SPEER

The South-central Partnership for Energy Efficiency as a Resource

Case Study - Comprehensive Retrofit Improves CHP Cost Effectiveness

February 2015

Consideration of CHP within the Context of a More Comprehensive Retrofit Evaluation

On August 30, 2012, President Obama signed the "Accelerating Investment in Industrial Energy Efficiency" Executive Order (EO) to promote American manufacturingthrough coordinated investments in industrial energy efficiencythat included the establishment of a national Combined Heat and Power (CHP) goal.The EO prioritizes efforts to achieve a new national goal of deploying 40 gigawatts of new, cost effective CHP capacity by 2020, as well as, convening stakeholders to develop and adopt best practice state policiesand investment models that overcome investment barriers to industrial energy efficiency and CHP. In support of this national goal, DOE's CHP Technical Assistance Partnerships (CHP TAPs) promote and assist in transforming the CHP market, waste heat to power, and district energy with CHP throughout the United States.

SPEER proposed, building on the efforts of the Southwest CHP TAP, to take one of the companies that rejected CHP following the initial screening and develop a case study. This case study was to evaluate the impact of a comprehensive suite of efficiency measures and processes, and was expected to reduce the payback period of the project, thus increasing adoption of efficiency projects including CHP.

SPEER actually identified two facilities where CHP did not meet the payback period criteria of the facility's management, which are instructive when considered within the context of a more comprehensive evaluation. Both facilities are real sites, located in Texas, although their names are not used for this report.Using the December 2014 assessment model developed by the DOE CHP TAP team, SPEER screened the two facilities for a standard CHP application.

Subsequent CHP Screenings were conducted with modification in the facilities'retrofit design that incorporated more comprehensive energy upgrades. We took advantage of high pay-back energy efficiency measures in one instance, and included thermal energy storage in the other. The Screening results for each siterevealed a significant reduction in the payback periods whenthese additional energy efficiency measures were used in conjunction with the CHP for different reasons.

The December 2014 version of the DOE CHP Screening was used to assess the simple payback of both facilities. Below we provide a brief summary of the Screening Studies and the inputs and results of our expanded analysis. The actual print-outs from the Screening tool for before and after the consideration of additional measures are attached.

Case Studies

Medical Center Facility

The 280,000 sq. ft. medical center was originally constructed in 2007. The facility has 85beds with complete inpatient, outpatient, surgical, an emergency care that operates 24-hours per day. The facility's management team was initially considering upgrades to its power conditioning, because it was experiencing twice-monthly brownouts that sometimes lasted more than one minute each, affecting patient care. CHP did not prove attractive for this project in an initial CHP TAP Screening study. The project was re-evaluated as part of a more comprehensive energy upgrade project that included other measures such as high efficiency lighting, which have shorter payback.

The initial Screening for the Medical Center, as shown below resulted in a 9.1 year payback estimate. Working with an ESCO from our Industry Advisory Council and the hospital staff, we obtained a proposal for additional energy savings measures, including efficient lighting, power conditioning and energy management controls, and envelop improvements, as well as the estimates of associated costs. Approximately $463,000 was estimated for additional Energy Conservation Measures (ECMs), that would result in 1,155,000 kWh/year saved. The size of the CHP unit remained the same after ECMs were installed; however, the simple payback period for the overall project, including CHP, was reduced 24 percent.Elimination of some of the higher cost ECMs could have improved the overall project with CHP further. The results are shown below.

- CHP Size: 500 kW
- Thermal Demand: 2.05 MMBtu/hr
- Natural Gas Rate: $6.50/MMBtu
- Electricity Rate: $0.097/kWh

Trial	Payback (yrs)	Annual Electricity (kWh)	
CHP	9.1	9,204,000	Baseline
CHP + ECMs	6.9	7,710,028	Given 1,155,182 kWh saved @ $463,000 cost
Percent Change:	-24%		

