CHP Feasibility Study – Screening Analysis

ABC Office

Presented by

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Executive Summary

The ABC Office is a 49 story building in downtown Houston, primarily housing office space. XYZ, owner of the building had requested a Combined Heat & Power Screening Analysis from the US DOE Gulf Coast Clean Energy Application Center.

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 on/off operation of the building during the weekdays and limited operation in the weekends, an hour-by-hour analysis of the electric and thermal loads was deemed necessary. As a result, the building was modeled using DOE 2.1 software and an hour-by-hour analysis was used to determine the loads and expected utility cost savings.

Due to the excellent part-load operation of engines relative to combustion turbines, a lean burn reciprocating engine was selected as a prime-mover in the analysis. Two CHP Plant configurations were analyzed:

1000 kW Cummins lean burn reciprocating engine with heat recovery unit and 210 ton absorption chiller

2,000 kW Cummins lean burn reciprocating enering with heat recovery unit and 420 ton absorption chiller

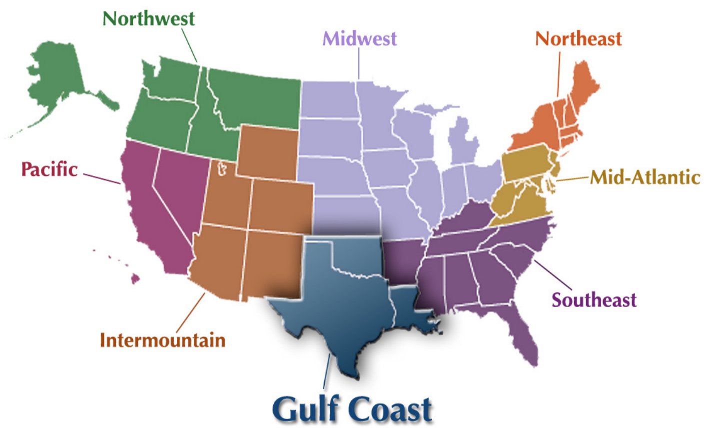
The analysis indicated associated annual utility cost savings were $386,923 and $478,816 for the 1,000 kW and 2,000 kW CHP plant, resulting in a simple payback of 4.7 and 7.8 years respectively.

The US DOE Gulf Coast Clean Energy Application Center believes that the ABC Office has 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 a CHP installation at ABC Office.

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:

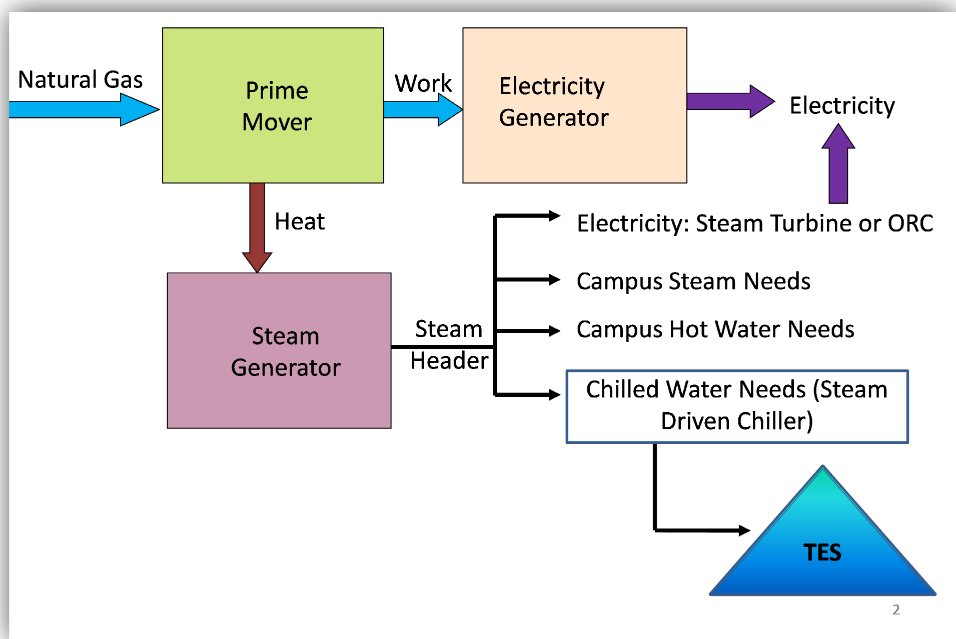
- On-site meetings including limited walkthrough site-assessment
- Data collection including building envelope characteristics, age, area, hours of operation, type of HVAC systems, current energy consumption, utility rates and costs, and additional information related to energy supply and use
- Hour 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 chill water, hot water, and electricity to ABC Office 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

