Combined Heat and Power (CHP) for Wastewater Treatment Plants

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In Today’s Webinar:

- DOE CHP Technical Assistance Partnerships (TAP)
- Overview of Combined Heat & Power (CHP)
  - Concept
  - Benefits
  - Market
- Example CHP Projects
- Biogas Conditioning
- Working with US DOE CHP TAPs
- Next Steps & Questions
Acknowledgements
DOE CHP Technical Assistance Partnerships (CHP TAPs)

- **End User Engagement**
  Partner with strategic End Users to advance technical solutions using CHP as a cost effective and resilient way to ensure American competitiveness, utilize local fuels and enhance energy security. CHP TAPs offer fact-based, non-biased engineering support to manufacturing, commercial, institutional and federal facilities and campuses.

- **Stakeholder Engagement**
  Engage with strategic Stakeholders, including regulators, utilities, and policy makers, to identify and reduce the barriers to using CHP to advance regional efficiency, promote energy independence and enhance the nation’s resilient grid. CHP TAPs provide fact-based, non-biased education to advance sound CHP programs and policies.

- **Technical Services**
  As leading experts in CHP (as well as microgrids, heat to power, and district energy) the CHP TAPs work with sites to screen for CHP opportunities as well as provide advanced services to maximize the economic impact and reduce the risk of CHP from initial CHP screening to installation.

www.energy.gov/chp
DOE CHP Technical Assistance Partnerships (CHP TAPs)

DOE CHP Deployment Program Contacts
www.energy.gov/CHPTAP

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Combined Heat & Power (CHP)

- Concept
- Benefits
- Market Potential
CHP Recaptures Heat of Generation, Increasing Energy Efficiency, and Reducing GHGs

Power Plant
32% efficiency (Including T&D)

Onsite Boiler
80% efficiency

Total Efficiency ~ 50%

Heat

Total Efficiency ~ 75%

30 to 55% less greenhouse gas emissions
CHP System Schematic

**Fuel**
- Natural Gas
- Propane
- Biogas
- Landfill Gas
- Coal
- Steam
- Waste Products
- Others

**Prime Mover**
- Reciprocating Engines
- Combustion Turbines
- Microturbines
- Steam Turbines
- Fuel Cells

**Generator**

**Electricity**
- On-Site Consumption
- Sold to Utility

**Heat Exchanger**

**Thermal**
- Steam
- Hot Water
- Space Heating
- Process Heating
- Space Cooling
- Process Cooling
- Refrigeration
- Dehumidification
Common CHP Technologies

- Microturbines
- Gas Turbines
- Reciprocating Engines
- Fuel Cells

Capacity ranges:
- 50 kW
- 100 kW
- 1 MW
- 10 MW
- 20 MW
What Are the Benefits of CHP?

- CHP is **more efficient** than separate generation of electricity and heating/cooling
- Higher efficiency translates to **lower operating costs** (but requires capital investment)
- Higher efficiency **reduces emissions** of pollutants
- CHP can also increase **energy reliability** and enhance power quality
- On-site electric generation can **reduce grid congestion** and avoid distribution costs.
Emerging National Drivers for CHP

- Benefits of CHP recognized by policymakers
  - State Portfolio Standards (RPS, EEPS), Tax Incentives, Grants, standby rates, etc.
- Favorable outlook for natural gas supply and price in North America
- Opportunities created by environmental drivers
- Utilities finding economic value
- Energy resiliency and critical infrastructure

DOE / EPA CHP Report
August 2012

Total CHP by Application

By Capacity - 82.6 GW

- Other Comm./Inst. 9,148 MW
- Chemistry 24,028 MW
- Refining 16,305 MW
- Oil/Gas Extraction 2,760 MW
- Primary Metals 3,837 MW
- Pulp and Paper 11,246 MW
- Other Industrial 6,676 MW
- Colleges/Univ. 2,654 MW
- Other/Unknown 167 MW

By Site - 4,395 Sites

- Multi-Family Buildings 333 Sites
- Schools 254 Sites
- Hospitals/Healthcare 220 Sites
- Other Industrial 1,017 Sites
- Other/Unknown 268 Sites
- Food Processing 244 Sites
- Colleges/Univ. 272 Sites
- Wastewater Treatment 220 Sites

Source: DOE CHP Installation Database (U.S. installations as of December 31, 2016)
Southcentral CHP TAP Region
Onsite Technical Potential

![Map of Southcentral CHP Region]

