Better Plants
U.S. DEPARTMENT OF ENERGY

CHP Technical Assistance Partnerships

Combined Heat and Power Systems
Virtual INPLT Training

Session 4 – Success Stories and Case Studies

Tuesday – Dec 13th, 2022

10 am – 12:30 pm EST

U.S. DEPARTMENT OF ENERGY

Today's Training Faculty – DOE Combined Heat and Power Technical Assistance Partnerships

Isaac Panzarella, PE

- Director, Southeast CHP TAP
- Associate Director, NC Clean Energy Technology Center at NC State University
- 25 years of experience in sustainable and clean energy and building systems design and project development

Carol Denning

- Director, Pacific CHP TAP
- Director - Energy Reliability and Resilience, Center for Sustainable Energy
- 30+ years of experience in business development in the energy industry including CHP and district energy

Gil McCoy, PE

- Assistant Director, Northwest CHP TAP
- Senior Energy Systems Engineer, Extension Energy Program at Washington State
- Over 40 years of experience in renewable energy development and industrial systems efficiency

Agenda – CHP Success Stories & Case Studies

Today's Content:

- What Makes a CHP Success Story?
- Case Studies
  - Penn Medicine Princeton Medical Center, Trenton, NJ
  - Shaw Industries, Columbia, SC
  - Perdue Agribusiness, Cromwell, KY
  - Durham and Gresham WWTPs, Oregon
- CHP Project Profiles & Other Resources
- Kahoot Quiz Game
- Q&A

Oak Ridge National Laboratory

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Better Buildings is an initiative of the U.S. Department of Energy

CHP Technical Assistance Partnerships

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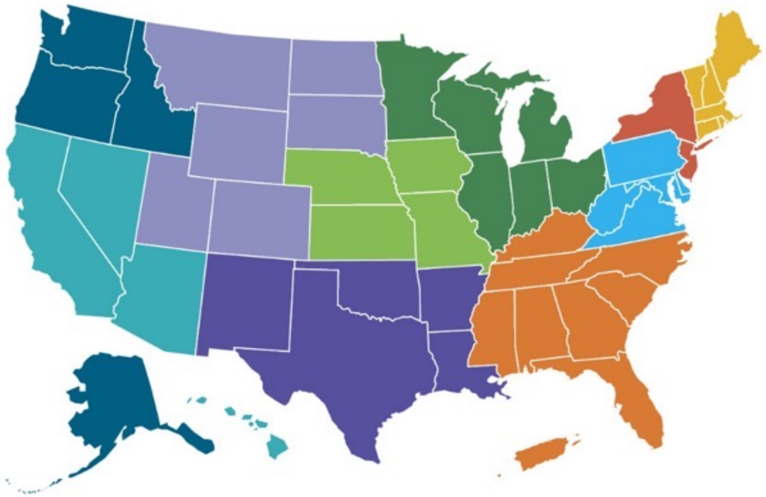

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DOE Combined Heat and Power Technical Assistance Partnerships

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

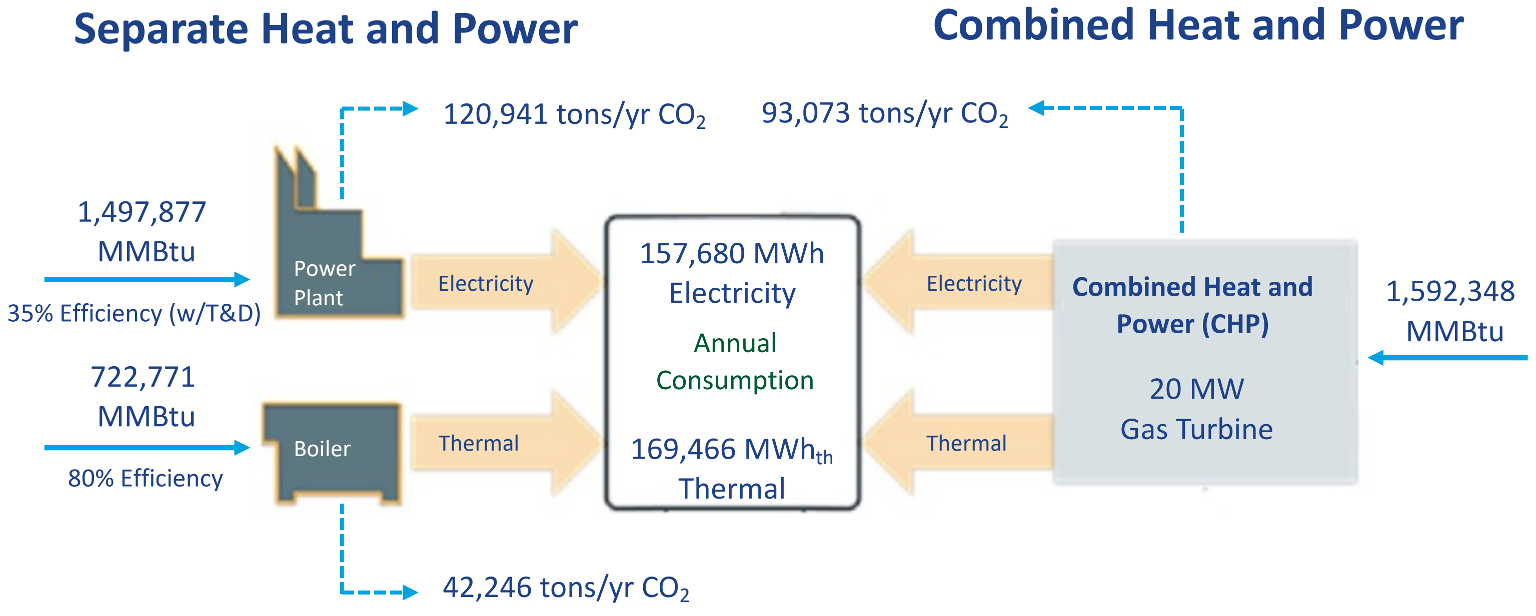
- As leading experts in CHP (as well as microgrids, heat to power, and district energy) the CHP TAPs work with sites to screen for CHP opportunities as well as provide advanced services to maximize the economic impact and reduce the risk of CHP from initial CHP screening to installation.

www.energy.gov/chp

CHP Value Lies in Energy and CO2 Emissions Savings

20 MW Gas Turbine CHP System

- Natural gas fuel
- 90% load factor (7,884 hours)
- 33.8% electric efficiency
- 75.7 MMBtu/hr steam output
- 100% thermal utilization
- Displaces 80% efficient natural gas boiler
- CO_2 savings based on displacing EPA AVERT Uniform EE grid emissions factor (1,534 lbs CO_2/MWh)