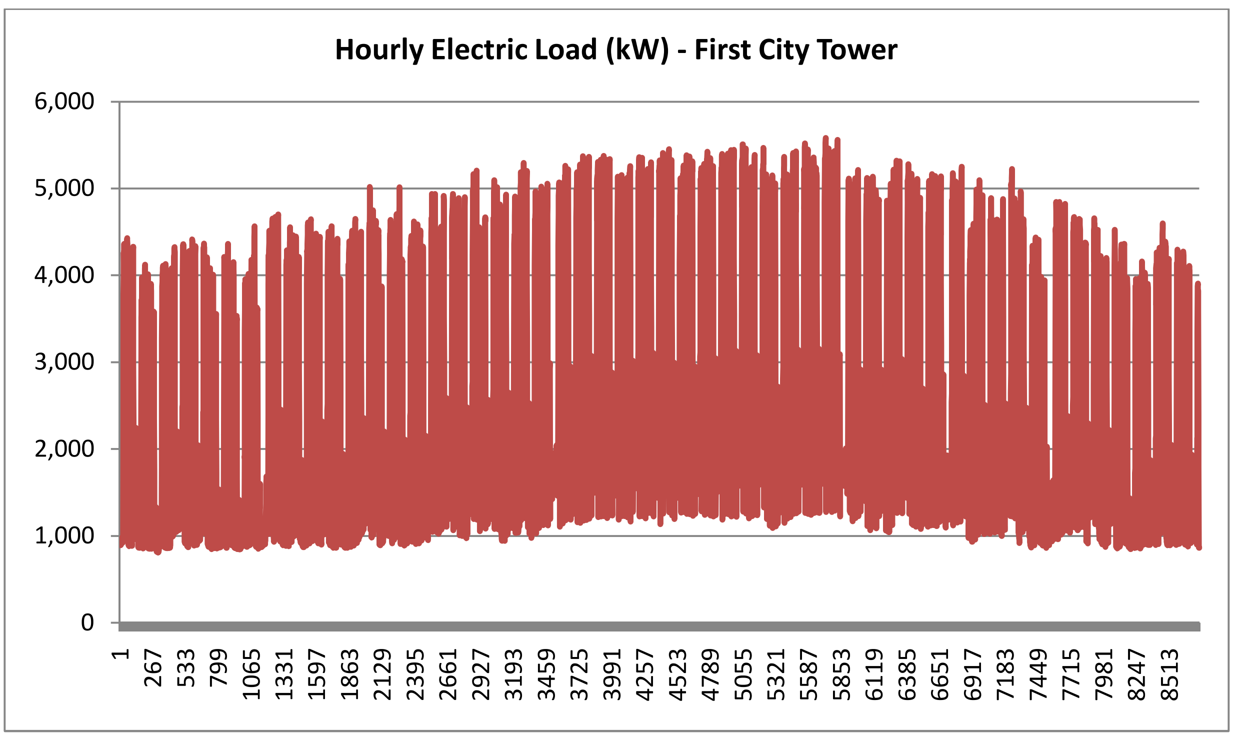
The ABC Office is a 49 story building in downtown Houston, primarily housing office space. The first 47 floors contain 1,278,867 square feet of office space while floors 48 & 49 contain 26,331 square feet of storage.