Micro Electro-Mechanical Systems (MEMS) Manufacturing Facility

This MEMS facility uses stringent quality procedures within clean-roomsassociated with its foundry, as it manufactures silicon wafers for the semiconductor industry. The facility is expecting increased electric rates as a result of larger shifts in the generation planning of its local utility. Its managers were willing to consider CHP as a means to control demand charges and reduce energy costs. Boilers and chillers continuously supply hot water, transported by nearly twomiles of pipeline throughout the plant for process heating and cooling, or to cool critical equipment, in addition to seasonal space conditioning. Energy is used year-round to keep the pipeline water hot or cold. An initial evaluation of the CHP TAP Screening for the plant showed a long payback under current rates. We also shared projections of payback periods under assumptions of different rate increases with its managers, in the event anticipated rate hikes were to materialize. In addition, however, on a periodic basislarge boilers are used to supply significant quantities of hot water used to wash equipment and flush filters. Similarly, a campus laundry and café use significant amounts of hot water for cleaning, but on an irregular schedule. At the suggestion of one of SPEER's Industry Advisory Council members we considered the incorporation of thermal energy storage. Its purpose would be to accumulate thermal energy continuously, for periodic discharge to provide hot water for the kitchen, laundry and regular flushing of the factories filters. And it would allow the plant owner to avoid purchase of new boilers for those purposes.

The initial Screening for the MEMS, using only the base-load thermal load resulted in a very long payback period. This was due to the low electric rates in the region today[1] and in part because of the scale of the project. By installing thermal storage rather than replacing the boilers[2]and providing periodic hot water for batch processes or cleanings, we were able to increase the size of the CHP from 1.5 MW to 3.6 MW. At this scale the economics improved markedly, at least in our high-level screening. This more comprehensive alternative plan reduced the payback period by 50 percent as shown on the following page.

[1] The payback period was as low as 17 to 19 years based on assumptions the Client provided about the likely rate increases in the near future due to factors beyond its control.

[2] For this simplified analysis we assumed the capital cost of the thermal storage tank would be roughly the same as the cost for new boilers. If the existing boilers were new, or were retained for reliability/redundancy, the savings improvement would have been less dramatic.

- Annual Electricity Use: 67,000,000 kWh
- Natural Gas Rate: $6.25/MMBtu
- Electricity Rate: $0.060/kWh

Trial	Payback (yrs)	Thermal Load (MMBtu/hr)	
CHP	28.7	5.79	Baseline CHP size = 1,500 kW
CHP w/ double thermal load and storage	14.4	11.58	CHP w Thermal Storage = 3,600 kW
Percent Change:	-50%		

Conclusion

There are many reasons to consider the installation of CHP, and many factors can affect the potential value of a CHP system within the context of a large campus or facility. When facilities consider CHP as part of a more comprehensive suite of efficiency improvement measures or processes, the approach has the potential to offer a more comprehensive project with a reduced payback period, thereby increasing the acceptance and implementation of CHP.

Appendix A: Screening Results

DOE TAP CHP Qualification Screen

Gas Fueled CHP - Recip Engine, Microturbine, Fuel Cell or Gas Turbine Systems / natural gas, LFG, biogas

Note: The results of this screening analysis use average values and assumptions and should not be utilized as an investment grade analysis.

Facility Information

Facility Name	Medical Center
Location (City, State)	Texas
Application	Hospital Baseline

Loads

Annual Hours of Operation	8,760	Annual operating hours with loads conducive to CHP
Average Power Demand, kW	1,051	Average power demand during operating hours
Annual Electricity Consumption, kWh	9,206,760	
Average Thermal Demand, MMBtu/hr	2.05	
Annual Thermal Demand, MMBtu	17,958	

Energy Costs	**Base Case**	**CHP Case**	
Boiler/Thermal Fuel Costs, $/MMBtu	$7.96	$7.96	
CHP Fuel Costs, $/MMBtu		$6.50	assumes 15 percent reduction in price
Average Electricity Costs, $/kWh	$0.097		Annual electricity costs (demand and commodit
Percent Average per kWh Electric Cost Avoided		90%	Option 1 - Percent of average electricity costs pe
Standby Rate, $/kW		$0.00	Option 2 - Monthly $/kW standby charge based

Existing System

Displaced Thermal Efficiency, %	80.0%	Displaced onsite thermal (boiler, heater, etc) efficiency

