Combined Heat and Power (CHP) Practicum

Western Missouri CHP Summit: Resiliency for Critical Infrastructure

Ben Campbell & Cliff Haefke
October 16, 2018
Agenda

• What are the CHP TAPs?
• CHP Project Development Process
• CHP TAP Screening – Step-by-Step Walk-Through
• Additional Considerations that can Impact CHP Economics
CHP Project Development Flow Process and CHP TAP Technical Assistance

1. **Screening and Preliminary Analysis**
   - Quick screening questions with spreadsheet payback calculator; Advanced technical assistance to explore equipment or operational scenarios.

2. **Feasibility Analysis**
   - Perform 3rd Party Reviews of site Feasibility Assessments: Estimates on savings, installation costs, simple paybacks, equipment sizing, and type.

3. **Investment Grade Analysis**
   - Perform 3rd Party reviews of Engineering Analysis. Review equipment sizing and choices.

4. **Procurement, Operations, Maintenance, Commissioning**
   - Review specifications and bids.
Overview of DOE TAP CHP Screening Analysis

- High level assessment to determine if site shows potential for a CHP project
  - Quantitative Analysis
    - Energy Consumption & Costs
    - Estimated Energy Savings & Payback
  - CHP System Sizing
  - Qualitative Analysis
    - Understanding project drivers
    - Understanding site peculiarities

### Annual Energy Consumption

<table>
<thead>
<tr>
<th></th>
<th>Base Case</th>
<th>CHP Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchased Electricity, kWh</td>
<td>88,250,160</td>
<td>5,534,150</td>
</tr>
<tr>
<td>Generated Electricity, kWh</td>
<td>0</td>
<td>82,716,010</td>
</tr>
<tr>
<td>On-site Thermal, MMBtu</td>
<td>426,000</td>
<td>18,372</td>
</tr>
<tr>
<td>CHP Thermal, MMBtu</td>
<td>0</td>
<td>407,128</td>
</tr>
<tr>
<td>Boiler Fuel, MMBtu</td>
<td>532,500</td>
<td>23,586</td>
</tr>
<tr>
<td>CHP Fuel, MMBtu</td>
<td>0</td>
<td>969,845</td>
</tr>
<tr>
<td>Total Fuel, MMBtu</td>
<td>532,500</td>
<td>993,435</td>
</tr>
</tbody>
</table>

### Annual Operating Costs

<table>
<thead>
<tr>
<th></th>
<th>Base Case</th>
<th>CHP Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchased Electricity, $</td>
<td>$7,060,013</td>
<td>$1,104,460</td>
</tr>
<tr>
<td>Standby Power, $</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>On-site Thermal Fuel, $</td>
<td>$3,195,000</td>
<td>$141,339</td>
</tr>
<tr>
<td>CHP Fuel, $</td>
<td>$0</td>
<td>$5,819,071</td>
</tr>
<tr>
<td>Incremental O&amp;M, $</td>
<td>$0</td>
<td>$744,444</td>
</tr>
<tr>
<td>Total Operating Costs, $</td>
<td>$10,255,013</td>
<td>$7,809,514</td>
</tr>
</tbody>
</table>

### Simple Payback

- Annual Operating Savings, $ | $2,445,499
- Total Installed Costs, $/kW | $1,400
- Simple Payback, Years | 5.3

### Operating Costs to Generate

<table>
<thead>
<tr>
<th></th>
<th>$/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Costs</td>
<td>$0.072</td>
</tr>
<tr>
<td>Thermal Credit</td>
<td>($0.037)</td>
</tr>
<tr>
<td>Incremental O&amp;M</td>
<td>$0.004</td>
</tr>
<tr>
<td>Total Operating Costs to Generate</td>
<td>$0.042</td>
</tr>
</tbody>
</table>
CHP TAP Qualification Screening Steps
(covered on subsequent slides)

