,963	0.87	$4,102,936
2018	11	$17,795	0.82	$6,634,652	0.89	$11,779,141	$410,173	0.82	$8,452,725	0.89	$5,368,792	$431,517	0.82	$8,849,963	0.89	$4,197,256
2019	12	$17,795	0.81	$6,553,742	0.89	$11,779,141	$410,173	0.81	$8,349,643	0.89	$5,368,792	$431,517	0.81	$8,742,037	0.89	$4,197,256
2020	13	$17,795	0.82	$6,634,652	0.89	$11,779,141	$410,173	0.82	$8,452,725	0.89	$5,368,792	$431,517	0.82	$8,849,963	0.89	$4,197,256
2021	14	$17,795	0.81	$6,553,742	0.89	$11,779,141	$410,173	0.81	$8,349,643	0.89	$5,368,792	$431,517	0.81	$8,742,037	0.89	$4,197,256
2022	15	$17,795	0.82	$6,634,652	0.89	$11,779,141	$410,173	0.82	$8,452,725	0.89	$5,368,792	$431,517	0.82	$8,849,963	0.89	$4,197,256
2023	16	$17,795	0.83	$6,715,563	0.89	$11,779,141	$410,173	0.83	$8,555,807	0.89	$5,368,792	$431,517	0.83	$8,957,890	0.89	$4,197,256
2024	17	$17,795	0.84	$6,796,473	0.89	$11,779,141	$410,173	0.84	$8,658,889	0.89	$5,368,792	$431,517	0.84	$9,065,816	0.89	$4,197,256
2025	18	$17,795	0.84	$6,796,473	0.90	$11,911,491	$410,173	0.84	$8,658,889	0.90	$5,429,115	$431,517	0.84	$9,065,816	0.90	$4,244,417
2026	19	$17,795	0.84	$6,796,473	0.89	$11,779,141	$410,173	0.84	$8,658,889	0.89	$5,368,792	$431,517	0.84	$9,065,816	0.89	$4,197,256
2027	20	$17,795	0.84	$6,796,473	0.89	$11,779,141	$410,173	0.84	$8,658,889	0.89	$5,368,792	$431,517	0.84	$9,065,816	0.89	$4,197,256
Column NPV		$264,751		$101,236,968		$175,363,473	$6,102,342		$128,978,610		$79,928,572	$6,419,889		$135,040,000		$62,487,193
Total NPV						$277,625,007					$220,377,567					$209,315,124
Total Saving (20 yr)							$ 57,247,440					$ 68,309,883				
Saving / yr							$ 2,862,372					$ 3,415,494				
							yr.	mo.				yr.	mo.			
Payback Period (yr)							1	7				1	4			

Completed Campus LCC w/ 75% increase in Electricity Cost by 2011

		Existing Design LCC					Alternate Design LCC w/ Scenario 1					Alternate Design LCC w/ Scenario 2				
Capital Cost		$ 759,814					$ 5,368,043					$ 5,368,043				
Ann. Elec. Cost		$ 13,234,990					$ 6,032,350					$ 4,716,019				
Ann. NG Cost		$ 8,091,039					$ 10,308,201					$ 10,792,638				
Real Discount rate		3%					3%					3%				
		O&M	Natural Gas		Electricity		O&M	Natural Gas		Electricity		O&M	Natural Gas		Electricity	
Date	Year	Boiler	Esc.	Cost	Esc.	Cost	Boiler & CHP	Esc.	Cost	Esc.	Cost	Boiler & CHP	Esc.	Cost	Esc.	Cost
2008	1	$17,795	0.96	$7,767,398	0.97	$12,837,941	$410,173	0.96	$10,360,932	0.97	$5,851,380	$431,517	0.96	$10,360,932	0.97	$4,574,538
2009	2	$17,795	0.92	$7,443,756	0.94	$12,440,891	$410,173	0.92	$9,929,227	0.94	$5,670,409	$431,517	0.92	$9,929,227	0.94	$4,433,057
2010	3	$17,795	0.89	$7,201,025	0.90	$11,911,491	$410,173	0.89	$9,605,448	0.90	$5,429,115	$431,517	0.89	$9,605,448	0.90	$4,244,417
2011	4	$17,795	0.85	$6,877,383	1.52	$20,150,273	$410,173	0.85	$9,173,742	1.52	$9,184,253	$431,517	0.85	$9,173,742	1.52	$7,180,138
2012	5	$17,795	0.83	$6,715,563	1.51	$19,918,660	$410,173	0.83	$8,957,890	1.51	$9,078,687	$431,517	0.83	$8,957,890	1.51	$7,097,608
2013	6	$17,795	0.81	$6,553,742	1.52	$20,150,273	$410,173	0.81	$8,742,037	1.52	$9,184,253	$431,517	0.81	$8,742,037	1.52	$7,180,138
2014	7	$17,795	0.80	$6,472,831	1.51	$19,918,660	$410,173	0.80	$8,634,110	1.51	$9,078,687	$431,517	0.80	$8,634,110	1.51	$7,097,608
2015	8	$17,795	0.80	$6,472,831	1.52	$20,150,273	$410,173	0.80	$8,634,110	1.52	$9,184,253	$431,517	0.80	$8,634,110	1.52	$7,180,138
2016	9	$17,795	0.80	$6,472,831	1.52	$20,150,273	$410,173	0.80	$8,634,110	1.52	$9,184,253	$431,517	0.80	$8,634,110	1.52	$7,180,138
2017	10	$17,795	0.82	$6,634,652	1.52	$20,150,273	$410,173	0.82	$8,849,963	1.52	$9,184,253	$431,517	0.82	$8,849,963	1.52	$7,180,138
2018	11	$17,795	0.82	$6,634,652	1.56	$20,613,497	$410,173	0.82	$8,849,963	1.56	$9,395,385	$431,517	0.82	$8,849,963	1.56	$7,345,199
2019	12	$17,795	0.81	$6,553,742	1.56	$20,613,497	$410,173	0.81	$8,742,037	1.56	$9,395,385	$431,517	0.81	$8,742,037	1.56	$7,345,199
2020	13	$17,795	0.82	$6,634,652	1.56	$20,613,497	$410,173	0.82	$8,849,963	1.56	$9,395,385	$431,517	0.82	$8,849,963	1.56	$7,345,199
2021	14	$17,795	0.81	$6,553,742	1.56	$20,613,497	$410,173	0.81	$8,742,037	1.56	$9,395,385	$431,517	0.81	$8,742,037	1.56	$7,345,199
2022	15	$17,795	0.82	$6,634,652	1.56	$20,613,497	$410,173	0.82	$8,849,963	1.56	$9,395,385	$431,517	0.82	$8,849,963	1.56	$7,345,199
2023	16	$17,795	0.83	$6,715,563	1.56	$20,613,497	$410,173	0.83	$8,957,890	1.56	$9,395,385	$431,517	0.83	$8,957,890	1.56	$7,345,199
2024	17	$17,795	0.84	$6,796,473	1.56	$20,613,497	$410,173	0.84	$9,065,816	1.56	$9,395,385	$431,517	0.84	$9,065,816	1.56	$7,345,199
2025	18	$17,795	0.84	$6,796,473	1.58	$20,845,110	$410,173	0.84	$9,065,816	1.58	$9,500,952	$431,517	0.84	$9,065,816	1.58	$7,427,729
2026	19	$17,795	0.84	$6,796,473	1.56	$20,613,497	$410,173	0.84	$9,065,816	1.56	$9,395,385	$431,517	0.84	$9,065,816	1.56	$7,345,199
2027	20	$17,795	0.84	$6,796,473	1.56	$20,613,497	$410,173	0.84	$9,065,816	1.56	$9,395,385	$431,517	0.84	$9,065,816	1.56	$7,345,199
Column NPV		$264,751		$101,236,968		$280,567,487	$6,102,342		$135,040,000		$127,879,303	$6,419,889		$135,040,000		$99,974,495
Total NPV						$382,829,021					$274,389,688					$246,802,427
Total Saving (30 yr)							$ 108,439,334					$ 136,026,594				
Saving / yr							$ 5,421,967					$ 6,801,330				
							yr.	mo.				yr.	mo.			
Payback Period (yr)							-	10				-	8			

