Combined Heat and Power
Increasing Awareness and Action

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North Carolina Solar Center
North Carolina State University
Why are CHP investments typically made? (> 4,100 installations & ~ 82 GW installed capacity)

- Reduces energy costs for the end-user
- Increases energy efficiency, helps manage costs, maintains jobs
- Provides stability in the face of uncertain electricity prices
- Reduces risk of electric grid disruptions & enhances energy reliability (Hurricanes Katrina & Sandy; 2004 Blackout)
- Used as compliance strategy for emission regulations (Boiler MACT & Reduced Carbon Footprint)
- Natural gas supply increases and price stability
Recent CHP Investments Trend and Factors

Natural gas reserves have increased confidence in price stability

More development in states with favorable regulatory or policy status

Spark Spread improving in areas; Northeast, Texas, California

Biomass and other opportunity fuels in Southeast, Midwest and Northwest

Awareness of strategic applications: universities, hospitals, wastewater treatment, institutions

Growing interest in power reliability and critical infrastructure

Opportunity to meet environmental performance requirements in industrial and institutional sectors

## CHP Value Proposition

<table>
<thead>
<tr>
<th>Category</th>
<th>10 MW CHP</th>
<th>10 MW PV</th>
<th>10 MW Wind</th>
<th>Combined Cycle (10 MW Portion)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Capacity Factor</td>
<td>85%</td>
<td>25%</td>
<td>34%</td>
<td>67%</td>
</tr>
<tr>
<td>Annual Electricity</td>
<td>74,446 MWh</td>
<td>21,900 MWh</td>
<td>29,784 MWh</td>
<td>58,692 MWh</td>
</tr>
<tr>
<td>Annual Useful Heat</td>
<td>103,417 MWh_t</td>
<td>None</td>
<td>None</td>
<td>None</td>
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<tr>
<td>Footprint Required</td>
<td>6,000 ft²</td>
<td>1,740,000 ft²</td>
<td>76,000 ft²</td>
<td>N/A</td>
</tr>
<tr>
<td>Capital Cost</td>
<td>$24 million</td>
<td>$60.5 million</td>
<td>$24.4 million</td>
<td>$10 million</td>
</tr>
<tr>
<td>Annual Energy Savings</td>
<td>343,747 MMBtu</td>
<td>225,640 MMBtu</td>
<td>306,871 MMBtu</td>
<td>156,708 MMBtu</td>
</tr>
<tr>
<td>Annual CO₂ Savings</td>
<td>44,114 Tons</td>
<td>20,254 Tons</td>
<td>27,546 Tons</td>
<td>27,023 Tons</td>
</tr>
<tr>
<td>Annual NOx Savings</td>
<td>86.9 Tons</td>
<td>26.8 Tons</td>
<td>36.4 Tons</td>
<td>59.2 Tons</td>
</tr>
</tbody>
</table>

Based on: 10 MW Gas Turbine CHP - 30% electric efficiency, 70% total efficiency, 15 PPM NOx
Electricity displaces National All Fossil Average Generation (eGRID 2010) -
9,720 Btu/kWh, 1,745 lbs CO₂/MWh, 2.3078 lbs NOx/MWh, 6% T&D losses
Thermal displaces 80% efficient on-site natural gas boiler with 0.1 lb/MMBtu NOx emissions
<table>
<thead>
<tr>
<th>State</th>
<th>50-500 kW (MW)</th>
<th>.5-1 MW (MW)</th>
<th>1-5 MW (MW)</th>
<th>5-20 MW (MW)</th>
<th>&gt;20 MW (MW)</th>
<th>Total MW</th>
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<tbody>
<tr>
<td>Alabama</td>
<td>116</td>
<td>107</td>
<td>351</td>
<td>227</td>
<td>602</td>
<td>1,404</td>
</tr>
<tr>
<td>Arkansas</td>
<td>64</td>
<td>62</td>
<td>182</td>
<td>199</td>
<td>236</td>
<td>742</td>
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<tr>
<td>Florida</td>
<td>190</td>
<td>115</td>
<td>377</td>
<td>241</td>
<td>156</td>
<td>1,079</td>
</tr>
<tr>
<td>Georgia</td>
<td>220</td>
<td>169</td>
<td>683</td>
<td>755</td>
<td>803</td>
<td>2,631</td>
</tr>
<tr>
<td>Kentucky</td>
<td>114</td>
<td>104</td>
<td>287</td>
<td>396</td>
<td>339</td>
<td>1,239</td>
</tr>
<tr>
<td>Louisiana</td>
<td>80</td>
<td>60</td>
<td>345</td>
<td>517</td>
<td>2,052</td>
<td>3,054</td>
</tr>
<tr>
<td>Mississippi</td>
<td>69</td>
<td>56</td>
<td>170</td>
<td>223</td>
<td>571</td>
<td>1,089</td>
</tr>
<tr>
<td>North Carolina</td>
<td>254</td>
<td>184</td>
<td>746</td>
<td>686</td>
<td>428</td>
<td>2,298</td>
</tr>
<tr>
<td>South Carolina</td>
<td>109</td>
<td>90</td>
<td>415</td>
<td>447</td>
<td>747</td>
<td>1,809</td>
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<tr>
<td>Tennessee</td>
<td>149</td>
<td>118</td>
<td>430</td>
<td>457</td>
<td>1,053</td>
<td>2,207</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,365</strong></td>
<td><strong>1,064</strong></td>
<td><strong>3,987</strong></td>
<td><strong>4,149</strong></td>
<td><strong>6,985</strong></td>
<td><strong>17,550</strong></td>
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</tbody>
</table>