1. Site Specific Information
2. Utility Costs
3. CHP System Specifications
4. Energy Consumption / CHP Operation
5. Annual Operating Costs
6. CHP System Economics
7. Operating Costs per kWh

Collected Data
- 12 months of utility data
  - Blended cost of utilities
  - Thermal and electric demand of the facilities (average, peak, seasonal)
  - Annual natural gas and electricity consumption
- Facility operating hours
- Existing equipment info
  - Heating and cooling capacities, efficiency, age, etc.
- Additional helpful info
  - Resiliency needs, climate goals, utility contract ending
### 1. Site Specific Information

- **12 months of utility data**
- **Thermal and electric demand of the facilities (average, peak, seasonal)**
- **Annual natural gas and electricity consumption**
- **Facility operating hours**

#### DOE TAP CHP Screening Technical Assistance

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**

<table>
<thead>
<tr>
<th>Facility Name</th>
<th>Location (City, State)</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital</td>
<td>City: Missouri</td>
<td>500-600 Bed Hospital</td>
</tr>
<tr>
<td></td>
<td>Date: 16-Oct-18</td>
<td></td>
</tr>
</tbody>
</table>

**Loads**

<table>
<thead>
<tr>
<th>Site Operating Schedule</th>
<th>24/7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Operating Hours of Site</td>
<td>8,760</td>
</tr>
<tr>
<td>Baseload Electric Demand, kW</td>
<td>3,416</td>
</tr>
<tr>
<td>Annual Site Electricity Consumption, kWh</td>
<td>41,924,572</td>
</tr>
<tr>
<td>Total Annual Thermal Demand, MMBtu/yr</td>
<td>142,869</td>
</tr>
<tr>
<td>Baseload Thermal Demand, MMBtu/hr</td>
<td>11.00</td>
</tr>
<tr>
<td>CHP Operating Schedule</td>
<td>12 Months</td>
</tr>
<tr>
<td>Annual Hours of CHP Operation</td>
<td>8,760</td>
</tr>
<tr>
<td>Baseload Power Demand during CHP Operation, kW</td>
<td>3,416</td>
</tr>
<tr>
<td>Electricity Consumption during CHP Operation, kWh</td>
<td>41,924,572</td>
</tr>
<tr>
<td>Thermal Demand during CHP Operation, MMBtu/yr</td>
<td>142,869</td>
</tr>
<tr>
<td>CHP Baseload Thermal Demand, MMBtu/hr</td>
<td>11.00</td>
</tr>
<tr>
<td>Annual CHP Addressable Thermal Demand, MMBtu/yr</td>
<td>142,869</td>
</tr>
</tbody>
</table>

**Addressable Thermal Load (MMBtu/hr)**

<table>
<thead>
<tr>
<th>Winter Thermal</th>
<th>Shoulder Thermal</th>
<th>Summer Thermal</th>
</tr>
</thead>
<tbody>
<tr>
<td>22.0</td>
<td>16.2</td>
<td>11.0</td>
</tr>
<tr>
<td>Avg Load Hours</td>
<td>2,160</td>
<td>4,392</td>
</tr>
</tbody>
</table>
2. Utility Costs

### Energy Costs

<table>
<thead>
<tr>
<th>Description</th>
<th>Base Case</th>
<th>CHP Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler/Thermal Fuel Costs, $/MMBtu</td>
<td>$4.20</td>
<td>$4.20</td>
</tr>
<tr>
<td>CHP Fuel Costs, $MM/Btu</td>
<td>$4.20</td>
<td>$4.20</td>
</tr>
<tr>
<td>Average Electricity Costs, $/kWh</td>
<td>$0.065</td>
<td></td>
</tr>
<tr>
<td>Percent Average per kWh Electric Cost Avoided</td>
<td></td>
<td>90%</td>
</tr>
<tr>
<td>Standby Rate, $/kW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excess Power Sales Price, $/kWh</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Existing System

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Displaced Thermal Equipment Efficiency, %</td>
<td>83.0%</td>
</tr>
</tbody>
</table>

Percent Average per kWh Electric Cost Avoided: Assesses how utility rates (i.e. fixed charges and standby rates) affect the blended rate savings (total kWh price for electricity) by comparing a customer's utility bills before and after a CHP installation. For example, an avoided rate of 100% means that one kWh generated onsite reduces the utility bill by the full blended cost of one kWh of purchased power. This is rarely the case in most tariff structures. This example incorporates an avoided rate of 90%, meaning one kWh of electricity generated from CHP reduces utility purchases by 90% of the blended rate prior to CHP.