Completed Campus w/ 15% increase in elec. cost by 2011																
		Existing Design LCC					Alternate Design LCC w/ Scenario 1					Alternate Design LCC w/ Scenario 2				
Capital Cost		$ 759,814					$ 5,368,043					$ 5,368,043				
Ann. Elec. Cost		$ 13,234,990					$ 6,032,350					$ 4,716,019				
Ann. NG Cost		$ 8,091,039					$ 10,308,201					$ 10,792,638				
Real Discount rate		3%					3%					3%				
		O&M	Natural Gas		Electricity		O&M	Natural Gas		Electricity		O&M	Natural Gas		Electricity	
Date	Year	Boiler	Esc.	Cost	Esc.	Cost	Boiler & CHP	Esc.	Cost	Esc.	Cost	Boiler & CHP	Esc.	Cost	Esc.	Cost
2008	1	$17,795	0.96	$7,767,398	0.97	$12,837,941	$410,173	0.96	$10,360,932	0.97	$5,851,380	$431,517	0.96	$10,360,932	0.97	$4,574,538
2009	2	$17,795	0.92	$7,443,756	1.08	$14,307,024	$410,173	0.92	$9,929,227	1.08	$5,098,016	$431,517	0.92	$9,929,227	1.08	$5,098,016
2010	3	$17,795	0.89	$7,201,025	1.04	$13,698,215	$410,173	0.89	$9,605,448	1.04	$4,881,079	$431,517	0.89	$9,605,448	1.04	$4,881,079
2011	4	$17,795	0.85	$6,877,383	1.00	$13,241,608	$410,173	0.85	$9,173,742	1.00	$4,718,377	$431,517	0.85	$9,173,742	1.00	$4,718,377
2012	5	$17,795	0.83	$6,715,563	0.99	$13,089,405	$410,173	0.83	$8,957,890	0.99	$4,664,142	$431,517	0.83	$8,957,890	0.99	$4,664,142
2013	6	$17,795	0.81	$6,553,742	1.00	$13,241,608	$410,173	0.81	$8,742,037	1.00	$4,718,377	$431,517	0.81	$8,742,037	1.00	$4,718,377
2014	7	$17,795	0.80	$6,472,831	0.99	$13,089,405	$410,173	0.80	$8,634,110	0.99	$4,664,142	$431,517	0.80	$8,634,110	0.99	$4,664,142
2015	8	$17,795	0.80	$6,472,831	1.00	$13,241,608	$410,173	0.80	$8,634,110	1.00	$4,718,377	$431,517	0.80	$8,634,110	1.00	$4,718,377
2016	9	$17,795	0.80	$6,472,831	1.00	$13,241,608	$410,173	0.80	$8,634,110	1.00	$4,718,377	$431,517	0.80	$8,634,110	1.00	$4,718,377
2017	10	$17,795	0.82	$6,634,652	1.00	$13,241,608	$410,173	0.82	$8,849,963	1.00	$4,718,377	$431,517	0.82	$8,849,963	1.00	$4,718,377
2018	11	$17,795	0.82	$6,634,652	1.02	$13,546,013	$410,173	0.82	$8,849,963	1.02	$4,826,845	$431,517	0.82	$8,849,963	1.02	$4,826,845
2019	12	$17,795	0.81	$6,553,742	1.02	$13,546,013	$410,173	0.81	$8,742,037	1.02	$4,826,845	$431,517	0.81	$8,742,037	1.02	$4,826,845
2020	13	$17,795	0.82	$6,634,652	1.02	$13,546,013	$410,173	0.82	$8,849,963	1.02	$4,826,845	$431,517	0.82	$8,849,963	1.02	$4,826,845
2021	14	$17,795	0.81	$6,553,742	1.02	$13,546,013	$410,173	0.81	$8,742,037	1.02	$4,826,845	$431,517	0.81	$8,742,037	1.02	$4,826,845
2022	15	$17,795	0.82	$6,634,652	1.02	$13,546,013	$410,173	0.82	$8,849,963	1.02	$4,826,845	$431,517	0.82	$8,849,963	1.02	$4,826,845
2023	16	$17,795	0.83	$6,715,563	1.02	$13,546,013	$410,173	0.83	$8,957,890	1.02	$4,826,845	$431,517	0.83	$8,957,890	1.02	$4,826,845
2024	17	$17,795	0.84	$6,796,473	1.02	$13,546,013	$410,173	0.84	$9,065,816	1.02	$4,826,845	$431,517	0.84	$9,065,816	1.02	$4,826,845
2025	18	$17,795	0.84	$6,796,473	1.04	$13,698,215	$410,173	0.84	$9,065,816	1.04	$4,881,079	$431,517	0.84	$9,065,816	1.04	$4,881,079
2026	19	$17,795	0.84	$6,796,473	1.02	$13,546,013	$410,173	0.84	$9,065,816	1.02	$4,826,845	$431,517	0.84	$9,065,816	1.02	$4,826,845
2027	20	$17,795	0.84	$6,796,473	1.02	$13,546,013	$410,173	0.84	$9,065,816	1.02	$4,826,845	$431,517	0.84	$9,065,816	1.02	$4,826,845
Column NPV		$264,751		$101,236,968		$199,798,391	$6,102,342		$135,040,000		$72,433,729	$6,419,889		$135,040,000		$71,194,077
Total NPV						$302,059,925					$218,944,114					$218,022,009
Total Saving (30 yr)							$ 83,115,811					$ 84,037,917				
Saving / yr							$ 4,155,791					$ 4,201,896				
							yr.	mo.				yr.	mo.			
Payback Period (yr)							1	1				1	1			

