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.

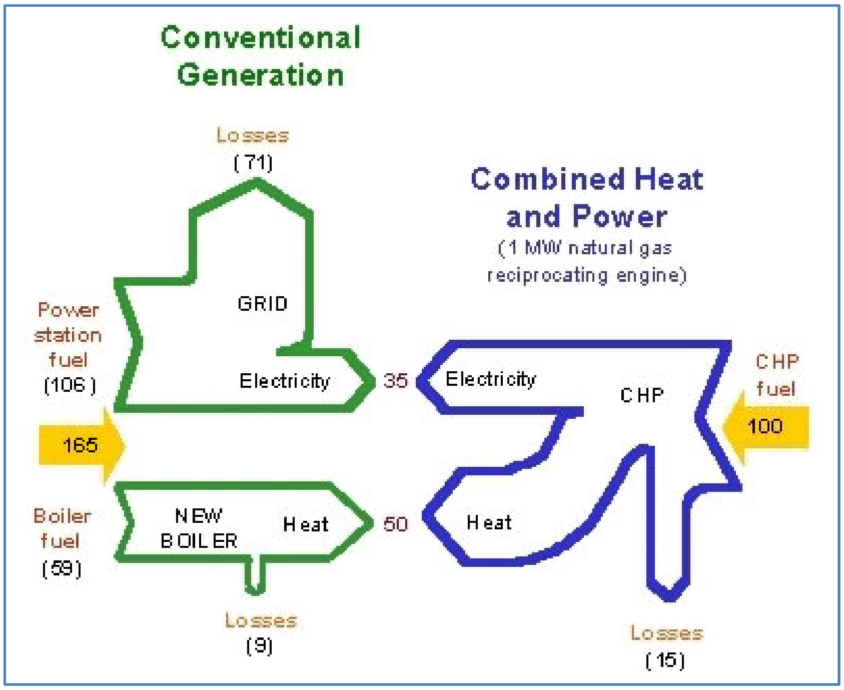

Figure 12: Separated vs. Combined Heat and Power (Source: DOE)

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.

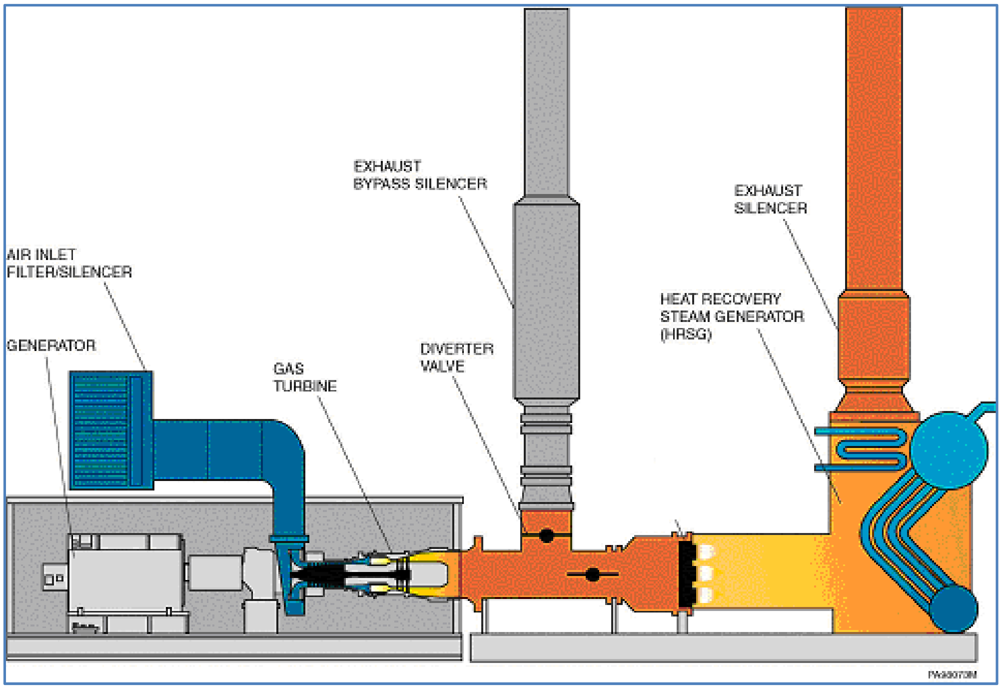

Figure 13: Typical CHP Layout (Source: Solar Turbine)

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*).