- **12 months of utility data**
  - Electricity and natural gas
  - Blended costs of utilities

- **Avoided Rate / Standby Rate**

- **Existing equipment info**
  - Heating and cooling capacities, efficiency, age, etc.
3. CHP System Specs

- Initial sizing of CHP system
- Utilizes typical CHP performance operating and cost data from U.S. DOE CHP Technology Fact Sheets

<table>
<thead>
<tr>
<th>CHP System</th>
<th>CHP Case 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales of Excess Power (Yes/No)</td>
<td>No</td>
</tr>
<tr>
<td>Net CHP Power, kW</td>
<td>3,402</td>
</tr>
<tr>
<td>CHP Electric Efficiency, % (HHV)</td>
<td>40.9%</td>
</tr>
<tr>
<td>CHP Thermal Output, Btu/kWh</td>
<td>3,233</td>
</tr>
<tr>
<td>CHP Thermal Output, MMBtu/hr</td>
<td>11.00</td>
</tr>
<tr>
<td>CHP Fuel</td>
<td>Nat Gas</td>
</tr>
<tr>
<td>CHP Availability, %</td>
<td>98%</td>
</tr>
<tr>
<td>Incremental O&amp;M Costs, $/kWh</td>
<td>$0.011</td>
</tr>
<tr>
<td>Thermal Utilization, %</td>
<td>100%</td>
</tr>
<tr>
<td>Total Installed Costs, $/kW</td>
<td>$1,800</td>
</tr>
</tbody>
</table>

### Comparison of CHP Characteristics for Typical Systems

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Reciprocating Engine</th>
<th>Gas Turbine</th>
<th>Microturbine</th>
<th>Fuel Cell</th>
<th>Steam Turbine</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size Range</strong></td>
<td>10 kW-10 MW</td>
<td>1 MW-300 MW</td>
<td>30 kW-330 kW (larger modular units available)</td>
<td>5 kW-2.8 MW (larger modular units available)</td>
<td>100 kW-250 MW</td>
</tr>
<tr>
<td><strong>Electric Efficiency (HHV)</strong></td>
<td>30-42%</td>
<td>24-36%</td>
<td>25-29%</td>
<td>38-42%</td>
<td>5-7%</td>
</tr>
<tr>
<td><strong>Overall CHP Efficiency (HHV)</strong></td>
<td>77-83%</td>
<td>65-71%</td>
<td>64-72%</td>
<td>62-75%</td>
<td>80%</td>
</tr>
<tr>
<td><strong>Total Installed Cost ($/kW) [3]</strong></td>
<td>$1,400–$2,900</td>
<td>$1,300–$3,300</td>
<td>$2,500–$3,200</td>
<td>$4,600–$10,000</td>
<td>$670–$1,100 [4]</td>
</tr>
<tr>
<td><strong>O&amp;M Cost ($/kWh)</strong></td>
<td>0.9-2.4</td>
<td>0.9-1.3</td>
<td>0.8-1.6</td>
<td>3.6-4.5</td>
<td>0.6-1.0</td>
</tr>
<tr>
<td><strong>Power to Heat Ratio</strong></td>
<td>0.6-1.2</td>
<td>0.6-1.0</td>
<td>0.5-0.8</td>
<td>1.3-1.6</td>
<td>0.07-0.10</td>
</tr>
<tr>
<td><strong>Thermal Output (Btu/kWh)</strong></td>
<td>2,900-6,100</td>
<td>3,400-6,000</td>
<td>4,400-6,400</td>
<td>2,200-2,600</td>
<td>30,000-50,000</td>
</tr>
<tr>
<td><strong>Fuel Pressure (psig) [5]</strong></td>
<td>1-75</td>
<td>100–500 (may require fuel compressor)</td>
<td>50-140 (may require fuel compressor)</td>
<td>0.5–45</td>
<td>n/a</td>
</tr>
<tr>
<td><strong>Part Load Efficiency</strong></td>
<td>Good at both part-load and full-load</td>
<td>Better at full-load</td>
<td>Better at full-load</td>
<td>Better at full-load</td>
<td>Good at both part-load and full-load</td>
</tr>
<tr>
<td><strong>Type of Thermal Output</strong></td>
<td>LP steam, hot water, space heating, chilled water</td>
<td>LP-HP steam, hot water, process heating, chilled water</td>
<td>LP steam, hot water, chilled water</td>
<td>LP steam, hot water, chilled water</td>
<td>LP-HP steam, hot water, chilled water</td>
</tr>
</tbody>
</table>