49% Total Efficiency

70% Total Efficiency

Energy savings: 628,300 MMBtu/yr

CO_2 Savings: 70,114 tons/yr

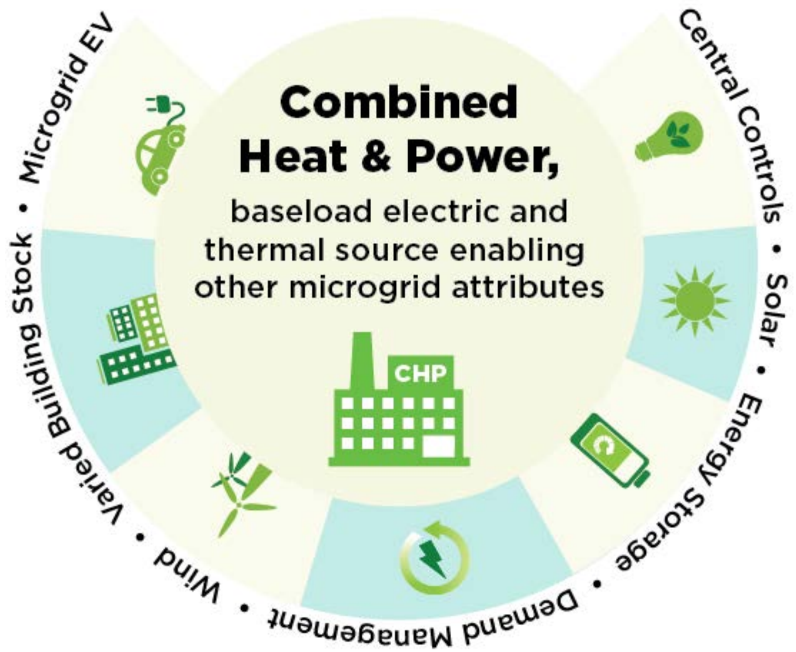
Prepared by Entropy Research, LLC, 11/1/2022

CHP Enables Reliable and Resilient Microgrids

A microgrid is a **group of interconnected loads and distributed energy resources** within clearly defined electrical boundaries that acts as a **single controllable entity** with respect to the grid.

A microgrid can **connect and disconnect** from the larger utility grid to enable it to operate in both **grid-connected** or **island-mode**.

Source: U.S. Department of Energy Microgrid Exchange Group



With a CHP system providing baseload electric and thermal energy, microgrids can add:

- Solar and wind resources
- Energy storage
- Demand management
- Central controls
- Electric vehicle charging

Flexible CHP systems can ramp up and down as needed to balance renewable loads and provide grid services

Steps to Developing a CHP Project and the Technical Assistance Available through the CHP TAPs

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.

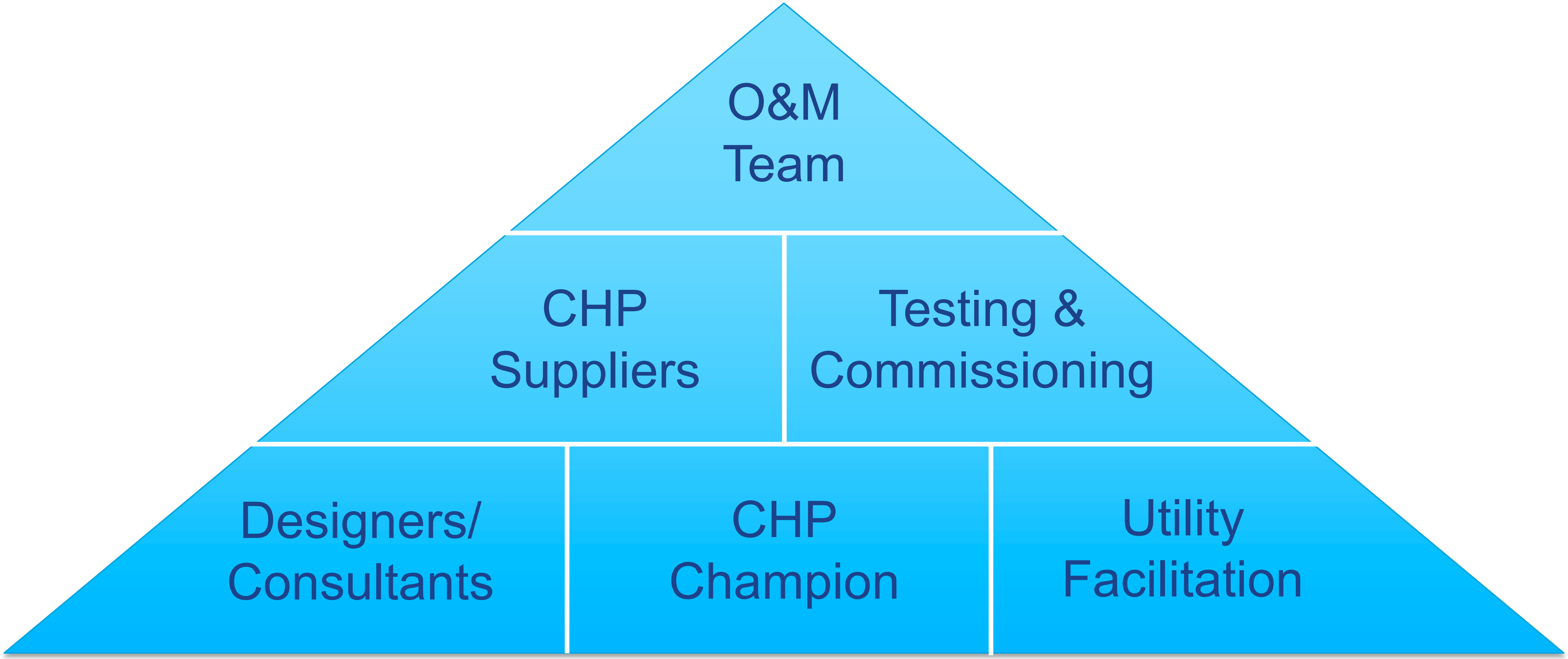
Investment Grade Analysis

Perform 3rd Party reviews of Engineering Analysis. Review equipment sizing and choices.

Procurement, Operations, Maintenance, Commissioning

Review specifications and bids.

CHP Success Requires a Great Team



Case Study:
Penn Medicine Princeton Medical Center
CHP Microgrid for Critical Facility Resilience

U.S. DEPARTMENT OF
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Overview

Today's Content:

- Introduction
- Key Drivers
- Project Leaders & Champions
- Lesson from other CHP End Users
- Partnering with CHP Company
- Startup and commissioning
- Detailed operations and maintenance lessons learned
- Benefits and Successes

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Penn Medicine Princeton Medical Center
Plainsboro, New Jersey

Penn Medicine Princeton Health

Project Snapshot:
CHP Microgrid

Application	Hospital
Capacity	4.6 MW
Prime Mover	Gas Turbine
Fuel Type	Natural Gas
Thermal Use	Space Heating & cooling
Installation Year	2010

Project Highlights: Penn Medicine Princeton Medical Center uses a CHP-anchored microgrid to ensure reliable operation of the facility. Incorporating CHP, solar panels, backup generators, and thermal energy storage, the facility rode through 50 power dips in 2018 without any adverse impacts on hospital function.

New York-New Jersey CHP TAP - https://chptap.lbl.gov/profile/181/PennMedicine-Project_Profile.pdf

Princeton Medical Center's CHP system provides $2.5 million dollars annually in energy savings. The project was developed via a public-private partnership with Clearway Energy, Inc, who Princeton Medical Center purchases energy from under an energy services agreement. *Photo courtesy of Clearway Energy, Inc.*

Project Testimonial

"CHP enables us to use environmentally sustainable energy as we fulfill our mission of providing high-quality healthcare. It meets our hospital's energy needs while reducing our operating costs and protecting the environment."