<table>
<thead>
<tr>
<th>State</th>
<th>Industrial (MW)</th>
<th>Commercial (MW)</th>
<th>Total (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arkansas</td>
<td>1,127</td>
<td>668</td>
<td>1,795</td>
</tr>
<tr>
<td>Louisiana</td>
<td>3,793</td>
<td>1,152</td>
<td>4,945</td>
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<tr>
<td>New Mexico</td>
<td>699</td>
<td>441</td>
<td>1,140</td>
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<tr>
<td>Oklahoma</td>
<td>955</td>
<td>962</td>
<td>1,917</td>
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<tr>
<td>Texas</td>
<td>6,648</td>
<td>7,414</td>
<td>14,062</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>13,222</strong></td>
<td><strong>10,637</strong></td>
<td><strong>23,859</strong></td>
</tr>
</tbody>
</table>

On-Site Technical Potential by State

- Texas: 14,062 MW
- Arkansas: 1,795 MW
- Louisiana: 4,946 MW
- New Mexico: 1,140 MW
- Oklahoma: 1,916 MW

On-Site Technical Potential by Application

- Chemicals: 4,720 MW
- Petroleum Refining: 4,598 MW
- Other Industrial: 2,387 MW
- Food Processing: 829 MW
- Paper: 689 MW
- Schools: 2,148 MW
- College/Univ.: 1,796 MW
- Comm. Office Buildings: 1,678 MW
- Hospitals: 1,098 MW
- Other Commercial: 3,918 MW

Critical Infrastructure

“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)

- 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
CHP and WWTP

- Water
- Heat Recovery Unit
- Steam or Hot Water
- Hot Exhaust Gases
- Engine Turbine Microturbine Fuel Cell
- Electricity
- Generator
- WWTF
- Grid
- Anaerobic Digester Biogas
- Sludge Drying Evaporation
- Digester Heat Space Heat Sludge Drying Evaporation
Why CHP at WWTPs?

- Reduce Energy Costs
- Energy Resilience
- Sustainability Planning
- Enhanced Reliability
- Lower Emissions
- Biogas production
- Utility load shedding
- Availability of incentives
- Biosolids management
- “Green” publicity

Technology Applications

- **Generate Electric Power**
  - Combustion turbines
  - Reciprocating engines
  - Microturbines
  - Fuel Cell

- **Use Recovered Heat**
  - Heat for Digestion Process
  - Building Heat
  - Feed Gas Preheat
  - Sludge Drying
  - Evaporation
Project Snapshots
Project Snapshot:

Downers Grove Sanitary District
Downers Grove, IL

Application/Industry: Wastewater Treatment
Facility Size: 11 Million gallons/day
Capacity (MW): 280 kW
Prime Mover: Reciprocating Engine
Fuel Type: Biomass
Thermal Use: Heat for the Digestion Process
Project Costs: $2.5 million
Installation Year: 2014

Testimonial: Waste grease from nearby restaurants helps power the CHP system, which offsets about 50% of the wastewater treatment plant’s energy consumption.
**Project Snapshot:**

**Southside Water Reclamation Plant**
Albuquerque, NM

**Application/Industry:** Wastewater Treatment

**Facility Size:** 76 Million gallons per day; peak 120 MGD

**Capacity (MW):** 6.6 MW

**Prime Mover:** Reciprocating Engine

**Fuel Type:** Biogas

**Thermal Use:** Digestion Process, Building Heat

**Installation Year:** 1986

**Testimonial:** CHP is a key part of Southside’s energy management: Cost savings for water users; making use of a renewable gas supply available on-site; providing back-up power to the plant.
Project Snapshot:

Southside Water Treatment Plant

dallas, TX

Application/Industry: Wastewater Treatment
Facility Size: 110 Million gallons per day; peak 195 MGD
Capacity (MW): 4.2 MW
Prime Mover: Reciprocating Engine
Fuel Type: Biogas – 46% of load
Thermal Use: Digestion Process, Building Heat
Installation Year: 2008

Testimonial: "This project has allowed Dallas to save money on its electrical costs and has increased reliability at the plant with another electrical feed. By utilizing a public-private partnership, the City was able to implement the project without additional capital to construct the facility or additional labor to operate and maintain the facility."
Project Snapshot: Village Creek Water Reclamation Facility
Fort Worth, TX

Application/Industry: Wastewater Treatment

Facility Size: 116 Million gallons per day (MGD) Design
Facility Peak Load: 12.5 MW
Facility Average Load: 8 MW

Equipment: Two Solar Taurus 60 Gas Turbine Driven Generator (one on standby), Heat Recovery Steam Generator

Fuel: Digester Gas, Landfill Gas and Natural Gas

Operation: 60-75 % of the electric load is covered by CHP

Thermal Energy Use: Steam turbines to drive centrifugal blower, Digester heat

CHP in Operation Since: 2012

Testimonial: “I highly recommend this type of project. Not only do you save money but you reduce your footprint and utilize resources that were once wasted.”