Completed Campus LCC w/ 15% increase in Natural Gas Cost by 2009																
		Existing Design LCC					Alternate Design LCC w/ Scenario 1					Alternate Design LCC w/ Scenario 2				
Capital Cost		$ 759,814					$ 5,368,043					$ 5,368,043				
Ann. Elec. Cost		$ 13,234,990					$ 6,032,350					$ 4,716,019				
Ann. NG Cost		$ 8,091,039					$ 10,308,201					$ 10,792,638				
Real Discount rate		3%					3%					3%				
		O&M	Natural Gas		Electricity		O&M	Natural Gas		Electricity		O&M	Natural Gas		Electricity	
Date	Year	Boiler	Esc.	Cost	Esc.	Cost	Boiler & CHP	Esc.	Cost	Esc.	Cost	Boiler & CHP	Esc.	Cost	Esc.	Cost
2008	1	$17,795	0.96	$7,767,398	0.97	$12,837,941	$410,173	0.96	$10,360,932	0.97	$5,851,380	$431,517	0.96	$10,360,932	0.97	$4,574,538
2009	2	$17,795	1.06	$8,560,320	0.94	$12,440,891	$410,173	1.06	$11,418,611	0.94	$5,670,409	$431,517	1.06	$11,418,611	0.94	$4,433,057
2010	3	$17,795	1.02	$8,281,179	0.90	$11,911,491	$410,173	1.02	$11,046,265	0.90	$5,429,115	$431,517	1.02	$11,046,265	0.90	$4,244,417
2011	4	$17,795	0.98	$7,908,991	0.87	$11,514,442	$410,173	0.98	$10,549,804	0.87	$5,248,145	$431,517	0.98	$10,549,804	0.87	$4,102,936
2012	5	$17,795	0.95	$7,722,897	0.86	$11,382,092	$410,173	0.95	$10,301,573	0.86	$5,187,821	$431,517	0.95	$10,301,573	0.86	$4,055,776
2013	6	$17,795	0.93	$7,536,803	0.87	$11,514,442	$410,173	0.93	$10,053,342	0.87	$5,248,145	$431,517	0.93	$10,053,342	0.87	$4,102,936
2014	7	$17,795	0.92	$7,443,756	0.86	$11,382,092	$410,173	0.92	$9,929,227	0.86	$5,187,821	$431,517	0.92	$9,929,227	0.86	$4,055,776
2015	8	$17,795	0.92	$7,443,756	0.87	$11,514,442	$410,173	0.92	$9,929,227	0.87	$5,248,145	$431,517	0.92	$9,929,227	0.87	$4,102,936
2016	9	$17,795	0.92	$7,443,756	0.87	$11,514,442	$410,173	0.92	$9,929,227	0.87	$5,248,145	$431,517	0.92	$9,929,227	0.87	$4,102,936
2017	10	$17,795	0.94	$7,629,850	0.87	$11,514,442	$410,173	0.94	$10,177,458	0.87	$5,248,145	$431,517	0.94	$10,177,458	0.87	$4,102,936
2018	11	$17,795	0.94	$7,629,850	0.89	$11,779,141	$410,173	0.94	$10,177,458	0.89	$5,368,792	$431,517	0.94	$10,177,458	0.89	$4,197,256
2019	12	$17,795	0.93	$7,536,803	0.89	$11,779,141	$410,173	0.93	$10,053,342	0.89	$5,368,792	$431,517	0.93	$10,053,342	0.89	$4,197,256
2020	13	$17,795	0.94	$7,629,850	0.89	$11,779,141	$410,173	0.94	$10,177,458	0.89	$5,368,792	$431,517	0.94	$10,177,458	0.89	$4,197,256
2021	14	$17,795	0.93	$7,536,803	0.89	$11,779,141	$410,173	0.93	$10,053,342	0.89	$5,368,792	$431,517	0.93	$10,053,342	0.89	$4,197,256
2022	15	$17,795	0.94	$7,629,850	0.89	$11,779,141	$410,173	0.94	$10,177,458	0.89	$5,368,792	$431,517	0.94	$10,177,458	0.89	$4,197,256
2023	16	$17,795	0.95	$7,722,897	0.89	$11,779,141	$410,173	0.95	$10,301,573	0.89	$5,368,792	$431,517	0.95	$10,301,573	0.89	$4,197,256
2024	17	$17,795	0.97	$7,815,944	0.89	$11,779,141	$410,173	0.97	$10,425,688	0.89	$5,368,792	$431,517	0.97	$10,425,688	0.89	$4,197,256
2025	18	$17,795	0.97	$7,815,944	0.90	$11,911,491	$410,173	0.97	$10,425,688	0.90	$5,429,115	$431,517	0.97	$10,425,688	0.90	$4,244,417
2026	19	$17,795	0.97	$7,815,944	0.89	$11,779,141	$410,173	0.97	$10,425,688	0.89	$5,368,792	$431,517	0.97	$10,425,688	0.89	$4,197,256
2027	20	$17,795	0.97	$7,815,944	0.89	$11,779,141	$410,173	0.97	$10,425,688	0.89	$5,368,792	$431,517	0.97	$10,425,688	0.89	$4,197,256
Column NPV		$264,751		$115,291,339		$175,363,473	$6,102,342		$153,787,126		$79,928,572	$6,419,889		$153,787,126		$62,487,193
Total NPV						$291,679,378					$245,186,083					$228,062,251
Total Saving (30 yr)							$ 46,493,295					$ 63,617,127				
Saving / yr							$ 2,324,665					$ 3,180,856				
							yr.	mo.				yr.	mo.			
Payback Period (yr)							1	11				1	5			

