CHP Feasibility Study – Screening Analysis

ABC Hospital

Presented by

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Executive Summary

Page Southerland Page (PSP) requested a Combined Heat & Power Screening Analysis from the U.S. DOE Gulf Coast Clean Energy Application Center (GC RAC) for the ABC Hospital.

The goal of the Screening Analysis is to show the potential for CHP at a specific site and not to determine an optimal equipment set or configuration. Typically, the Screening Analysis uses monthly averages to determine savings. However, due to the wealth of hourly electric and thermal data supplied to the GC RAC, an hour-by-hour analysis was done. Three new buildings are schedlued to be constructed and their average hourly electric and thermal loads have been included as part of the analysis.

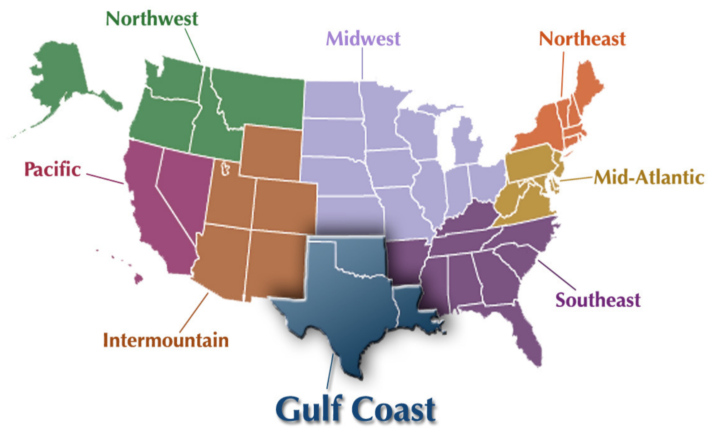
As part of the analyses, different prime-mover makes and sizes, having varying heat rates and steam production were applied to the electric and thermal loads. Primarily, gas turbines were analyzed with sizes ranging from 3.5 MW – 7.5 MW. Among the systems that were analyzed, resultant annual savings ranged between $1.3 - $2.2 million , with a simple payback between 4.4 and 6.4 years. The associated emissions reductions of CO_2 ranged between 20,073 tons/year to 43,014 tons/year.

The GC RAC believes that the ABC Hospital has excellent potential to host a Combined Heat and Power project. This Screening Analysis report presents the process used to estimate loads, selected equipment, the associated savings and environmental benefits possible with the CHP installation.

Introduction

This report was prepared by the U.S. Department of Energy's Gulf Coast Clean Energy Application Center (GC RAC). Located that the Houston Advanced Research Center in The Woodlands, Texas, the GC RAC is one of eight centers established by the U.S. Department of Energy to promote the use of combined heat and power (CHP) through outreach programs, project specific support, and policy development initiatives. The figure below, which shows all eight regions, highlights the states of Texas, Louisiana, and Oklahoma served by the GC RAC.

The GC RAC uses a two-step approach to conduct feasibility studies. The first evaluation involves a quick, inexpensive screening analysis, which is performed to assess the *potential* for CHP at a specific site. This screening study uses average electricity and natural gas utility costs, monthly energy consumption, and industry "rules-of-thumb" to estimate project costs. The screening study results in a simple payback, where annual energy savings and project capital costs are accurate to about +/-30%.



A detailed analysis is performed if the screening analysis shows sufficient potential to implement CHP at the site, then. The goal of the detailed analysis is to establish whether CHP is technically and economically *viable.* The detailed analysis uses simulation software to determine building loads on an hour-by-hour basis. Detailed load information facilitates an in depth comparison of of the conventional separate heat and power approach to the combined heat and power option. The analysis evaluates the life cycle capital and operating costs of both approaches using the discounted cash flow method. The analysis results in a financial pro forma and internal rate of return for the CHP project. To accomplish the detailed analysis, the GC RAC engaged in the following:

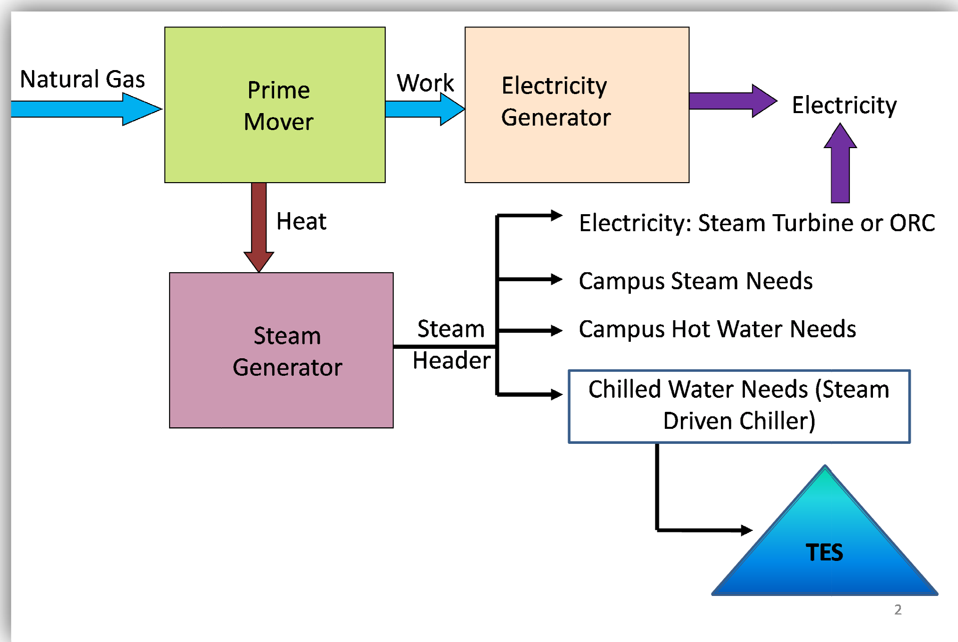
- On-site meetings including limited walkthrough site-assessment
- Data collection including building envelope characteristics, age, area, hours of operation, type of HVAC systems, current energy consumption, utility rates and costs, and additional information related to energy supply and use
- Hour by hour building simulation using DOE software
- Calibration of baseline model to actual utility bills
- Hourly simulation of electric and thermal loads with and without CHP
- Examination of alternate CHP plant configurations
- Utility rate structure analysis
- Use of financial models to generate internal rate of return

Combined Heat and Power Overview

The combined heat and power (CHP) approach can provide steam and electricity to ABC Hospital at a much higher energy efficiency, generating electricity on-site, while using the resulting heat to off-set boiler and electric chiller use. The CHP approach typically consume 40% less fuel than the conventional separate heat and power approach, which results in cost savings and environmental benefits. CHP systems provide a similar degree of cooling and heating comfort and indoor air quality, while delivering a superior level of power reliability and power quality. A schematic comparing the two approaches is provided at the right.

In its simplest form, CHP involves a conventional natural gas fired engine[1] that turns a generator to make electricity. Hot gases created by combusting the natural gas are captured by a heat exchanger to produce steam or hot water. If the site has a steam need equal to or larger than the amount produced by the CHP system, then all of the resulting steam can be used to reduce boiler operations, thereby saving the natural gas normally consumed in the boiler. The most common alternate use is to make chill water by using the steam to drive a stream powered chiller, such as an absorption chiller or steam turbine chiller, which is the approach considered in this report. In some cases, excess steam can be used to generate additional electricity, using a steam turbine or organic rankine cycle technology, although this option is not considered in this analysis. Typical configuration of CHP systems and common uses of the waste heat are shown in Figure 1.

Figure 1. *Combined Heat & Power : Typical CHP System Configuration*



[1] In this case, "engine" is a general term that could refer to number of different types of prime movers including combustion turbines, micro-turbines, reciprocating engines, and fuel cells. For purposes of this study, only reciprocating engines have been evaluated.

Facility Profile

ABC Hospital is a full service hospital and part of the Texas health Care System. Currently, the hospital is served by a combination of steam driven and electric chillers to meet its cooling demand. On-site boilers provide steam to drive the steam chillers and for other heating needs at the hospital. Three new buildings are scheduled for construction, thereby adding to the existing electric and thermal loads. All of the data has been aggregated based on input from PSP. Figure 2 through Figure 6 depict the electric and thermal load shapes for both the existing (blue stack) and new construction (red stack) buildings.