Data prepared by ICF International for U.S. DOE, October 2013
## Southeast Commercial CHP Technical Potential

<table>
<thead>
<tr>
<th>State</th>
<th>50-500 kW (MW)</th>
<th>.5-1 MW (MW)</th>
<th>1-5 MW (MW)</th>
<th>5-20 MW (MW)</th>
<th>&gt;20 MW (MW)</th>
<th>Total MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alabama</td>
<td>329</td>
<td>219</td>
<td>219</td>
<td>136</td>
<td>104</td>
<td>1,006</td>
</tr>
<tr>
<td>Arkansas</td>
<td>190</td>
<td>146</td>
<td>174</td>
<td>72</td>
<td>20</td>
<td>601</td>
</tr>
<tr>
<td>Florida</td>
<td>1,433</td>
<td>1,543</td>
<td>1,332</td>
<td>376</td>
<td>210</td>
<td>4,894</td>
</tr>
<tr>
<td>Georgia</td>
<td>695</td>
<td>492</td>
<td>566</td>
<td>182</td>
<td>166</td>
<td>2,101</td>
</tr>
<tr>
<td>Kentucky</td>
<td>268</td>
<td>193</td>
<td>237</td>
<td>92</td>
<td>65</td>
<td>855</td>
</tr>
<tr>
<td>Louisiana</td>
<td>324</td>
<td>258</td>
<td>236</td>
<td>144</td>
<td>0</td>
<td>963</td>
</tr>
<tr>
<td>Mississippi</td>
<td>184</td>
<td>137</td>
<td>195</td>
<td>92</td>
<td>0</td>
<td>607</td>
</tr>
<tr>
<td>North Carolina</td>
<td>574</td>
<td>403</td>
<td>438</td>
<td>211</td>
<td>148</td>
<td>1,774</td>
</tr>
<tr>
<td>South Carolina</td>
<td>315</td>
<td>216</td>
<td>294</td>
<td>39</td>
<td>0</td>
<td>864</td>
</tr>
<tr>
<td>Tennessee</td>
<td>450</td>
<td>287</td>
<td>350</td>
<td>132</td>
<td>22</td>
<td>1,241</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4,762</strong></td>
<td><strong>3,894</strong></td>
<td><strong>4,040</strong></td>
<td><strong>1,476</strong></td>
<td><strong>735</strong></td>
<td><strong>14,908</strong></td>
</tr>
</tbody>
</table>

Data prepared by ICF International for U.S. DOE, October 2013
State Awareness and Policy Activities

- DOE SEP Competitive Funding Selections for “Advancing Industrial Energy Efficiency” Nov 2013; Alabama, Iowa, Kentucky, Minnesota, Mississippi, Oregon, Texas and Wisconsin.
- Continued Federal support for states through DOE CHP Technical Assistance Partnerships and SEE Action Network
“Critical infrastructure” refers to those assets, systems, and networks that, if incapacitated, would have a substantial negative impact on national security, national economic security, or national public health and safety.”