– Ana Julia Peña-Tijerina Sr. Professional Engineer

Village Creek Water Reclamation Facility, Fort Worth Water Department

Bio-gas Turbine (Left) and Heat Recovery Steam Generator & Duct Burner (Right)
Landfill Gas to Energy plant in the Southeast

Zero Liquid Discharge
## CHP Installation Status in US WWTPs

### Prime Mover Type in WWTPs

<table>
<thead>
<tr>
<th>Prime Mover Type</th>
<th># of CHP Systems</th>
<th>CHP Gen. Capacity (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combustion Turbine</td>
<td>15</td>
<td>365.1</td>
</tr>
<tr>
<td>Reciprocating Engine</td>
<td>155</td>
<td>273.2</td>
</tr>
<tr>
<td>Boiler/Steam Turbine</td>
<td>4</td>
<td>58.3</td>
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<tr>
<td>Microturbine</td>
<td>36</td>
<td>6.7</td>
</tr>
<tr>
<td>Fuel Cell</td>
<td>10</td>
<td>10.1</td>
</tr>
<tr>
<td>Combined Cycle</td>
<td>1</td>
<td>28.0</td>
</tr>
<tr>
<td>Organic Rankine Cycle</td>
<td>1</td>
<td>0.6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>222</strong></td>
<td><strong>742.0</strong></td>
</tr>
</tbody>
</table>

### Prime Mover Type in WWTPs / Biogas Only

<table>
<thead>
<tr>
<th>Prime Mover Type</th>
<th># of CHP Systems</th>
<th>CHP Gen. Capacity (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reciprocating engine</td>
<td>117</td>
<td>190.9</td>
</tr>
<tr>
<td>Microturbine</td>
<td>24</td>
<td>5.0</td>
</tr>
<tr>
<td>Fuel cell</td>
<td>8</td>
<td>9.7</td>
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<tr>
<td>Combustion turbine</td>
<td>6</td>
<td>79.8</td>
</tr>
<tr>
<td>Steam turbine</td>
<td>3</td>
<td>38.3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>158</strong></td>
<td><strong>323.7</strong></td>
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</table>

Source: U.S. DOE CHP Installation Database [https://doe.icfwebservices.com/chpdb/](https://doe.icfwebservices.com/chpdb/)
Where are the Southcentral opportunities for CHP in WWTPs?
(34 MW of CHP Potential at 179 WWTPs)

CHP Technical Potential in Wastewater Treatment

Arkansas
Louisiana
New Mexico
Oklahoma
Texas

50-500 kW (MW)  0.5-1 MW (MW)  1-5 MW (MW)  5-20 MW  >20 MW
Biogas and CHP
Biogas Cleaning System

- **Contaminants to remove**
  - Hydrogen Sulfide
  - Moisture
  - Siloxanes and particulates

![Diagram of Biogas Cleaning System]

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**U.S. Department of Energy**

**CHP Technical Assistance Partnerships**

**SOUTHCENTRAL**
Biogas Siloxane Damage

- Siloxane in biogas will damage the engine

Monthly Analysis - Energy

- Monthly supply and demand changes as sludge rate varies
- CHP supplies partial thermal demand due to restricted biogas production

![Graph showing monthly supply and demand variations]

- Maximum CHP Supply
- Thermal Demand of WWTP

Scale is blocked due to confidentiality
Monthly Analysis – Operation

- Engine load is set by economically maximizing consumption of biogas
- Engine load changes as biogas production varies

Scale is blocked due to confidentiality
How to Implement a CHP Project with the Help of the CHP TAP
CHP TAP Role: Technical Assistance

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

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

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

**Procurement, Operations, Maintenance, Commissioning**
- Review specifications and bids.
High level assessment to determine if site shows potential for a CHP project

- Qualitative Analysis
  - Energy Consumption & Costs
  - Estimated Energy Savings & Payback
  - CHP System Sizing