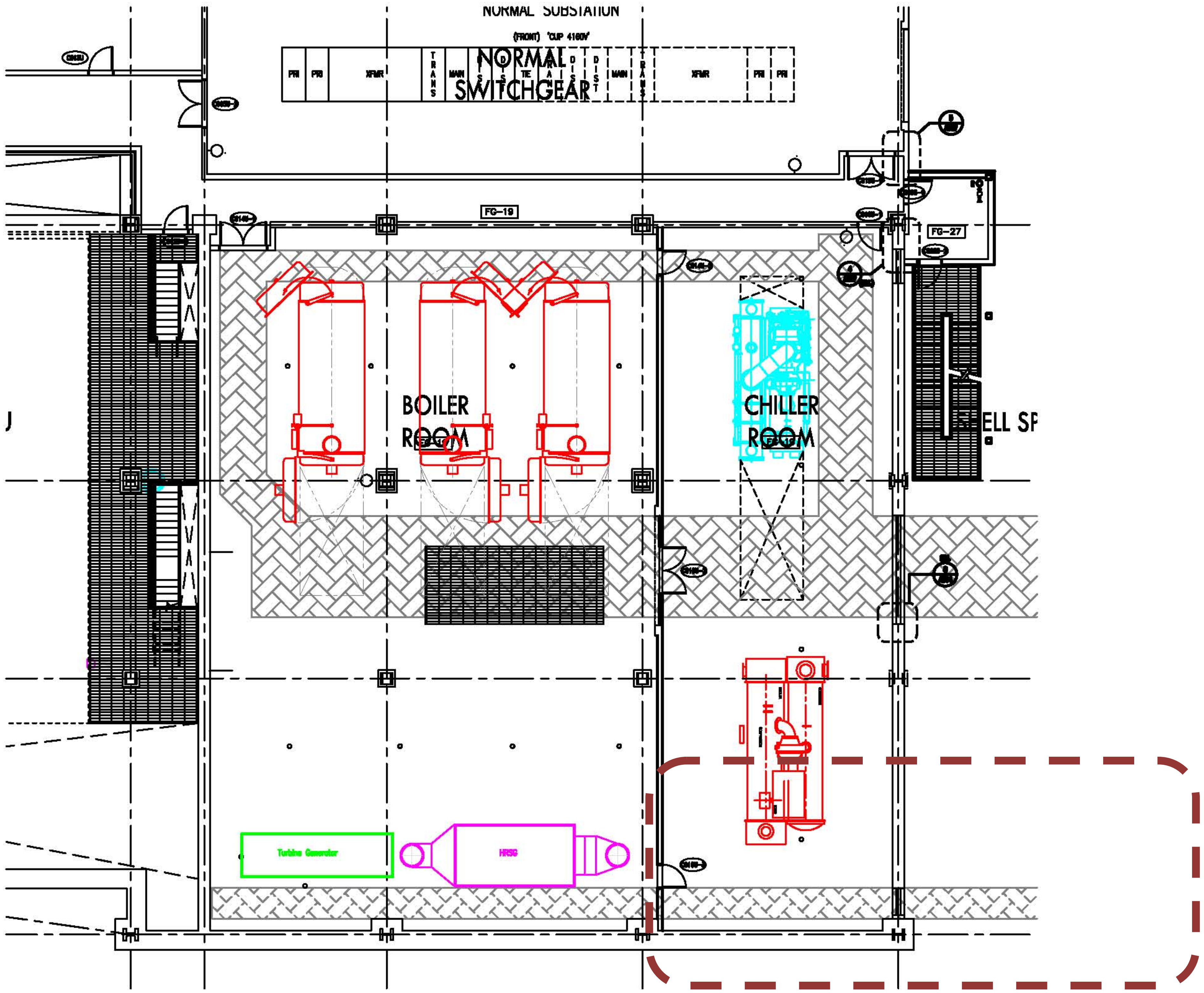
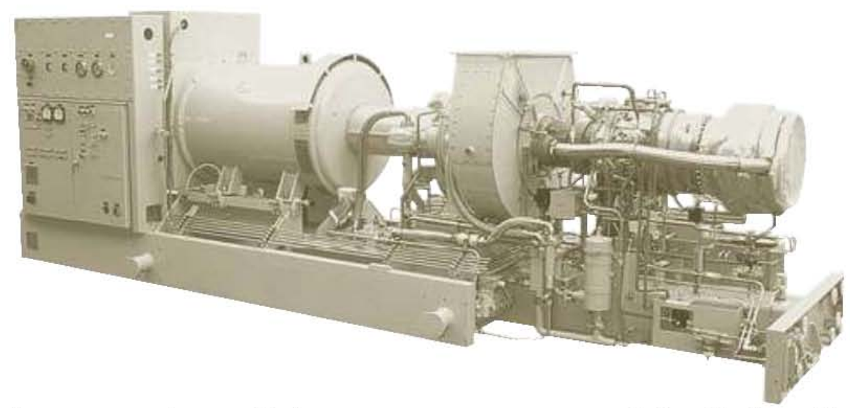


