CHP Feasibility Study – Screening Analysis

XYZ Energy

Presented by

Krishnan Umamaheswar, LEED AP, CEM, CDSM, DGCP

U.S. DOE Gulf Coast Clean Energy Application Center
4800 Research Forest Drive
The Woodlands, Texas 77381
O: (281) 363-7906
M: (979) 575-9471
F: (281) 363-7935
ukrishnan@harc.edu

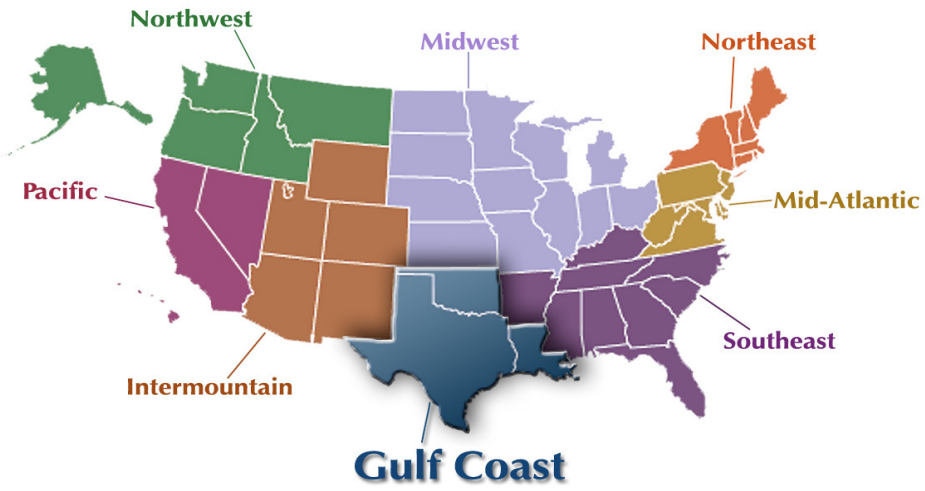
U.S. Department of Energy
Gulf Coast Clean Energy Application Center

Table of Contents

Introduction

This **Screening Analysis** has been prepared by the Houston Advanced Research Center (HARC), one among eight of the U.S. Department of Energy Clean Energy Application Centers in the country. Figure 1 illustrates the Application Centers and their respective jurisdictions.

Figure 1. US Department of Energy Clean Energy Application Centers



The US DOE Gulf Coast Clean Energy Application Center conducts CHP Feasibility Studies via a two-step approach; a Screening Analysis and a Detailed Analysis. The goal of the Screening Analysis is to establish if a site has the potential to be a good candidate for Combined Heat and Power (CHP). Industry rules of thumb, average utility costs, average monthly load profiles are used in the Screening Analysis. The results may have a range in accuracy of +/-30% in terms of savings, costs and simple payback. If the Screening Analysis shows CHP potential at the site, then a Detailed Analysis is performed. The goal of the Detailed Analysis is to establish whether CHP is viable from a technical and economic standpoint. While externalities, specific to a particular site, such as the availability of information, type and complexity of the systems and needs of the building owner dictate the level of detail, the following activities are conducted as part of the Detailed Analysis

- Walkthrough site-assessment
- Utility rate structure analysis
- Hour by hour 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
- Sensitivity analysis
- Use of financial models to generate internal rate of return