- Barry Rabner, President and CEO

Penn Medicine Princeton Health

Princeton Medical Center (PMC)

- Penn Medicine Princeton Medical Center (PMC) formally known as the University Medical Center of Princeton
  - 355-bed non-profit, academic medical center located in Plainsboro Township of New Jersey.
  - PMC serves western New Jersey & central New Jersey areas.
  - The hospital is owned by Penn Medicine Health Systems

- PMC CHP Microgrid
  - Energy is provided by a state-of-the-art CHP microgrid
  - Microgrid is owned and operated by Cordea Energy
  - Cordea was formally known as NRG & Clearway Energy

Key Project Drivers

Cost savings and operational improvements	• Cost savings from purchasing grid electricity & reducing demand charges • Cost savings for thermal energy production – steam, hot water, & chilled water • Costs savings from grid arbitrage
Business risks	• Moving CHP capital cost to third-party energy provider balance sheet allowed Hospital to focus capital on core business and building. • 3rd party insulated the hospital from CHP Microgrid project development risks • 3rd party accepted full responsibility for plant operations and maintenance thus insulating the hospital from CHP O&M risk
Reputation risks	• High Risk of grid disruption – has operational and reputational cost • Hospital required – a resilient power system to support the hospital with reliable, continuous energy supply, 24/7 regardless of grid conditions.

Project Leaders & Champions

Visionary leadership prompted an exploration of non-traditional energy-efficiency solutions, to determine if there was an opportunity to capitalize on operational and cost savings.

Barry Rabner
CEO Princeton Medical Center
2002 -2021
Visionary Healthcare Leader

David Crane
CEO NRG Energy
2003-2015
Visionary Energy Leader

Princeton Medical Center - Initial Plan

- Princeton Medical Center Needs
  - Hospitals in the Northeast are extremely competitive
  - To compete, Princeton needed incorporate the highest-level sophisticated equipment and robotics to offer top-tier procedures
  - Robotic surgery, and MRI machines are capital intensive and energy intensive
- Central Utility Plant
  - Initial CUP was planned for boilers and chillers with electricity from the grid.
  - Upgrades surgical equipment would require a top-tier energy system
  - Learned from other end users nearby

Learning from other CHP End Users - Princeton University

Best in Class CHP Microgrid

- CHP provides power, heating, and cooling on campus for 25 years

CHP as part of the long-term solutions

- The **CHP** integral part of achieving the clean energy goals of the University's Sustainability Action Plan.
- **CHP microgrid** –will continue to play a significant role as the University drives toward its goal of net zero emissions by 2046

Training & Demonstration

- Co-gen plant serves as a learning laboratory for energy efficiency , water conservation, reliability.

https://facilities.princeton.edu/news/princeton-s-co-gen-plant-marks-25-powerful-years-of-operation-points-clean-energy-future

Third-Party Partner – CHP Provider

- ## Princeton Medical Center Needs
  - **Princeton Medical Center** - CEO Barry Rabner realized that, as he puts it,
  - "Buying, producing, and delivering power is something we don't do. So, we looked around the country at potential partners who could help us achieve what we were looking for".

    https://www.theatlantic.com/sponsored/nrg/running-the-21st-century-hospital/431/

- ## Experienced 3rd Party
  - At the time – NRG -largest Independent Power Procurer – Fortune 200
  - Own/operated- **7 DESs (**District Energy Systems) & **11 CHP** plants nationally
  - Had the capital and experience to DBOOM the project
  - Long-term O&M agreement - critical component
  - Same team – Ownership has changed over the years

Central Utility Plant – Microgrid in Action

CHP

4.6MW natural gas plant supplies 100% of heating & cooling needs and electrical CHP acts as microgrid backbone

Enterprise Energy Management

Empowers the plant to make smarter energy decisions

Backup generation

The Joint Commission Mandates backup generation for all hospitals and skilled nursing centers

With the grid down, PMCs 3 backup generators can support the hospital's essential power needs.

Chillers

Three 1,000-ton electric chillers and one 700-ton absorption chiller provide chilled water

Grid

PMC plant draw power from or export to the PJM power grid.

Grid Services:
Voltage support & Frequency Reserve

Thermal Storage

1.2 M gallon chilled water storage for cooling the hospital

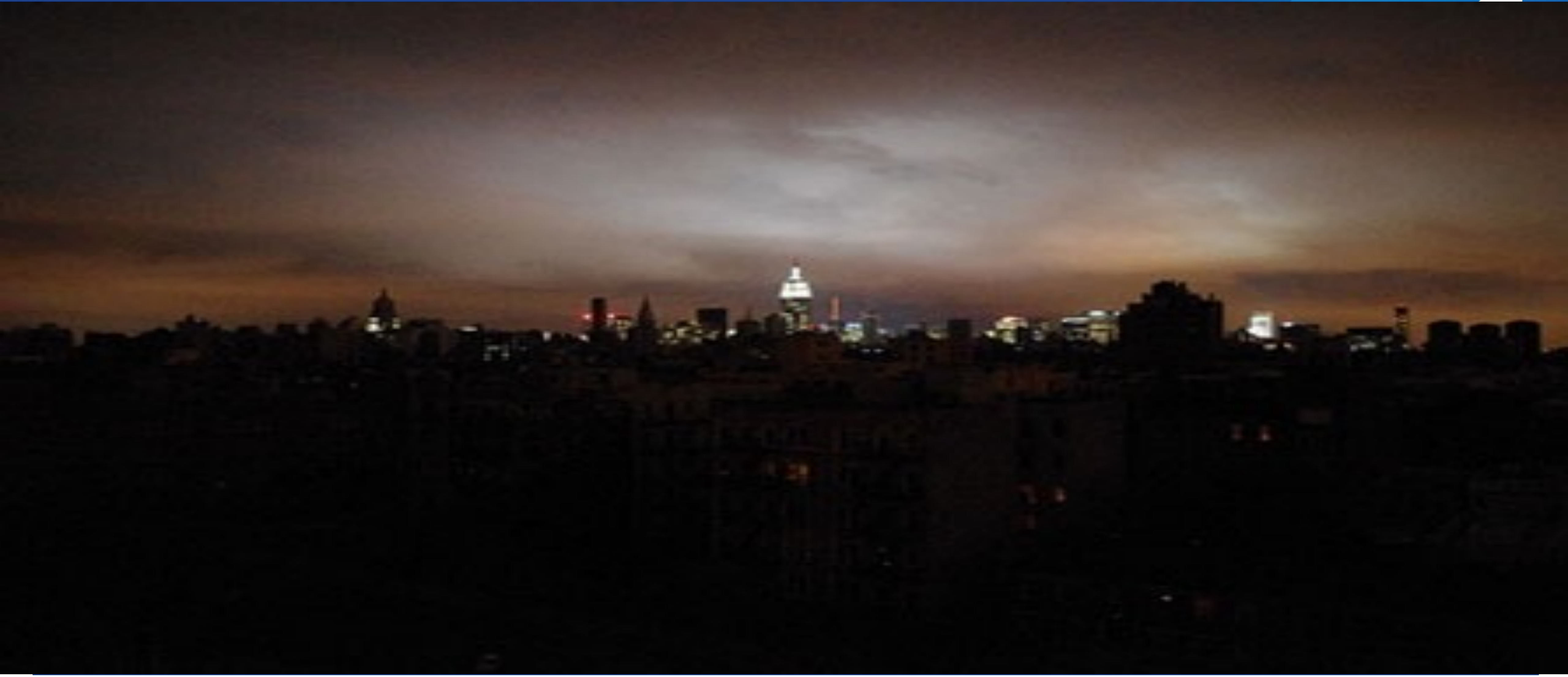
Solar

200kW Solar Array provides electricity and shaded parking

EVI

Two 30-amp electric vehicle charging stations (2012)