Patriot Act of 2001 Section 1016 (e)

Applications:
- Hospitals and healthcare centers
- Water / wastewater treatment plants
- Police, fire, and public safety
- Centers of refuge (often schools or universities)
- Military/National Security
- Food distribution facilities
- Telecom and data centers
Power Outage Cost Estimates

Superstorm Sandy

- Nearly $20 billion in losses from suspended business activity
- Total losses estimated between $30 to $50 billion
- Two-day shutdown of the NY Stock Exchange, costing an estimated $7 billion from halted trading
- Rutgers estimates economic losses of $11.7 billion for New Jersey GDP


One estimate states that over $150 billion per year is lost by U.S. industries due to electric network reliability problems

Source: [https://www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_critical_facilities.pdf](https://www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_critical_facilities.pdf)
CHP Operates Through Super Storm Sandy

- South Oaks Hospital - Amityville, NY, 1.25 MW reciprocating engine
- Greenwich Hospital - Greenwich, CT, 2.5 MW reciprocating engine
- Christian Health Care Center - Wyckoff, NJ, 260 kW microturbine
- Princeton University - Princeton, NJ, 15 MW gas turbine
- The College of New Jersey - Ewing, NJ, 5.2 MW gas turbine
- Salem Community College - Carney’s Point, NJ, 300 kW microturbine
- Public Interest Data Center - New York, NY, 65 kW microturbine
- Co-op City - The Bronx, NY, 40 MW combined cycle
- Nassau Energy Corporation – Garden City, NY, 57 MW combined cycle
- Bergen County Utilities Wastewater Plant – Little Ferry, NJ, 2.8 MW reciprocating engine
- New York University – New York, NY, 14.4 MW gas turbine
- Sikorsky Aircraft Corporation – Stratford, CT, 10.7 MW gas turbine

For more information:
CHP and Microgrids

Microgrid generally considered to be self-contained grid systems equipped with on-site power generation

“A group of interconnected loads and distributed energy resources (DER) with clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid [and can] connect and disconnect from the grid to enable it to operate in both grid connected or island mode.” (DOE Microgrid Working Group Definition)

- CHP systems act as the backbone of microgrids by providing base load reliably
- Microgrids must be capable of “island” mode in anticipation of or in event of grid power failure
- Intermittent renewables & storage, complementary to CHP
Microgrid Example:
Gainesville Regional Utilities / Shands Hospital

- 4.3 MW GT CCHP
- chilled water: 4,200 tons
- steam: 14,500 pph
- 100% island / blackstart capability
- Category 4 Hurricane

Advantages
- utility–private partnership
- critical power
- no-low capital
- 50 yr life

Savings
- 36.2% cost
- $1.68 M/year
- 68% less CO2
- 99% less SOX
- 98% less NOX
Recent State / Local Policy Measures

- DOE/State of New Jersey/ NJ Transit/New Jersey Board of Public Utilities – announces microgrid to power the transit system among Newark, Jersey City, and Hoboken.

- Connecticut – first state to launch an microgrid program: $18M awarded to 9 microgrid projects in July 2013 – Gov. Malloy to commit additional $30M over the next 2 years.
EPA’s Boiler MACT Rule (CHP Role)

- ICI Boiler MACT - Standards for hazardous air pollutants from major sources: industrial, commercial and institutional boilers and process heaters
  - Final rule December 2012 – Compliance by January 31, 2016
- Compliance with MACT limits will be expensive for many coal and oil users (standard compliance measures)
- May consider converting to natural gas
  - Conversion for some oil units, replacements for coal units?
- May consider moving to natural gas fueled CHP (trade off of benefits versus additional costs)
  - Represents a productive investment
  - Potential for lower steam costs due to generating own power
  - Higher overall efficiency and reduced emissions
  - Higher capital costs, but partially offset by required compliance costs or new gas boiler costs
<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Number of Facilities</th>
<th>Number of Affected Units</th>
<th>Boiler Capacity (MMBtu/hr)</th>
<th>CHP Potential (MW)</th>
<th>CO₂ Emissions Savings (MMT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>332</td>
<td>751</td>
<td>180,525</td>
<td>18,055</td>
<td>114.2</td>
</tr>
<tr>
<td>Heavy Liquid</td>
<td>170</td>
<td>367</td>
<td>48,296</td>
<td>4,830</td>
<td>22.9</td>
</tr>
<tr>
<td>Light Liquid</td>
<td>109</td>
<td>241</td>
<td>22,133</td>
<td>2,214</td>
<td>10.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>611</strong>*</td>
<td><strong>1,359</strong></td>
<td><strong>250,954</strong></td>
<td><strong>25,099</strong></td>
<td><strong>147.6</strong></td>
</tr>
</tbody>
</table>