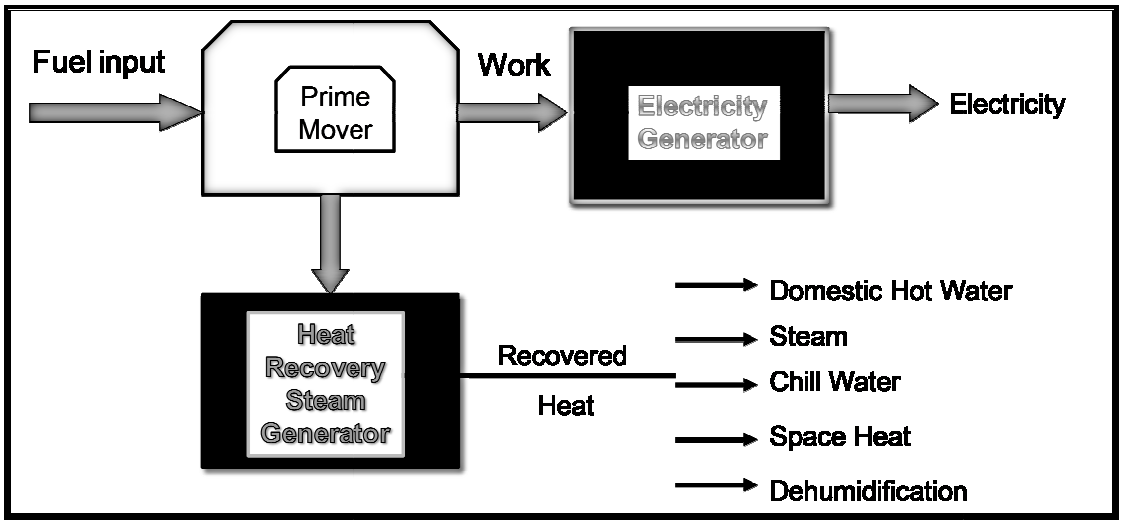
Combined Heat and Power - Overview

Combined heat and power (CHP) systems can offer much higher energy efficiency than conventional stand-alone equipment items for similar degree of power reliability, comfort cooling, and heating and indoor air quality. Because of the higher energy efficiency of the CHP system, it consumes nearly 40% less fuel than conventional systems. Combined heat and power systems offer a number of advantages to both private building owners as well as to society in general. Some of the key benefits are listed below:

- Attractive ROI – energy efficiency lowers total energy cost
- Environmental – dramatic reduction in CO2 and other emissions and low water use
- Energy Security – improves energy reliability
- Operating Flexibility – creates energy choices
- Power Quality – fewer voltage sags and noise

The illustration below lists on a very fundamental level, the key components of a CHP system and the ways that the waste heat can be captured for useful work.

Figure 2. CHP System illustration



Plant Profile

The processing plant located in ABC, TX processes between 500mm and 700mm cubic feet per day of natural gas. It uses a lean oil technology using both power and steam for process energy. The plant capacity has a planned all electric expansion to process an additional 300mm cubic feet per day of gas. Electricity to the plant is served by San Bernard Electric Cooperative, which is a distribution cooperative and has no generation. The distribution system is located on the LCRA 69 kV transmission system.

Energy Consumption Data

Table 1 lists the electricity and natural gas consumption. Included in the analysis is the future addition of an 8 MW electric load. Table 2 lists the rates assumed as part of the analysis.

Table 1. Utility Data

Month	Current Monthly Demand (kW)	Current Electricity Consumption (kWh)	Proposed Average Additional Demand (kW)	Proposed Average Monthly Electricity Consumption (kWh)	Average Gas Consumption (Therms)
January	3,327	1,925,228	8,000	7,282,028	2,123,860
February	3,396	2,318,146	8,000	7,156,546	1,785,050
March	3,588	2,084,044	8,000	7,440,844	2,003,870
April	3,383	2,067,866	8,000	7,251,866	2,021,270
May	3,143	2,219,196	8,000	7,575,996	2,016,020
June	3,143	2,219,196	8,000	7,403,196	2,083,070
July	3,352	2,175,610	8,000	7,532,410	2,088,120
August	3,280	2,233,804	8,000	7,590,604	2,137,110
September	3,268	2,194,589	8,000	7,378,589	2,130,610
October	2,922	1,828,738	8,000	7,185,538	2,099,310
November	3,424	2,187,084	8,000	7,371,084	1,997,570
December	3,335	2,149,795	8,000	7,506,595	2,057,350

