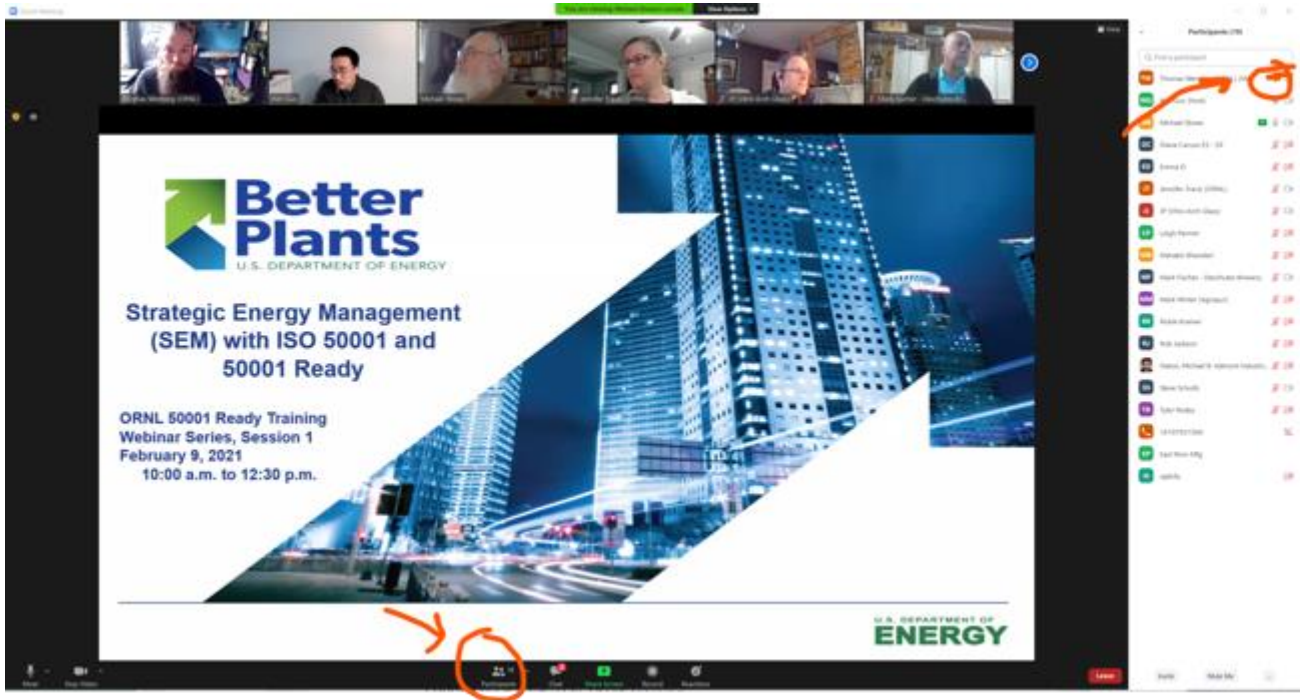
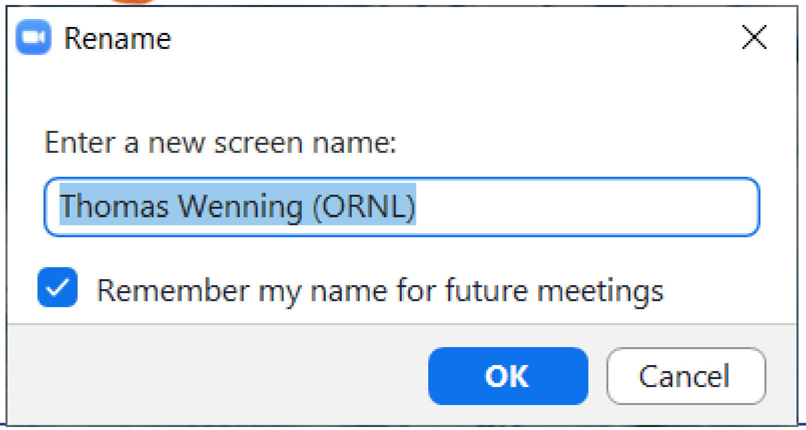
# Rename Yourself to be your Real Name (Company Name)

1. Click on Participant list
2. Go to the right and hover over your name
3. Select “More” & “Rename”
4. Enter your company name in brackets
5. Turn on your camera ☺



# Virtual Training: Combined Heat & Power Systems

## CHP 101

Session #1
December 5, 2024
10:00am – 12:30pm EST

# Important Info

- Schedule: Every Tue and Thu (Dec 5, 10, 12, 17) morning @ 10am ET
- Sessions will be recorded
- We want these VT to be interactive!
- We're hoping you finish the VT with some big progress
- There will be homework – just try your best!
    - "You'll get out what you put in!"

**Links:**
https://bptraining.ornl.gov/
http://betterbuildingssolutioncenter.energy.gov/better-plants
https://measur.ornl.gov

Better Plants®
U.S. DEPARTMENT OF ENERGY

# Big Wins and Ambitious Actions in Energy Reduction

Wei Guo, PhD, PE
Oak Ridge National Laboratory

U.S. DEPARTMENT OF ENERGY

# DOE's Better Plants Program

Helping manufacturers, water/wastewater utilities and other industrial organizations save money, improve their competitiveness and reduce impacts on the climate

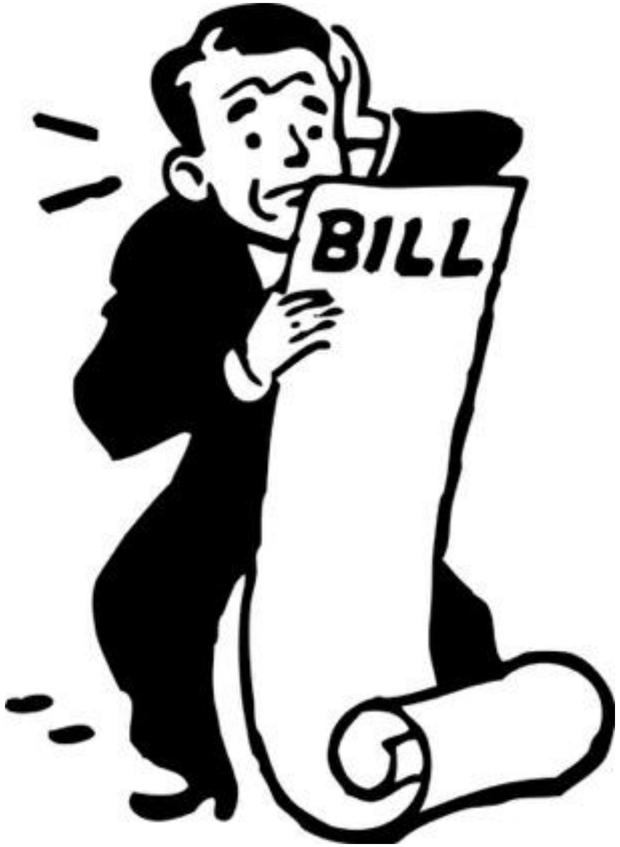
**Increased Energy Productivity**

**Water Savings**

**Waste Reduction**

**Decarbonization**
(Better Climate Challenge)

# Manufacturing and Municipalities – Why do we care?




Manufacturers and utilities spend $200+ Billion/year on energy to operate their plants

DOE data demonstrates most plants have big opportunities to reduce energy use with relatively short payback periods

Resiliency, Competitiveness, Workforce

# How Does Better Plants Work?

Voluntary and Free to Participate

Partners set long-term strategic goals

DOE works with you to achieve your goal

# What Market Leadership Looks Like

# Better Plants Resources

## NO-COST SOFTWARE & TOOLS

Access no-cost software and tools to identify and implement energy saving opportunities and manage energy use.

**60+** Calculators

**20+** No-Cost Tools for Loan

Financing Navigator

No-Cost Resources & Guides

## RECOGNITION

**49** Better Projects & Better Practice Winners

For innovative and industry-leading accomplishments in implementing and promoting company-wide practices, principles, and procedures of energy management, as well as improvement projects at individual facilities.

**59** Goal Achievers

**350+** Solutions on Solution Center

National Recognition in Media and Online

## TRAINING & EDUCATION

**Over 120** In-Plant Trainings Conducted to Date

Multi-day training for staff to identify, implement, and replicate energy-savings projects.

**45** No-Cost Webinars & Growing

## INNOVATION & LABS

**17** National Labs Across the Country

Partner with the National Labs to spur innovation.

Lab Technology Days

Sneak peek at early-stage R&D technologies.

Field Validation

A new pilot for partners to accelerate the voluntary adoption of cost-effective, high-impact technologies while reducing adoption risks.

# Technical Assistance: In-Person and Virtual Trainings

Teach plant workers how to conduct assessments, use DOE tools, and implement projects

## In-Plant Trainings (INPLTs)

175+ In-Plants - 3,200 participants since 2011
Identified more than $75M+ in energy savings

## Virtual Trainings

Over 28 trainings completed
All sessions were recorded and posted online
Results: ~2,000 trained and ~$11M+ in savings

## Bootcamp Trainings (Energy and Decarbonization)

385+ participants since Aug 2022
112 unique companies

http://bptraining.ornl.gov/

## Training Topics:

- Pump Systems
- Fan Systems
- Compressed Air
- Processed Heat
- Process Cooling
- Steam Systems
- Motors
- CHP
- Industrial Refrigeration
- Water/Wastewater Treatment
- Municipal Water
- Energy Management
- Water Efficiency
- Treasure Hunts
- Mfg Waste Reduction

# Virtual Training 2024 and 2025

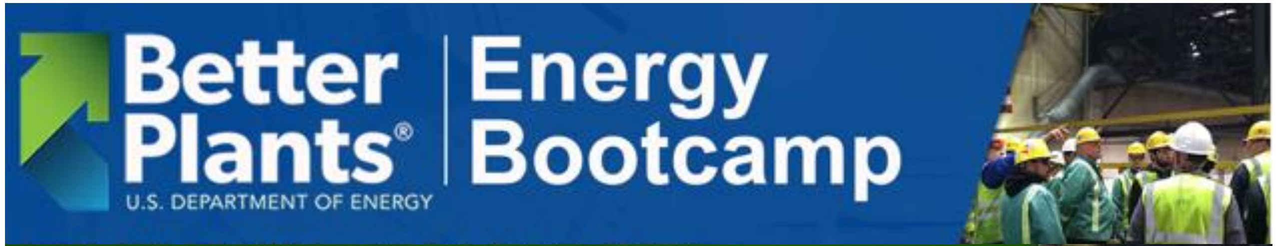
| Topic | Dates |
|---|---|
| Combined Heat and Power | Dec 2024 |
| Compressed Air | Jan to Feb 2025 |
| Waste Reduction | Feb to Mar 2025 |
| Process Heating | Apr to May 2025 |
| Cyber Security | Apr to May 2025 |
| Onsite Energy Generation and Storage | Jun to Jul 2025 |
| Utility Bills Analysis | Jul to Sep 2025 |
| Renewable Energy Contracting Options and RECs | Aug to Sep 2025 |
| Drinking Water | Oct to Nov 2025 |
| Motor | Dec 2025 |

https://bptraining.ornl.gov

# Bootcamps 2025

https://energybootcamp.ornl.gov
https://decarbbootcamp.ornl.gov

| Bootcamp | Dates |
|---|---|
| Energy | Feb 24 to 28, 2025 |
| Decarb | May 6 to 9, 2025 |
| Energy | Sep 29 to Oct 3, 2025 |
| Decarb | Nov 4 to 7, 2025 |





# Field Validation & Diagnostic Equipment Program

Helping Better Plants Partners measure operating data to evaluate equipment performance and quantify energy performance improvement






## Field data is best for evaluating system performance

- Free of charge, including shipping
- Use equipment for one day, or up to four weeks
- Technical assistance to help w/ selection, tool use
- First come, first serve application

https://betterbuildingssolutioncenter.energy.gov/better-plants/diagnostic-tools

# Thank You!

For More Information:

Wei Guo, guow@ornl.gov, 865-574-8632
Thomas Wenning, wenningtj@ornl.gov, 865-576-9257

**Better Plants Website:**
http://betterbuildingssolutioncenter.energy.gov/better-plants
https://bptraining.ornl.gov/

# IEDO Technical Assistance and Workforce Development

**Direct engagement with industry to drive the widespread adoption of proven technologies and practices to improve energy performance and reduce GHG emissions**

Support the deployment of energy efficiency and decarbonization technologies and practices

Foster feedback from stakeholders on critical technology challenges that may be addressed through RD&D

## IEDO offers no-cost tools and programs to improve energy efficiency, competitiveness, & sustainability:

**Better Plants®** U.S. DEPARTMENT OF ENERGY

- Expert technical assistance and training on energy efficiency
- Access to Innovation & instruments
- National recognition for achievements

**Better Climate CHALLENGE** U.S. DEPARTMENT OF ENERGY

- Energy efficiency + decarbonization technical assistance & training
- Facilitated peer-to-peer knowledge sharing
- National recognition for achievements

**50001 Ready** U.S. DEPARTMENT OF ENERGY

- Tools, guidance and recognition for facilities that implement an ISO 50001-based energy management system
- No-cost, self-paced, audit-free

**Onsite Energy** U.S. DEPARTMENT OF ENERGY

- Regional network of Onsite Energy Technical Assistance Partnerships (TAPs)
- Site screenings for multi-technology solutions and more advanced analysis
- Market analysis, outreach, and stakeholder engagement

**NO-COST TOOLS & SOFT-WARE**

- MEASUR Software Suite
- 50001 Ready Navigator Tool
- REopt Web Tool
- Financing Navigator
- Low Carbon Action Plan Tool
- Carbon Inventory Calculator
- Electrification Impact Calculator

# Onsite Energy Technical Assistance Partnerships (TAPs)

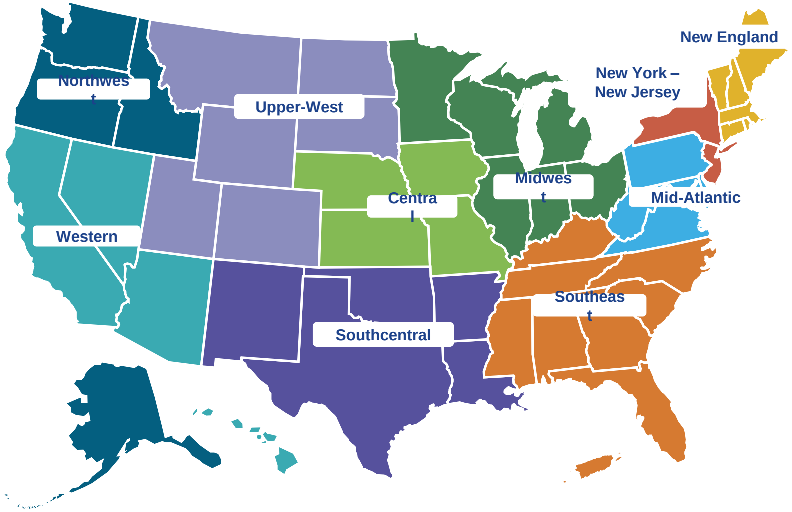
DOE's 10 regional Onsite Energy TAPs provide technical assistance to end users and other stakeholders about technology options for achieving clean energy objectives. Key services include:

**Technical Assistance**: Screen sites for opportunities to implement onsite energy technologies and provide advanced services to maximize economic impact and reduce risk from initial screening to installation to operation and maintenance.

**End-User Engagement**: Partner with organizations representing industrial and other large energy users to advance onsite energy as a cost-effective way to transition to a clean energy economy.