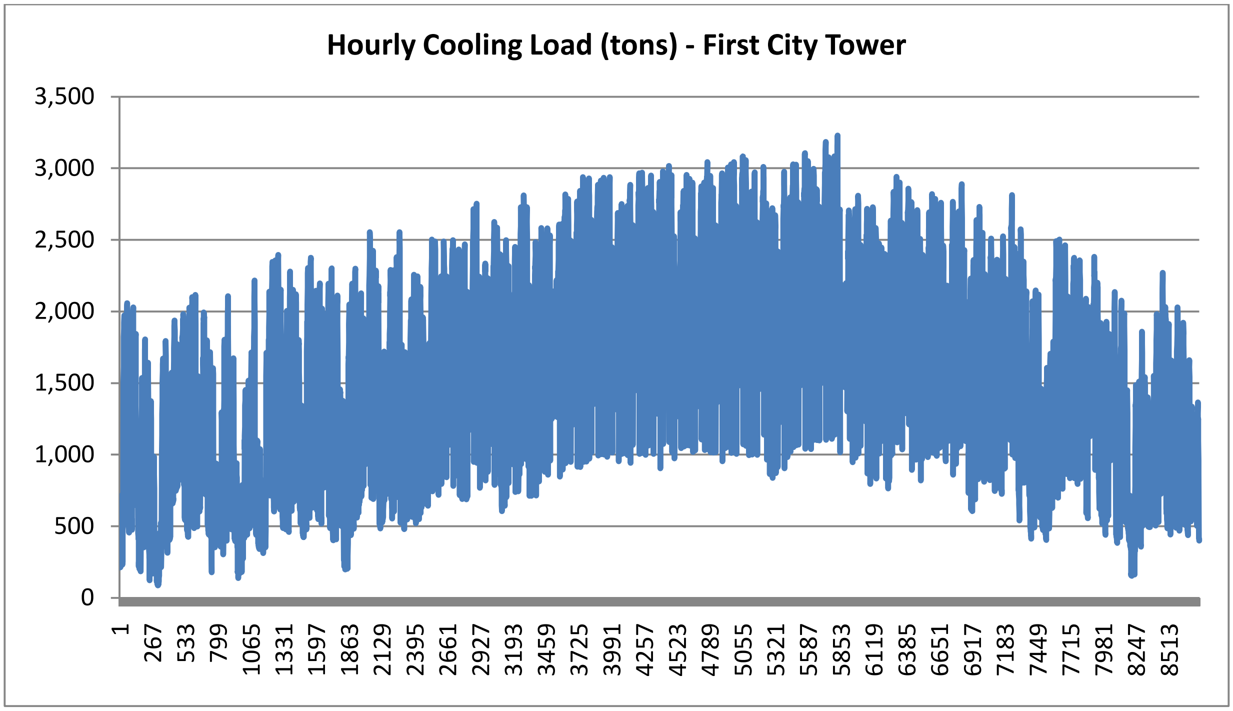
Load Determination

Typically, monthly averages are used in the Screening Analysis. However, due to the varied loads at ABC Office, this approach was deemed unsuitable. Certain inputs from the building personnel along with typical office building characteristics were used and the building was modeled using Building Energy Analyzer™ Pro (BEA Pro).

At the backbone of the software tool is a DOE-2.1e simulation engine which uses Typical Meteorological Year – data set 2 (TMY2) to simulate building loads. BEA Pro uses 8,760 hourly increments for modeling a year to mitigate the risks associated with simulation using longer time spans. Hourly heating coil load, cooling coil load, electric consumption and gas use modeled by BEA Pro are among the key outputs used in the load determination at ABC Office.

As per communique with facility personnel, the building operates between 7:00 AM – 7:00 PM during weekdays and between 8 AM – 1 PM on Saturdays. The charts below show the modeled hourly electric loads and chill water tonnage for the whole year at ABC Office.