***May utility bill unavailable. Consumption for May estimated to be the same as June**

Table 2. Rates

Parameter	Cost ($/unit)
Demand Charge ($/kW)	$1.89
Electricity Charge ($/kWh)	$0.0647
Gas Costs ($/therm)	$0.434

Figures 3 and 4 illustrate the observed load shape patterns for electricity consumption and gas consumption at the plant

Figure 3. Monthly Load Shape - Electricity Consumption

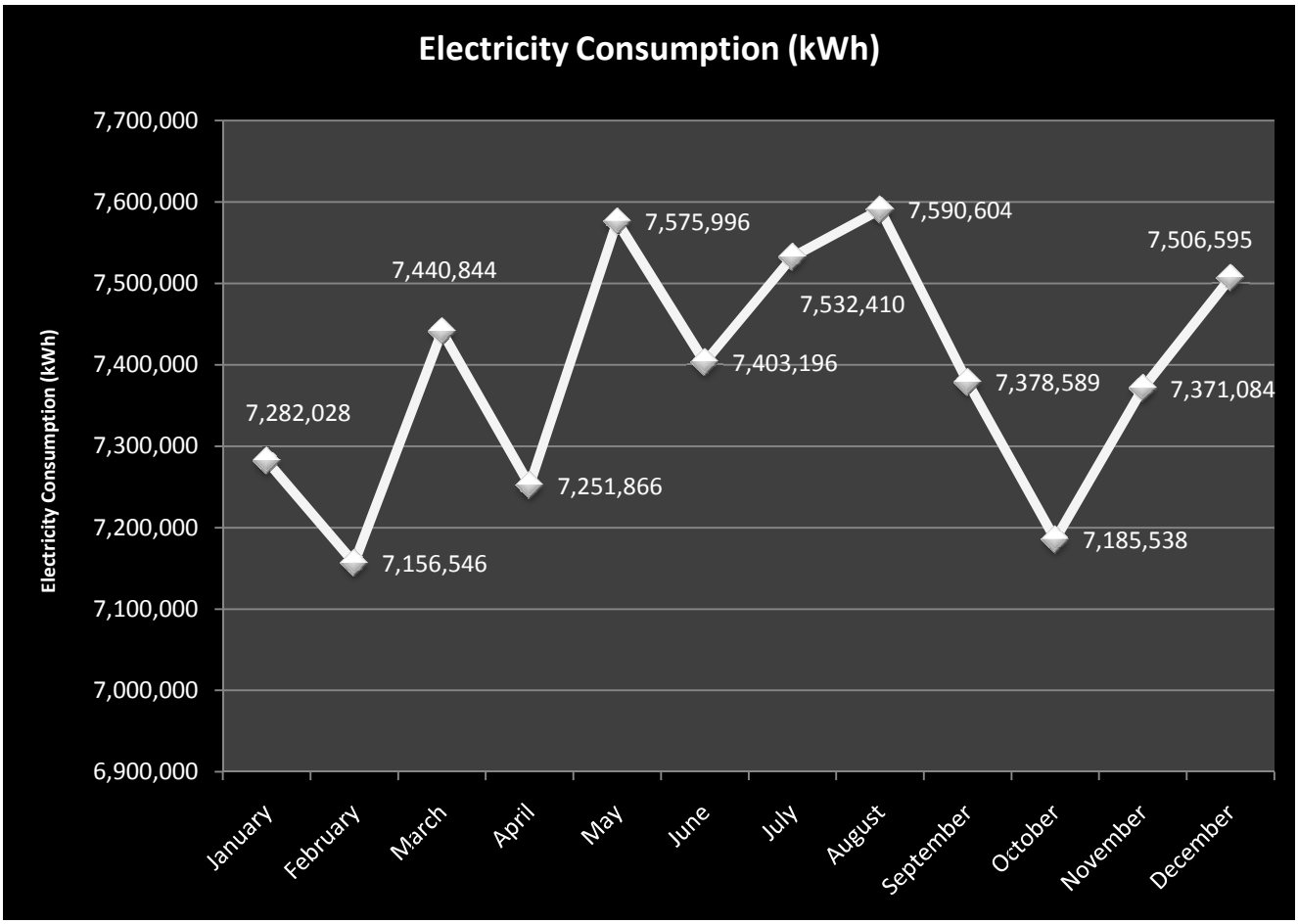
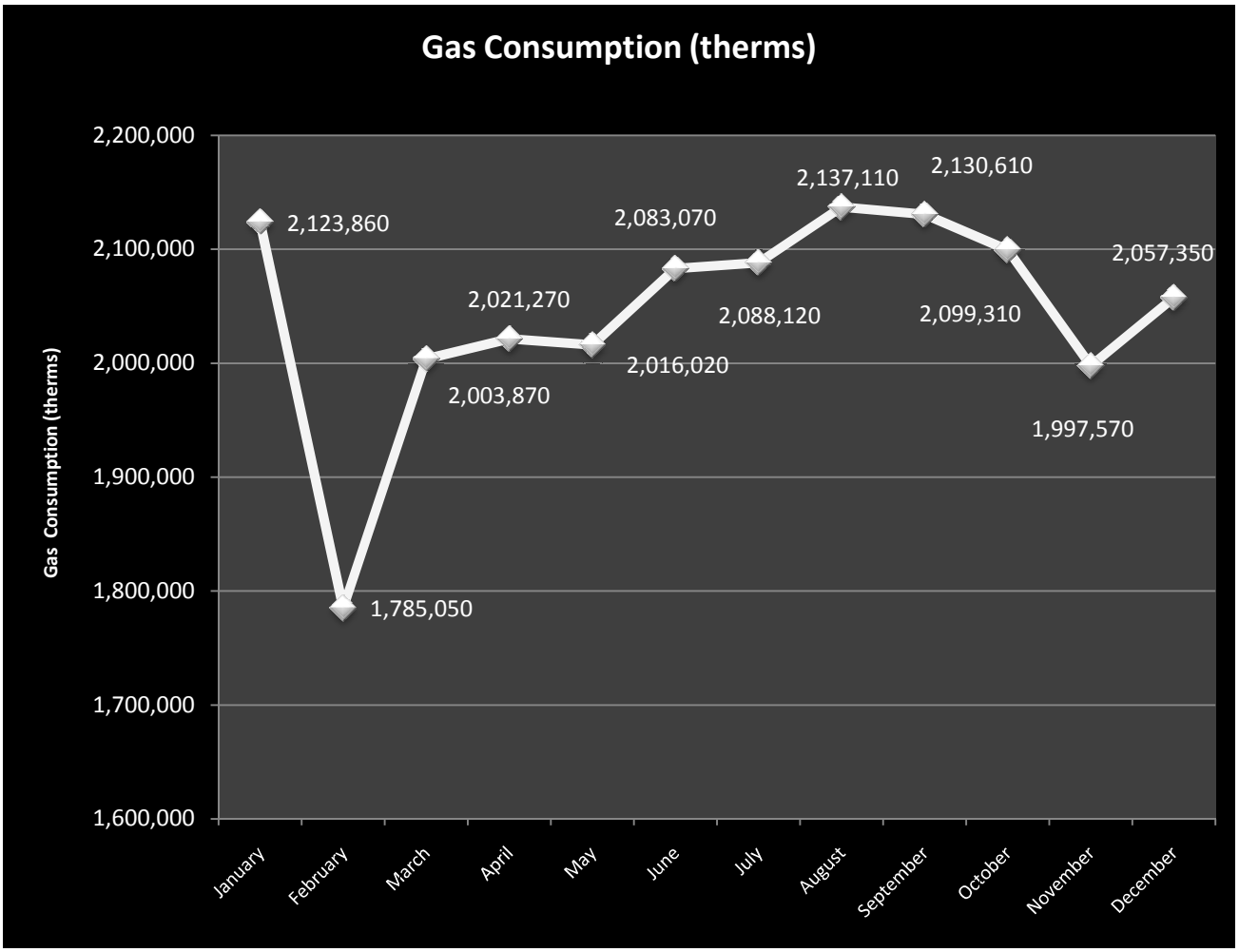