Testing, Startup and Commissioning – Super Storm Sandy 2012



Long term O&M – Lessons Learned Power Generation

- Gas Turbine
  - In PMC case the Gas Turbine Compressor was built in an inaccessible modular building. Place prime to ensure easy maintenance and rigging access.
  - GT are susceptible to fouling. High-Efficiency Air Inlet filters dramatically reduce compressor fouling.
  - HEPA - filters keep compressor cleaner which helps maintain a higher power level.
  - CORE/Firm GAS -GT is a gas only prime mover. If the gas supply is interruptible the plant will face the full effect of electrical costs if gas is curtailed.
  - Firm gas considerations a way to hedge this risk - expensive
- Emergency Backup Generation
  - Consider one emergency diesels to be dual fuel with NOX controls.
  - During a Super Storm Sandy endurance became more important that response time
  - Check with Joint commission

Long term O&M –Lessons Learned Thermal

- Chilled Water (CHW)
  - CHW is as critical to health care yet there are no life safety requirements. Consider spare equipment for N+1.
  - If potential CHW capacity constraint -plan for additional CHW and electrical connections to handle CHW rentals.
- Water Harvesting & Conservation
  - New hospitals should harvest air handler condensate & pipe to cooling towers.
  - PMC Plant recovers condensate from inlet cooler. This low conductivity, clean water is perfect cooling tower makeup water.
  - Hospitals use a massive amount of fresh air - making the air inlet cooler coils, water-generating machines.
  - PMC recovers ~4000 gal/day from just the air inlet cooler when it is in service.

Long term O&M –Lessons Learned Thermal

- Cooling Towers
  - There should be sufficient cooling tower capacity to allow routine cleaning and inspection of cooling towers as a legionella protection measure
  - No mud = no bugs
  - In PMC case the Gas Turbine Compressor was built in an inaccessible modular building. Place prime to ensure easy maintenance and rigging access
- Cooling Tower Cleaning
  - Each tower system should be configured with a hydrogen peroxide dosing tank.
  - H2O2 is used as the disinfecting agent (no bleach) which eliminates the need for flushing and protects the downstream sewer plants from the bleach.
  - H2O2 dissipates after about 20 minutes. It is an excellent disinfectant. Disinfecting can be done while plant is in full operation and has no objectionable odor.
- Thermal Energy Storage (TES)
  - TES tank allows plant to shut down to inspect and clean cooling towers as necessary
  - Provides optimal plant flexibility

Lessons Learned- Energy Management System (EMS)

- EMS - Predictive
  - Predictive analytics should bring tools to increase efficiency, economic and carbon performance and optimize hedge positions while decreasing market risk.
- EMS Productive
  - Real-time and forward-looking analytics can provide guidance or control that is focused on efficiency and economic performance.
  - These efficiency gains increase as more diverse assets are integrated, i.e., renewables and storage
- EMS Self Sustaining
  - EMS allows facilities to achieve master plan energy goals, including
    - Cost reduction
    - Thermal efficiency optimization
    - Carbon footprint management
- EMS GHG impacts & reporting
  - PMC report 500 MTN CO_2/year

Land Planning - Lessons Learned

- **CHP & Land planning**
  - CHP can support additional buildings and/or facilities on contiguous properties.
  - CHP is a technology that enjoys over-the-fence rules
- **Electricity**
  - In most jurisdictions, wheeling electricity across public rights-of-way is not allowed.
- **Lesson learned**
  - In this case, Children's Hospital cannot be served by the CHP microgrid because of the public street between the CUP and CHOP
  - Early planning could have potentially located CHOP on a contiguous property.

Microgrid Success

- **Operating Success**
  - Enhanced reliability and 100% redundancy for power needs
  - Enhanced use of condensate lines and makeup water
  - Islands from the grid and serves critical loads during grid outages
- **Environmental & Community Benefits**
  - Carbon footprint reduced by 50% (reporting ~500 CO_2/MWh)
  - Optimal energy efficiency – CHP enhanced with "smart" controls and meters.
- **Financial Benefits**
  - The third-party investment allowed the Hospital to focus capital dollars on hospital building instead of the central plant
  - CHP project cut hospital energy costs by 25%
  - Robust energy efficiency = cost savings even with a third-party owner

Case Study:
Shaw Industries
CHP for Cost Savings and Sustainability

U.S. DEPARTMENT OF ENERGY

Shaw Industries
Columbia, South Carolina

Project Snapshot:
CHP for Cost Savings and Sustainability

Application	Carpet Fiber Production
Capacity	14.1 MW
Prime Mover	Gas Turbine
Fuel Type	Natural Gas
Thermal Use	Process Steam
Installation Year	2018

CHP System at Shaw Industries

Project Highlights: The 14.1 MW CHP system has the capacity to meet 100% of the plant's thermal needs as well as 75% of its electric demand and reduces GHG emissions by 26,000 metric tons per year. Shaw Industries has been significantly investing in their operations to minimize its environmental footprint. The company achieved a 2030 goal to reduce corporate GHG emissions by 40% from a 2010 baseline nine years early.

Southeast CHP TAP – https://chptap.lbl.gov/profile/201/ShawIndustries-Project_Profile.pdf

Project Testimonial

"Climate change is a complex, global issue. While no one company or individual can tackle this challenge alone, as a globally oriented company we have a responsibility to positively contribute to the solution. The Combined Heat and Power Plant (at Plant 8S) exemplifies one of many ways we are doing our part to have a positive impact on the world we all share."

- Troy Virgo, Director of Sustainability

Shaw Industries Plant 8S in Columbia, SC

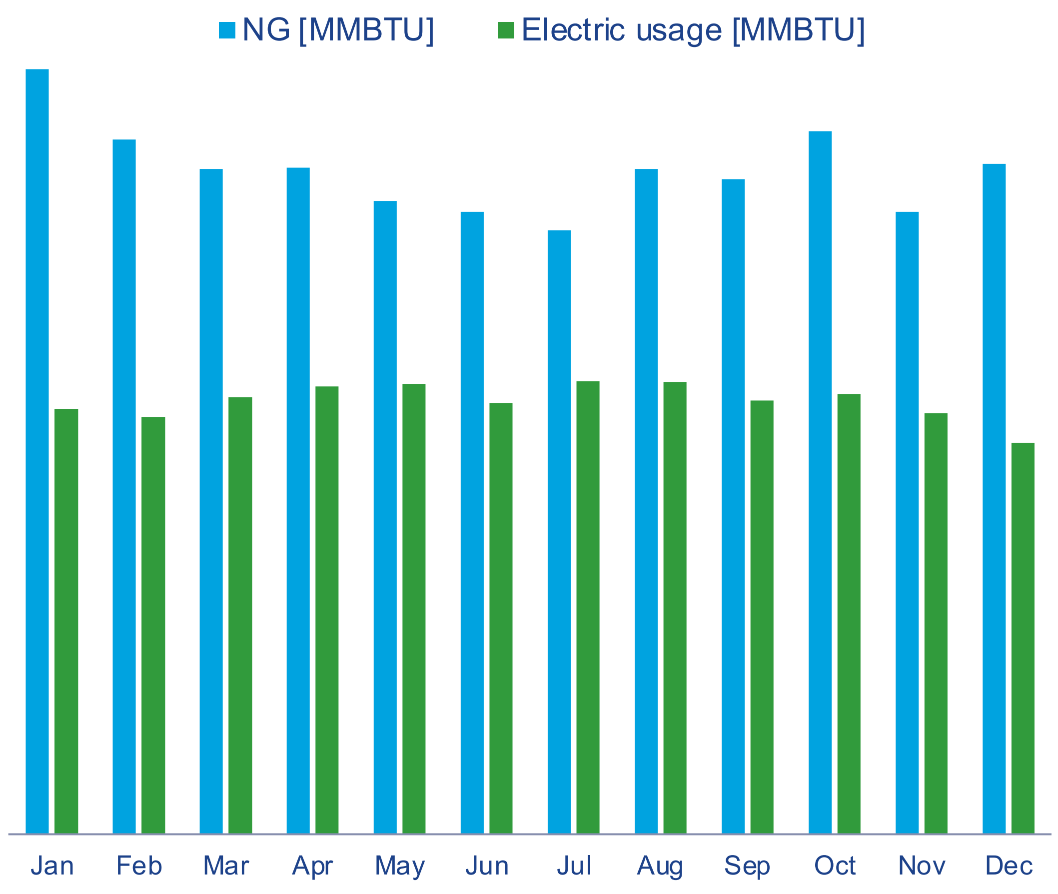
Plant 8S Produces carpet fibers, and includes recently expanded and modernized fiber extrusion operations, which include the use of recycled plastic beverage bottles.