The electric consumption and gas use was compared to actual utility bills. Table 1 lists the peak demand, electricity consumption and costs as modeled by the load. Table 2 lists the rates assumed as part of the analysis.

Table 1. **Electricity Consumption & Costs**

Month	Peak Demand (kW)	Monthly Electricity Consumption (kWh)	Electricity Costs ($)	Thermal Load (MMBTU)
January	4,430	1,417,405	$97,066	8,543
February	4,701	1,268,523	$86,871	7,771
March	5,020	1,543,941	$105,732	10,656
April	5,167	1,623,912	$111,208	12,552
May	5,295	1,835,610	$125,706	15,114
June	5,376	1,972,700	$135,094	17,331
July	5,510	2,056,398	$140,826	18,393
August	5,584	2,110,413	$144,525	18,626
September	5,319	1,812,760	$124,141	16,017
October	5,251	1,803,297	$123,493	14,923
November	4,967	1,523,699	$104,345	11,557
December	4,597	1,391,546	$95,295	8,883
Totals	**5,584**	**20,360,205**	**$1,394,301**	**160,364**

Table 2. **Rates**

Parameter	Cost ($/unit)
Demand Charge ($/kW)	$8.317
Electricity Charge ($/kWh)	$0.068
Gas Costs ($/therm)	$0.60

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 was utilized to useful work and all of the electricity generated was consumed on-site. A turbine in conjunction with an absorption chiller and a thermal energy storage tank was analyzed. Due to the excellent part load operation and lower capital costs, reciprocating engines were deemed the more appropriate choice as the prime-mover for ABC Office.

CHP Plant configuration

As a result of the analysis of the various system types, a CHP system consisting of a reciprocating engine, heat exchanger and absorption chiller was selected, primarily due to the excellent part load operation of engines. Both engines use the Advanced Reciprocating Engines Systems (ARES) technology. The US DOE ARES program promotes cooperation between engine manufacturers, universities, national laboratories, and engine consultants to obtain maximum engine efficiency and low emissions from natural gas reciprocating engines for power generation. Details with regards to the ARES program and detailed product cut sheets can be found in Appendix B. The product data for the selected engines is summarized in Table 3.

Table 3. **Cummins Engine – Product specifications**

	Option 1	**Option 2**
Model	Cummins C1000 N6C	Cummins C2000 N6C
Rated Capacity (Full Load)	1,000 kW	2,000 kW
Fuel Input (kW)	2,370 kW	5,398 kW
Usable heat (kW)	1,107 kW	2,943 kW
Absorption Chiller (tons)	210	420

The demand, electric consumption, gas consumption and costs were compared between the existing scenario (without CHP) and a scenario with the afore-mentioned CHP systems. Table 4 & Table 5 illustrate the results of the analysis.

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Table 4. **Energy & Cost Analysis - 1,000 kW Reciprocating Engine**