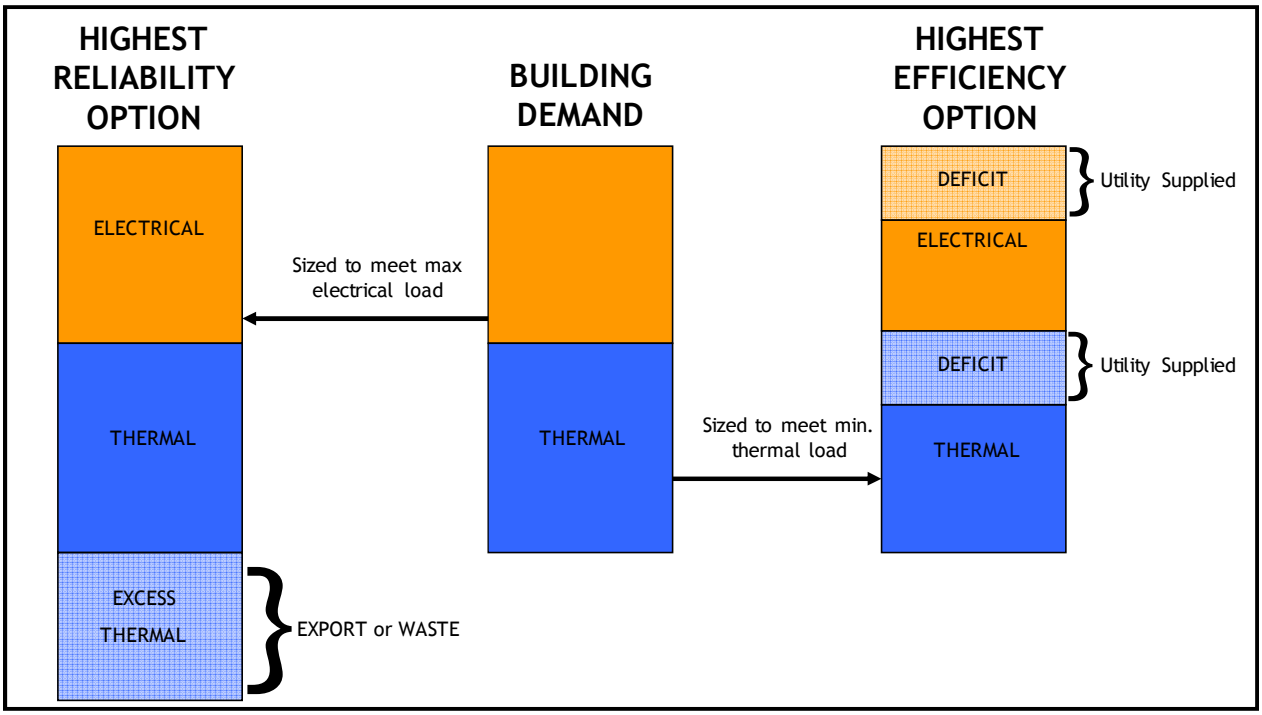
Figure 4. Monthly Load Shape - Gas Consumption



Preliminary Assessment

The following figure illustrates typical design strategies associated with CHP systems. *Power exports are not a driving design requirement*.

Figure 8. CHP Design Strategies



Three 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. With reference to the above figure, the highest reliability option and the associated benefits for XYZ Energy was not examined, due to lack of pertinent data.

CHP Plant serving average steam requirement

Information received indicated that the average steam requirement of the plant was 220,000 lbs/hr. A CHP system consisting of a turbine and heat recovery steam generator to supply the average steam requirement was analyzed. For purposes of illustration, actual manufacturer data from Solar Turbines was used. **Two Centaur 50 gas turbines** operating in tandem were selected for this analysis. The product data from the manufacturer's cut-sheets is summarized in Table 3.