Figure 2. *Monthly Peak Demand Profile*

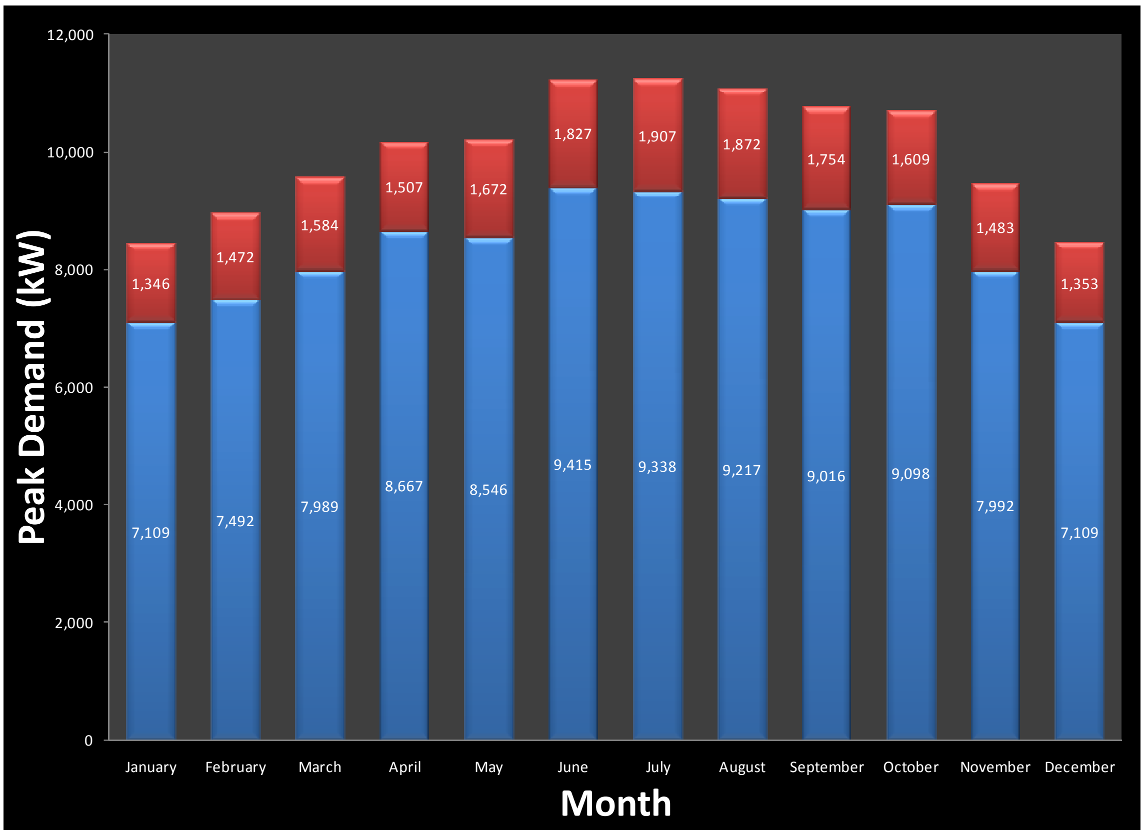


Figure 3. *Monthly Electricity Consumption*

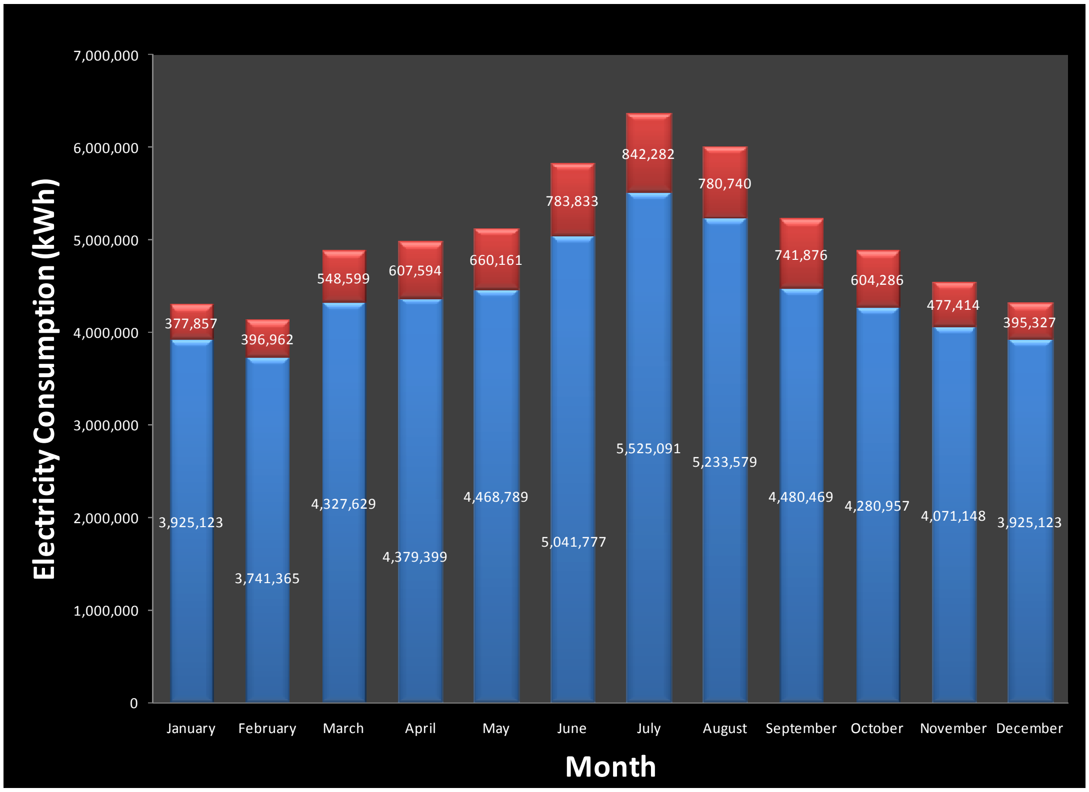


Figure 4. *Monthly Gas Use*

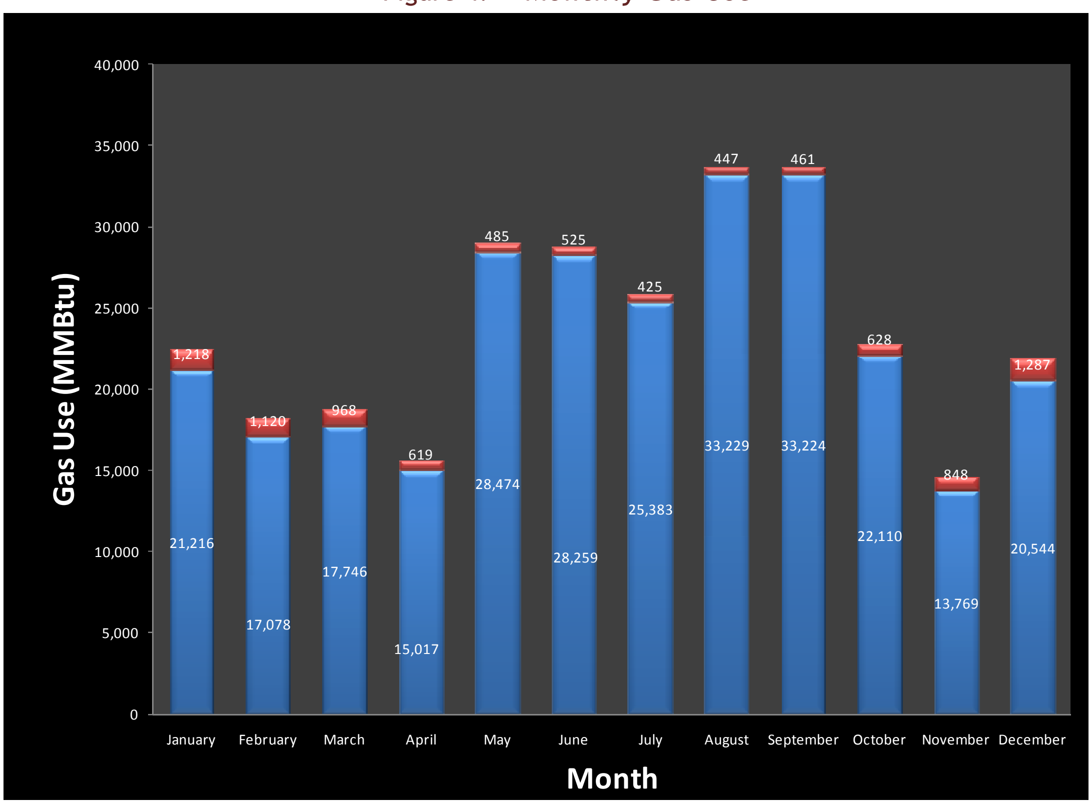


Figure 5. *Hourly Electric Profile : Full Year(Existing+New)*

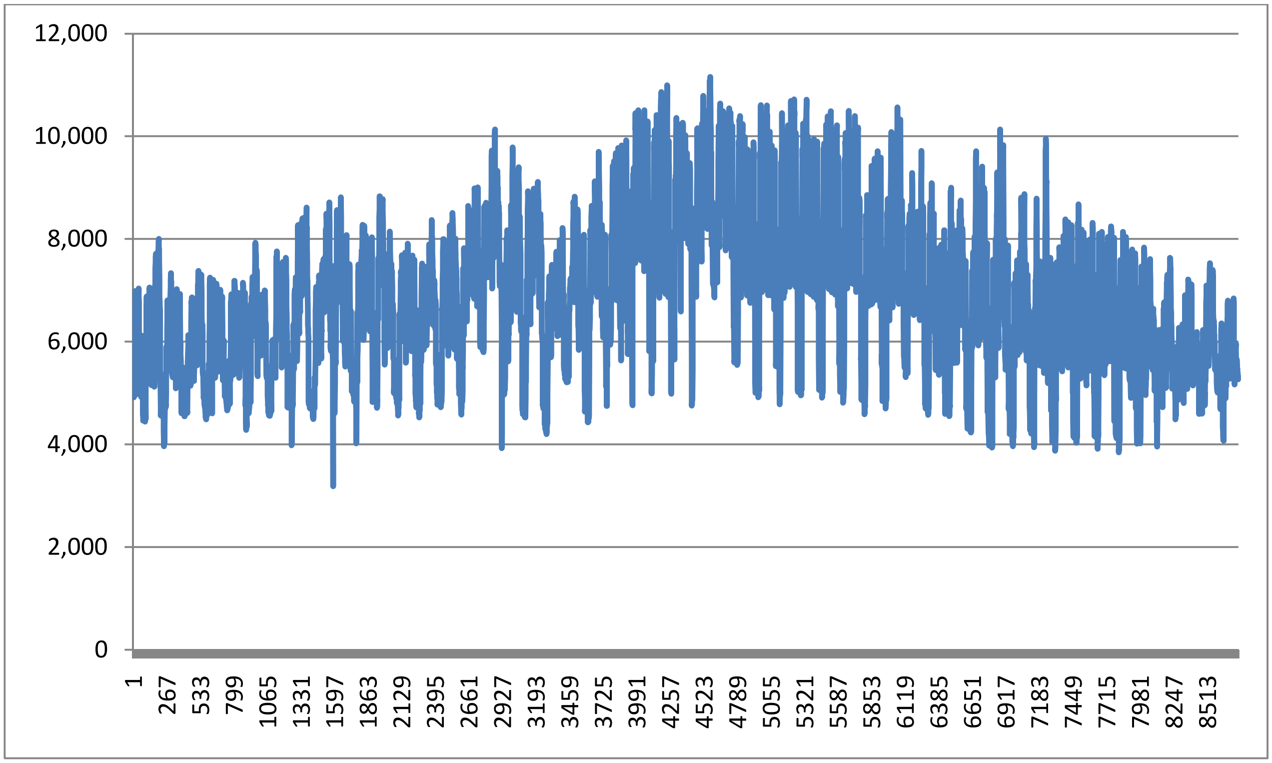


Figure 6. *Hourly Steam Profile : Full Year (Existing+New)*

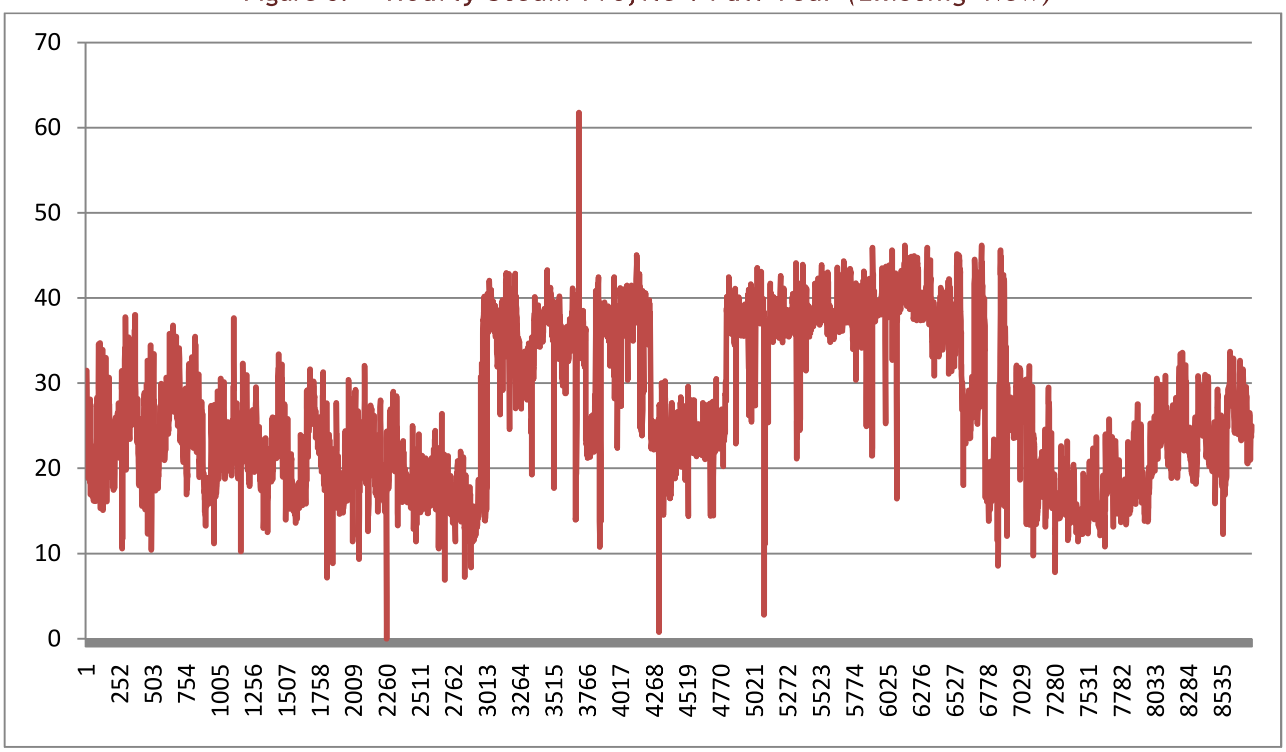


Table 2 lists the rates assumed as part of the analysis.

Table 1. **Rates**

Parameter	Cost ($/unit)
Blended Electricity Charge ($/kWh)	$0.08
Gas Costs ($/MMBtu)	$6.00

Preliminary Assessment

Different plant configurations were analyzed as part of the screening analysis. The configurations differed in the utilization of the recovered waste heat, the size of the CHP plant and the associated capital required. All the analyses were restricted to ensure that a majority of the heat and electricity generated was consumed on-site. *Export options have not been investigated.* The product data for the analyzed turbines is summarized in Table 2.

Table 2. **Analyzed Options : Product Data**

	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8
Manufacturer	Solar Turbines	Solar Turbines	Solar Turbines	Solar Turbines	Siemens	Siemens	Kawasaki	Kawasaki
Model	Centaur 40	Mercury 50	Taurus 60	Taurus 70	SGT-100	SGT-200	GPB - 60D	GPB - 70D
Full Load Capacity (kW)	3,500	4,600	5,700	7,500	5,250	6,750	5,280	6,530
Fuel Input (therms)	427	405	610	753	588	731	658	789
Steam Output (lbs/hr)	19,600	13,800	29,800	34,400	29,211	34,906	32,414	36,383