**Stakeholder Engagement**: Engage with strategic stakeholders, including utilities and policymakers, to identify and reduce barriers to onsite energy through fact-based, unbiased education.

Onsite Energy Technical Assistance Partnerships
U.S. DEPARTMENT OF ENERGY




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

# Onsite Energy Technical Assistance Partnerships

U.S. DEPARTMENT OF ENERGY

## Northwest
AK, ID, OR, WA

Georgine Yorgey, M.P.A.
Washington State University
360-956-2038
yorgey@energy.wsu.edu

## Western
AZ, CA, HI, NV

Jonathan Whelan
Optony, Inc.
415-450-7032
jonathan.whelan@optonyusa.com

## Upper-West
CO, MT, ND, SD, UT, WY

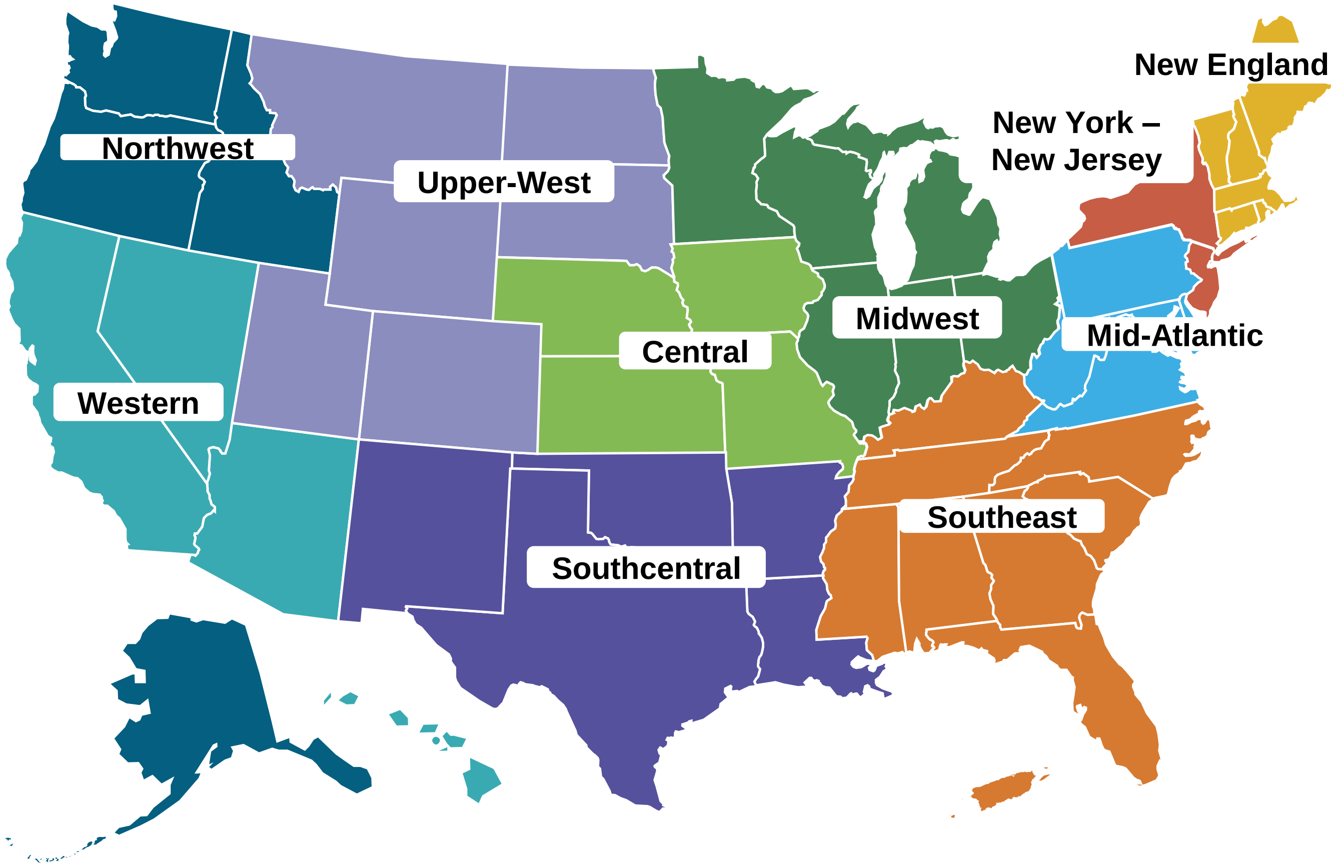
Doug Heredos
Cascade Energy, Inc.
866-321-4573
doug.heredos@cascadeenergy.com

## Southcentral
AR, LA, NM, OK, TX

Carlos Gamarra, Ph.D., P.E.
Houston Advanced Research Center
281-364-6032
cgamarra@harcresearch.org

## Midwest
IL, IN, MI, MN, OH, WI

Cliff Haefke
University of Illinois at Chicago
312-355-3476
chaefke1@uic.edu




## Central
IA, KS, MO, NE

Cliff Haefke
University of Illinois at Chicago
312-355-3476
chaefk1@uic.edu

## Southeast
AL, FL, GA, KY, MS, NC, PR, SC, TN, VI

Isaac Panzarella, P.E.
North Carolina State University
919-515-0354
ipanzarella@ncsu.edu

## Mid-Atlantic
DC, DE, MD, PA, VA, WV

Jim Freihaut, Ph.D.
The Pennsylvania State
University 814-863-2091
jdf11@psu.edu

## New York-New Jersey
NJ, NY

Jim Freihaut, Ph.D.
The Pennsylvania State
University 814-863-2091
jdf11@psu.edu

## New England
CT, MA, ME, NH, RI, VT

Matt Davis, Ph.D.
University of New Hampshire
603-862-3171
matt.davis@unh.edu

# Training Overview

1. Thursday 12/5: **CHP 101**
2. Tuesday 12/10: **Alternative Fuels for CHP**
3. Thursday 12/12: **Overview of GHG “Project Accounting” Methodology and Communicating CHP’s Decarbonization Impact**
4. Tuesday 12/17: **Integrating CHP with Microgrids and Other Renewable Onsite Energy Technologies**

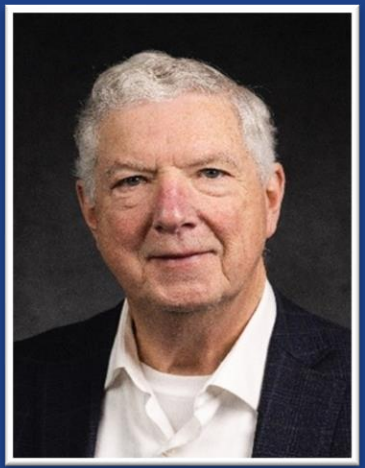
# Agenda

1. Better Plants Overview
   - Wei Guo, *ORNL*
2. Onsite Energy Program and Onsite Energy TAPs Overview
   - Mahabir Bhandari, *ORNL*
3. Fundamentals of CHP: Overview, Implementation Considerations and Business Case
   - Gearoid Foley, *DOE Onsite Energy TAPs*
4. CHP Technology Options, eCatalog and Site Assessments
   - Jim Freihaut, *DOE Mid-Atlantic and New York-New Jersey Onsite Energy TAPs*
5. Resiliency Through CHP
   - Art Samberg, *DOE Southeast Onsite Energy TAP*
6. Q&A

# Today’s Speakers

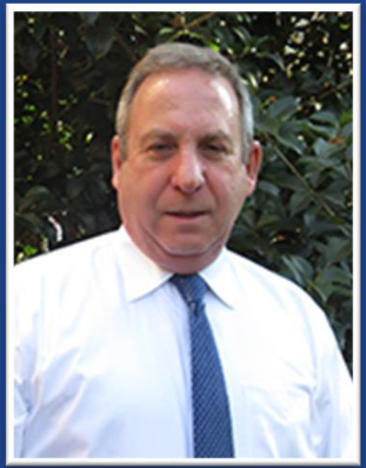
**Gearoid Foley**

*Senior Advisor,*
DOE Onsite Energy TAPs



**Jim Freihaut**

*Director,*
DOE Mid-Atlantic and New York-New Jersey Onsite Energy TAPs



**Art Samberg**

*Assistant Director,*
DOE Southeast Onsite Energy TAP

# Fundamentals of CHP: Overview, Implementation Considerations and Business Case

Gearoid Foley
DOE Onsite Energy TAPs

# CHP: A Key Part of Our Energy Future

Form a Distributed Generation (DG)

An integrated system

Located at or near a building/facility

Provides at least a portion of the electrical load

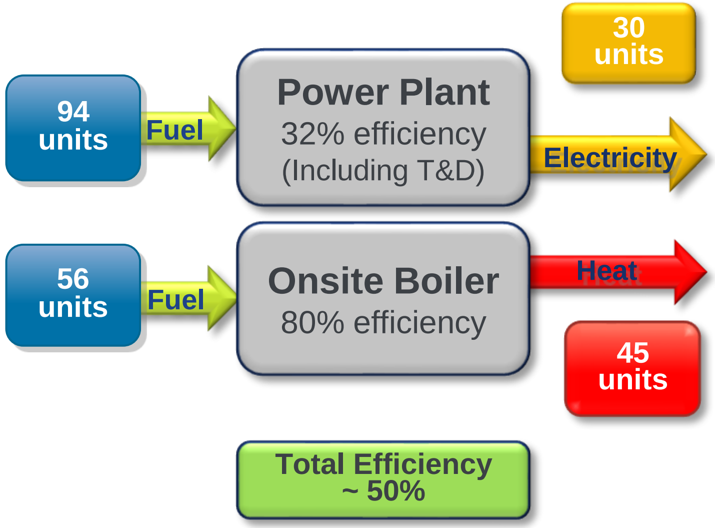
Uses thermal energy for:

- Heating / Cooling / Refrigeration / Dehumidification

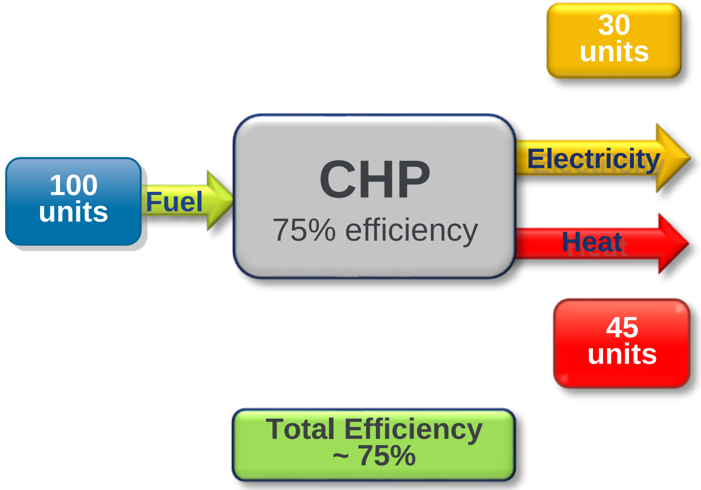
**CHP provides efficient, clean, reliable, affordable energy – today and for the future.** *Source: www.energy.gov/chp*