4. Energy Consumption – CHP Operation

<table>
<thead>
<tr>
<th>Annual Energy Consumption</th>
<th>Base Case</th>
<th>CHP Case</th>
<th>CHP Fuel Use Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchased Electricity, kWh</td>
<td>41,924,572</td>
<td>12,719,082</td>
<td>29,205,490</td>
</tr>
<tr>
<td>Generated Electricity, kWh</td>
<td>0</td>
<td>29,205,490</td>
<td>99,649</td>
</tr>
<tr>
<td>Generated Electricity Used on Site, kWh</td>
<td>0</td>
<td>29,205,490</td>
<td>94,421</td>
</tr>
<tr>
<td>Generated Electricity Sold, kWh</td>
<td>0</td>
<td>0</td>
<td>243,641</td>
</tr>
<tr>
<td>On-site Boiler/Heater Thermal, MMBtu/yr</td>
<td>142,869</td>
<td>48,447</td>
<td>79.7%</td>
</tr>
<tr>
<td>CHP Thermal Used, MMBtu/yr</td>
<td>0</td>
<td>94,421</td>
<td>1.06</td>
</tr>
<tr>
<td>Boiler/Heater Fuel, MMBtu/yr</td>
<td>172,131</td>
<td>58,370</td>
<td></td>
</tr>
<tr>
<td>CHP Fuel, MMBtu/yr</td>
<td>0</td>
<td>243,641</td>
<td></td>
</tr>
<tr>
<td>Total Fuel, MMBtu/yr</td>
<td>172,131</td>
<td>302,011</td>
<td></td>
</tr>
</tbody>
</table>

- Estimated annual energy performance is compared between the Base Case (no CHP) and the CHP Case (with CHP)
- CHP efficiencies and the Power-to-Heat Ratio are calculated
5. Annual Operating Costs/Savings

<table>
<thead>
<tr>
<th>Annual Operating Costs</th>
<th>Base Case</th>
<th>CHP Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase Electricity</td>
<td>$2,725,097</td>
<td>$1,016,576</td>
</tr>
<tr>
<td>Standby Charges (Option 2)</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>On-site Boiler/Heater Fuel</td>
<td>$722,950</td>
<td>$245,155</td>
</tr>
<tr>
<td>CHP Fuel</td>
<td>$0</td>
<td>$1,023,292</td>
</tr>
<tr>
<td>Incremental O&amp;M</td>
<td>$0</td>
<td>$321,260</td>
</tr>
<tr>
<td><strong>Total Operating Costs</strong></td>
<td><strong>$3,448,047</strong></td>
<td><strong>$2,606,283</strong></td>
</tr>
<tr>
<td>Excess Power Sales</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td><strong>Operating Savings</strong></td>
<td><strong>$0</strong></td>
<td><strong>$841,764</strong></td>
</tr>
</tbody>
</table>