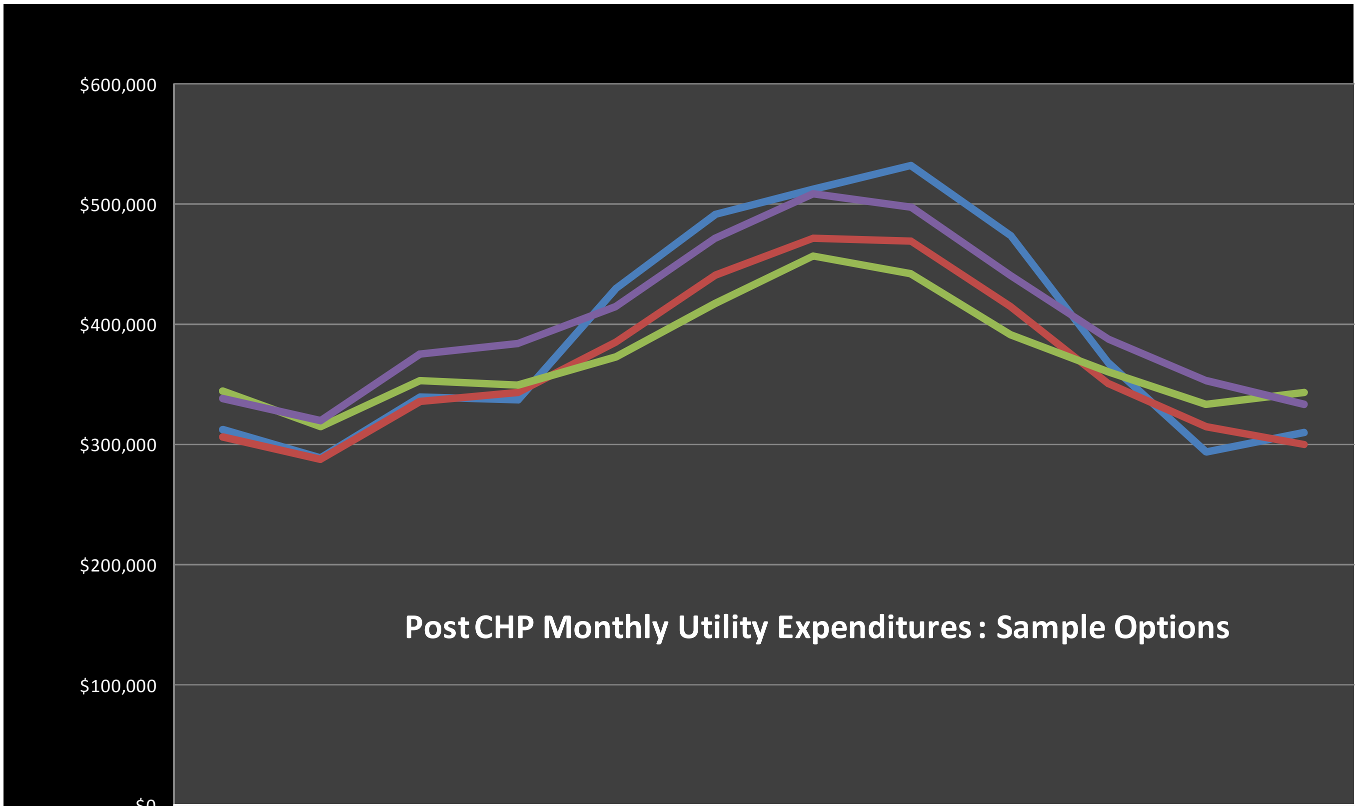
The on-site electricity consumption, heat utilization, savings and simple payback costs have been summarized in Table 3.

Table 3. **Analyzed Options : Results**

Prime Mover	Rated Capacity (kW)	Annual Average On-Site Electric Utilization (%)	Annual Average On-Site Heat utilization (%)	Annual Savings ($)	Estimated Capital Costs [2] ($)	Simple Payback (yrs)
Centaur 40	3,500	100%	97%	$1,345,634	$6,490,575	4.82
Mercury 50	4,600	100%	100%	$1,870,547	$8,277,976	4.43
Taurus 60	5,700	97%	83%	$2,142,632	$9,944,619	4.64
Taurus 70	7,500	87%	77%	$2,190,343	$12,411,375	5.67
SGT-100	5,250	98%	84%	$2,004,727	$9,277,406	4.63
SGT-200	6,750	91%	76%	$2,080,901	$11,422,856	5.49
GPB - 60D	5,280	98%	79%	$1,736,853	$9,322,516	5.37
GPB - 70D	6,530	92%	74%	$1,721,620	$11,122,242	6.46