Figure 1: Alternate Design Boiler Room Layout Scale: 1/16" = 1'-0"

Solar Turbines
A Caterpillar Company

SATURN 20
Gas Turbine Generator Set

POWER GENERATION



Package Arrangement

Gas Turbine
- *Saturn*® 20 Industrial, Single-Shaft
- Axial Compressor – 8 Stages
- Annular Combustion Chamber
  - 12 Fuel Injectors
- Coatings
  - Compressor: Inorganic Aluminum
  - Turbine and Nozzle Blades: Precious Metal Diffusion Aluminide
- Velocity Vibration Transducers

Main Reduction Drive
- Epicyclic
  - 1800 or 1500 rpm
  - Acceleration Vibration Transducers

Generator
- Salient Pole, 3 Phase, 6 Wire, Wye Connected, Synchronous with Brushless Exciter
- Open Drip-Proof Construction
- Sleeve Bearings
- Velocity Vibration Transducers
- Solid-State Voltage Regulation with Permanent Magnet Generator
- NEMA Class H Insulation with H Rise
- Continuous Duty Rating

Package
- Steel Base Frame with Drip Pans
- Direct-Drive AC or Pneumatic Start System
- Natural Gas Fuel System
- Control System
  - Microprocessor-Based PLC
  - Generator Control
  - Vibration and Temperature Monitoring
  - Auto Synchronizing
- Integrated Lube Oil System
  - Turbine-Driven Lube Pump
  - AC Pre/Post Lube Pump
  - Air/Oil Cooler
  - Integral Lube Oil Tank
  - Lube Oil Filter
- Documentation
  - Drawings
  - Quality Control Data Book
  - Inspection and Test Plan
  - Test Reports
  - O&M Manuals
- Factory Testing of Turbine and Package
- Weatherproof Acoustic Enclosure

Optional Equipment/Services
- Generator Options:
  - Standby Duty Rating
  - Standard Voltages: 380, 415, 3300 50 Hz; 240, 480 2400, 4160 60 Hz
- Fuel Systems
  - Liquid
  - Dual (Gas/Liquid)
  - Water Injection for NOx Control
  - Alternate Fuels (such as naphtha, propane, low Btu)
- Lube Oil System
  - Water/Oil Lube Cooler
  - Electrostatic Demister
  - Lube Oil Tank Heater
- Control System
  - Remote Display/Control Terminal
  - Heat Recovery Application Interface
  - Serial Link Supervisory Interface
  - KW Control
  - KVAR/Power Factor Control
- Accessory Equipment
  - Turbine Cleaning System: On-Crank and On-line
  - Package Lifting Kit
- Ancillary Equipment: Various Air Inlet and Exhaust Systems
  - Inlet and Exhaust Silencers
  - Self-Cleaning or Prefilter/Barrier Air Inlet Filter
  - Inlet Evaporative Cooler
  - Inlet Chiller Coils
  - Ancillary Support Frame

Solar Turbines
A Caterpillar Company

SATURN 20
Gas Turbine Generator Set

POWER GENERATION

Nominal Performance

Output Power	1210 kWe
Heat Rate	14 795 kJ/kWe-hr (14,025 Btu/kWe-hr)
Exhaust Flow	23 540 kg/hr (51,890 lb/hr)
Exhaust Temp.	505°C (940°F)

Nominal Rating – per ISO At 15°C (59°F), at sea level

No inlet/exhaust losses

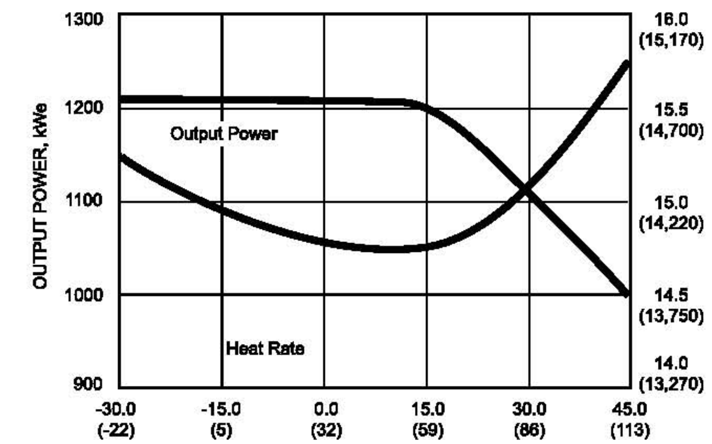
Relative humidity 60%

Natural gas fuel with LHV = 31.5 to 43.3 MJ/nm³ (800 to 1100 Btu/scf)