- Quantitative 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>18,872</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>23,500</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>
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### Annual Operating Costs

<table>
<thead>
<tr>
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<th>Base Case</th>
<th>CHP Case</th>
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<tbody>
<tr>
<td>Purchased Electricity, $</td>
<td>$7,060,013</td>
<td>$1,104,460</td>
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<tr>
<td>Standby Power, $</td>
<td>$0</td>
<td>$0</td>
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<tr>
<td>On-site Thermal Fuel, $</td>
<td>$3,195,000</td>
<td>$141,539</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
- Total Installed Costs, $/k  $12,990,000
- Simple Payback, Years  5.3

### Operating Costs to Generate

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Fuel Costs, $/kWh</td>
<td>$0.070</td>
</tr>
<tr>
<td>Thermal Credit, $/kWh</td>
<td>($0.037)</td>
</tr>
<tr>
<td>Incremental O&amp;M, $/kWh</td>
<td>$0.009</td>
</tr>
<tr>
<td>Total Operating Costs to Generate, $/kWh</td>
<td>$0.042</td>
</tr>
</tbody>
</table>
Screening Questions

- Do you pay more than $.06/kWh on average for electricity (including generation, transmission and distribution)?
- Are you concerned about the impact of current or future energy costs on your operations?
- Are you concerned about power reliability? What if the power goes out for 5 minutes… for 1 hour?
- Does your facility operate for more than 3,000 hours per year?
- Do you have thermal loads throughout the year? (including steam, hot water, chilled water, hot air, etc.)
Does your facility have an existing central plant?
Do you expect to replace, upgrade, or retrofit central plant equipment within the next 3-5 years?
Do you anticipate a facility expansion or new construction project within the next 3-5 years?
Have you already implemented energy efficiency measures and still have high energy costs?
Are you interested in reducing your facility's impact on the environment?
Do you have access to on-site or nearby biomass resources? (i.e., landfill gas, farm manure, food processing waste, etc.)
CHP in WWTPs – Early Questions

1. How reliable is the electricity coming into your facility?
2. What is the average price of electricity and natural gas you are paying?
3. What sources of heat are needed within the facility?
4. Can you provide one year’s worth of electric and thermal energy bills / consumption?
5. What is the critical load in power outages?
6. What is the maximum and average flow of your facility (MGD)?
7. How do you treat your waste? Do you utilize anaerobic digesters? If so...
   a) Are you producing biogas? How much? Does it change seasonally? How is the biogas currently being used (e.g. flaring, electric generation, thermal)?
   b) Have you had an analysis of your biogas? What level of contaminants are in the biogas (e.g. H2S, moisture, siloxanes)?
   c) What additional revenue streams can result from a biogas CHP system?

What Helps Make a Biogas CHP Project Feasible in a WWTP?

• Maximizing revenue streams

• Using co-digestion
  — Some co-digestion feedstocks are amazing producers of biogas, including animal waste and food processing waste

• Having a proper design for the climate zone and technology choice matches solids content of the feedstock

• Scrubbing the biogas – biogas can contain H₂S, Siloxanes, CO₂, and other impurities that could harm the CHP system and lower the fuel heat content

• Maximizing heat recovery

• Strong O&M support

Source: USDA, US EPA, & US DOE Biogas Opportunities Roadmap
CHP Project Resources

DOE CHP Technologies Fact Sheet Series

Good Primer Report

www.energy.gov/chp-technologies

www.eere.energy.gov/chp
CHP Project Resources

DOE Project Profile Database

EPA dCHPP (CHP Policies and Incentives Database)

energy.gov/chp-projects

www.epa.gov/chpdchpp-chp-policies-and-incentives-database
CHP Project Resources

DOE CHP Installation Database
(List of all known CHP systems in U.S.)

And of course...
No Cost CHP Screening and Other Technical Assistance from the CHP TAP
Next Steps

Resources are available to assist in developing CHP Projects

Contact the Southcentral CHP TAP to:

▪ Perform CHP Qualification Screening for a particular facility
▪ Identify existing CHP sites for Project Profiles
▪ Advanced Technical Assistance
Summary

- CHP is a proven technology in WWTPs providing energy savings, reduced emissions, and opportunities for resiliency.
- Emerging drivers are creating new opportunities to evaluate CHP and numerous examples exist to learn more about how other WWTPs have incorporated CHP.
- Engage with the US DOE Southcentral CHP TAP to learn more about the technical assistance offerings in evaluating CHP in your WWTP.
Thank You!

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