**30% to 55% reduction in Scope 1&2 Greenhouse Gas Emissions**

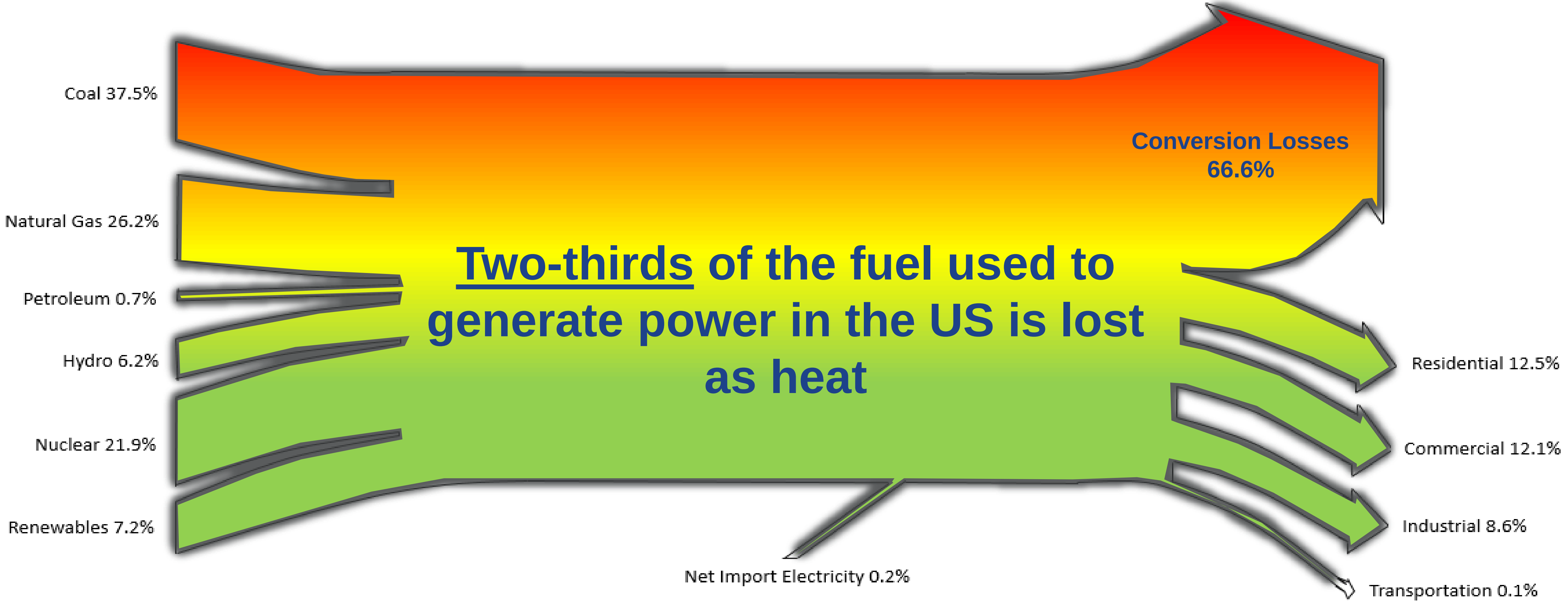
## CONVENTIONAL System




## CHP System



# Why CHP?

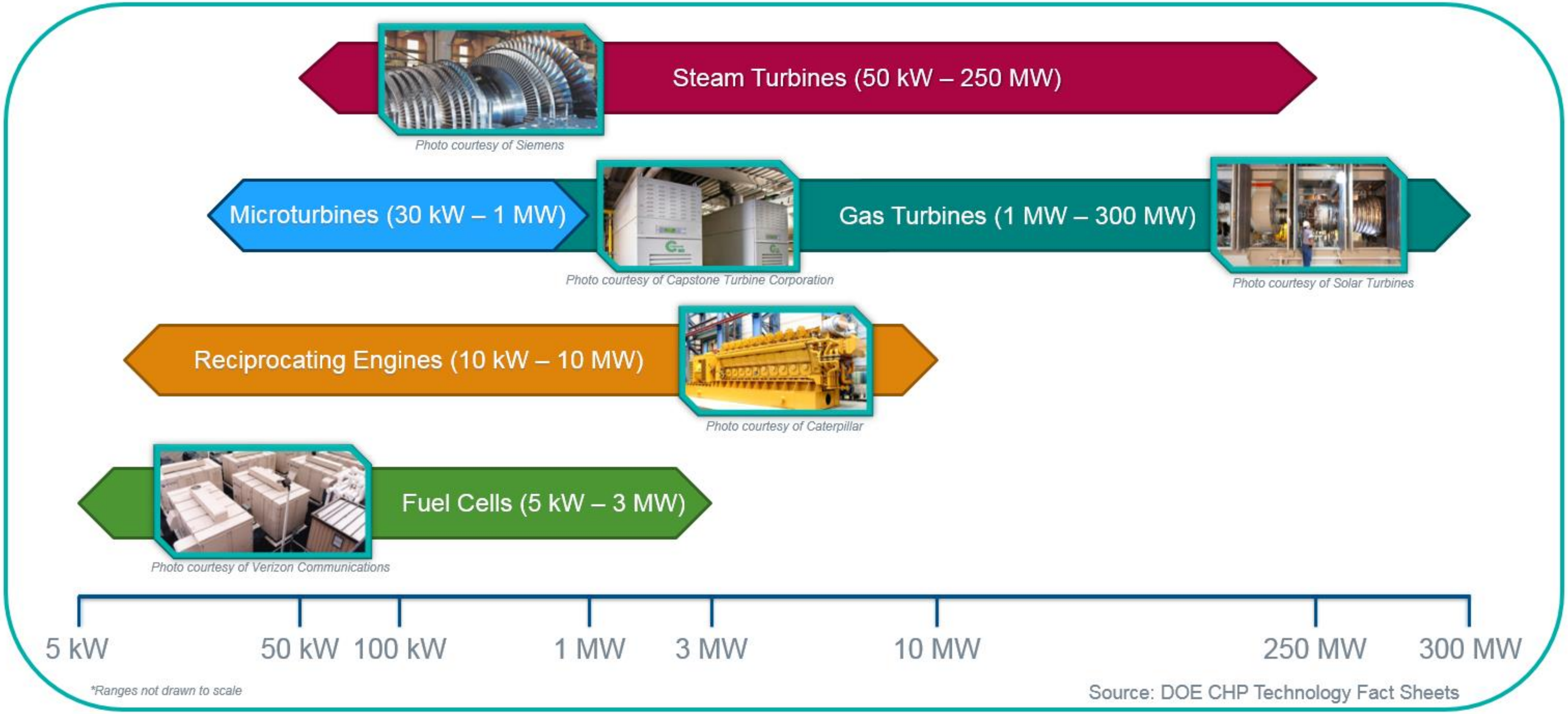



**Two-thirds of the fuel used to generate power in the US is lost as heat**

# What are the Benefits of CHP?

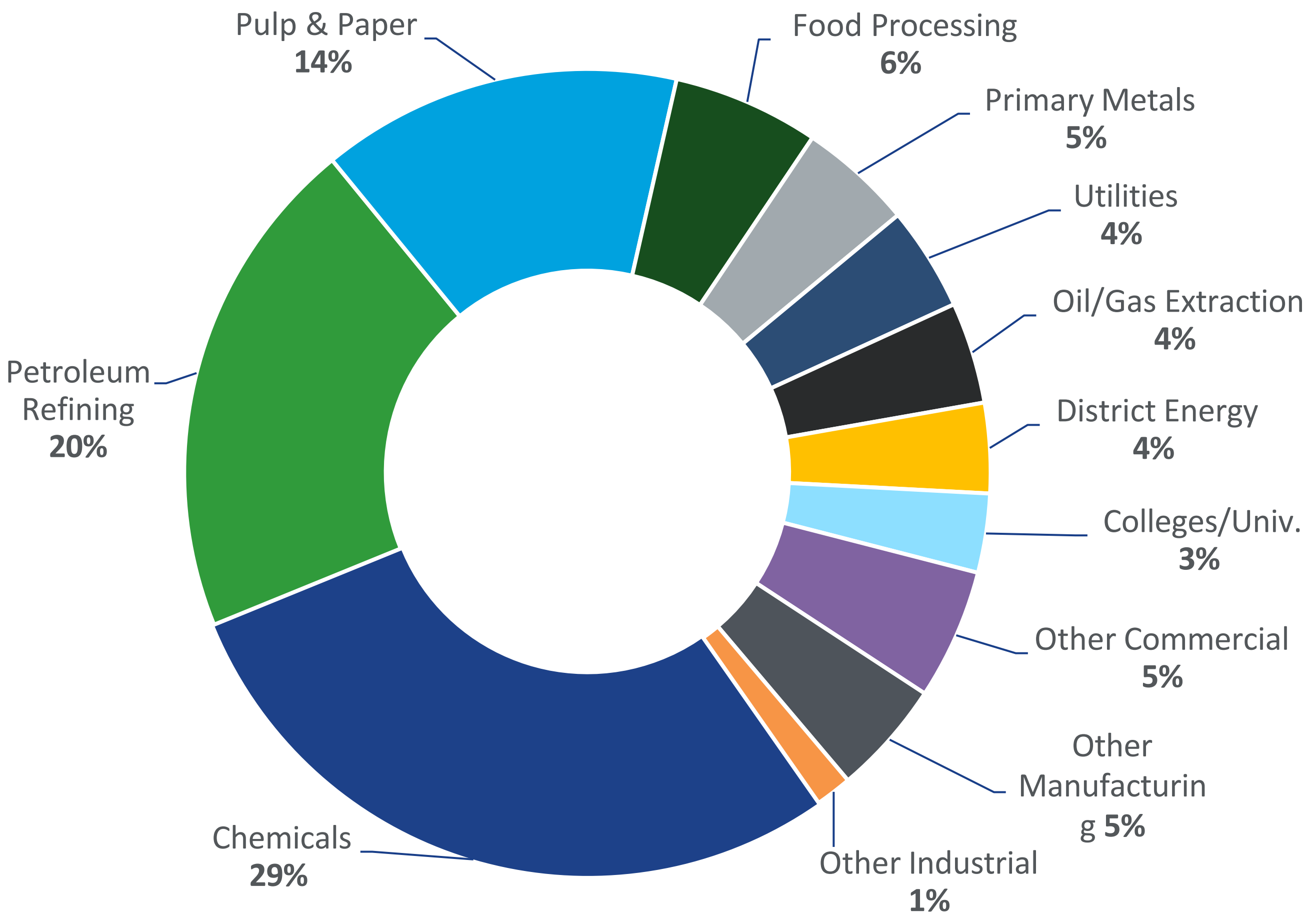
- More efficient than separate generation of electricity and heating/cooling
  - Lower carbon and other pollutant emissions
  - Lower operating costs (but requires capital investment)
- Works with any fuel, including carbon neutral fuels
  - Efficiency becomes more important as fuels become scarce
- Increases energy reliability and resiliency
- Reduces grid congestion and avoid distribution costs
  - Complements intermittent renewable resources

# Common CHP Technologies and Capacity Ranges



# CHP Today in the United States

## Existing CHP Capacity (79.2 GW)




Source: DOE CHP Installation Database (U.S. installations through December 31, 2023 as of August 2024)

Avoids **1.2 Quadrillion Btus** of fuel consumption annually.

Avoids **200 million tons of $CO^2$** compared to separate production.

**79.2 GW of installed CHP** at more than **4,700** industrial and commercial facilities.

**6% of U.S. electric generating capacity**; 13% of generation.

# Food Processing

## Taylor Foods

### One 2.0 MW CHP System

LOCATION: Gonzales, California

FACILITY SIZE: 250,000 sq. ft. Processing Plant

PEAK LOAD: 6 MW

EQUIPMENT: One 2 MW recip engine generator with heat recovery driving a 240-ton ammonia absorption chiller.

FUEL: Natural gas

# Flooring Production

## Mohawk

Five 1 MW CHP Systems

LOCATION: Dickson, Tennessee

EQUIPMENT: Five Capstone C1000s

USE OF THERMAL ENERGY: Supplement the burner in their spray dryer

FUEL: Natural Gas

# Carpet Fiber Production

## Shaw Industries

One 14.1 MW CHP System

LOCATION: Columbia, South Carolina

EQUIPMENT: Solar Turbines Titan 130

USE OF THERMAL ENERGY: Process steam, hot water, cooling

FUEL: Natural Gas


# Project Development Tasks


1. Carry out project scoping
2. Conduct financial grade feasibility analysis
3. Select CHP configuration
4. Create a financial pro forma

---

5. Obtain environmental and site permits
6. Secure financing
7. Contract with engineering, construction, and equipment supply firms
8. Provide overall project management
9. Deliver completed and commissioned CHP plant to the owner

Project Implementation

# Project Development

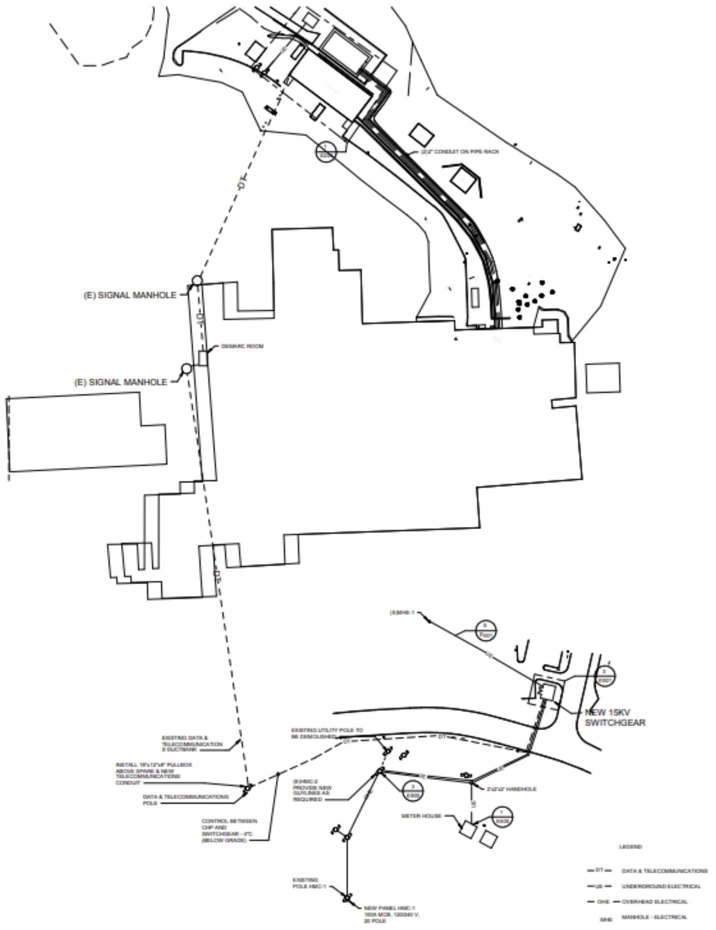
Successful CHP projects share the following features:

- Collaborative environment
- Independent review
- Clear procurement methods
- A Master Plan based on fact

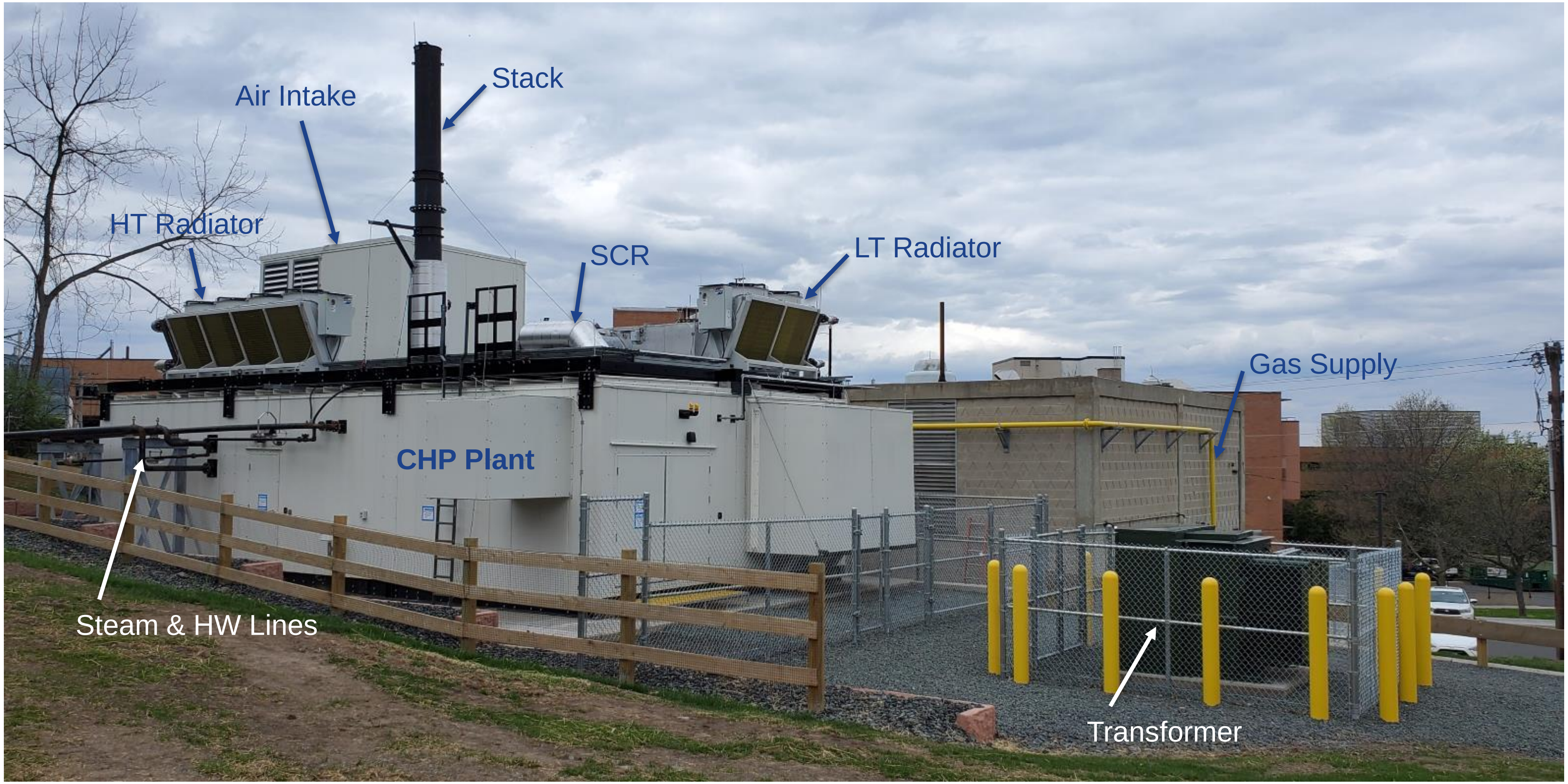
# CHP Project Scope

- Project complexity can vary widely from a single parallel interconnection located inside the facility with hot water heating to incorporate any or all of the following:
  - major electric infrastructure upgrades
  - zoning and planning changes
  - significant civil/structural work
  - addition of cooling output
  - retrofitting into an existing facility

- Financing and contracting mechanism should be informed by size and complexity of the project.