*Some facilities are listed in multiple categories due to multiple fuel types; there are 567 ICI affected facilities

- CHP potential based on average efficiency of affected boilers of 75%; Average annual load factor of 65%, and simple cycle gas turbine CHP performance (power to heat ratio = 0.7)
- GHG emissions savings based on 8000 operating hours for coal and 6000 hours for oil, with a CHP electric efficiency of 32%, and displacing average fossil fuel central station generation

The data on this chart is still being refined
Proposed Carbon Pollution Standard for New Power Plants

- Issued Proposed New Power Plant Standards on September 20, 2013

- Utility Boilers fired with Coal and IGCC Units
  - 1,100 lb CO2/MWh gross over a 12-operating month period, or
  - 1,000-1,050 lb CO2/MWh gross over an 84-operating month (7-year) period

- Stationary Gas Combustion Units SC/CC
  - 1,000 lb CO2/MWh gross for larger units (> 850 mmBtu/hr)
  - 1,100 lb CO2/MWh gross for smaller units (≤ 850 mmBtu/hr)
Relative Carbon Emissions from Power Generation

Based on US EPA Egrid Averages for United States
Industrial Plant, Institutional Campus, etc.

Carbon Emissions Reduction from CHP

Conventional Power / Heat

- 74,031 tons CO₂
- Grid Electric
- 1,779 lbs CO₂/MWh

On-site Boiler

- 23,029 tons CO₂

Power Plant

83,220 MWh/yr

Industrial Plant, Institutional Campus, etc.

10MW CHP System, NG CT

- 28,123 tons CO₂
- CHP Electric
- 676 lbs CO₂/MWh

Results from EPA CHP Emissions Calculator

43% Reduction of CO₂ Equivalents

CHP Electric

- 74,031 tons CO₂
- 676 lbs CO₂/MWh

Grid Electric

- 1,779 lbs CO₂/MWh

Results:

- 23,029 tons CO₂ recovered thermal
What does this mean for CHP?

- States may consider flexible approaches to meeting carbon pollution standards, including support for CHP to mitigate other emissions.
- Emissions savings from CHP could be captured in a number of ways:
  - Through utility ownership
  - Efficiency programs
  - Credit trading
Two Prominent Barriers to CHP

- Large Capital Investment which most companies are reluctant to make
  - Long payback periods by their standards
  - Not directly related to their main area of business

- Discouraged by many electric utilities
  - Utility regulatory framework often does not encourage CHP
  - Utilities encouraged to invest in central station power and upgrading the present grid structure (larger rates of return on their investments)
  - Requires state policy changes
Utility CHP Benefits

- Competitive cost with traditional centralized power
- Speed of deployment
- Avoids significant line losses
- Defer significant grid upgrades (reduces congestion)
- Reduce emission compliance costs
- Ability to function as a capacity resource
- Ability to balance system power fluctuations
- Ability to supplement and support greater renewable energy deployment
Example CHP Installations w/ Utilities

- We Energies (Domtar Paper Mill), Rothschild, WI, 50 MW boiler/steam turbine (2013)\(^1\)
- Lansing Board of Water & Light (REO Town Cogeneration Plant), Lansing, MI, 100 MW boiler / steam turbine (2013)\(^2\)
- City of Macon (Northeast Missouri Grain, LLC), Macon, MO, 10 MW combustion turbine (2003)\(^3\)
- City of Russell (U.S. Energy Partners, LLC), Russell, Kansas, 15 MW combustion turbine (2002)\(^4\)
- Detroit Thermal Energy (Cristal Global), Ashtabula, OH, 28 MW combustion turbine (2001)\(^5\)
- Muscatine Power & Water (Grain Processing Corp.), Muscatine, IA, 18 MW boiler / steam turbine (2000)\(^6\)
- Southern Co. approx 700MW CHP across its service area

\(^1\) [http://www.jsonline.com/business/power-plant-to-run-on-wisconsin-biomass-b9985790z1-221960911.html]
\(^3\) [http://www.midwestcleanenergy.org/profiles/ProjectProfiles/NortheastMissouriGrain.pdf]
\(^4\) [http://www.eea-inc.com/chpdata/States/OH.html]
\(^5\) [http://www.eea-inc.com/chpdata/States/OH.html]
\(^6\) [http://www.eea-inc.com/chpdata/States/IA.html]