CHP System

Net CHP Power, kW	500	CHP System Specs	A	Based on tl
CHP Electric Efficiency, % (HHV)	30.0%	CHP system specs	A	
CHP Thermal Output, Btu/kWh	6,700	CHP system specs	A	
CHP Thermal Output, MMBtu/hr	3.4	CHP system specs	A	
CHP Power to Heat Ratio	0.51	Calculated based on CHP power output and ther		
CHP Availability, %	95%	90 to 98%		
Incremental O&M Costs, $/kWh	$0.022	CHP system specs	A	
Thermal Utilization, %	90%	Amount of available thermal captured and used		
Total Installed Costs, $/kW	$2,600	CHP system specs	A	

Annual Energy Consumption	**Base Case**	**CHP Case**
Purchased Electricity, kWh	9,206,760	5,045,760
Generated Electricity, kWh	0	4,161,000
On-site Boiler/Heater Thermal, MMBtu	17,958	0
CHP Thermal, MMBtu	0	25,091
Boiler/Heater Fuel, MMBtu	22,448	0
CHP Fuel, MMBtu	0	47,324
Total Fuel, MMBtu	*22,448*	*47,324*

Annual Operating Costs		
Purchased Electricity, $	$893,056	$529,800
Standby Charges (Option 2), $	$0	$0
On-site Boiler/Heater Fuel, $	$178,682	$0
CHP Fuel, $	$0	$307,609
Incremental O&M, $	$0	$91,542
Total Operating Costs, $	*$1,071,738*	*$928,951*

Simple Payback

Annual Operating Savings	$142,787
Total Installed Costs	$1,300,000
Incentives	$0
Simple Payback, Years	**9.1**

Operating Costs to Generate

Fuel Costs, $/kWh	$0.074
Thermal Credit, $/kWh	($0.043)
Incremental O&M, $/kWh	$0.022
Total Operating Costs to Generate, $/kWh	**$0.053**

DOE TAP CHP Qualification Screen

Gas Fueled CHP - Recip Engine, Microturbine, Fuel Cell or Gas Turbine Systems / natural gas, LFG, biogas

Note: The results of this screening analysis use average values and assumptions and should not be utilized as an investment grade analysis.

Facility Information

Facility Name	Medical Center
Location (City, State)	Texas
Application	Hospital w ECMs

Loads

Annual Hours of Operation	8,760	Annual operating hours with loads conducive to CHP
Average Power Demand, kW	1,051	Average power demand during operating hours
Annual Electricity Consumption, kWh	9,206,760	
Average Thermal Demand, MMBtu/hr	2.05	
Annual Thermal Demand, MMBtu	17,958	

Energy Costs

	Base Case	CHP Case	
Boiler/Thermal Fuel Costs, $/MMBtu	$7.96	$7.96	
CHP Fuel Costs, $/MMBtu		$6.50	assumes 15 percent reduction in price
Average Electricity Costs, $/kWh	$0.097		Annual electricity costs (demand and commodit
Percent Average per kWh Electric Cost Avoided		90%	Option 1 - Percent of average electricity costs pe
Standby Rate, $/kW		$0.00	Option 2 - Monthly $/kW standby charge based

Existing System

Displaced Thermal Efficiency, %	80.0%	Displaced onsite thermal (boiler, heater, etc) efficiency

CHP System

Net CHP Power, kW	500	CHP System Specs	A Based on tl
CHP Electric Efficiency, % (HHV)	30.0%	CHP system specs	A
CHP Thermal Output, Btu/kWh	6,700	CHP system specs	A
CHP Thermal Output, MMBtu/hr	3.4	CHP system specs	A
CHP Power to Heat Ratio	0.51	Calculated based on CHP power output and ther	
CHP Availability, %	95%	90 to 98%	
Incremental O&M Costs, $/kWh	$0.022	CHP system specs	A
Thermal Utilization, %	90%	Amount of available thermal captured and used	
Total Installed Costs, $/kW	$2,600	CHP system specs	A