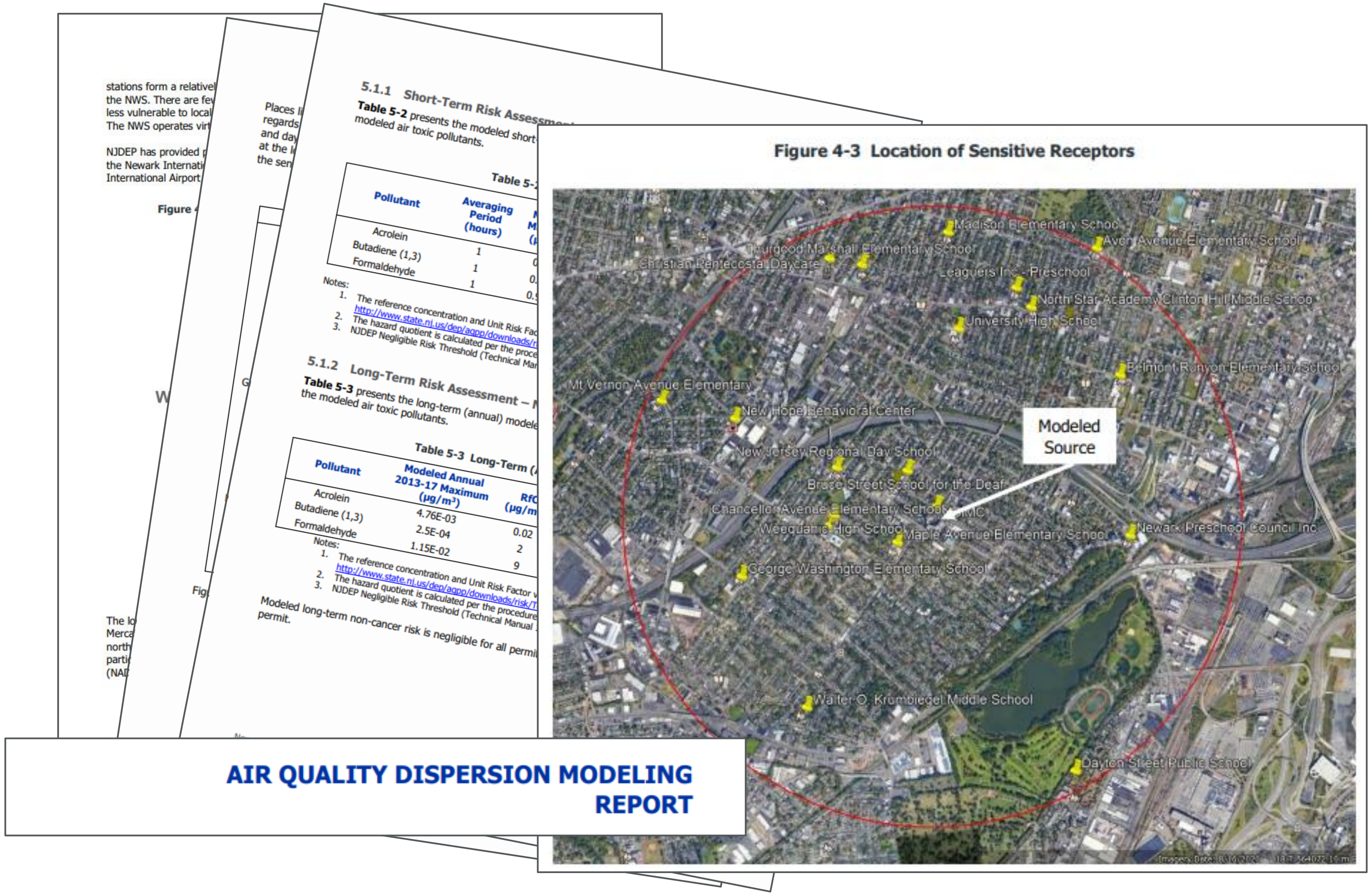
# Project Snapshot



# Project Snapshot

- Noise is a significant concern for any mechanical equipment and particularly for reciprocating engines.
- Noise from the engine unit itself is fairly easily contained behind sound proofing walls. Exhaust stacks, radiators and cooling/combustion air are also significant sources of sound.
- Duct size and silencers combined to mitigate noise from air movement.

# Project Snapshot




Depending on local area or state requirements and size of project (volume of emissions), one or more pollutants may be subject to further study including air dispersion modeling.

# Contractor/Partner Risk

- Issuing a request for qualifications (RFQ) is often a good way to attract and evaluate partners early in the process. A request for proposals (RFP) can be issued when enough is known about financing and project parameters to RFQ approved, invited, or to all in an open bid.
- A partner reduces risks to the facility owner by bearing or sharing the responsibilities of project development, although the amount of risk reduction provided depends on the type of partner chosen. For example, a "pure developer" partner will usually take the risk/responsibility of construction, equipment performance, environmental permitting, site permitting, and financing, whereas an equipment vendor partner may only bear the risks of equipment performance.

# Selecting Project Partners


- Pure developer
  - A firm primarily in the business of developing, owning, and/or operating energy projects. Some developers focus on onsite power projects, while others may be involved in a broad project portfolio of technologies and fuel types. Pure developers usually will own the completed CHP facility, but sometimes a developer will build a turnkey facility.
- Equipment vendor
  - A firm primarily in the business of selling power or energy equipment, although it will participate in project development and/or ownership in specific situations where its equipment is being used. The primary objective of this type of developer is to help facilitate purchases of its equipment and services.
- EPC firm
  - A firm primarily engaged in providing engineering, procurement, and construction services. Many EPC firms have project development groups that develop energy projects and/or take an ownership position.

# Selecting a Turnkey Developer

TURNKEY SUB

- Selecting a turnkey developer to manage the development process is a way to shed development responsibility and risks, and get the project built at a guaranteed cost.

- In addition, the developer typically provides strong development skills and experience. Other reasons for selecting a turnkey developer include:
  - The developer's skills and experience may be invaluable in bringing a successful project online and keeping it operational.
  - Many developers have access to financing.
  - In return for accepting project risks, most turnkey projects cost more than self-built systems.

# What Are the Benefits of CHP?

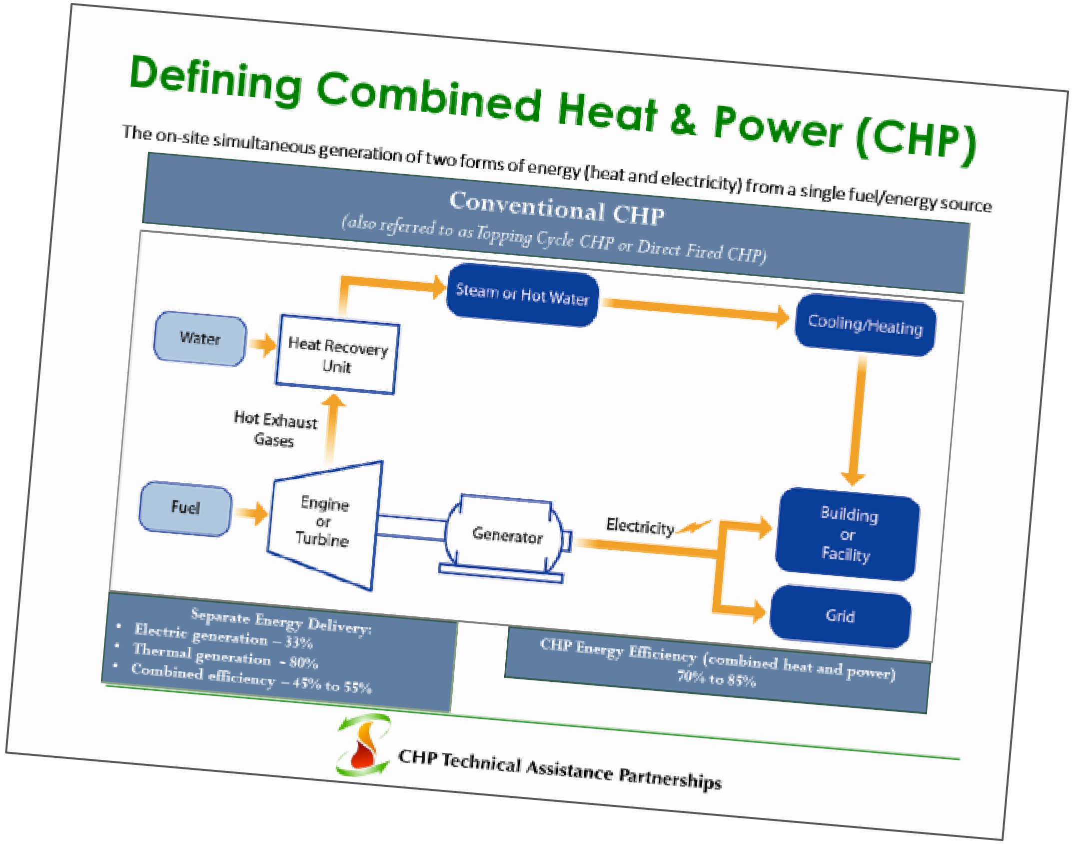
- CHP is more efficient than separate generation of electricity and heating/cooling
- Higher efficiency translates to lower operating costs (but requires capital investment)
- Higher efficiency reduces emissions of pollutants
- CHP can also increase energy reliability and enhance power quality
- On-site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

- Institutional

- Industrial

# Business Case – Thermal is a Prerequisite

- CHP is defined by the beneficial utilization of the heat output from the electric or mechanical power generation process.
- CHP heat can be converted to hot air, hot water, steam, chilled water, refrigeration or dehumidification.
- In all scenarios a thermal load must be present that is uniform with the CHP plant thermal output.



# Business Case – Energy Cost Component

- Industries that have a large energy component in their process such as metals processing, distillation, food processing, pulp and paper, etc. are more sensitive to energy costs and more likely to implement energy cost saving measures.

- Food processing typically may have 30% of its cost base be energy and in a highly competitive market, a 10% reduction in energy cost could have significant impact on the bottom line.

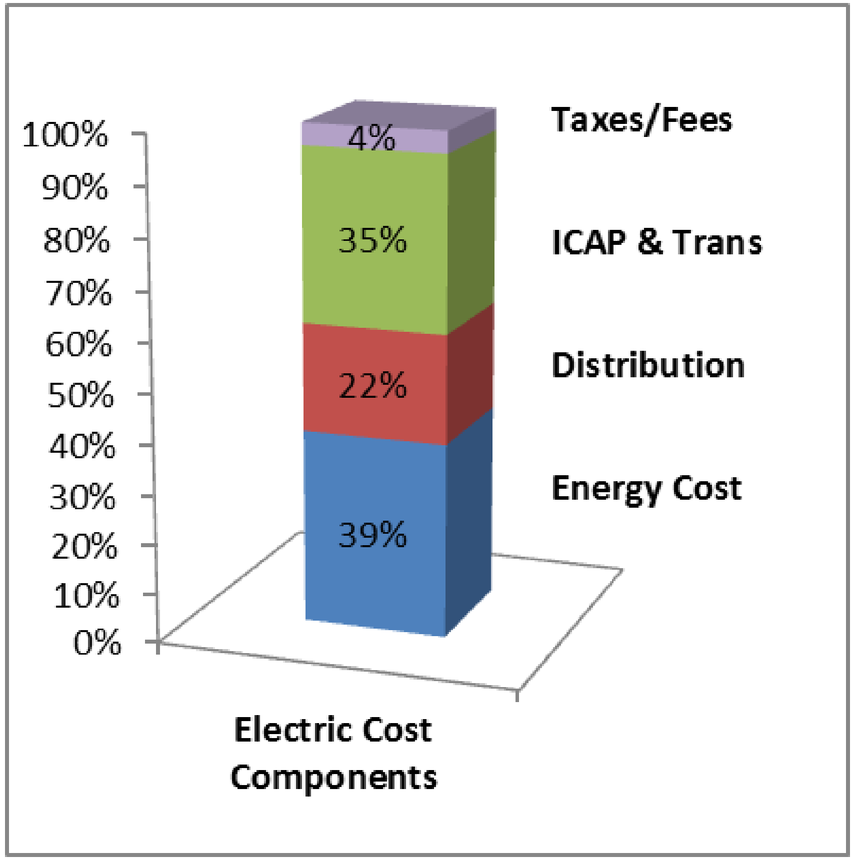
High energy component
High volume/Low margin

# Energy Costs – Spark Spread

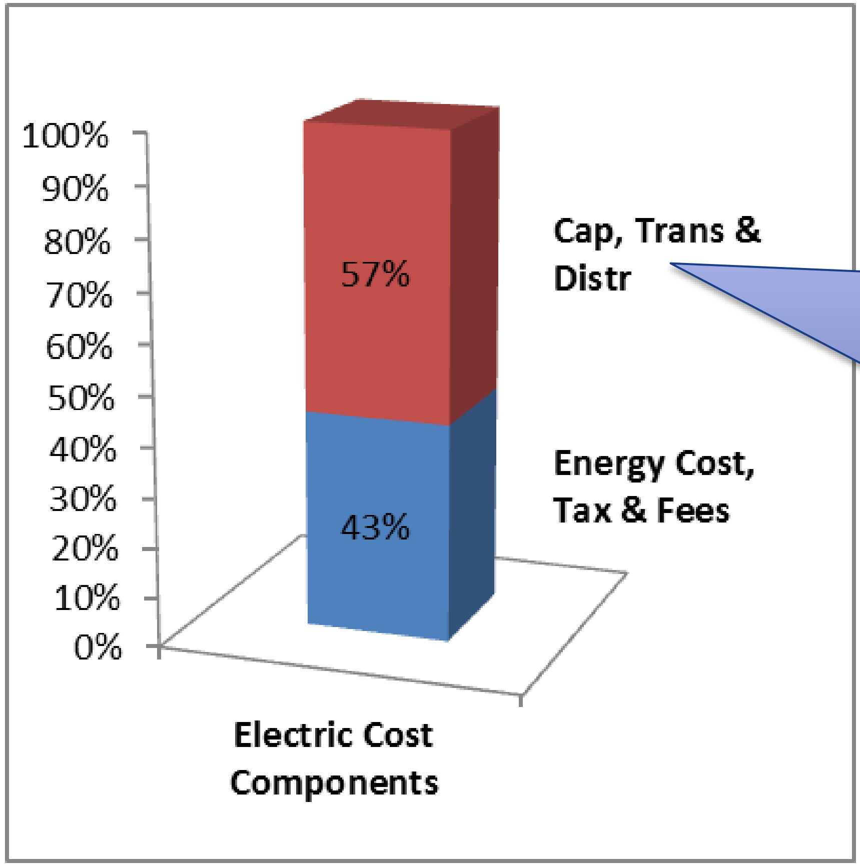
- The cost to generate electricity locally through CHP is offset by reduced load on the boiler plant resulting in a lower net cost to generate power.
- Spark spread is difference between the utility price for power and the cost to generate power locally.
- Typically, CHP costs less to generate the same energy output using natural gas than separate power and heating devices. CHP's lower fuel requirement means that CHP is always more efficient no matter what fuel is being used when a thermal load is present.

# Spark Spread – Electric Price versus Offset Value

## Identify and understand energy cost, not usage




PJM RFC-East Cost Breakout



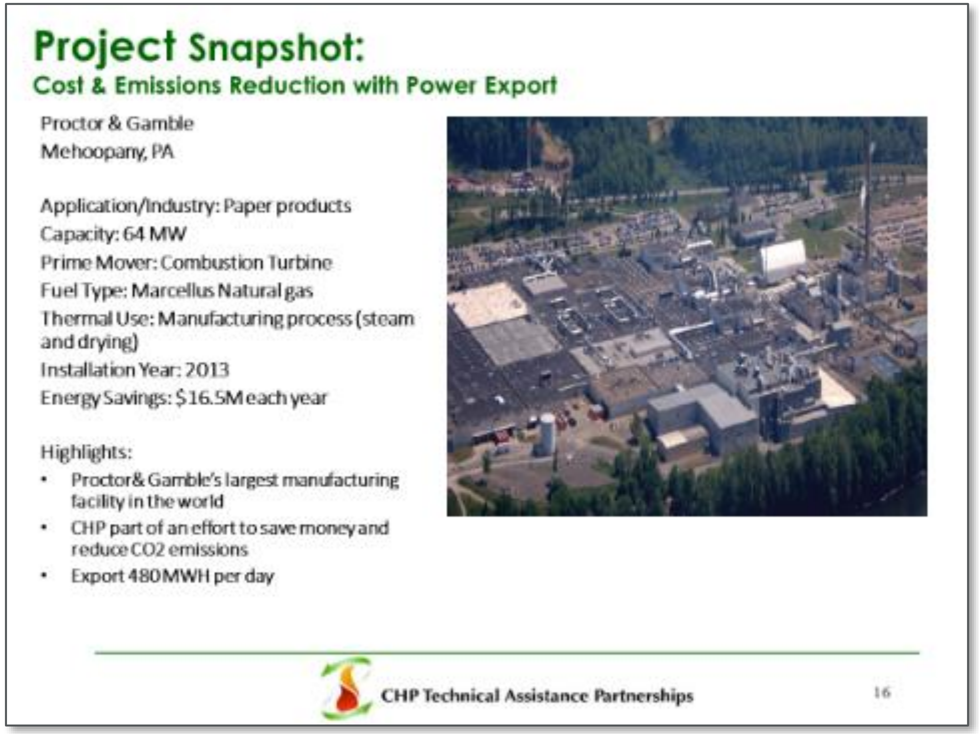

PJM RFC-East Cost Breakout

At low natural gas costs prevalent in the recent past, non-energy costs represented more than half of the wholesale charge

# Business Case – Power Quality/Reliability/Availability

- CHP is not only a way to generate power efficiently, but also a way to obtain additional electric power or improve power quality and reliability when the utility cannot provide the service required.