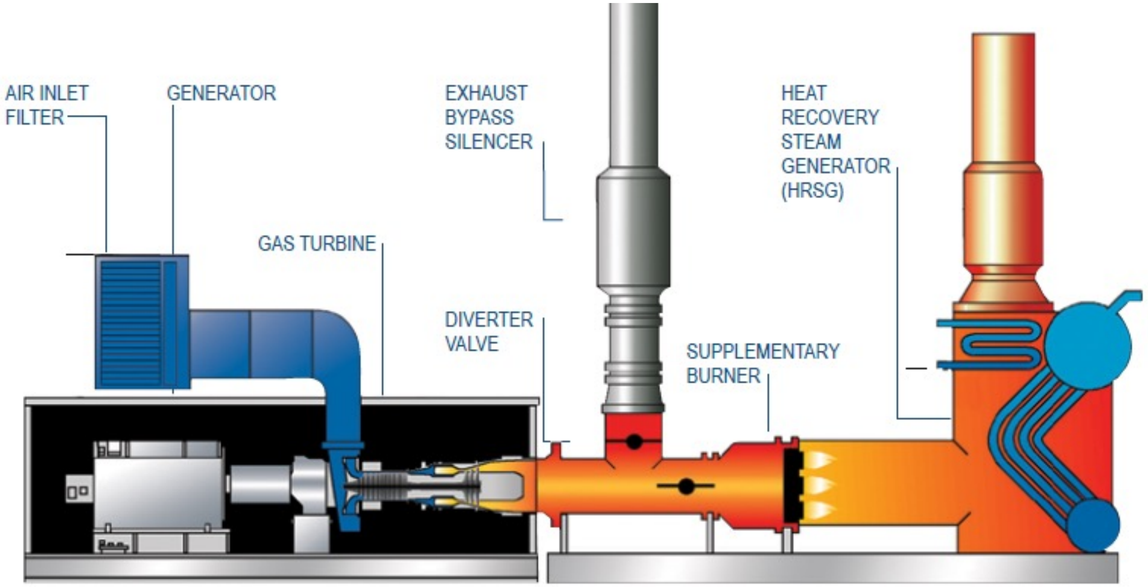
Over 3 billion plastic bottles are recycled in Fayetteville, NC at Clear Path Recycling, a joint venture between Shaw and DAK Industries.

Shaw Industries CHP Success Elements

- A team led by energy/reliability engineer included the plant manager, plant engineers, utilities superintendent, maintenance engineer, energy group and plant finance manager supported CHP project
- Feasibility study by DOE Southeast CHP TAP showed $6 million in savings in the first year and discounted payback in less than three years (included 10% Federal ITC and accelerated depreciation)
- Training for operators included visit to CHP plant NC State
- Along with other measures, CHP helped Shaw to meet 2030 GHG reduction goal of 40% from 2010 baseline nine years early
- Turbine supplier Solar Turbines provides overhaul service

Shaw Typical Annual Electric & Natural Gas Profile

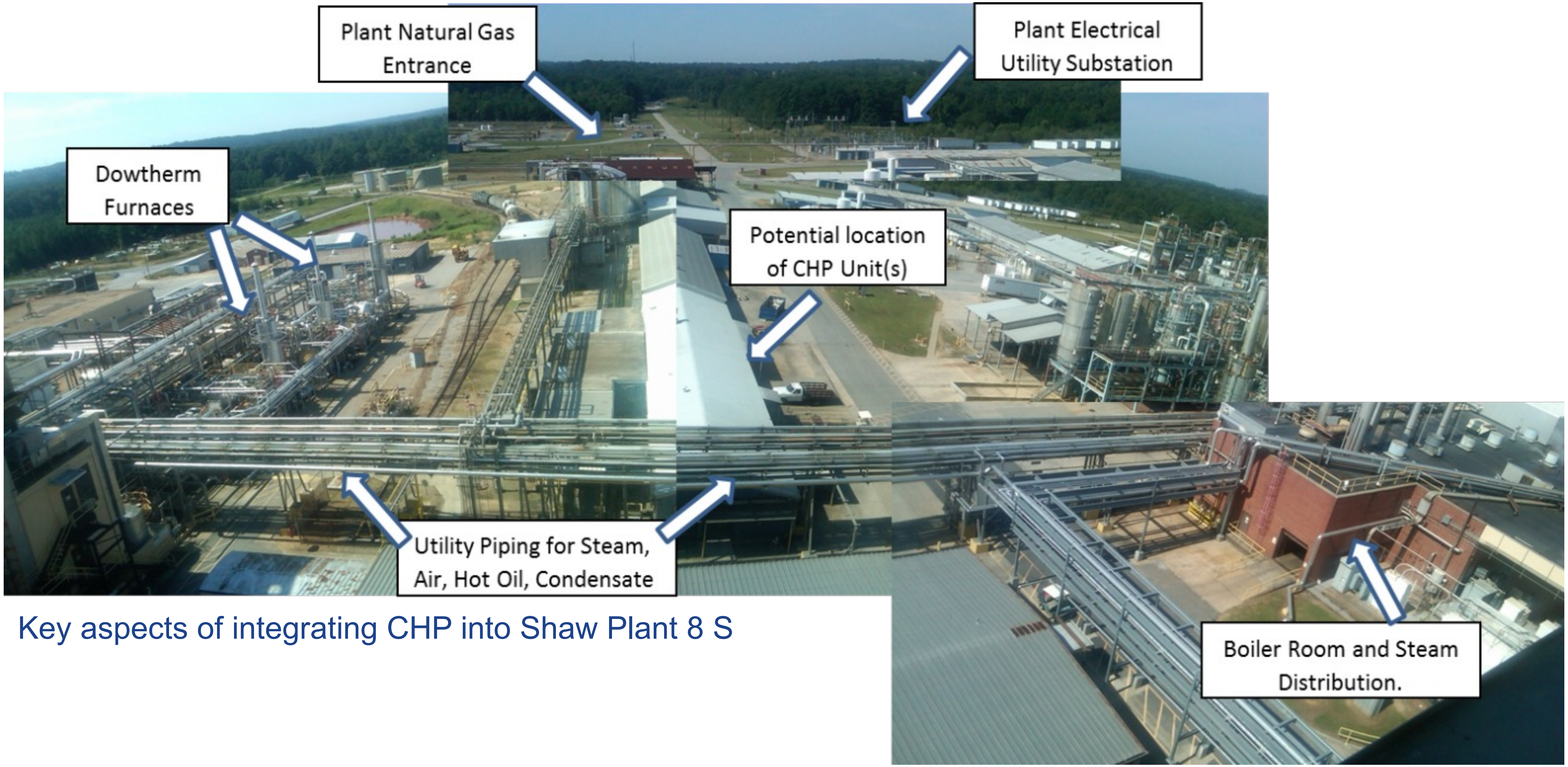




Solar Turbines Titan 130	
Net kW	13,949
Fuel Input [MMBtu/hr.]	144.3
Steam Output [k#/hr.]	64.5
Duct Burner Fuel Input [MMBTU/hr]	78.5
Duct Burner Steam Output [k#/hr]	76.9