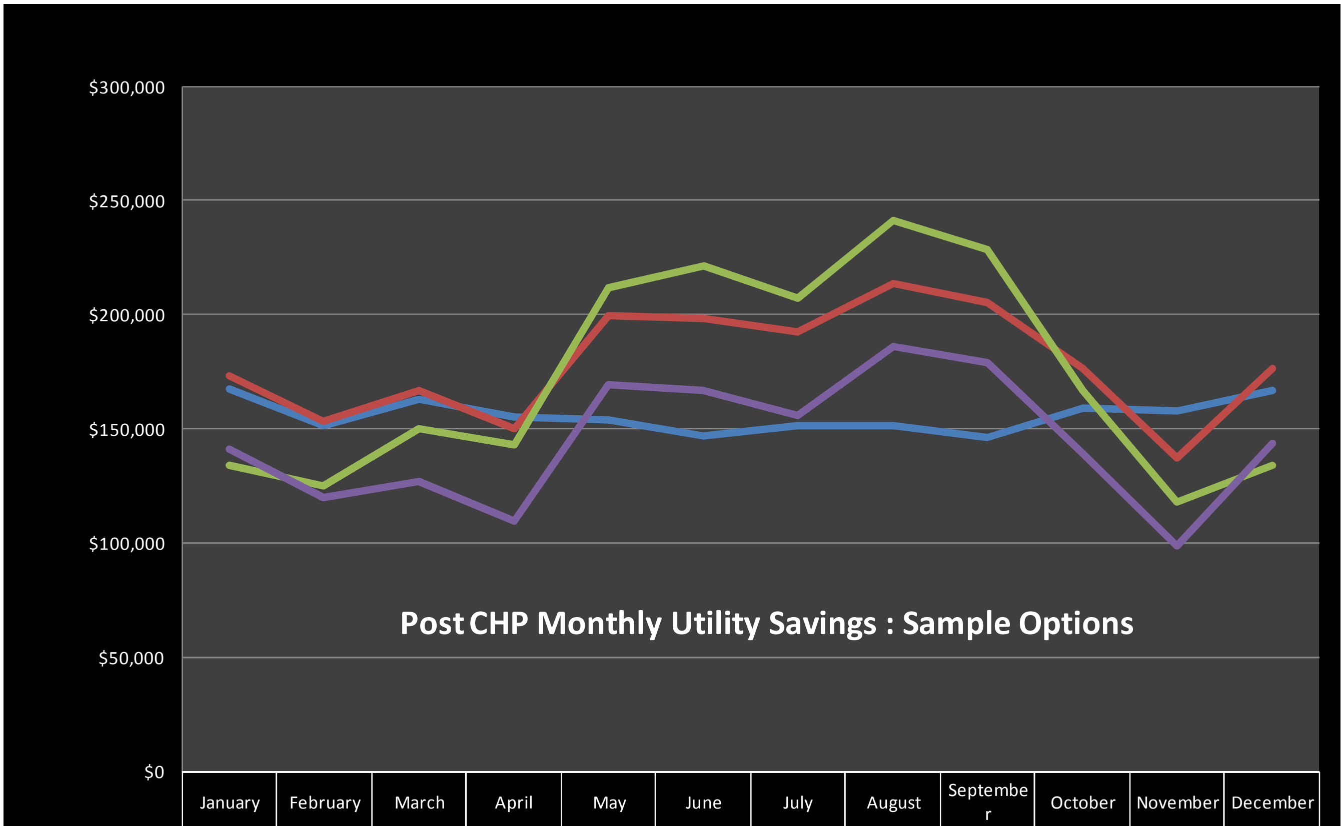
[2] Capital Costs are as-built costs, including prime-mover, HSRG, related equipment & controls, design and labour. They have been estimated based on rules of thumb, derived from past manufacturer quotes. They can increase or decrease based on a variety of site-specific parameters and related market factors.

Figure 7. *Post CHP Monthly Utility Expenditures : Sample Options*



	January	February	March	April	May	June	July	August	September	October	November	December
Mercury 50	$311,724	$289,140	$339,214	$337,334	$430,086	$491,571	$512,749	$531,770	$473,885	$368,206	$293,756	$309,884
Taurus 60	$305,879	$287,200	$335,817	$342,553	$384,554	$440,312	$471,651	$469,327	$414,791	$350,957	$314,227	$299,963
SGT-200	$344,886	$314,945	$352,588	$349,548	$372,214	$417,535	$456,970	$441,648	$391,590	$360,507	$333,849	$342,682
GPB - 60D	$337,718	$320,124	$375,521	$383,401	$414,604	$471,712	$508,495	$496,894	$440,960	$387,801	$352,896	$332,886

Figure 8. *Post CHP Monthly Savings: Sample Options*



	January	February	March	April	May	June	July	August	September	October	November	December
Mercury 50	$167,118	$151,115	$163,164	$155,443	$153,986	$147,179	$151,492	$151,433	$146,010	$159,039	$157,832	$166,737
Taurus 60	$172,963	$153,054	$166,561	$150,223	$199,518	$198,437	$192,589	$213,876	$205,103	$176,288	$137,361	$176,657
SGT-200	$133,956	$125,310	$149,790	$143,228	$211,858	$221,214	$207,271	$241,554	$228,305	$166,738	$117,739	$133,939
GPB - 60D	$141,124	$120,131	$126,857	$109,376	$169,468	$167,038	$155,745	$186,309	$178,935	$139,444	$98,692	$143,735

Table 4 & Table 5 illustrate the potential environmental benefits and associated reductions in greenhouse gases for a 4.6 MW CHP Plant and a 6.7 MW CHP Plant respectively . The reductions have been calculated using the Environmental Protection Agency's (EPA) emissions calculator.