- Remote areas near natural gas pipe infrastructure can use CHP as a cost effective way to provide additional reliable power.



# Business Case – ESG

- ESG (environmental, social, and corporate governance) data reflect the externalities (costs to others) an organization is generating with respect to the environment, to society and to corporate governance.
- Organizational stakeholders may include but not be limited to customers, **suppliers**, employees, leadership, and **the environment**.
- Key performance indicators such as GHG emissions or $CO_2$e emissions per unit of production or throughput are important.

# Business Case – Energy Resilience

- For end users:
  - Provides continuous supply of electricity and thermal energy for critical loads
  - Can be configured to operate in “island mode” during a utility outage
  - Ability to withstand long, multiday power outages
- For utilities:
  - Enhances grid stability and relieves grid congestion
  - Enables microgrid deployment for balancing renewable power and providing a diverse generation mix
- For communities:
  - Keeps critical facilities like hospitals and emergency services operating and responsive to community needs

# Business Case – Capital Cost Recovery

- Spark spread taking into account O&M should be in the order of 2 ₵ per kWh for reasonable rate of return on the capital investment not including interest or profit. Interest and profit can add from 50% to 100% of the borrowed amount over the term of the loan depending on terms and rates requiring a spark spread of 4 ₵ per kWh in order to consider the project.

$2,500/kW at 8,760 hrs x 95% available = $0.30/kWh in first year or $0.02/kWh in 15 years

| **Operating Costs to Generate** | **$/kWh** |
|---|---|
| Fuel Costs, $/kWh | 0.0545 |
| Thermal Credit, $/kWh | (0.0175) |
| Incremental O&M, $/kWh | 0.0190 |
| **Total Operating Costs to Generate, $/kWh** | **$0.056** |

- Capital Cost recovery is based on net investment after credits and offsets

# Business Case – Internal Rate of Return (IRR)

- Developing a CHP plant at a site requires a financial investment or alternate financing mechanism that enables the financial investment.
- The investment is fixed and to be returned to the investor with interest and profit.
- In cases where the spark spread is favorable, the savings are used to pay down the investment. The IRR is the rate of return on the initial investment over the life-time of the investment.
- The IRR is proportional to energy cost reductions, capital cost and operating hours. High operating hours directly increases the IRR.

# Identifying the Right Candidate

- There is a large constant thermal load
- Spark spread is favorable (higher energy costs are better)
- Multi-shift operation or long run hours
- Tax credits or performance payments are available
- State and/or Corporate goals include GHG reduction
- Regulatory mandates for GHG reduction
- Resilience improvements are valued
- Utilities are supportive
- Grid policy supports distributed resources

Facility Location

Codes & Regs

Policy

# 5 Minute Break

# CHP Technology Options, eCatalog and Site Assessments

Jim Freihaut, Ph.D.

DOE Mid-Atlantic and New York-New Jersey Onsite Energy TAPs

# Prime Mover Technologies & Configurations

- Five Prime Movers
  - Reciprocating engines
  - Gas turbines
  - Microturbines
  - Steam turbines
  - Fuel cells
- Three Main Configurations (described on following slides)
  - Engine/Turbine with Heat Recovery
  - Boiler & Steam Turbine
  - Fuel Cell with Heat Recovery
- Information based on Overview of CHP Technologies, CHP Technology Fact Sheet Series
  - https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/Overview_of_CHP_Technologies.pdf

# Reciprocating Engines

- Well-established and widely used technology
- Diesel and spark-ignition configurations
- Important for both transportation and stationary uses
- Sizes range from very small (<5 kW) to very large (>80MW, 5-story tall marine propulsion systems weighing over 5 million pounds)
- Engines are rugged, reliable, and economic choice as a prime mover for CHP applications
- Pros: High part-load operation efficiency, fast start-up, suitable for a variety of applications
- Cons: Lower temperature output for CHP applications, routine maintenance

Reciprocating engine CHP installation at an industrial facility.
*Photo courtesy of Caterpillar.*

# Gas Turbines

- Aircraft applications drove innovations and technology development, with millions of hours of operation, making it a dependable and trusted technology
- Range in size from 500 kW to over 300 MW
- Pros: GT have high reliability, high efficiency, low emissions, benefit from economies of scale, and can offer a wide range of power-to-thermal ratios (e.g. from a high thermal duct-fired SCGT to a high power CCGT)
- Cons: GT at industrial size applications can be expensive

Gas turbine CHP installation at a university.
*Photo courtesy of Solar Turbines*

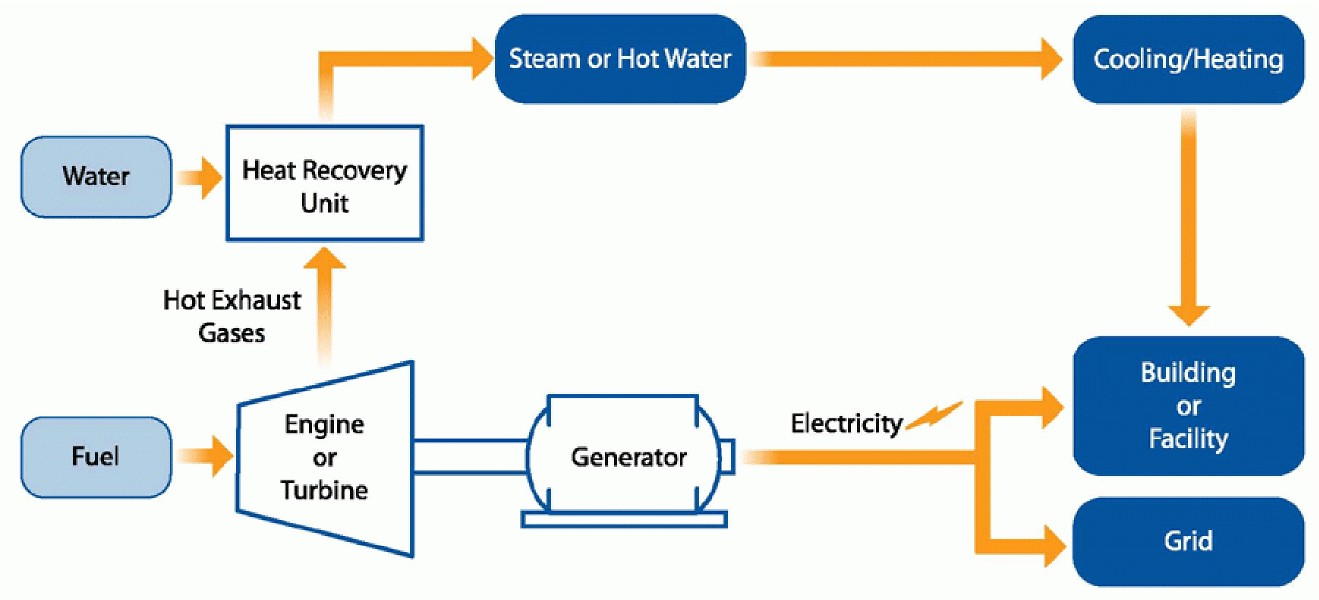
# Microturbines

- Relatively newer prime mover that entered the market in 1990s
- Sizes range from 30 kW to 250 kW (with modular packages exceeding 1 MW)
- Fuel flexible including natural gas, sour gas, and liquid fuels such as gasoline, diesel, and heating oil
- Exhaust in the 500 to 600°F range, suitable for supplying a variety of thermal needs.
- Pros: Microturbines have small number of moving parts, compact size and light weight, low emissions, no cooling required
- Cons: Microturbines are higher in costs, relatively low part load efficiency

Microturbine CHP installation at a commercial facility.
*Photo courtesy of Capstone Turbine Corporation*

# Reciprocating Engine or Turbine with Heat Recovery

- Gas or liquid fuel is combusted in a prime mover, such as a reciprocating engine, microturbine, or gas turbine
- The prime mover is connected to a generator that produces electricity
- Energy normally lost in the prime mover's hot exhaust and cooling system is recovered to provide useful thermal energy for the site



# Heat Recovery

- Heat Exchangers
  - Recover exhaust gas from prime mover
  - Transfers exhaust gas into useful heat (steam, hot water) for downstream applications
  - Heat Recovery Steam Generators (HRSG) the most common

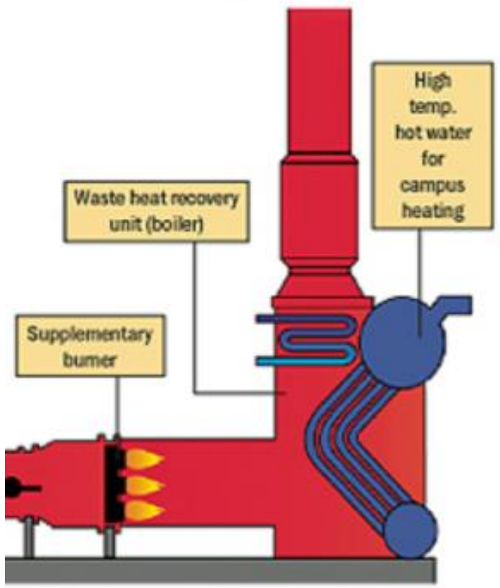



*Image Source: University of Calgary*

- Heat-Driven Chillers
  - Steam Turbine Centrifugal Chiller
  - Absorption Chiller
    - Use heat to chill water
    - Chemical process (not mechanical)

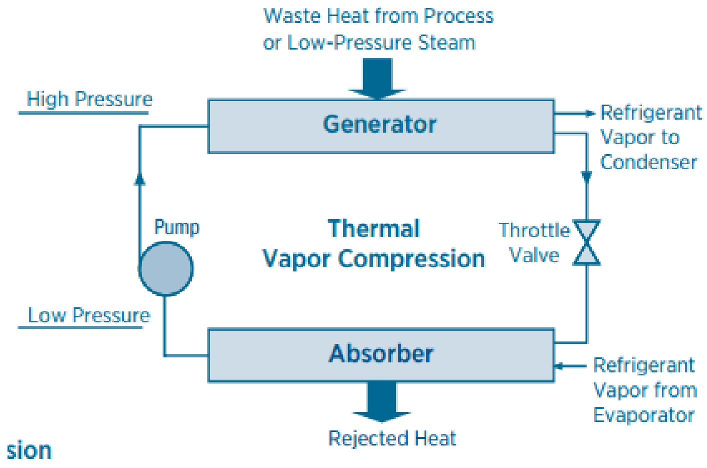



*Image Source: DOE - EERE*

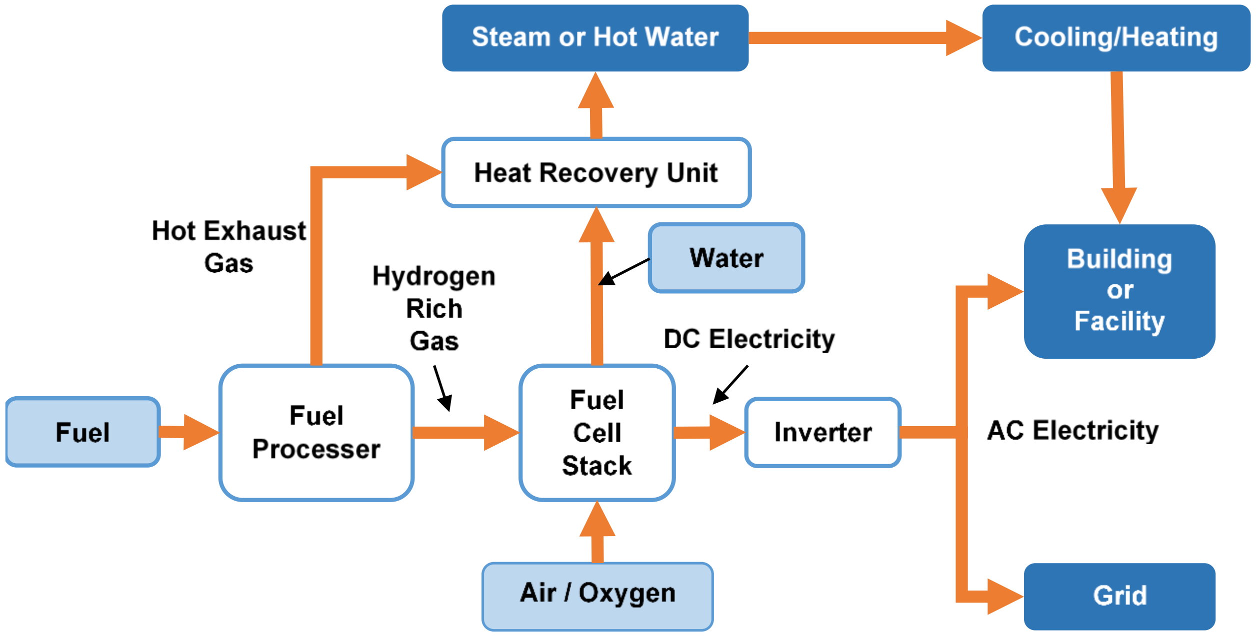
# Fuel Cells

- A fuel, such as natural gas, is reformed in a fuel processor to create hydrogen
- Hydrogen and oxygen are converted to direct current (DC) electricity using an electrochemical process in a fuel cell stack
- An inverter is used to convert DC electricity to alternating current (AC) electricity
- Heat from the fuel processor and fuel cell stack are recovered to provide useful thermal energy for the site
- Pros: High Efficiency, Environmentally Friendly, Low Noise
- Cons: Very High Capital Cost, Long term reliability in commercial operations not yet proven, except for Phosphoric Acid fuel cells

CHP fuel cell installation at Verizon data center.[1]
*Photo courtesy of Verizon Communications.*

# Fuel Cell with Heat Recovery

- A fuel, such as natural gas, is reformed in a fuel processor to create hydrogen
- Hydrogen and oxygen are converted to direct current (DC) electricity using an electrochemical process in a fuel cell stack
- An inverter is used to convert DC electricity to alternating current (AC) electricity
- Heat from the fuel processor and fuel cell stack are recovered to provide useful thermal energy for the site