• Annual operating costs are compared between the Base Case (no CHP) and the CHP Case (with CHP)
• In this scenario, standby charges are accounted for in the purchased electricity in the terms of avoided costs
6. CHP System Economics

<table>
<thead>
<tr>
<th>Simple Payback</th>
<th>CHP Case 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHP Installed Costs</td>
<td>$6,123,600</td>
</tr>
<tr>
<td>Additional Costs</td>
<td>$0</td>
</tr>
<tr>
<td>Federal Investment Tax Credit (Yes/No)</td>
<td>No</td>
</tr>
<tr>
<td>Avoided Equipment Credits*</td>
<td>$0</td>
</tr>
<tr>
<td>Total Installed Costs with Equipment Credit</td>
<td>$6,123,600</td>
</tr>
<tr>
<td>Value of Resiliency</td>
<td>$0</td>
</tr>
<tr>
<td>Total Installed Costs less Incentives</td>
<td>$6,123,600</td>
</tr>
<tr>
<td>Annual Operating Savings</td>
<td>$841,764</td>
</tr>
<tr>
<td>Simple Payback, Years (w/o incentives)</td>
<td>7.3</td>
</tr>
<tr>
<td>Simple Payback, Years (with incentives)</td>
<td>7.3</td>
</tr>
</tbody>
</table>

- Simple payback is determined with typical CHP installed costs and operating savings
- A variety of factors can be incorporated to analyze the financial impacts on a potential CHP project (next section)
7. Operating Costs per kWh

Operating Costs to Generate

<table>
<thead>
<tr>
<th></th>
<th>$/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Costs, $/kWh</td>
<td>0.0350</td>
</tr>
<tr>
<td>Thermal Credit, $/kWh</td>
<td>($0.0164)</td>
</tr>
<tr>
<td>Incremental O&amp;M, $/kWh</td>
<td>0.0110</td>
</tr>
<tr>
<td><strong>Total Operating Costs to Generate, $/kWh</strong></td>
<td><strong>$0.030</strong></td>
</tr>
</tbody>
</table>

- Operating costs are calculated to determine the costs to generate in terms of $/kWh
- Fuel costs, thermal credit from offset boiler fuel, and incremental O&M are incorporated
Continuing the Analysis...
Factors to Consider that can Impact CHP Economics

I. Utility Costs (discounted natural gas costs) – increased natural gas consumption may provide opportunity for discounted natural gas price

II. Utility Costs (lower/higher energy prices) – impacts of current/future electric and/or natural gas prices can be reflected in sensitivity analyses

III. Redundancy (multiple generating units) – multiple CHP units can provide redundancy and additional resiliency benefits, but typically with higher upfront costs

IV. Avoid Boiler Replacement – apply credit to CHP installation costs from allocated funds of new boiler(s)
--- Absorption Cooling – an absorption chiller can utilize CHP thermal output during summer months and could provide an alternative option to new electric chillers (note: new absorption chiller not analyzed in this exercise due to existing absorption chiller)

V. Reducing Avoided Rate Percentage – assessing how to reduce the utility rate impact through analyzing utility rate class impacts, energy consumption, system availability, scheduling of maintenance, etc.

VI. Avoided Installation of Diesel Backup Gensets – apply credit to CHP costs from funds for backup gensets

VII. Value of Resiliency – factor in monetary value of resiliency benefits

VIII. Federal Investment Tax Credit – 10% investment tax credit (ITC)
I. Impact of Discounted Natural Gas Price

- Increased natural gas consumption may provide opportunity for discounted natural gas price
- Annual savings increase from $842K to $969K
- Simple Payback reduces from 7.3 years to 6.3 years
## I. Impact of Discounted Natural Gas Price (cont.)