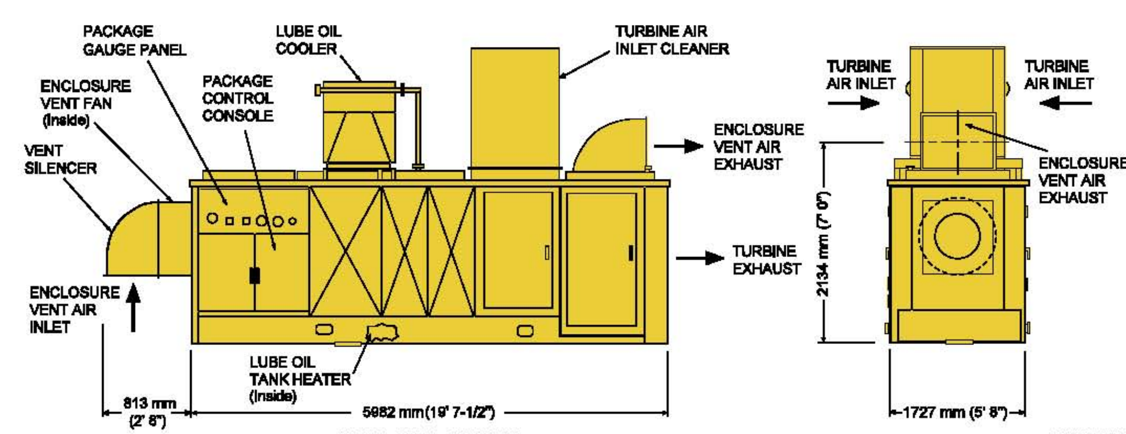
AC-driven accessories

Engine efficiency: 24.3%

Available Power



Typical Package Configuration



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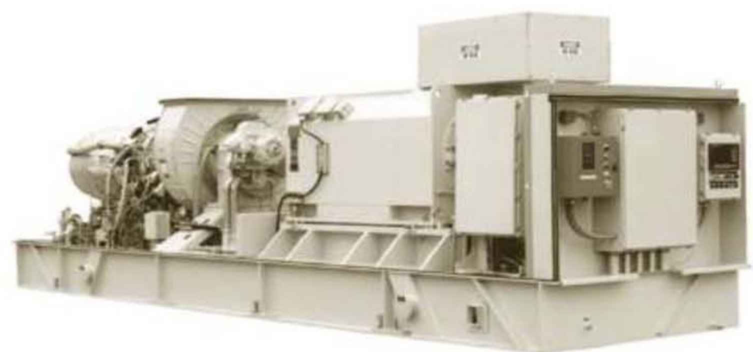
Solar Turbines
A Caterpillar Company

CENTAUR 40
Gas Turbine Generator Set

POWER GENERATION



Package Arrangement

Gas Turbine
- Centaur® 40 Industrial, Single-Shaft
- Axial Compressor – 11 Stages
- Annular Combustion Chamber
  - 10 Fuel Injectors
- Coatings
  - Compressor: Inorganic Aluminum
  - Turbine and Nozzle Blades: Precious Metal Diffusion Aluminide
- Velocity Vibration Transducers

Main Reduction Drive
- Epicyclic
  - 1800 or 1500 rpm
  - Acceleration Vibration Transducers

Generator
- Salient Pole, 3 Phase, 6 Wire, Wye Connected, Synchronous with Brushless Exciter
- Open Drip-Proof Construction
- Sleeve Bearings
- Velocity Vibration Transducers
- Solid-State Voltage Regulation with Permanent Magnet Generator
- NEMA Class F Insulation with F Rise
- Continuous Duty Rating

Package
- Steel Base Frame with Drip Pans
- Direct-Drive AC Start System
- Natural Gas Fuel System
- Control System
  - Microprocessor-Based PLC
  - Generator Control
  - Vibration and Temperature Monitoring
  - Auto Synchronizing
- Integrated Lube Oil System
  - Turbine-Driven Lube Pump
  - AC Pre/Post Lube Pump
  - Backup Lube Pump
  - Air/Oil Cooler
  - Integral Lube Oil Tank
  - Lube Oil Tank Heater
  - Lube Oil Filter
- Documentation
  - Drawings
  - Quality Control Data Book
  - Inspection and Test Plan
  - Test Reports
  - O&M Manuals
- Factory Testing of Turbine and Package

Optional Equipment/Services
- Generator Options:
  - WPII, TEWAC
  - Standby Duty Rating
  - Standard Voltages: 3300, 6600, 11,000 50 Hz; 4160, 6900, 12,470, 13,800 60 Hz
- Fuel Systems
  - Liquid
  - Dual (Gas/Liquid)
  - SoLoNOx, Dry, Low Emission
  - Alternate Fuels (such as naphtha, propane, low Btu)
- Lube Oil System
  - Water/Oil Lube Cooler
  - Electrostatic Demister
  - Duplex Lube Oil Filters
- Control System
  - Remote Display/Control Terminal
  - Heat Recovery Application Interface
  - Serial Link Supervisory Interface
  - KW Control
  - KVAR/Power Factor Control
  - Turbine Performance Map
  - Historical Displays
  - Printer/Logger
  - Predictive Emissions Monitoring
  - Field Programming Terminal
- Accessory Equipment
  - 24-VDC Battery/Charger System
  - Turbine Cleaning System: On-Crank and On-line
  - Package Lifting Kit
- Weatherproof Acoustic Enclosure
- Ancillary Equipment: Various Air Inlet and Exhaust Systems
  - Inlet and Exhaust Silencers
  - Self-Cleaning or Prefilter/Barrier Air Inlet Filter
  - Inlet Evaporative Cooler
  - Inlet Chiller Coils
  - Ancillary Support Frame