Diagram and specifications courtesy of Solar Turbines

Shaw CHP Site Location



Key aspects of integrating CHP into Shaw Plant 8 S

Shaw CHP Operations & Maintenance Team Training

Two groups of Shaw operators visited NC State University's 11 MW CHP Plant to gain knowledge from the operations staff

Case Study:
Perdue Agribusiness
CHP for Onsite Renewable Energy

U.S. DEPARTMENT OF ENERGY

Purdue Farms Inc
Cromwell, Kentucky

Project Snapshot: Digester Gas CHP System

Application	Food processing
Capacity	999 kW
Prime Mover	Reciprocating Engine
Fuel Type	Anaerobic Digester Gas
Thermal Use	Process hot water
Installation Year	2011

Project Highlights: The biogas project was developed to reduce energy costs and improve the site's wastewater operations. The CHP system was configured to sell electricity to the grid and provide hot water to the Perdue plant, reducing the amount of natural gas required to heat water.

Southeast CHP TAP - https://chptap.lbl.gov/profile/182/perdue_cromwell-Project_Profile1.pdf

Covered lagoon anaerobic digester. The digester uses the waste Purdue produces by processing 1.2 million chickens weekly

Project Testimonial

"The recovered heat from our Renewable fuel CHP engine at Purdue Farms in Cromwell, Kentucky, nearly eliminates our needs for hot water heating during the summer months and replaces 22% of our purchased natural gas fuel.
-John DeVinney, Senior Project Manager, Purdue Farms

Perdue Farms / Perdue Agribusiness Cromwell, KY

- Produces fresh, ready to cook chicken in retail tray packs
- 1,200 associates
- Digester installed in 2010 and and the CHP engine in 2011
- Onsite water treatment and wastewater treatment plants
  - Rinse and wash water, tiny fat and protein particles, blood and limited manure are all delivered by gravity to the digestion process
  - No Class A waste
- Anaerobic Digester (covered pond)
  - Converts organic waste into +75% methane & Co products
  - Reduces the organic loading (COD) 95%
  - Further treated water is returned to river water source

Perdue Farms CHP System Elements

Covered anaerobic digester pond
Has an area of 3 acres and holds 12 million gallons. Effluent is retained for 7-10 days and organic loading is reduced by at least 95%. Lagoon cover stores a 7-day supply of biogas.

Biogas collection point and flare
Methane is centrally collected, cleaned to remove contaminants and moisture. The captured methane avoids 52,000 tons of CO2 equivalents per year.

Packaged CHP System
Integrates a 999 kW GE Jenbacher 320 engine, heat recovery unit and auxiliary heat rejection. Power is sold to TVA under the Generation Partners / Green Power Switch Program.

Perdue CHP Success Elements

- Biogas capture has substantial emissions reduction effect
  - 52,000 tons of CO2 equivalents removed annually
  - Approx 535,000 MMBTU of renewable fuel produced annually
- The system energy efficiency (CHP) is ~ 82%
- 5,573 MWh produced annually (~20% of present needs)
  - Digester is food limited and have engine hours available (cold months)
  - Our source river water temperature drives amount of gas generated
- The waste heat recovered (3.2mm btu's/hr) is used to make hot water for operations (about 20% of annual needs, nearly 100% in summer months).
- The engine has been used to keep the plant online during utility shutdowns
- Engine is a GE Jenbacher 320 de rated to 999 kw for the PPA.
- We have a trip / transfer function with the utility.

Perdue CHP Success Elements

- Environmental
  - 2 -3 magnitude better emission destruction than a flare or boiler
  - Boiler & water heaters required full biogas scrubbing
    - Carbon Dioxide removal (absorption with methane loss)
    - H_2S Treatment (w methane loss)
    - Temperature and moisture adjustments
- Advantages
  - Better system efficiency than boilers - heaters
  - Heat and fuel needs matched biogas availability
  - Highest economic return
  - Long term PPA was available (TVA has been a tremendous partner!)
  - Project was not fundable without PPA
  - $240,000 in ARRA Stimulus funds provided through State of Kentucky

Case Study:
Durham Advanced WWTP & Gresham WWTP

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Overview

- Success stories:
  Durham Advanced WWTP – Evolution into a Resource Recovery Facility
  Gresham WWTP – Net zero energy use with CHP
- How to identify attractive candidates for co-digestion
- Characteristics of Fats, Oils, and Greases (FOG) feedstock
- FOG receiving station and storage
- Increased CHP generation
- Biogas Conditioning

CHP Projects at WWTPs: Drivers & Benefits

- Energy cost savings
- Federal, state and local utility incentives
- Energy/sustainability plans and emissions reductions
- Green publicity/public relations benefits
- Enhanced reliability
- Increased biogas production with FOG co-digestion
- Enhanced biosolids management/soil amendment
- Utility load shedding and/or demand management benefits with biogas storage

A typical WWTP processes 100 gallons/day of wastewater for each person served

Each million gallons per day (MGD) of wastewater flow can produce enough biogas in an anaerobic digester to produce 30 kW of electric generating capacity

Avoid Flaring: Biogas is a Source of Free Fuel

- Stable source of renewable biogas fuel flow to prime mover

- Btu content of biogas is between 450 to 620 Btu/scf; so example produces about 26,000 MMBtu/year

	Boiler/ Digester Heating	Candlestick flare	Total MMscf
May-17	0.22	3.21	3.44
Jun-17	0.70	2.81	3.51
Jul-17	0.25	2.80	3.05
Aug-17	0.71	2.59	3.29
Sep-17	1.03	2.33	3.36
Oct-17	1.37	2.39	3.76
Nov-17	1.26	2.45	3.71
Dec-17	1.30	2.14	3.44
Jan-18	1.45	2.27	3.72
Feb-18	1.71	1.99	3.70
Mar-18	1.76	2.25	4.01
Apr-18	1.57	2.47	4.04
Annual	14.36	29.02	43.38
		Biogas Flow = 82.5 scfm	

Best Candidates for Boosting CHP Generation at WWTPs

- Existing anaerobic digester
- Consistent source of organic matter to produce biogas
- High and constant thermal load
- High electrical energy costs (> $0.10/kWh)
- Desire for high reliability
- Concern over future electricity prices
- Goals or policies to reduce environmental impact
- Interest in removing FOG and/or organic food wastes from landfill (driver is reduced greenhouse gas emissions)
- Planned plant expansion or new construction; or equipment replacement within the next 3-5 years

WWTP Project Snapshot: Durham Advanced WWTP

Location: Durham, OR

Application: WWTP treating an average of 26 MGD

Capacity (kW): two 848 kW units

Prime Mover: The Jenbacher reciprocating engines produce 12 million kWh/year

Fuel Type: Biogas from co-digestion with FOG in two 1.3 million gallon anaerobic digesters

Thermal Use: Digester and space heating

Co-Digestion: FOG co-digestion allowed for a doubling of biogas production and a tripling of electrical generation due to the new engine capacity eliminating flaring.