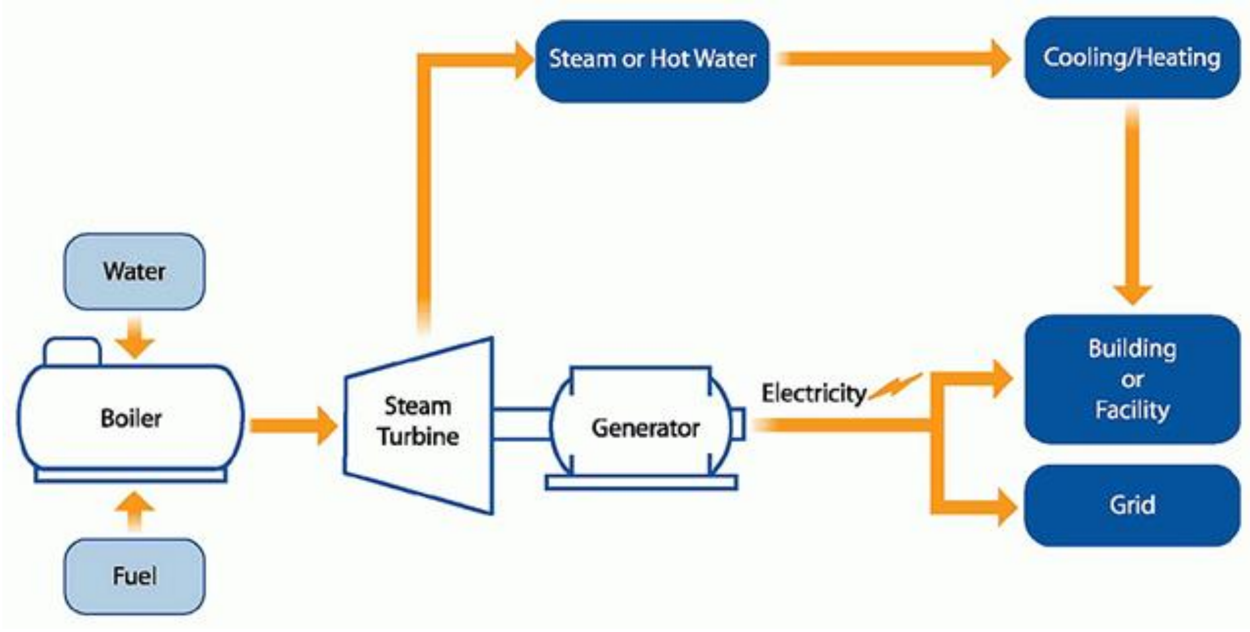
# Steam Turbines

- Invented in 1884, quickly replaced reciprocating engines as main prime mover technology
- Wide power range from 50kW (0.05 MW) to 250 MW
- Boilers can operate on variety of fuels (e.g. natural gas, solid waste, coal, wood, wood waste, agricultural byproducts)
- Good efficiency combined with relative cleanliness of the feedstock lead to relatively low carbon dioxide, nitrogen oxides and other emissions
- Two typical designs:
  - Single-stage back-pressure or condensing turbines
  - Multi-stage turbines (higher power ranges)
- Pros: Variety of applications where steam is expanded from high pressure to low, emissions depend on feedstock,
- Cons: Relatively high capital costs

Steam turbine CHP installation at an industrial facility in New York.
*Photo courtesy of Recycled Energy Development*

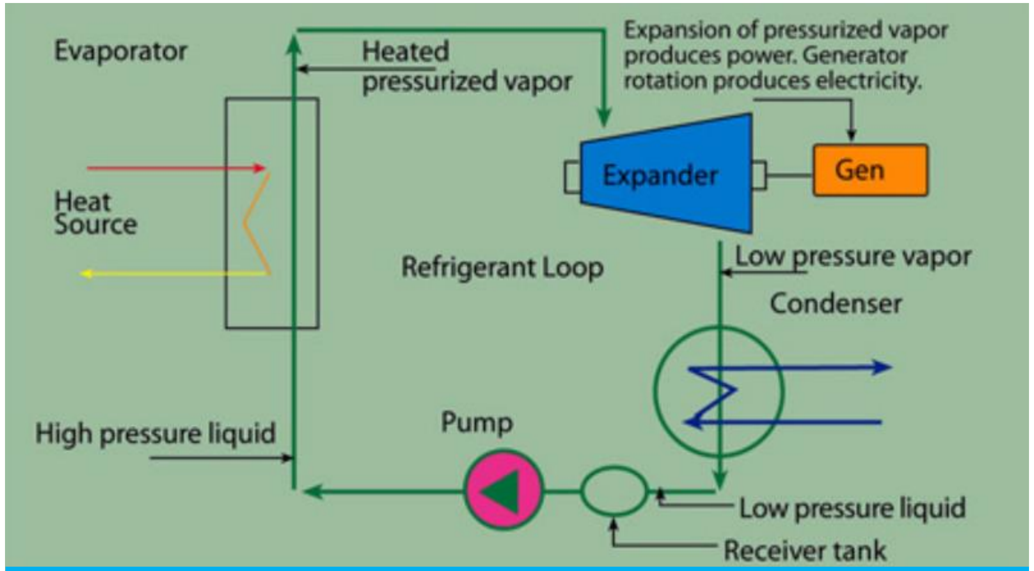
# Boiler / Steam Turbine

- Fuel is burned in a boiler to produce high pressure steam that is sent to a backpressure or extraction steam turbine
- The steam turbine is connected to an electric generator that produces electricity
- Low pressure steam exits the turbine and provides useful thermal energy for the site



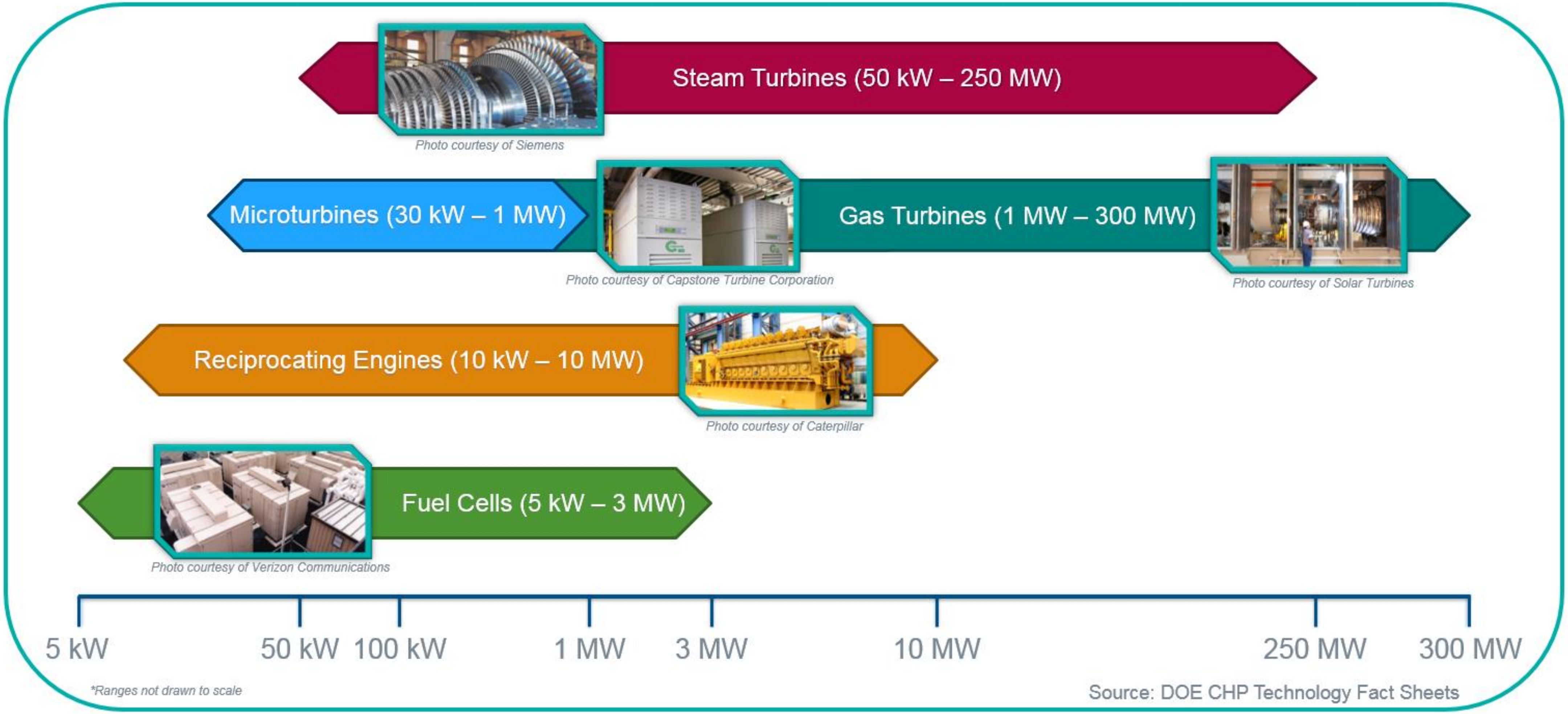
# Organic Rankine Cycle

- For low-temperature waste heat recovery applications typically between 170-600°F
- Commercially available size ranges from 100 kW to 8 MW
- Uses working fluid other than water/steam such as a hydrocarbon or ammonia, allowing for lower working temperatures, potentially eliminating need for 24/7 boiler operators
- Pros: Variety of temperature and size range applications across numerous market sectors, no emissions
- Cons: High installation costs (~1.5 X Steam Turbine costs), complex engineering




Organic Rankine Cycle Thermodynamic Cycle
*Photo courtesy of gulfcoastgreenenergy.com*

# Common CHP Technologies and Capacity Ranges



# Comparison of CHP Characteristics [1, 2]

| Characteristic | Technology | | | | |
|---|---|---|---|---|---|
| | Reciprocating Engine | Gas Turbine | Microturbine | Fuel Cell | Steam Turbine |
| **Size Range** | 10 kW – 10 MW | 1 – 300 MW | 30 kW – 330 kW (larger modular units available) | 5 kW – 1.4 MW (larger modular units available) | 100 kW – 250 MW |
| **Electric Efficiency (HHV)** | 30% – 42% | 24% – 36% | 25% – 29% | 38% – 42% | 5% – 7% |
| **Overall CHP Efficiency (HHV)** | 77% – 83% | 65% – 71% | 64% – 72% | 62% – 75% | 80% |
| **Total Installed Cost ($/kW) [3]** | $1,400 – $2,900 | $1,300 – $3,300 | $2,500 – $3,200 | $4,600 –$10,000 | $670 – $1,100 [4] |
| **O&M Cost (¢/kWh)** | 0.9-2.4 | 0.9-1.3 | 0.8-1.6 | 3.6-4.5 | 0.6-1.0 |
| **Power to Heat Ratio** | 0.6 – 1.2 | 0.6 – 1.0 | 0.5 – 0.8 | 1.3 – 1.6 | 0.07 – 0.10 |
| **Thermal Output (Btu/kWh)** | 2,900 --6,100 | 3,400 --6,000 | 4,400 --6,400 | 2,200 --2,600 | 30,000 --50,000 |

**Notes:**

1) Unless noted otherwise, information based on U.S. Department of Energy, CHP Technology Fact Sheet Series, 2016, 2017.
2) All performance and cost characteristics are typical values and are not intended to represent a specific product.
3) Costs will vary depending on site specific conditions and regional variations.
4) Costs shown are for a steam turbine only, and do not include costs for a boiler, fuel handling equipment, steam loop, and controls.

# Comparison of CHP Characteristics Continued…

| Characteristic | Technology | | | | |
|---|---|---|---|---|---|
| | Reciprocating Engine | Gas Turbine | Microturbine | Fuel Cell | Steam Turbine |
| Fuel Pressure (psig) [1] | 1-75 | 100-500 (may require fuel compressor) | 50-140 (may require fuel compressor) | 0.5-45 | n/a |
| Part Load Efficiency | Good at both part-load and full-load | Better at full-load | Better at full-load | Better at full-load | Good at both part-load and full-load |
| Type of Thermal Output | LP steam, hot water, space heating, chilled water | LP-HP steam, hot water, process heating, chilled water | LP steam, hot water, chilled water | LP steam, hot water, chilled water | LP-HP steam, hot water, chilled water |
| Fuel | Can be operated with a wide range of gas and liquid fuels. For CHP, the most common fuel is natural gas. | | | Hydrogen, natural gas, propane, methanol | Steam turbines for CHP are used primarily where a solid fuel (e.g., coal or biomass) is used in a boiler. [2] |

**Notes:**
1) Adapted from Catalog of CHP Technologies, U.S. Environmental Protection Agency Combined Heat and Power Partnership, 2015.
2) Backpressure steam turbines can be used to produce power by replacing pressure reducing valves (PRVs) in existing steam systems.

# Benefits of Packaged Systems

- Self Contained Units or Modules
  - Prime Mover
  - Heat Recovery
  - Controls
  - Ancillary Equipment
- Standardized yet customizable
- Code Compliant
- Tested
- Factory assembled
- Moveable

2 MW package

7.5 MW (3 modules)

3.3 MW (3 modules)

1 MW Package (5 MTs)

# DOE Packaged CHP eCatalog

- A national web-based searchable catalog of DOE-recognized packaged CHP systems and suppliers with the goal to reduce risks for end-users and vendors through partnerships with:
  - *CHP Packagers that assemble and support recognized packaged CHP Systems*
  - *Solution Providers that install, commission and service packaged CHP systems*
  - *CHP Engagement partners that provide CHP market deployment programs at the state, local and utility level*
- Pre-engineered and tested packaged CHP systems that meet DOE performance requirements.
- eCatalog audience: end-users with engineering staff, consulting engineers, utilities, state energy offices, regulators, federal agencies, and project developers.
- Users search for applicable CHP system characteristics, and get connected to packagers, installers and CHP engagement programs
- Allows users to compare technology options on a common basis.