	Without CHP					With CHP						
Month	**Demand (kW)**	**Electricity Consumption (kWh)**	**Electricity Costs ($)**	**Demand Costs ($)**	**Gas Costs ($)**	**Demand (kW)**	**Electricity Consumption (kWh)**	**Engine Fuel (Therms)**	**Electricity Costs ($)**	**Demand Costs ($)**	**Gas Costs ($)**	**Savings ($)**
January	4,430	1,447,660	$99,138	$36,843	$906	3,220	650,525	34,774	$44,549	$27,970	$34,774	$29,595
February	4,701	1,283,153	$87,873	$39,099	$761	3,491	569,652	31,289	$39,011	$30,228	$31,289	$27,205
March	5,020	1,554,949	$106,486	$41,748	$862	3,810	741,002	35,213	$50,745	$32,878	$35,213	$30,261
April	5,167	1,623,912	$111,208	$42,978	$807	3,957	794,114	34,672	$54,382	$34,107	$34,672	$31,833
May	5,295	1,835,610	$125,706	$44,043	$799	4,085	948,653	35,989	$64,965	$35,166	$35,989	$34,428
June	5,376	1,972,700	$135,094	$44,717	$729	4,166	1,101,796	34,841	$75,453	$35,835	$34,841	$34,413
July	5,510	2,056,398	$140,826	$45,830	$689	4,300	1,156,269	36,002	$79,183	$36,943	$36,002	$35,217
August	5,584	2,110,413	$144,525	$46,441	$721	4,374	1,210,773	36,002	$82,916	$37,551	$36,002	$35,218
September	5,319	1,812,760	$124,141	$44,239	$613	4,109	945,404	34,841	$64,743	$35,349	$34,841	$34,061
October	5,251	1,803,297	$123,493	$43,671	$711	4,041	921,045	35,981	$63,075	$34,782	$35,981	$34,037
November	4,967	1,523,699	$104,345	$41,310	$687	3,757	706,057	34,417	$48,352	$32,426	$34,417	$31,148
December	4,597	1,401,915	$96,006	$38,238	$753	3,387	602,521	34,867	$41,262	$29,360	$34,867	$29,509
Totals		**20,426,466**	**$1,398,839**	**$509,158**	**$9,040**		**10,347,808**	**383,978**	**$708,636**	**$402,593**	**$418,885**	**$386,923**

Table 5. **Energy & Cost Analysis – 2,000 kW Reciprocating Engine**

	Without CHP					With CHP						
Month	**Demand (kW)**	**Electricity Consumption (kWh)**	**Electricity Costs ($)**	**Demand Costs ($)**	**Gas Costs ($)**	**Demand (kW)**	**Electricity Consumption (kWh)**	**Engine Fuel (Therms)**	**Electricity Costs ($)**	**Demand Costs ($)**	**Gas Costs ($)**	**Savings ($)**
January	4,430	1,447,660	$99,138	$36,843	$906	2,010	309,799	60,585	$21,216	$18,556	$60,585	$36,531
February	4,701	1,283,153	$87,873	$39,099	$761	2,281	273,870	54,039	$18,755	$20,814	$54,039	$34,124
March	5,020	1,554,949	$106,486	$41,748	$862	2,600	371,065	62,285	$25,411	$23,464	$62,285	$37,936
April	5,167	1,623,912	$111,208	$42,978	$807	2,747	404,435	63,425	$27,696	$24,693	$63,425	$39,179
May	5,295	1,835,610	$125,706	$44,043	$799	2,875	489,813	69,222	$33,543	$25,752	$69,222	$42,031
June	5,376	1,972,700	$135,094	$44,717	$729	2,956	575,831	71,302	$39,434	$26,421	$71,302	$43,384
July	5,510	2,056,398	$140,826	$45,830	$689	3,090	598,808	74,540	$41,007	$27,529	$74,540	$44,268
August	5,584	2,110,413	$144,525	$46,441	$721	3,164	639,342	74,675	$43,783	$28,137	$74,675	$45,092
September	5,319	1,812,760	$124,141	$44,239	$613	2,899	462,783	69,595	$31,692	$25,935	$69,595	$41,772
October	5,251	1,803,297	$123,493	$43,671	$711	2,831	477,967	68,349	$32,732	$25,368	$68,349	$41,425
November	4,967	1,523,699	$104,345	$41,310	$687	2,547	349,787	61,766	$23,954	$23,012	$61,766	$37,611
December	4,597	1,401,915	$96,006	$38,238	$753	2,177	283,699	60,159	$19,428	$19,946	$60,159	$35,463
Totals	**5,584**	**20,426,466**	**$1,398,839**	**$509,158**	**$9,040**	**3,164**	**5,237,200**	**789,944**	**$358,652**	**$289,625**	**$789,944**	**$478,816**

Table 6 summarizes the installed costs, potential credits and incentives, annual savings and the corresponding simple payback for the analyzed CHP Systems.