Annual Energy Consumption

	Base Case	CHP Case
Purchased Electricity, kWh	9,206,760	3,890,578
Generated Electricity, kWh	0	4,161,000
On-site Boiler/Heater Thermal, MMBtu	17,958	0
CHP Thermal, MMBtu	0	25,091
Boiler/Heater Fuel, MMBtu	22,448	0
CHP Fuel, MMBtu	0	47,324
Total Fuel, MMBtu	*22,448*	*47,324*

Annual Operating Costs (CHP)

	Base Case	CHP Case
Purchased Electricity, $	$893,056	$529,800
Standby Charges (Option 2), $	$0	$0
On-site Boiler/Heater Fuel, $	$178,682	$0
CHP Fuel, $	$0	$307,609
Incremental O&M, $	$0	$91,542
Total Operating Costs, $	*$1,071,738*	*$928,951*

Simple Payback

Annual Operating Savings (CHP + ECMs)	$254,839	1,155,182	kWh/yr Saved
Total Installed Costs (CHP + ECMs)	$1,763,000	8,051,578	Tot. kWh/yr w ECMs
Incentives	$0	$463,000	ECM cost
Simple Payback, Years	**6.9**		

Energy Savings (GIVEN)

Operating Costs to Generate

Fuel Costs, $/kWh	$0.074
Thermal Credit, $/kWh	($0.043)
Incremental O&M, $/kWh	$0.022
Total Operating Costs to Generate, $/kWh	**$0.053**

DOE TAP CHP Qualification Screen

Gas Fueled CHP - Recip Engine, Microturbine, Fuel Cell or Gas Turbine Systems / natural gas, LFG, biogas

Note: The results of this screening analysis use average values and assumptions and should not be utilized as an investment grade analysis.

Facility Information

Facility Name	Micro-Electro Mechanical Systems Manufacturing
Location (City, State)	Texas
Application	Semiconductor Manufacturer - Baseline

Loads

Annual Hours of Operation	8,760	Annual operating hours with loads conducive to CHP
Average Power Demand, kW	7,644	Average power demand during operating hours
Annual Electricity Consumption, kWh	66,959,400	
Average Thermal Demand, MMBtu/hr	5.79	
Annual Thermal Demand, MMBtu	50,720	

Energy Costs	**Base Case**	**CHP Case**	
Boiler/Thermal Fuel Costs, $/MMBtu	$7.35	$6.25	
CHP Fuel Costs, $/MMBtu		$6.25	assumes 15 percent reduction in price
Average Electricity Costs, $/kWh	$0.060		Annual electricity costs (demand and commodity
Percent Average per kWh Electric Cost Avoided		90%	Option 1 - Percent of average electricity costs pe
Standby Rate, $/kW		$0.00	Option 2 - Monthly $/kW standby charge based

Existing System

Displaced Thermal Efficiency, %	80.0%	Displaced onsite thermal (boiler, heater, etc) efficiency

CHP System

Net CHP Power, kW	1,502	CHP System Specs	C	Based on th
CHP Electric Efficiency, % (HHV)	36.8%	CHP system specs	C	
CHP Thermal Output, Btu/kWh	3,854	CHP system specs	C	
CHP Thermal Output, MMBtu/hr	5.8	CHP system specs	C	
CHP Power to Heat Ratio	0.89	Calculated based on CHP power output and ther		
CHP Availability, %	95%	90 to 98%		
Incremental O&M Costs, $/kWh	$0.019	CHP system specs	C	
Thermal Utilization, %	90%	Amount of available thermal captured and used		
Total Installed Costs, $/kW	$2,335	CHP system specs	C	

Annual Energy Consumption	**Base Case**	**CHP Case**
Purchased Electricity, kWh	66,959,400	54,455,999
Generated Electricity, kWh	0	12,503,400
On-site Boiler/Heater Thermal, MMBtu	50,720	7,354
CHP Thermal, MMBtu	0	43,366
Boiler/Heater Fuel, MMBtu	63,401	9,193
CHP Fuel, MMBtu	0	115,832
Total Fuel, MMBtu	*63,401*	*125,025*