Solar Turbines
A Caterpillar Company

CENTAUR 40
Gas Turbine Generator Set

POWER GENERATION

Nominal Performance

Output Power	3515 kWe
Heat Rate	12 910 kJ/kWe-hr (12,240 Btu/kWe-hr)
Exhaust Flow	68 365 kg/hr (150,715 lb/hr)
Exhaust Temp.	445°C (830°F)

Nominal Rating – per ISO At 15°C (59°F), at sea level

No inlet/exhaust losses

Relative humidity 60%

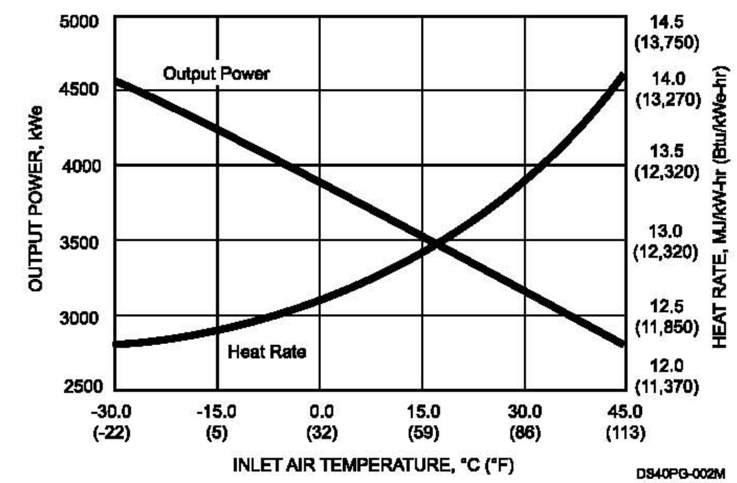
Natural gas fuel with LHV = 31.5 to 43.3 MJ/nm³ (800 to 1100 Btu/scf)

No Accessory losses

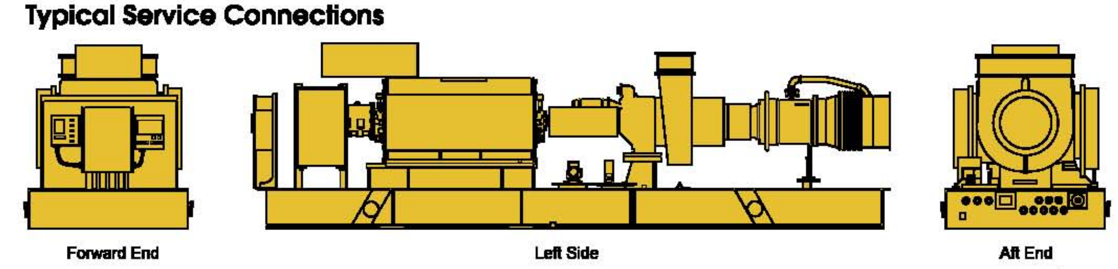
Engine efficiency: 27.9%

Standard and high-ambient ratings available

Available Power



Typical Service Connections



Package Dimensions

Length:	9754 mm (32' 0")
Width:	2438 mm (8' 0")
Height:	2591 mm (8' 6")
Approx. Weight:	26 015 kg (57,350 lb)

Forward End
- Turbine Control Box

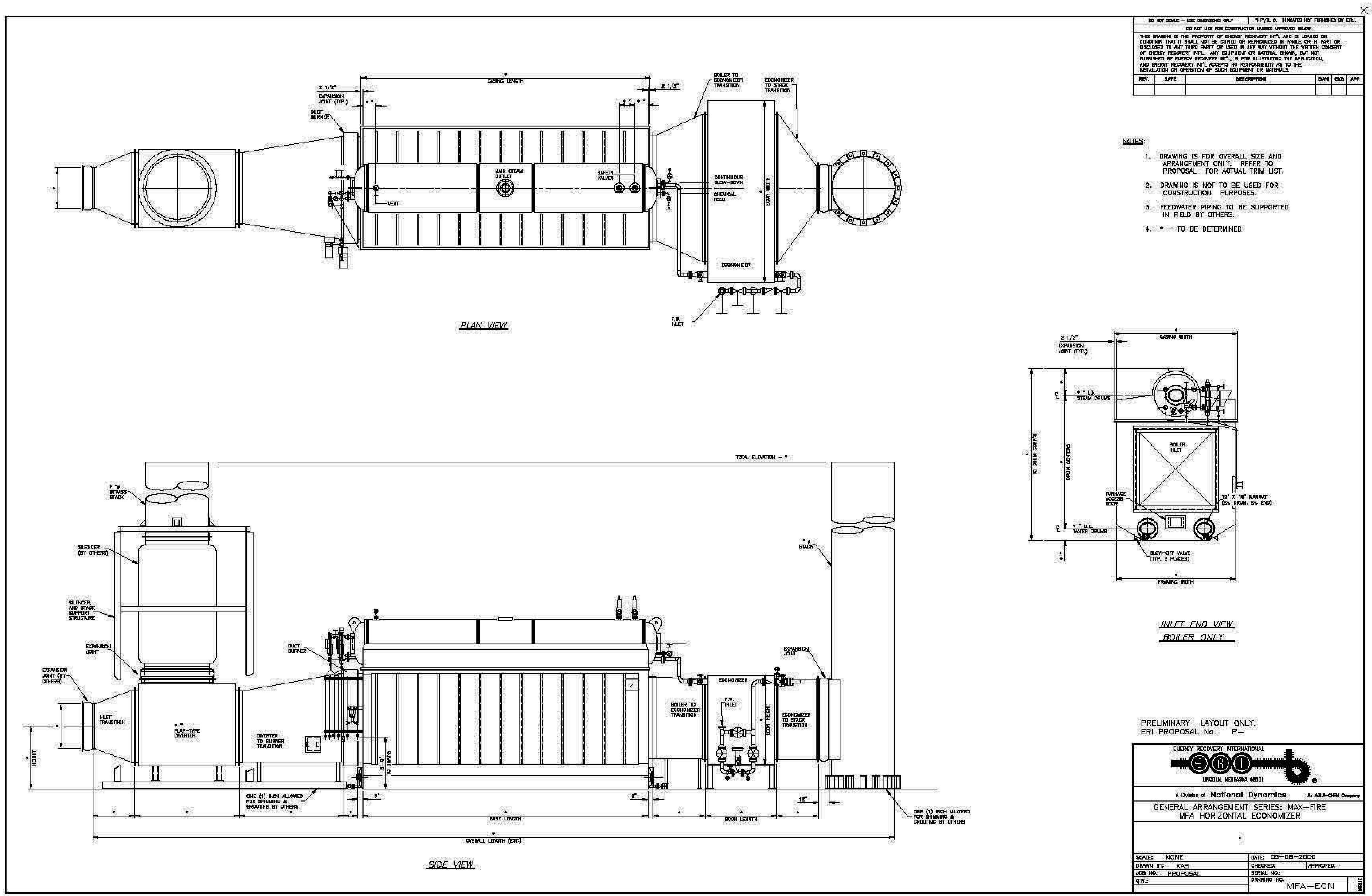
Aft End
- Fuel Inlet
- Turbine Cleaning
- Fuel Filter, Combustor and Exhaust Collector Drains
- Auxiliary Air (optional) for:
  - Liquid Fuel Atomizing
  - Self-Cleaning Filter
- AC Power
  - Liquid Fuel Pump (optional)
- Package Ground