Table 6. **Economic Summary**

	1,000 kW	2,000 kW
Annual Utility Costs - No CHP ($)	$1,917,037	$1,917,037
Annual Utility Costs - With CHP ($)	$1,530,114	$1,438,222
Annual Savings ($)	$386,923	$478,816
Estimated Capital Costs ($)	$2,200,000	$4,400,000
Incentives ($)	$145,382	$246,977
Investment Tax Credits ($)	$220,000	$440,000
Simple Payback (yrs)	4.7	7.8

Table 7 & Table 8 illustrate the environmental benefits and associated reductions in greenhouse gases for the two options. The reductions have been calculated using the Environmental Protection Agency's (EPA) emissions calculator.

Table 7. **Environmental Analysis – 1,000 kW Reciprocating Engine**

Annual Emissions Analysis					
	CHP System	Displaced Electricity Production	Displaced Thermal Production	Emissions/Fuel Reduction	Percent Reduction
NOx (tons/year)	0.39	5.79	0.09	5.49	93%
SO2 (tons/year)	0.01	17.68	0.00	17.67	100%
CO2 (tons/year)	2,870	7,961	107	5,199	64%
Carbon (metric tons/year)	710	1,969	26	1,285	64%
Fuel Consumption (MMBtu/year)	49,187	97,067	1,837	49,716	50%
Acres of Forest Equivalent				**1,071**	
Number of Cars Removed				**859**	

Table 8. **Environmental Analysis – 2,000 kW Reciprocating Engine**

Annual Emissions Analysis					
	CHP System	Displaced Electricity Production	Displaced Thermal Production	Emissions/Fuel Reduction	Percent Reduction
NOx (tons/year)	0.63	9.37	0.15	8.89	93%
SO2 (tons/year)	0.02	28.63	0.00	28.61	100%
CO2 (tons/year)	4,647	12,890	174	8,417	64%
Carbon (metric tons/year)	1,149	3,187	43	2,081	64%
Fuel Consumption (MMBtu/year)	79,637	157,157	2,974	80,494	50%
Acres of Forest Equivalent				**1,734**	
Number of Cars Removed				**1,390**	

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 of $2,200/kW that the GCRAC received from Cummins.
- 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.
- Investment Tax Credit – the IRS allows a 10% ITC for CHP projects. Congress is currently considering increasing the ITC to 30%.
- Rapid Depreciation – the IRS allows for rapid depreciation of CHP projects.
- 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.

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.

Permitting

The site will need to permit the CHP Plant for NO_x emissions. Since the site is located in downtown Houston, a non-attainment area, selective catalytic reduction (SCR) would need to be installed as part of the overall installation of the CHP plant. The basic principle of SCR is the reduction of NO_x to N_2 and H_2O by the reaction of NO_x and ammonia (NH_3) within a catalyst bed. The use of SCR has enabled projects in the Methodist Hospital & TECO, located in the Houston Medical Center District to obtain an air-permit.

Summary

Based on the Screening Analysis, U.S. DOE Clean Energy Application Center believes that the ABC Office has 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. Detailed engineering calculations using hourly load profiles, financial models and other pertinent software will be used as part of the detailed analysis. Appended below are some of the key activities that would be included as part of the Detailed Analysis

- Walkthrough site assessment, interviews with staff and review of EMCS data
- Evaluation of site specfic construction requirements and costs
- Review of the Existing Electric Service Infrastructure
- Review of the Existing Gas Service Infrastructure
- Review of Electricity (demand charges, ratchet clauses) and Gas Rate Structures
- Review of alternate scenarios and CHP Plant configurations including microturbines & combustion turbines
- 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 pricing
- Inclusion of the Investment Tax Credit (ITC) and Depreciation Rates
- Generation of Internal Rate of Return and Life Cycle Costing
- Third Party Ownership of CHP Plant

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/

APPENDIX B- Manufacturer cut sheets