Annual Operating Costs		
Purchased Electricity, $	$4,017,564	$3,342,380
Standby Charges (Option 2), $	$0	$0
On-site Boiler/Heater Fuel, $	$465,994	$57,457
CHP Fuel, $	$0	$723,947
Incremental O&M, $	$0	$237,565
Total Operating Costs, $	*$4,483,558*	*$4,361,349*

Simple Payback

Annual Operating Savings	$122,209
Total Installed Costs	$3,508,224
Incentives	$0
Simple Payback, Years	**28.7**

Operating Costs to Generate

Fuel Costs, $/kWh	$0.058
Thermal Credit, $/kWh	($0.033)
Incremental O&M, $/kWh	$0.019
Total Operating Costs to Generate, $/kWh	**$0.044**

DOE TAP CHP Qualification Screen

Gas Fueled CHP - Recip Engine, Microturbine, Fuel Cell or Gas Turbine Systems / natural gas, LFG, biogas

Note: The results of this screening analysis use average values and assumptions and should not be utilized as an investment grade analysis.

Facility Information

Facility Name	Micro-Electro Mechanical Systems Manufacturing
Location (City, State)	Texas
Application	Semiconductor Manufacturer w/ thermal demand

Loads

Annual Hours of Operation	8,760	Annual operating hours with loads conducive to CHP
Average Power Demand, kW	7,644	Average power demand during operating hours
Annual Electricity Consumption, kWh	66,959,400	
Average Thermal Demand, MMBtu/hr	11.58	
Annual Thermal Demand, MMBtu	101,441	

Energy Costs	**Base Case**	**CHP Case**	
Boiler/Thermal Fuel Costs, $/MMBtu	$7.35	$6.25	
CHP Fuel Costs, $/MMBtu		$6.25	assumes 15 percent reduction in price
Average Electricity Costs, $/kWh	$0.060		Annual electricity costs (demand and commodity
Percent Average per kWh Electric Cost Avoided		90%	Option 1 - Percent of average electricity costs pe
Standby Rate, $/kW		$0.00	Option 2 - Monthly $/kW standby charge based

Existing System

Displaced Thermal Efficiency, %	80.0%	Displaced onsite thermal (boiler, heater, etc) efficiency

CHP System

Net CHP Power, kW	3,581	CHP System Specs	D Based on th
CHP Electric Efficiency, % (HHV)	40.4%	CHP system specs	D
CHP Thermal Output, Btu/kWh	3,233	CHP system specs	D
CHP Thermal Output, MMBtu/hr	11.6	CHP system specs	D
CHP Power to Heat Ratio	1.06	Calculated based on CHP power output and ther	
CHP Availability, %	95%	90 to 98%	
Incremental O&M Costs, $/kWh	$0.013	CHP system specs	D
Thermal Utilization, %	90%	Amount of available thermal captured and used	
Total Installed Costs, $/kW	$1,917	CHP system specs	D

Annual Energy Consumption	**Base Case**	**CHP Case**
Purchased Electricity, kWh	66,959,400	37,154,629
Generated Electricity, kWh	0	29,804,771
On-site Boiler/Heater Thermal, MMBtu	101,441	14,709
CHP Thermal, MMBtu	0	86,732
Boiler/Heater Fuel, MMBtu	126,801	18,386
CHP Fuel, MMBtu	0	251,970
Total Fuel, MMBtu	*126,801*	*270,356*

Annual Operating Costs

Purchased Electricity, $	$4,017,564	$2,408,106
Standby Charges (Option 2), $	$0	$0
On-site Boiler/Heater Fuel, $	$931,987	$114,913
CHP Fuel, $	$0	$1,574,810
Incremental O&M, $	$0	$375,540
Total Operating Costs, $	*$4,949,551*	*$4,473,369*

Simple Payback

Annual Operating Savings	$476,182
Total Installed Costs	$6,865,627
Incentives	$0
Simple Payback, Years	**14.4**

Operating Costs to Generate

Fuel Costs, $/kWh	$0.053
Thermal Credit, $/kWh	($0.027)
Incremental O&M, $/kWh	$0.013
Total Operating Costs to Generate, $/kWh	**$0.038**

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