Table 3. Centaur 50 gas turbine – Product specifications

Centaur 50 gas turbine	
Rated Capacity	4.6 MW
Fuel Input	53.1 MMBtu/hr
Additional Fuel Input to Burner	90.9 MMBtu/hr
Steam Production (Fired)	112,400 lbs/hr

Table 4 summarizes the capacity, fuel consumption and steam production of the CHP Plant

Table 4. CHP Plant Output

Total Capacity	9.2 MW
Total Fuel Input	288.0 MMBtu/hr
Steam Production (Fired)	224,800 lbs/hr

The demand, electric consumption, gas consumption, related utilities, and costs were compared between the existing scenario (without CHP) and a scenario with the afore-mentioned CHP system. The analysis assumes an *annual turbine downtime* of 2 weeks in the month of October for routine maintenance. Tables 5 and 6 illustrate the results of the energy and cost analysis on a monthly basis.

Table 5. Energy Analysis - Option 1

Month	Without CHP				With CHP								
	Current Monthly Demand (kW)	Average Monthly Electricity Consumption (kWh)	Average Gas Consumption (Therms)	Average Steam (lbs/hr)	Demand - CHP Plant (kW)	Electricity Generation - CHP Plant (kWh)	Gas Consumption - CHP Plant (therms)	Steam Generated (lbs/hr)	Additional Steam needed (lbs/hr)	Boiler Gas reqd for steam (therms)	Total Gas consumption (therms)	Net Electricity from Grid (kWh)	Net Demand from Grid (kW)
January	3,327	7,282,028	2,123,860	220,000	9,551	7,106,123	2,142,720	224,800	0	0	2,142,720	175,905	1,776
February	3,396	7,156,546	1,785,050	220,000	9,408	6,322,064	1,935,360	224,800	0	0	1,935,360	834,482	1,988
March	3,588	7,440,844	2,003,870	220,000	9,190	6,837,137	2,142,720	224,800	0	0	2,142,720	603,707	2,398
April	3,383	7,251,866	2,021,270	220,000	8,918	6,420,685	2,073,600	224,800	0	0	2,073,600	831,181	2,465
May	3,143	7,575,996	2,016,020	220,000	8,693	6,467,602	2,142,720	224,800	0	0	2,142,720	1,108,394	2,450
June	3,143	7,403,196	2,083,070	220,000	8,503	6,122,240	2,073,600	224,800	0	0	2,073,600	1,280,956	2,640
July	3,352	7,532,410	2,088,120	220,000	8,424	6,267,270	2,142,720	224,800	0	0	2,142,720	1,265,140	2,928
August	3,280	7,590,604	2,137,110	220,000	8,428	6,270,355	2,142,720	224,800	0	0	2,142,720	1,320,249	2,852
September	3,268	7,378,589	2,130,610	220,000	8,540	6,148,944	2,073,600	224,800	0	0	2,073,600	1,229,645	2,728
October**	2,922	7,185,538	2,099,310	220,000	4,464	3,321,250	1,071,360	112,400	107,600	1,563,032	2,634,392	3,864,288	6,458
November	3,424	7,371,084	1,997,570	220,000	9,133	6,575,823	2,073,600	224,800	0	0	2,073,600	795,261	2,291
December	3,335	7,506,595	2,057,350	220,000	9,423	7,010,347	2,142,720	224,800	0	0	2,142,720	496,248	1,912