Installation Year: 2015

A Unison gas conditioning system is located outside of the CHP building

Two 70,000 gallon FOG storage tanks accept 100,000 gallons weekly of FOG

Benefits of FOG and Co-Digestion

- FOG collection consists of collecting grease from food services establishments. It offers an added benefit as it keeps grease from clogging the sewer system.
- Keep FOG (and food wastes) out of landfills. Decomposition in landfills produces methane gas—some of which is not captured in the landfill gas collection system. Remember that methane has a global warming potential (GWP) of 25.
- Co-digestion of FOG at a WWTP can double digester biogas production.
- Consider biogas storage if your utility has time-of-day rates
- Renewable Energy Credits provide added value

FOG Collection for Increased Energy Production

- A FOG receiving station can generate tipping fee revenue plus keep FOG from entering the sewer collection system or from being landfilled.
- As FOG loads are variable in solids content and haulers cannot guarantee a specific quantity on a given date, storage tanks are provided to both store, blend and meter multiple loads.
- Co-digestion of FOG with sewage sludge can double biogas production, resulting in increased generating capacity while providing economies of scale in biogas treatment and electrical generating equipment.

Upgrades at the Durham WWTP to Accommodate FOG Collection and Co-Digestion

- The $16.8 million facility upgrade at the Durham WWTP consists of a FOG receiving station; FOG storage tanks; a gas treatment system to remove hydrogen sulfide, particulates, siloxanes, and moisture from the raw biogas; two 848 kW Jenbacher biogas-rated engines; and a waste heat recovery system.
- The CHP project saves $800,000/year in energy costs (including $100,000 in heating benefits), while also providing $340,000 in annual revenues from tipping fees.
- The new CHP project was supported through $3 million in incentives from the Energy Trust of Oregon and $2.8 million in transferrable tax credits from the Oregon Department of Energy.

Co-Digestion Lessons Learned

- Energy champions are necessary for project success
- FOG can contain contaminates such as bones, eating utensils and rags. Plan for screening and removal.
- Scheduling problems can exist with FOG haulers (they don't like to deliver on weekends). Offer a reduced tipping fee for haulers that deliver the promised amount of FOG on the scheduled day.
- Budget for engine certification training for maintenance staff or purchase a full maintenance contract.
- Use local service support if/when available. Determine critical parts to have on-site as spares.

WWTP Project Snapshot: Gresham WWTP

Location: Gresham, OR

Application: WWTP that treats an average of 13 MGD plus FOG

Capacity (kW): two 395 kW units

Prime Mover: Caterpillar reciprocating engines generate 5.8 million kWh/year

Fuel Type: Conditioned biogas produced through co-digestion with FOG

Tipping Fee Revenue: About $350,000 annually

Net Zero Operation: Adding a second reciprocating engine and a 420 kW solar array allows the WWTP to produce all of its own energy on site

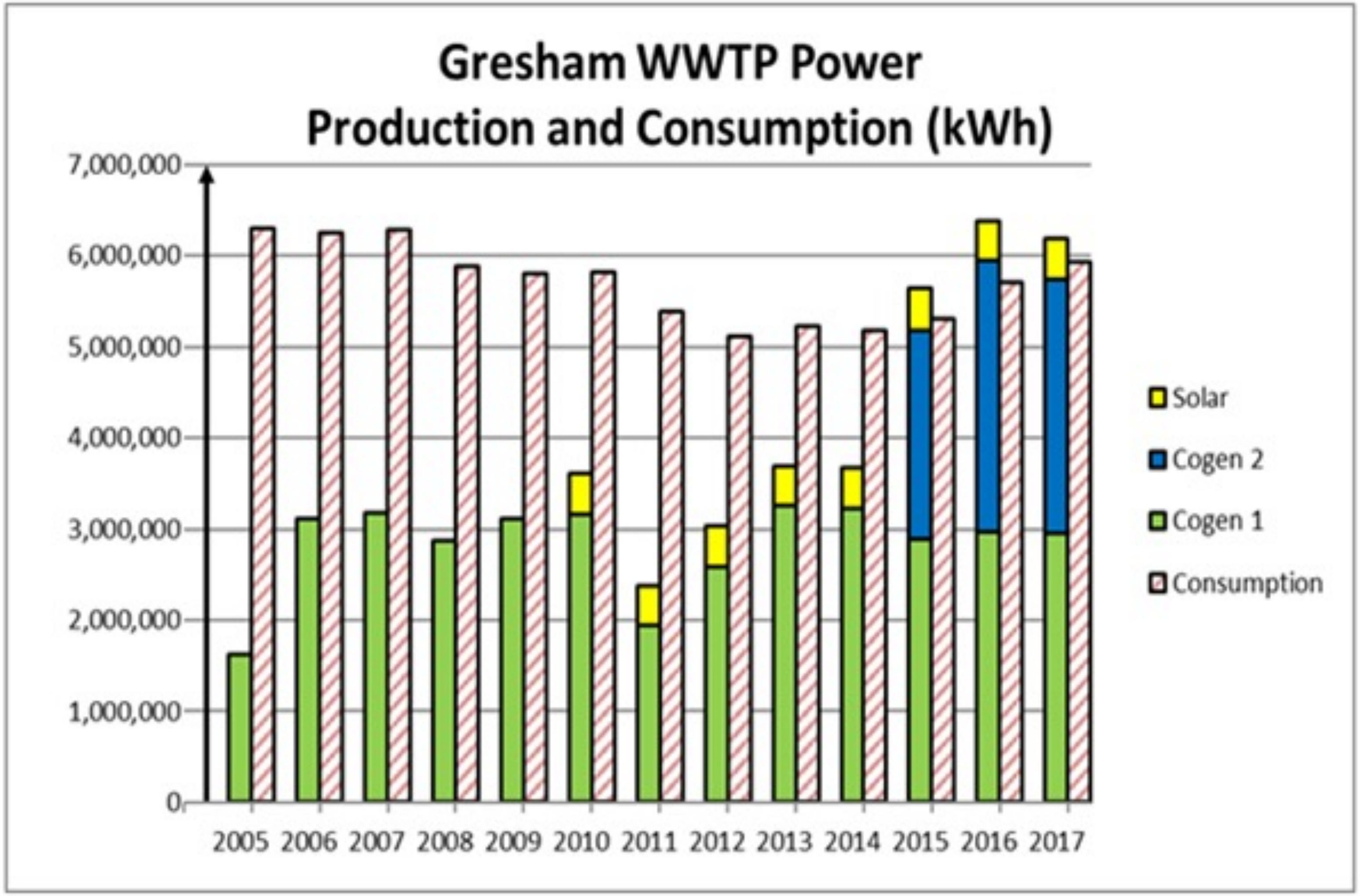
Installation Year: 2015

Delivered FOG is stored and blended in tanks, then metered into the digesters for co-digestion with sewage sludge

The Gresham WWTP produces 5.8 million kWh/year with its two 395 kW Caterpillar engines

Gresham's March to Net Zero

Since 2015, the Gresham facility has been the first WWTP in the Northwest to achieve net zero energy status



Gresham WWTP Practices

- Engine repair and maintenance was contracted out to a local Caterpillar dealer. With 48-hour spare parts availability, a 95% availability factor is maintained.
- The biogas treatment system reduces H_2S concentrations in the biogas to less than 100 ppm with undetectable levels of siloxanes.
- Siloxane testing costs (at $2,000/test) are minimized through replacing filter media at recommended intervals.

Biogas Conditioning: Is it really required?