<table>
<thead>
<tr>
<th>Simple Payback</th>
<th>CHP Case 1</th>
<th>CHP Case 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHP Installed Costs</td>
<td>$6,123,600</td>
<td>$6,123,600</td>
</tr>
<tr>
<td>Additional Costs</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Federal Investment Tax Credit (Yes/No)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Avoided Equipment Credits*</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Total Installed Costs with Equipment Credit</td>
<td>$6,123,600</td>
<td>$6,123,600</td>
</tr>
<tr>
<td>Value of Resiliency</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Total Installed Costs less Incentives</td>
<td>$6,123,600</td>
<td>$6,123,600</td>
</tr>
<tr>
<td>Annual Operating Savings</td>
<td>$841,764</td>
<td>$968,608</td>
</tr>
<tr>
<td>Simple Payback, Years (w/o incentives)</td>
<td>7.3</td>
<td>6.3</td>
</tr>
<tr>
<td>Simple Payback, Years (with incentives)</td>
<td>7.3</td>
<td>6.3</td>
</tr>
</tbody>
</table>

- Decreased marginal rate due to increased natural gas consumption
- Annual savings increase from $842K to $969K
- Simple Payback reduces from **7.3 years** to **6.3 years**
II. Utility Rates – Sensitivity Analyses
Impact of Natural Gas Rate Increases/Decreases

- Natural gas prices (current/future) can impact economics of a CHP project
- With a 10% ($0.42/MMBtu) decreased price of natural gas (both in the Base Case and CHP Case), the simple payback reduces from **7.3 years to 6.8 years**

![Natural Gas Rate Sensitivity Analysis](chart.png)
II. Utility Rates – Sensitivity Analyses (cont.)

Impact of Electricity Rate Increases/Decreases

- Natural gas prices (current/future) can impact economics of a CHP project
- With a 15% (1¢/kWh) rate increase in the price of electricity (both in the Base Case and CHP Case), the simple payback reduces from 7.3 years to 5.5 years
II. Utility Rates – Sensitivity Analyses (cont.)
Impact of Combined Energy Price Increases/Decreases

- Combined impact of natural gas and electric prices should be analyzed
- With a 10% ($0.42/MBtu) decrease in the natural gas price and a 15% (1¢/kWh) rate increase in the price of electricity, the simple payback reduces from 7.3 years to 5.2 years
III. Redundancy (multiple generating units)

- Installing multiple generating units provides redundancy and increases resiliency benefits
  - Maintenance can be staggered for multiple generating units
  - Unplanned outage may only affect one unit while second unit can maintain operation
- Simple Payback increases from 7.3 years to 11 years

<table>
<thead>
<tr>
<th>CHP System</th>
<th>CHP Case 1</th>
<th>CHP Case 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales of Excess Power (Yes/No)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Net CHP Power, kW</td>
<td>3,402</td>
<td>3,402</td>
</tr>
<tr>
<td>CHP Electric Efficiency, % (HHV)</td>
<td>40.9%</td>
<td>37.5%</td>
</tr>
<tr>
<td>CHP Thermal Output, Btu/kWh</td>
<td>3,233</td>
<td>3,979</td>
</tr>
<tr>
<td>CHP Thermal Output, MMBtu/hr</td>
<td>11.00</td>
<td>13.54</td>
</tr>
<tr>
<td>CHP Fuel</td>
<td>Nat Gas</td>
<td>Nat Gas</td>
</tr>
<tr>
<td>CHP Availability, %</td>
<td>98%</td>
<td>98%</td>
</tr>
<tr>
<td>Incremental O&amp;M Costs, $/kWh</td>
<td>$0.011</td>
<td>$0.015</td>
</tr>
<tr>
<td>Thermal Utilization, %</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Total Installed Costs, $/kW</td>
<td>$1,800</td>
<td>$2,300</td>
</tr>
</tbody>
</table>