Table 4. **Environmental Analysis : 4.6 MW CHP Plant**

Annual Emissions Analysis					
	CHP System	Displaced Electricity Production	Displaced Thermal Production	Emissions/Fuel Reduction	Percent Reduction
NOx (tons/year)	1.82	24.33	8.42	30.94	94%
SO2 (tons/year)	0.14	74.34	0.10	74.30	100%
CO2 (tons/year)	26,750	33,469	19,663	26,382	50%
Carbon (metric tons/year)	6,614	8,275	4,862	6,523	50%
Fuel Consumption (MMBtu/year)	458,434	408,049	336,985	286,600	38%
Acres of Forest Equivalent				5,436	
Number of Cars Removed				4,358	

Table 5. **Environmental Analysis : 6.7 MW CHP Plant**

Annual Emissions Analysis					
	CHP System	Displaced Electricity Production	Displaced Thermal Production	Emissions/Fuel Reduction	Percent Reduction
NOx (tons/year)	2.65	35.44	12.27	45.06	94%
SO2 (tons/year)	0.20	108.27	0.14	108.22	100%
CO2 (tons/year)	38,961	48,748	28,640	38,426	50%
Carbon (metric tons/year)	9,634	12,053	7,081	9,501	50%
Fuel Consumption (MMBtu/year)	667,719	594,333	490,826	417,440	38%
Acres of Forest Equivalent				7,918	
Number of Cars Removed				6,347	

Discussion

Capital Cost Factors

Certain factors that can significantly affect the project's upfront capital requirement including. At the current time they have not been analyzed in detail:

- Site specific construction costs – Site specific construction costs could vary from the estimated capital costs.
- Capital budget plans – potential future costs incurred to replace aging chillers, cooling towers, backup generators, boilers, and related equipment or to expand the facility capabilities can be offset by a new CHP plant. To the extent this equipment can be avoided, these costs could be subtracted from the capital cost of a CHP plant, thereby reducing the simple payback.
- Utility Incentives – the Public Utility Commission of Texas allows CHP projects less than 10 MW to participate in and earn an incentive through utility Standard Offer Programs. Contact Oncor for more information about this program.
- Investment Tax Credit – the IRS allows a 10% ITC for CHP projects. Congress is currently considering increasing the ITC to 30%. (if taxpaying entity)
- Rapid Depreciation – the IRS allows for rapid depreciation of CHP projects. (if taxpaying entity)

Energy Costs

The relative costs of electricity and natural gas are paramount in determining the annual savings achieved by the CHP options. With the installation of the CHP Plant, the site would likely have more flexibility to pursue better pricing for natural gas supplies. Certain factors such as electricity rate increases have not been factored into the current calculations.

Operating Strategy

Currently, the steam chillers operate in summer-time only. Operating the steam chillers year-round can increase the steam load during the winter months, while reducing the electric loads. Under this operating strategy, a CHP plant with a greater capacity can potentially be more efficient, resulting in greater savings and faster paybacks.

Electric vs. Steam Chiller

The potential to install steam chillers in lieu of electric chillers exist for the new construction. This can increase the steam load and potentially increase size and efficiency of the CHP Plant. Under this scenario, greater savings and faster paybacks are possible.

Export Power

The analysis does not assume any credit for potential export power. A CHP Plant, matching the entire thermal load, could at times export electricity to the grid. This can result in a revenue stream, potentially resulting in faster paybacks.

Summary

Based on the Screening Analysis, U.S. DOE Clean Energy Application Center believes that the ABC Hospital has excellent potential for CHP. Should sufficient interest exist to investigate the CHP options further, the Center can perform a more detailed CHP analysis. In addition to improving the accuracy of savings and costs, the detailed analysis will determine whether CHP is a viable option from a technical and financial perspective. Refinements to the hourly load profiles, inclusion of financial models and other pertinent software will be part of the detailed analysis. Appended below are some of the key activities that would be included as part of the Detailed Analysis

- Evaluation of site specfic construction requirements and costs
- Avoided Costs Examination
- Review of Electricity (demand charges, ratchet clauses) and Gas Rate Structures
- Review of Operating Strategy
- Review of alternate scenarios and CHP Plant configurations
    - Steam Chillers vs. Electric Chillers
    - Absorption Chiller
    - Organic Rankine Cycle
- Refinements to the hour-by-hour analysis by calibration to model inputs
- Increased accuracy and refinements to capital Cost estimates using budgetary quotes from vendors
- Sensitivity analysis regarding natural gas and electricity pricing
- Inclusion of Incentives, Investment Tax Credit (ITC) and Depreciation Rates, if applicable
- Generation of Internal Rate of Return and Life Cycle Costing

APPENDIX A – Useful Links & More Information

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U.S. DOE Gulf Coast Clean Energy Application Center

- http://www.gulfcoastcleanenergy.org/

U.S. DOE Industrial Technologies Program

- http://www1.eere.energy.gov/industry/distributedenergy/

U.S. EPA CHP Partnership

- http://www.epa.gov/chp/

Texas CHP Initiative

- http://www.texaschpi.org/

U.S. Clean Heat and Power Association

- http://www.uschpa.org/