# Navigating the eCatalog

## PACKAGED CHP SYSTEM HIGHLIGHTS

| | |
|---|---|
| **Solution Provider** | 2G Energy Inc. |
| **Model** | agenitor 404c NG |
| **Thermal Outputs** | Hot Water |
| **Assurance Plan** | Depends on location |
| **Grid Connection Type** | Grid Parallel and Stand-alone<br>Transition: Automatic |
| **Outdoor Placement** | Standard Option |

## KEY PERFORMANCE DATA

| | |
|---|---|
| **Prime Mover** | Reciprocating engines<br>2G<br>agenitor 404c NG |
| **Number of Prime Movers** | 1 |
| **Net Power Output (kW)2** | 154 |
| Fuel | Natural Gas or Pipeline RNG and up to 40% Hydrogen |

*Note: The ratings below are based on the fuel designated above without any hydrogen. Contact the Packager for Package rating with hydrogen blending.*

1. *(Net Power Output + Thermal Output) / Energy Input at 59°F and 100% gross power*
2. *Net Power Output is Gross Prime Mover Power less CHP system parasitics, less fuel gas booster if required and less chiller parasitics during chiller operation*
3. *Hot water capacity is usable energy assuming 180F supply and minimum allowable return temperature to the Packaged CHP System*

## INSTALLATION EXPERIENCE

| 3,850 | 3 | - | - |
|---|---|---|---|
| **Total Company Installs** | **Total Company Installs In MA** | **Installs Of This Package** | **Company Installs Of This Package** |
| Total systems installed by 2G Energy Inc. | Total systems installed by 2G Energy Inc. in MA | Total packages with this prime mover and fuel | Installs of this package (prime mover and fuel) by 2G Energy Inc. |

## PERFORMANCE DATA

| | | 100% GROSS POWER | | | 75% GROSS POWER | | | 50% GROSS POWER | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Ambient Temperature | 95°F | 59°F | 0°F | 95°F | 59°F | 0°F | 95°F | 59°F | 0°F |
| | CHP Fuel Input (MMBtu per hour HHV) | 1.49 | 1.51 | 1.51 | 1.20 | 1.20 | 1.20 | 0.86 | 0.86 | 0.86 |
| POWER | Gross Electricity Output (kW) | 157 | 160 | 160 | 120 | 120 | 120 | 80 | 80 | 80 |
| POWER | Net Electricity Output (kW) | 150 | 154 | 154 | 114 | 114 | 115 | 74 | 74 | 75 |
| POWER | Net Electric Efficiency % (HHV) | 34.4 | 34.7 | 34.8 | 32.3 | 32.5 | 32.6 | 29.4 | 29.4 | 29.6 |
| HOT WATER | Supply Temp to Site (°F) | | 180 °F | | | 180 °F | | | 180 °F | |
| HOT WATER | HW flow (GPM) | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 |
| HOT WATER | Return Temp from Site (°F) | 153 | 153 | 153 | 158 | 158 | 158 | 164 | 164 | 164 |
| HOT WATER | Hot Water Capacity (MMBtu/hr) | 0.60 | 0.61 | 0.61 | 0.49 | 0.49 | 0.49 | 0.37 | 0.37 | 0.37 |
| HOT WATER | Thermal Efficiency % (HHV) | 40.3 | 40.4 | 40.4 | 40.8 | 40.8 | 40.8 | 43.0 | 43.0 | 43.0 |

| EMISSIONS | | |
|---|---|---|
| | **Emissions Aftertreatment** | Lean-burn engine with no aftertreatment |
| | **NOx Emissions (lb/MWhe)** | 3.50 |
| | **CO Emissions (lb/MWhe)** | 6.20 |

# CHP eCatalog

## PERFORMANCE DATA

Performance data presented below is based on capacity that is available at the respective prime mover load conditions. Fuel data is in Higher Heating Value (HHV). Note that when multiple thermal capacities are presented e.g. hot water, steam, chilled water and/or ORC kW, these capacities are based on using all the thermal heat available from the prime mover and should be viewed as independent and not concurrent with other thermal capacities. Exception, for reciprocating engines steam production is generally using only exhaust heat so that hot water or chilled water capacity is concurrent with the steam capacity. All performance ratings are at sea level and adjustments should be made for operation at altitude, particularly for microturbines and combustion turbines. In all cases, contact th Packager or Solution Provider for site specific details.

| | | 100% GROSS POWER | | | 75% GROSS POWER | | | 50% GROSS POWER | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Ambient Temperature | 95°F | 59°F | 0°F | 95°F | 59°F | 0°F | 95°F | 59°F | 0°F |
| | CHP Fuel Input (MMBtu per hour HHV) | 79.0 | 89.0 | 102.3 | 64.7 | 72.6 | 92.6 | 52.2 | 58.0 | 65.5 |
| POWER | Gross Electricity Output (kW) | 6,710 | 7,968 | 9,332 | 5,033 | 5,976 | 6,999 | 3,355 | 3,984 | 4,666 |
| POWER | Net Electricity Output (kW) | 6,660 | 7,918 | 9,282 | 4,983 | 5,926 | 6,949 | 3,305 | 3,934 | 4,616 |
| POWER | Net Electric Efficiency % (HHV) | 28.8 | 30.4 | 31.0 | 26.3 | 27.9 | 25.6 | 21.6 | 23.2 | 24.1 |

*Note for Gas Turbines: Direct drying/heating must have 4" of inlet and outlet losses incorporated in the ratings*

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| DIRECT PROCESS HEAT | Exhaust temperature (after heat recovery) Type Selection | Standard Drying (200°F) | | | | | | | | |
| DIRECT PROCESS HEAT | Oxygen Content in Exhaust Gas in percent by volume (%) | 14 | 14 | 13 | 14 | 14 | 13 | 14 | 14 | 13 |
| DIRECT PROCESS HEAT | Direct Process Heat Capacity (MMBtu/hr) | 41.40 | 44.00 | 47.40 | 35.30 | 37.50 | 39.90 | 30.40 | 32.10 | 34.00 |

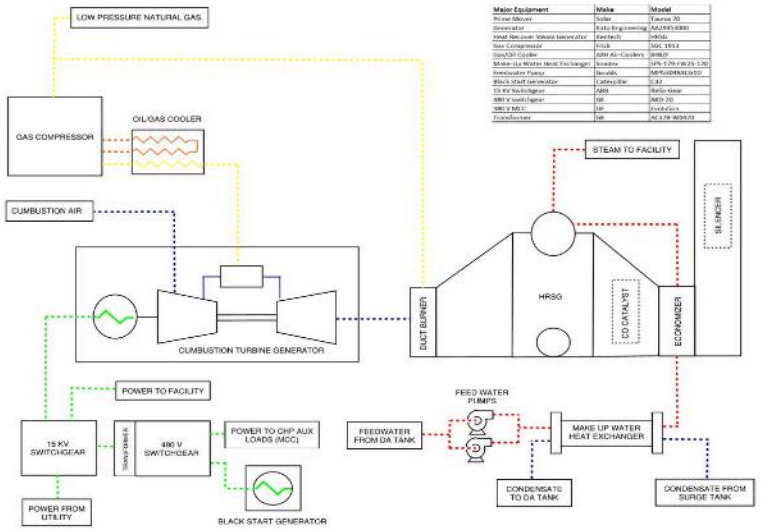
| | | | | | |
|---|---|---|---|---|---|
| Fuel Gas Pressure to Packaged CHP System (psig) | 1 | 25 | 50 | 100 | 300 |
| Fuel Gas Booster Compressor Power Required (kW) | 416 | 258 | 189 | 131 | 11 |

| | | |
|---|---|---|
| EMISSIONS | Emissions Aftertreatment | Combustion turbine with no aftertreatment |
| EMISSIONS | NOx Emissions (lb/MWhe) | 0.64 |
| EMISSIONS | CO Emissions (lb/MWhe) | 0.66 |

## FOOTPRINT

| | WIDTH IN FEET | LENGTH IN FEET | HEIGHT IN FEET | WEIGHT IN POUNDS |
|---|---|---|---|---|
| Prime Mover/Generator system (Includes maintenance clearances) | 20 | 47 | 17 | 123,000 |
| Heat Recovery subsystem if separate (Includes maintenance clearances) | 20 | 65 | 20 | 380,000 |
| Chiller if separate (Includes maintenance clearances) | 0 | 0 | 0 | 0 |
| Total System Layout (Includes maintenance clearances) | 40 | 112 | 20 | 503,000 |
| Largest part for delivery | 9 | 37 | 12 | 116,557 |
| Heaviest part for delivery | 9 | 37 | 12 | 116,557 |

## PACKAGED CHP SYSTEM SIMPLIFIED SCHEMATIC



# DOE TAP CHP Screening Analysis

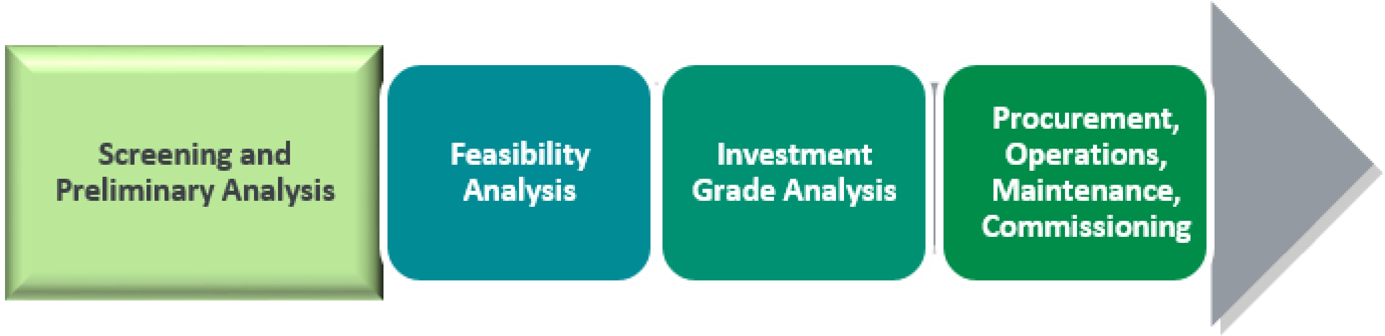
- High level assessment to determine if site shows potential for a CHP project
  - Quantitative Analysis
    - Energy Consumption & Costs
    - Estimated Energy Savings & Payback
    - CHP System Sizing
  - Qualitative Analysis
    - Understanding project drivers
    - Understanding site peculiarities

| Annual Energy Consumption | | |
|---|---|---|
| | Base Case | CHP Case |
| Purchased Electricty, kWh | 88,250,160 | 5,534,150 |
| Generated Electricity, kWh | 0 | 82,716,010 |
| On-site Thermal, MMBtu | 426,000 | 18,872 |
| CHP Thermal, MMBtu | 0 | 407,128 |
| Boiler Fuel, MMBtu | 532,500 | 23,590 |
| CHP Fuel, MMBtu | 0 | 969,845 |
| Total Fuel, MMBtu | 532,500 | 993,435 |
| **Annual Operating Costs** | | |
| Purchased Electricity, $ | $7,060,013 | $1,104,460 |
| Standby Power, $ | $0 | $0 |
| On-site Thermal Fuel, $ | $3,195,000 | $141,539 |
| CHP Fuel, $ | $0 | $5,819,071 |
| Incremental O&M, $ | $0 | $744,444 |
| Total Operating Costs, $ | $10,255,013 | $7,809,514 |
| **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** | | |
| Fuel Costs, $/kWh | | $0.070 |
| Thermal Credit, $/kWh | | ($0.037) |
| Incremental O&M, $/kWh | | $0.009 |
| **Total Operating Costs to Generate, $/kWh** | | **$0.042** |

# The Process and Required Data Points for CHP Project Screening

- Site Qualification Questions
- Site Data Collection
- Utility Bill Analysis
  - Utility Billing Data
  - Site Operating Schedule
  - Displaced thermal Equipment Information
  - CHP Operating Schedule
- CHP Screening Analysis
- Additional Considerations

# Screening Questions




- Do you pay more than $0.06/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.)

# Screening Questions (cont.)

- 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 Screening Analysis

| | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Billing days per month | | 31 | 28 | 31 | 30 | 31 | 30 | 31 | 31 | 30 | 31 | 30 | 31 | 365 |
| **Electricity Bill Data** | | | | | | | | | | | | | | |
| Monthly Electric Use kWh | | 314,896 | 415,658 | 399,882 | 288,952 | 553,359 | 518,596 | 514,023 | 500,416 | 380,979 | 469,093 | 489,757 | 453,181 | 5,298,792 |
| Monthly Peak Demand kW | | 905 | 902 | 948 | 926 | 1,057 | 1,083 | 1,131 | 1,138 | 1,031 | 989 | 953 | 915 | 998 |
| All-in Monthly Cost (Commodity plus T&D) | | $33,471 | $40,725 | $38,031 | $32,339 | $43,026 | $57,081 | $61,210 | $56,314 | $55,570 | $46,210 | $44,281 | $48,463 | $556,722 |
| Average 'all-in' $/kWh | | $0.1063 | $0.0980 | $0.0951 | $0.1119 | $0.0778 | $0.1101 | $0.1191 | $0.1125 | $0.1459 | $0.0985 | $0.0904 | $0.1069 | $0.1051 |
| **Fuel Bill Data:** Fuel Type | **Nat Gas** | | | | | | | | | | | | | |
| Monthly Fuel Use | Therm | 10,648 | 14,274 | 14,846 | 9,390 | 20,020 | 15,395 | 12,257 | 10,224 | 8,337 | 12,464 | 13,716 | 15,134 | 156,705 |
| Monthly Fuel Cost | $ | $8,429 | $9,863 | $10,219 | $4,631 | $10,417 | $7,532 | $5,674 | $5,145 | $4,815 | $6,738 | $11,094 | $11,809 | $96,368 |
| Average Cost of Fuel | $/MMBtu | $7.9163 | $6.9098 | $6.8833 | $4.9317 | $5.2036 | $4.8929 | $4.6293 | $5.0322 | $5.7759 | $5.4057 | $8.0885 | $7.8031 | $6.1496 |
| Fuel for Addressable Thermal Load | % | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | |
| Addressable Thermal Load Fuel | MMBtu | 1,065 | 1,427 | 1,485 | 939 | 2,002 | 1,539 | 1,226 | 1,022 | 834 | 1,246 | 1,372 | 1,513 | 15,670 |

## Step 2 - Site Operating Schedule

Site Operating Schedule: Other

If operating schedule is "other", fill in monthly hours in Table 1 in green highlighted cells

**Table 1 - Addressable Thermal Load**

| | Monthly Hours | MMBtu Fuel | MMBtu Load | MMBtu Load/Hr | Seasonal Thermal Load | |
|---|---|---|---|---|---|---|
| January | **705** | 1,065 | 905 | 1.28 | Winter | |
| February | **633** | 1,427 | 1,213 | 1.92 | 3,405 | MMBtu |
| March | **705** | 1,485 | 1,262 | 1.79 | **1.8** | MMBtu/hr |
| April | **681** | 939 | 798 | 1.17 | | |
| May | **705** | 2,002 | 1,702 | 2.41 | Shoulder | |
| June | **681** | 1,539 | 1,309 | 1.92 | 6,696 | MMBtu |
| July | **537** | 1,226 | 1,042 | 1.94 | **1.6** | MMBtu/hr |
| August | **705** | 1,022 | 869 | 1.23 | | |
| September | **681** | 834 | 709 | 1.04 | Summer | |
| October | **705** | 1,246 | 1,059 | 1.50 | 3,220 | MMBtu |
| Novmber | **681** | 1,372 | 1,166 | 1.71 | **1.7** | MMBtu/hr |
| December | **537** | 1,513 | 1,286 | 2.40 | | |
| Total | 7956 | 15,670 | 13,320 | **1.67** | | |
| Displaced Thermal Efficiency | | | 85.0% | | | |