2 x 1,700 kW Engines
## IV. Avoided Boiler Replacement Costs

<table>
<thead>
<tr>
<th>Simple Payback</th>
<th>CHP Case 1</th>
<th>CHP Case 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHP Installed Costs</td>
<td>$6,123,600</td>
<td>$6,123,600</td>
</tr>
<tr>
<td>Additional Costs</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Federal Investment Tax Credit (Yes/No)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Avoided Equipment Credits*</td>
<td>$240,110</td>
<td>($240,110)</td>
</tr>
<tr>
<td>Total Installed Costs with Equipment Credit</td>
<td>$6,123,600</td>
<td>$5,883,490</td>
</tr>
<tr>
<td>Value of Resiliency</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Total Installed Costs less Incentives</td>
<td>$6,123,600</td>
<td>$5,883,490</td>
</tr>
<tr>
<td>Annual Operating Savings</td>
<td>$841,764</td>
<td>$841,764</td>
</tr>
<tr>
<td>Simple Payback, Years (w/o incentives)</td>
<td>7.3</td>
<td>7.0</td>
</tr>
<tr>
<td>Simple Payback, Years (with incentives)</td>
<td>7.3</td>
<td>7.0</td>
</tr>
</tbody>
</table>

- CHP can offset the need for a facility to purchase new boiler equipment
- For this example, the CHP system can provide 11 MMBtu/hr offsetting the cost of purchasing a boiler of equivalent size (source: boiler cost from previous study)
- Total Installed Costs reduced from $6.1M to $5.9M
- Simple Payback reduces from **7.3 years to 7.0 years**
V. Percent Average per kWh Electric Cost Avoided

- Assessing how to reduce the utility rate impact through analyzing utility rate class impacts, energy consumption, system availability, scheduling of maintenance, etc.
- With a 5% increase in avoided cost percentage of kWh, the simple payback reduces from 7.3 years to 6.5 years
### Simple Payback

<table>
<thead>
<tr>
<th></th>
<th>CHP Case 1</th>
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</tr>
</thead>
<tbody>
<tr>
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<td>$6,123,600</td>
</tr>
<tr>
<td>Additional Costs</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Federal Investment Tax Credit (Yes/No)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Avoided Equipment Credits*</td>
<td>$714,000</td>
<td>$0</td>
</tr>
<tr>
<td>Total Installed Costs with Equipment Credit</td>
<td>$6,123,600</td>
<td>$5,409,600</td>
</tr>
<tr>
<td>Value of Resiliency</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Total Installed Costs less Incentives</td>
<td>$6,123,600</td>
<td>$5,409,600</td>
</tr>
<tr>
<td>Annual Operating Savings</td>
<td>$841,764</td>
<td>$841,764</td>
</tr>
<tr>
<td>Simple Payback, Years (w/o incentives)</td>
<td>7.3</td>
<td>6.4</td>
</tr>
<tr>
<td>Simple Payback, Years (with incentives)</td>
<td>7.3</td>
<td>6.4</td>
</tr>
</tbody>
</table>

- CHP can offset the need for a facility to purchase backup diesel generator sets
- For this example, 3.4 MW of backup diesel gensets are avoided due to the 3.4 MW CHP System (calculated at an installed cost of $/kW analyzing 500 kW units, Source: RS Means 2015)
- Total Installed Costs reduced from $6.1M to $5.4M
- Simple Payback reduces from 7.3 years to 6.4 years
VII. Impact of Value of Resiliency

- Value of resiliency can impact CHP economics (value determined on case-by-case basis)
- For an example resiliency value of ~$150/kW (i.e. $500K), the Simple Payback reduces from 7.3 years to 6.7 years
### VIII. Impact of 10% Federal Investment Tax Credit