Left Side
- Lube Oil: Drain, Vent, Cooler
- Generator Control Box, Power
- Generator Drip Pan Drain
- AC Power
  - Lube Tank Heater
  - Pre/Post Lube Pump
  - Backup Lube Pump

Right Side
- AC Power - Start Motor
- Generator Monitor Box

Solar Turbines Incorporated
P.O. Box 85376
San Diego, CA 92186-5376

FOR MORE INFORMATION
Telephone: (+1) 619-544-5352
Telefax: (+1) 858-694-6715
E-mail:powergen@solarturbines.com
Internet: www.solarturbines.com


PLAN VIEW
SIDE VIEW
INLET END VIEW
BOILER ONLY
NOTES:
1. DRAWING IS FOR OVERALL SIZE AND ARRANGEMENT ONLY. REFER TO PROPOSAL FOR ACTUAL TRIM LIST.
2. DRAWING IS NOT TO BE USED FOR CONSTRUCTION PURPOSES.
3. FEEDWATER PIPING TO BE SUPPORTED IN FIELD BY OTHERS.
4. * – TO BE DETERMINED
PRELIMINARY LAYOUT ONLY.
ERI PROPOSAL No. P–
ENERGY RECOVERY INTERNATIONAL
National Dynamics
GENERAL ARRANGEMENT SERIES: MAX–FIRE
MFA HORIZONTAL ECONOMIZER
SCALE: NONE
DATE: 05–08–2000
DRAWN BY: KAB
CHECKED:
APPROVED:
JOB NO.: PROPOSAL
SERIAL NO.:
QTY.:
DRAWING NO.
MFA–ECN
ISSUE

Typical Engine-Generator Configurations

The 4000 Series standard engineering design demonstrates how easily you can customize a system to your specific requirements.

A Master Control module and Dual Generator module comprise digital generator paralleling control switchgear for a two engine-generator emergency, standby, and prime power system.

Two modules—a Single Generator with Master Control and a Dual Generator with redundant control—comprise switchgear for a three engine power system. Three engine systems requiring redundant master control would need three modules—Master Control, Single Generator and Dual Generator.

BELOW
A Master Control module and four Dual Generator modules comprise switchgear for an eight engine-generator power system.

4000 Series System

AS YOU LEARN ABOUT THE 4000 SERIES, IT'S NATURAL TO ASK IF IT CAN SATISFY THE SPECIFIC REQUIREMENTS YOU HAVE FOR A POWER CONTROL SYSTEM.

If the system is for a healthcare facility, for example, can the touch screen quickly access JCAHO* records and information to help satisfy reporting requirements?

Does it have automatic load shed control? How about a system one line schematic overview?

The answers are, 'Yes.' What are your specific requirements?

Standard Features

- Load demand with operator adjustment of settings
- Ethernet or RS-485 connectivity to Building Management System
- Test with load
- Test without load
- Automated manual paralleling with graphical synchroscope
- Alarms
- LCD touch screen
- Automatic synchronizing and paralleling controls

Optional Features

- One touch screen per section
- Remote annunciation
- Redundant master processor
- Load control for up to 64 ATS's

* Joint Commission on Accreditation of Healthcare Organizations

Controls

- Touch screen is standard with the Master module; optional with Generator modules
- Automatic synchronizing and paralleling controls
- Touch screen has dual processors, one dedicated to logic, one to graphics
- Controls hardware
  - Dual processor control
  - Distributed processing
  - High speed CANbus

Touch Screen

- 12" color TFT on Master module
- Display on each pair of generators is optional
- System overview screen with one line schematic
- Real time clock
- JCAHO records are available if the generator(s) is/are properly equipped
- Screens:
  - Main Menu
  - System One Line Schematic
  - Metering
  - System Status
  - Alarm Status
  - ATS Status
  - Dual Metering
  - kW Trend
  - Multi-Trend
  - Manual Paralleling
  - Log In

System Control

- Automatic standby
- Load management control
- Automatic load shed control
- Controller on each generator, optional
- Redundant master controllers, optional
- Automatic generator load demand control
- Emergency stop

Engine-Generator Control

- Engine-generator of your choice
- Automatic engine start
- Adjustable engine cool-down timer
- Automatic synchronizer
- Engine governor control, load sharing, soft loading/unloading
- Voltage regulator control VAR/PF sharing
- Automated manual paralleling