- Hydrogen Sulfide (H_2S) and Siloxane concentrations are found in the biogas produced from all WWTP anaerobic digesters
- H_2S oxidizes into sulfur dioxide in the combustion process, forming sulfuric acid when dissolved into water droplets. This can damage a prime mover exhaust system, heat exchangers, and stack liners
- SOx releases can violate air permit requirements and release of an acid mist can damage paint on cars

Siloxane Removal is Necessary

- Siloxanes are a family of organic silicon compounds that originate as additives to personal care products such as soaps, shampoos, sunscreens, lotions, hair sprays, deodorants, and shaving products
- Siloxanes pass through the WWTP processes, accumulate in sludge and volitalize to form a contaminant in anaerobic digester biogas
- When combusted, the siloxanes form a glass-like deposit that is harmful to reciprocating engines, gas turbines, microturbines, and fuel cells

Siloxane Deposits Result in Engine Damage

- A decrease in CHP project efficiency
- An increase in heat rate (Btu/kWh)
- A reduction in power output (kW)
- Formation of “hot spots”
- Increased maintenance costs, and
- **Premature equipment failure**

Microturbine Recuperator

A Piston Head

Biogas Conditioning Equipment

Contaminants to remove from biogas

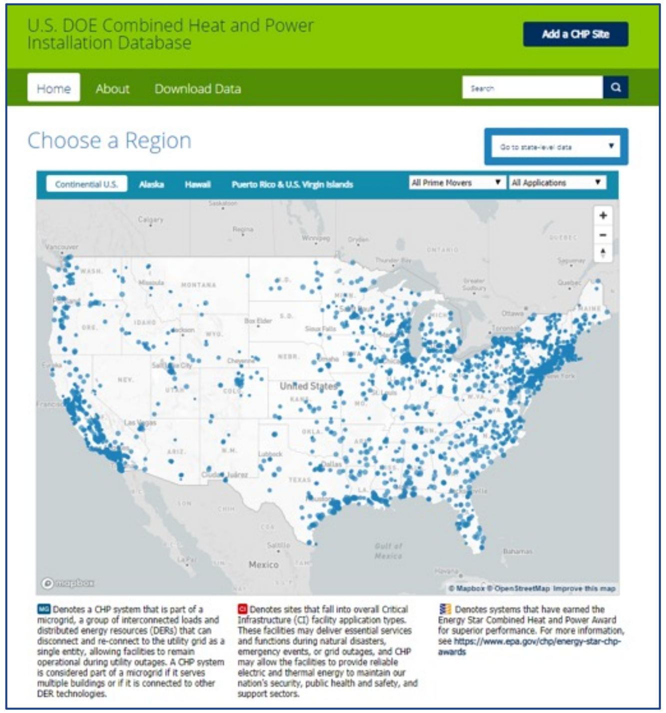
- Hydrogen Sulfide
- Moisture
- Siloxanes and particulates

Biogas conditioning equipment for 250 kW CHP project at Central Kitsap WWTP, WA

CHP Project Profiles & Other Resources

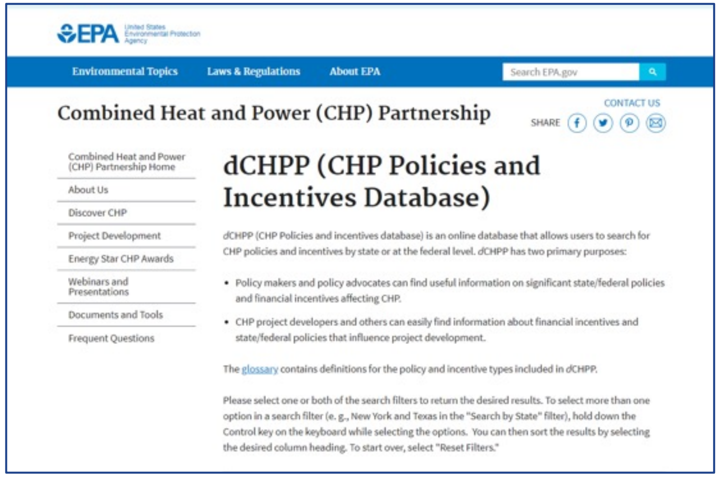
U.S. DEPARTMENT OF
ENERGY

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



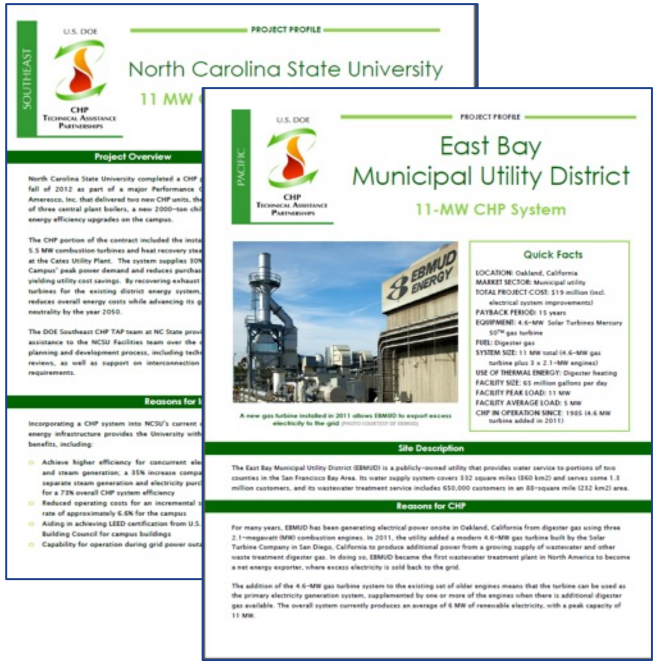
https://doe.icfwebservices.com/chp

EPA dCHPP (CHP Policies and Incentives Database)



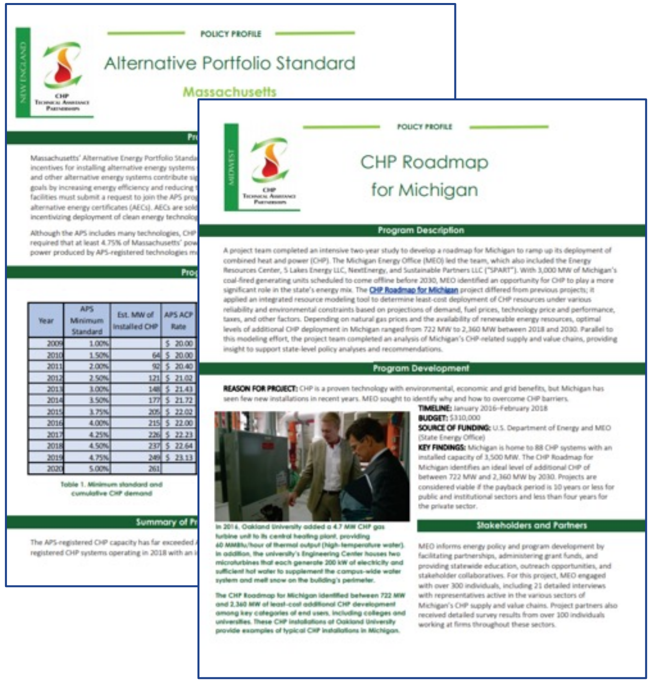
https://www.epa.gov/chp/dchpp-chp-policies-and-incentives-database

- DOE Project Profile Database



https://betterbuildingssolutioncenter.energy.gov/chp/chp-project-profiles-database

DOE Policy/Program Profiles



https://betterbuildingssolutioncenter.energy.gov/chp/chp-taps

THANK YOU

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