<table>
<thead>
<tr>
<th>Simple Payback</th>
<th>CHP Case 1</th>
<th>CHP Case 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHP Installed Costs</td>
<td>$6,123,600</td>
<td>$6,123,600</td>
</tr>
<tr>
<td>Additional Costs</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Federal Investment Tax Credit (Yes/No)</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Avoided Equipment Credits*</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Total Installed Costs with Equipment Credit</td>
<td>$6,123,600</td>
<td>$5,511,240</td>
</tr>
<tr>
<td>Value of Resiliency</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Total Installed Costs less Incentives</td>
<td>$6,123,600</td>
<td>$5,511,240</td>
</tr>
<tr>
<td>Annual Operating Savings</td>
<td>$841,764</td>
<td>$841,764</td>
</tr>
<tr>
<td>Simple Payback, Years (w/o incentives)</td>
<td>7.3</td>
<td>6.5</td>
</tr>
<tr>
<td>Simple Payback, Years (with incentives)</td>
<td>7.3</td>
<td>6.5</td>
</tr>
</tbody>
</table>

- A federal investment tax credit (ITC) of 10% is available for a for-profit organization and/or a 3rd party owned/operated CHP system.
- Total Installed Costs reduced from $6.1M To $5.5M
- Simple Payback reduces from 7.3 years to 6.5 years
Factoring All Considerations
(Initial Simple Payback of 7.3 years... when All Factors Applied, Resulting Simple Payback is 2.9 years)

<table>
<thead>
<tr>
<th>#</th>
<th>Impacting Factor</th>
<th>Individual Measure Impact on Simple Payback (years)</th>
<th>Cumulative Measure Impact on Simple Payback (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Discounted Natural Gas Rate of 10% (CHP Case Only)</td>
<td>6.3 years</td>
<td>6.3 years</td>
</tr>
<tr>
<td>2a</td>
<td>Decreased Natural Gas Price of 10% (both in Base Case and CHP Case)</td>
<td>6.8 years</td>
<td>6.1 years</td>
</tr>
<tr>
<td>2b</td>
<td>Increased Electric Price of 15% (in both Base Case and CHP Case)</td>
<td>5.5 years</td>
<td>4.8 years</td>
</tr>
<tr>
<td>3</td>
<td>Redundancy (multiple CHP units)</td>
<td>11 years</td>
<td>Not Included</td>
</tr>
<tr>
<td>4</td>
<td>Avoided Boiler Replacement Credit</td>
<td>7.0 years</td>
<td>4.6 years</td>
</tr>
<tr>
<td>5</td>
<td>Avoided Rate Percentage Increase of 5%</td>
<td>6.5 years</td>
<td>4.3 years</td>
</tr>
<tr>
<td>6</td>
<td>Avoided Installation Credit of Diesel Backup Emergency Genset</td>
<td>6.4 years</td>
<td>3.7 years</td>
</tr>
<tr>
<td>7</td>
<td>Adding Value of Resiliency (~$150/kW or ~$500K)</td>
<td>6.7 years</td>
<td>3.4 years</td>
</tr>
<tr>
<td>8</td>
<td>10% Federal Investment Tax Credit</td>
<td>6.5 years</td>
<td>2.9 years</td>
</tr>
</tbody>
</table>
Typical Next Steps Following CHP Qualification Screening by the CHP TAP

- Following a qualification screening review with a client, the US DOE CHP TAP can provide advanced technical assistance to address site specific criteria.

- If the analysis shows favorable potential, the site is recommended to move forward with a feasibility study.

- The CHP TAP is available to provide no-cost, unbiased 3rd party reviews on behalf of the clients moving forward for all stages of implementing combined heat and power.
Collecting data and implementing a screening analysis are the first steps towards evaluating the initial economics of a CHP project.

Emerging drivers are creating new opportunities to evaluate CHP.

Factors in addition to spark spread need to be accounted for and can significantly impact the economics of a potential CHP project.

Resources are available through the US DOE CHP TAP to discuss CHP project opportunities and to receive technical assistance.
Next Steps

- Contact the US DOE CHP TAP:
  - To receive a complementary CHP qualification screening or other technical assistance
  - If you already have an existing CHP plant and interested in expanding it
  - If you need an unbiased 3rd Party Review of a proposal
Thank You

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