Table 6. Cost Analysis – Option 1

Month	Without CHP				With CHP				Savings ($)
	Gas cost ($)	kWh Cost ($)	kW Cost ($)	TOTAL Cost ($)	Gas cost ($)	kWh Cost ($)	kW Cost ($)	TOTAL Cost ($)	
January	$921,755	$471,428	$6,288	$1,399,472	$929,940	$11,388	$3,356	$944,684	$454,787
February	$774,712	$463,305	$6,418	$1,244,435	$839,946	$54,023	$3,758	$897,727	$346,708
March	$869,680	$481,710	$6,781	$1,358,171	$929,940	$39,083	$4,533	$973,556	$384,614
April	$877,231	$469,476	$6,394	$1,353,101	$899,942	$53,810	$4,660	$958,411	$394,689
May	$874,953	$490,459	$5,940	$1,371,352	$929,940	$71,756	$4,630	$1,006,327	$365,025
June	$904,052	$479,272	$5,940	$1,389,265	$899,942	$82,927	$4,989	$987,859	$401,406
July	$906,244	$487,638	$6,335	$1,400,217	$929,940	$81,903	$5,534	$1,017,378	$382,839
August	$927,506	$491,405	$6,199	$1,425,110	$929,940	$85,471	$5,390	$1,020,802	$404,308
September	$924,685	$477,679	$6,177	$1,408,541	$899,942	$79,605	$5,156	$984,703	$423,837
October*	$911,101	$465,182	$5,523	$1,381,805	$1,143,326	$250,169	$12,206	$1,405,700	-$23,895
November	$866,945	$477,194	$6,471	$1,350,610	$899,942	$51,484	$4,330	$955,756	$394,854
December	$892,890	$485,966	$6,303	$1,385,159	$929,940	$32,126	$3,615	$965,682	$419,478
TOTALS	$10,651,753	$5,740,714	$74,770	$16,467,237	$11,162,685	$893,746	$62,156	$12,118,587	$4,348,650

Table 7 summarizes the installed costs, annual savings and the corresponding simple payback.

Table 7. Economic Summary - Option 1

Bid Type	Low Bid	High Bid
Savings	$4,348,650	
Estimated CHP Cost per kW	$1,300	$1,690
Total CHP Installed Cost	$11,960,000	$15,548,000
Simple PAYBACK	**2.75**	**3.58**

Table 8 illustrates the environmental benefits and associated reductions in greenhouse gases. The reductions have been calculated using the Environmental Protection Agency's (EPA) emissions calculator.

Table 8. Environmental Impact - Option 1

Annual Emissions Analysis					
	CHP System	**Displaced Electricity Production**	**Displaced Thermal Production**	**Emissions/Fuel Reduction**	**Percent Reduction**
NOx (tons/year)	72.81	41.57	140.13	108.89	60%
SO2 (tons/year)	0.70	126.69	0.83	126.81	99%
CO2 (tons/year)	139,464	57,090	163,532	81,157	37%
Carbon (metric tons/year)	34,484	14,116	40,435	20,067	37%
Acres of Forest Equivalent				**16,722**	
Number of Cars Removed				**13,405**	

Next Steps

Based on the Screening Analysis, U.S. DOE Clean Energy Application Center believes that the ABC facility is an excellent candidate for a detailed analysis, and recommends XYZ Energy conduct the same. The feasibility study 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 included in the Detailed Analysis are bulleted below

- Walkthrough site assessment, interviews with staff and review of EMCS data
- 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
- Refinement of turbine capacity based on annual hour-by-hour weather data
- Determination of peaks and troughs for demand and steam needs
- Hour-by-hour analysis and superimposition of demand and steam requirements
- Hour by hour comparison of site utility consumption with and without the CHP Plant
- Increased accuracy and refinements to Savings and Cost Estimates
- Inclusion of the Investment Tax Credit (ITC) and Depreciation Rates
- Generation of Internal Rate of Return and Life Cycle Costing

APPENDIX A – Useful Links & More Information

Daniel Bullock
U.S. DOE Gulf Coast Clean Energy Application Center
dbullock@harc.edu
281-364-6087

Krishnan Umamaheswar, LEED AP, CEM, CDSM
U.S. DOE Gulf Coast Clean Energy Application Center
ukrishnan@harc.edu
281-363-7906

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/