## Step 3 - Displaced Thermal Equipment Efficiency

Displaced Thermal Efficiency: 85.0%

# Prime Mover Driven CHP Performance Assumptions

## Table 1. Comparison of CHP Characteristics for Typical Systems [1, 2]

| Characteristic | Technology | | | | |
|---|---|---|---|---|---|
| | Reciprocating Engine | Gas Turbine | Microturbine | Fuel Cell | Steam Turbine |
| Size Range | 10 kW–10 MW | 1 MW–300 MW | 30 kW–330 kW (larger modular units available) | 5 kW–2.8 MW (larger modular units available) | 100 kW–250 MW |
| Electric Efficiency (HHV) | 30–42% | 24–36% | 25–29% | 38–42% | 5–7% |
| Overall CHP Efficiency (HHV) | 77–83% | 65–71% | 64–72% | 62–75% | 80% |
| Total Installed Cost ($/kW) [3] | $1,400–$2,900 | $1,300–$3,300 | $2,500–$3,200 | $4,600–$10,000 | $670–$1,100 [4] |
| O&M Cost (¢/kWh) | 0.9–2.4 | 0.9–1.3 | 0.8–1.6 | 3.6–4.5 | 0.6–1.0 |
| Power to Heat Ratio | 0.6–1.2 | 0.6–1.0 | 0.5–0.8 | 1.3–1.6 | 0.07–0.10 |
| Thermal Output (Btu/kWh) | 2,900–6,100 | 3,400–6,000 | 4,400–6,400 | 2,200–2,600 | 30,000–50,000 |
| Fuel Pressure (psig) [5] | 1–75 | 100–500 (may require fuel compressor) | 50–140 (may require fuel compressor) | 0.5–45 | n/a |
| Part Load Efficiency | Good at both part-load and full-load | Better at full-load | Better at full-load | Better at full-load | Good at both part-load and full-load |
| Type of Thermal Output | LP steam, hot water, space heating, chilled water | LP-HP steam, hot water, process heating, chilled water | LP steam, hot water, chilled water | LP steam, hot water, chilled water | LP-HP steam, hot water, chilled water |
| Fuel | Can be operated with a wide range of gas and liquid fuels. For CHP, the most common fuel is natural gas. | | | Hydrogen, natural gas, propane, methanol | Steam turbines for CHP are used primarily where a solid fuel (e.g., coal or biomass) is used in a boiler. |

https://betterbuildingssolutioncenter.energy.gov/chp/resources-publications

Better Plants®
U.S. DEPARTMENT OF ENERGY

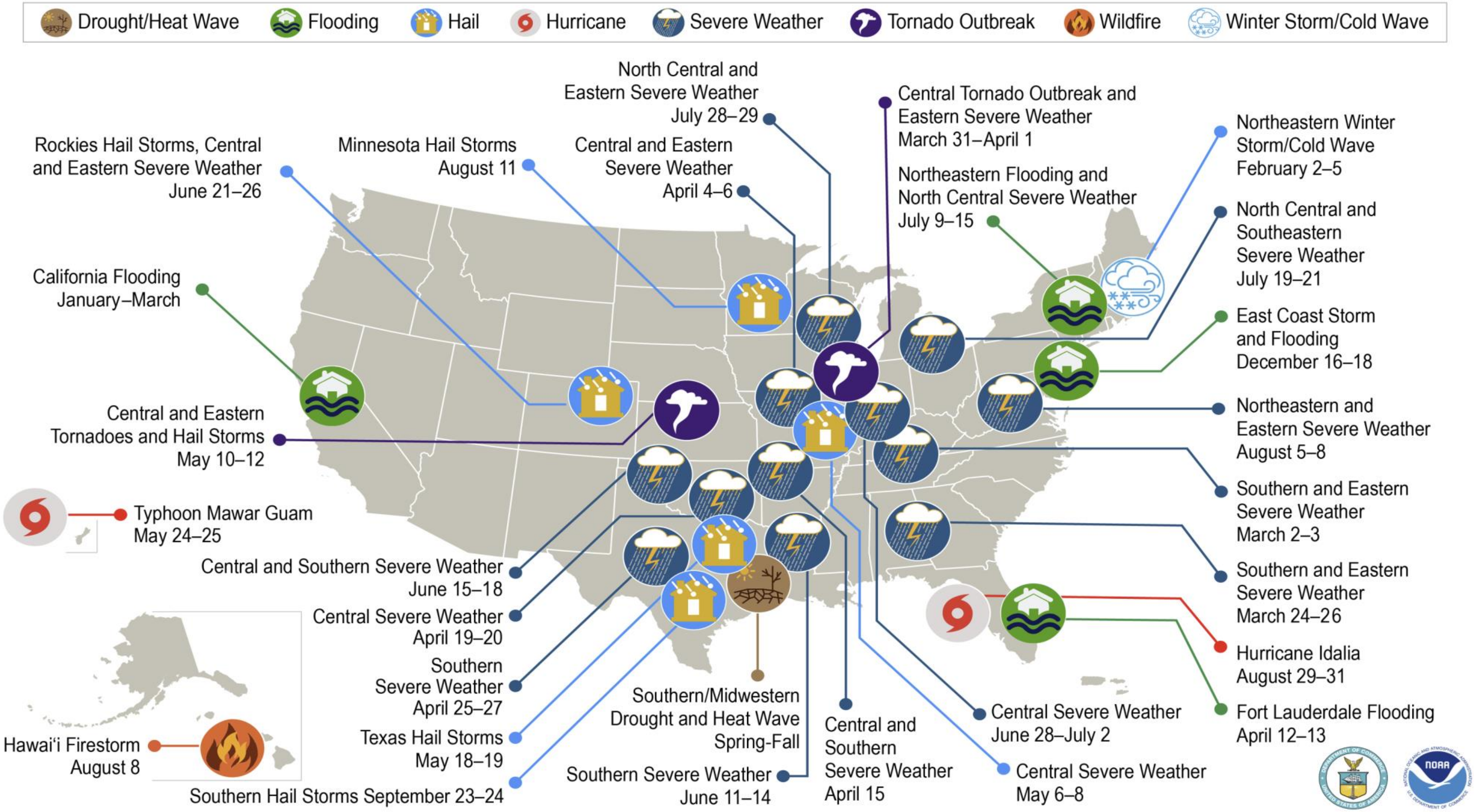
# Achieving Resiliency with CHP: Why the Focus on Resilience?

Art Samberg

DOE Southeast Onsite Energy TAP

U.S. DEPARTMENT OF ENERGY

# U.S. 2023 Billion-Dollar Weather and Climate Disasters




*This map denotes the approximate location for each of the **28 separate billion-dollar weather and climate disasters that impacted the United States in 2023.***

Source: NOAA/National Centers for Environmental Information

# U.S. 2024 Billion-Dollar Weather and Climate Disasters


*This map denotes the approximate location for each of the **24 separate billion-dollar weather and climate disasters that impacted the United States through October 2024.***

Source: NOAA/National Centers for Environmental Information

# Billion Dollar Weather/Climate Disaster Events

- Based on data from the National Oceanic and Atmospheric Administration

- Through November 1, 2024 there have been:
  - 24 weather/climate disaster events resulting in losses exceeding $1 Billion
  - Consisting of 17 severe storm outbreaks, 4 tropical cyclones, 1wildfire and 2 winter storms

- The frequency of $1 Billion loss events is increasing (even when adjusting for the CPI)
  - Annual average number of events (1980-2023) = 8.5
  - Annual average number of events (2019-2023) = 20.4

- Notable years with high climate disaster costs (in CPI-adjusted billions of dollar)
  - 2012 ($158.9)
  - 2021 ($164.2)
  - 2022 ($182.5)
  - 2005 ($267.0)
  - 2017 ($395.7)
  - 2024 ($61.6 – preliminary as of 11/1)

Source: NOAA/National Centers for Environmental Information

# Key Definitions

## 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.”*

Source: Patriot Act of 2001 Section 1016(e)

## Resilience

*The ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions; includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents.*

Source: National Infrastructure Protection Plan, U.S. Department of Homeland Security, 2013

# Critical Infrastructure Requires Energy Resilience
# CHP Provides Resilience

Facilities warranting enhanced energy resilience:

- Emergency Shelters
- Emergency Operations Centers (includes police/fire)
- Government Buildings/Military Installations
- Hospitals
- Community Centers
- Water/wastewater operations
- Universities
- Grocery Stores
- Cold Storage facilities
- Hotels
- Energy Infrastructure; fuel depots, gas stations
- Cellphone Tower
- Data Centers
- EV Charging Stations

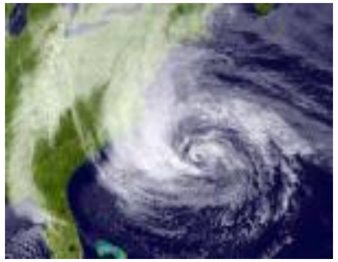
CHP (when properly configured)

- Offers the opportunity to improve Critical Infrastructure (CI) resiliency
- Can continue to operate, providing uninterrupted supply of electricity and heating/cooling to the host facility
- Supports resilient communities that recover more quickly from natural disasters

# CHP Increases Resilience

- For end users and the utility grid:
  - Provides continuous supply of electricity and thermal energy for critical loads
  - Can be configured to automatically switch to “island mode” during a utility outage, and to “black start” without grid power
  - Ability to withstand long, multiday outages

- For utilities:
  - Enhances grid stability and relieves grid congestion
  - Enables microgrid deployment for balancing renewable power and providing a diverse generation mix



- For communities:
  - Keeps critical facilities like hospitals and emergency services operating and responsive to community needs

# Distributed Energy Resources Disaster Matrix

***Ranking Criteria***

*Four basic criteria were used to estimate the vulnerability of a resource during each type of disaster event. They include the likelihood of experiencing:*

1. *a fuel supply interruption,*
2. *damage to equipment,*
3. *performance limitations, or*
4. *a planned or forced shutdown*

○ *indicates the resource is unlikely to experience any impacts*

◒ *indicates the resource is likely to experience one, two, or three impacts*

● *indicates the resource is likely to experience all four impacts*

| Natural Disaster or Storm Events | *Flooding* | *High Winds* | *Earthquakes* | *Wildfires* | *Snow/Ice* | *Extreme Temperature* |
|---|---|---|---|---|---|---|
| Battery Storage | ◒ | ○ | ◒ | ● | ○ | ◒ |
| Biomass/Biogas CHP | ◒ | ◒ | ◒ | ● | ○ | ○ |
| Distributed Solar | ○ | ◒ | ◒ | ● | ◒ | ◒ |
| Distributed Wind | ○ | ◒ | ◒ | ◒ | ◒ | ◒ |
| Natural Gas CHP | ○ | ○ | ◒ | ◒ | ○ | ○ |
| Standby Generators | ◒ | ○ | ◒ | ● | ◒ | ○ |

# CHP Microgrids with DERs

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.

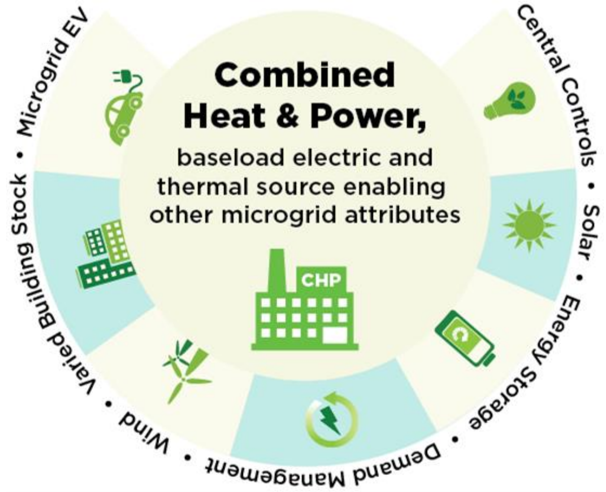
A microgrid can **connect and disconnect** from the larger utility grid to enable it to operate in both **grid-connected** or **island-mode**.

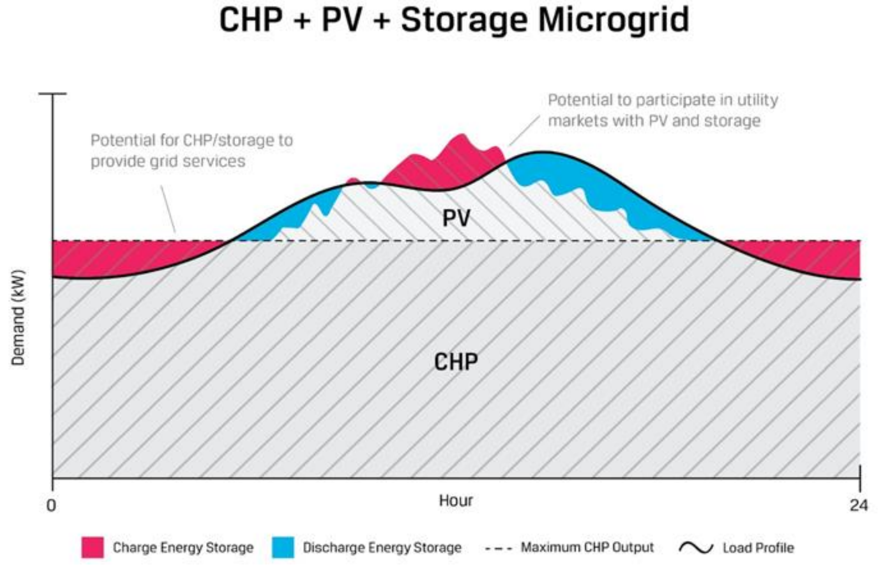
Source: U.S. Department of Energy Microgrid Exchange Group

With a CHP system providing reliable baseload electric and thermal energy, microgrids can support renewable generation and energy storage.

Increased focus on resilience for critical infrastructure:

- Universities, Hospitals, Military bases, Communities



# CHP Versus Backup Generation

- CHP provides continuous benefits to host facilities rather than just during emergencies
- CHP can result in daily operating cost savings
- CHP offsets capital costs associated with investments in traditional backup power

# CHP Versus Backup Generation

| | CHP | Backup Generation |
|---|---|---|
| **System Performance** | • Designed and maintained to run continuously<br>• Improved performance reliability | • Only used during emergencies |
| **Fuel Supply** | • Natural gas infrastructure typically not impacted by severe weather | • Limited by on-site storage |
| **Transition from Grid Power** | • May be configured for “flicker-free” transfer from grid connection to “island mode” | • Lag time may impact critical system performance |
| **Energy Supply** | • Electricity<br>• Thermal (heating, cooling, hot/chilled water) | • Electricity |
| **Emissions** | • Typically natural gas fueled<br>• Achieve greater system efficiencies (80%)<br>• Lower emissions | • Commonly burn diesel fuel |

# Uninterrupted Operation Requirements

Black start capability

Allows the system to start-up  independently from the grid

Generators capable of grid-independent operation

The system must be able to operate without the grid power signal

Ample carrying capacity

System size must match critical loads

Parallel utility interconnection and switchgear controls

The system must be able to disconnect from the grid, support critical loads, and reconnect after an event

# Hospital de la Conception, San Germán, PR

## Project Snapshot:

| | |
|---|---|
| **Application** | Hospital |
| **Capacity** | 1.2 MW |
| **Prime Mover** | Reciprocating Engine |
| **Fuel Type** | Liquified Propane Gas (LPG) |
| **Thermal Use** | Cooling, domestic hot water |
| **Installation Year** | 2018 |


**Testimonial:**
For a hospital, business continuity is critical, and we are in the business of preserving life. The CHP system helps secure our facility during power outages and provides a feeling of security and safety for patients and faculty, even during the most extreme events such as Hurricane Maria.
- Edgar Crespo Campos, HDLC Administrator

# Erlanger Baroness Hospital, Chattanooga, Tennessee

## **Project Snapshot:** CHP Microgrid

| | |
|---|---|
| **Application** | Hospital |
| **Capacity** | 8 MW |
| **Prime Mover** | Reciprocating Engine |
| **Fuel Type** | Natural Gas |
| **Thermal Use** | Heating, sterilization, and laundry |
| **Installation Year** | 2018 |


The CHP system at Erlanger Baroness Hospital is configured into a microgrid, enabling the facility to remain operational in the event of a grid outage.

**Project Highlights:**
Erlanger Baroness Hospital received a grant from the Tennessee Valley Authority to install a CHP system. The CHP system saves the hospital $1.5 million on their annual energy expenses, generating 52,000 MWh of power, 12,000 lb/hr of 115 psi steam, as well as hot and chilled water.

### Project Testimonial

"This innovative project not only saves energy, but it increases tremendously our reliability in the event of an ice storm, a tornado, cybersecurity threats; anything happening on the grid. We can power critical operations despite those interruptions."

- John Loetscher, III

Vice President of Facilities, Engineering, and Construction, Erlanger Health System

# 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 |

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 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.

### 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

# Shands Hospital, Gainesville, Florida

UFHealth
UNIVERSITY OF FLORIDA HEALTH

## Project Snapshot: District Energy

| | |
|---|---|
| **Application** | Hospital |
| **Capacity** | 11.7 MW |
| **Prime Mover** | Combustion Turbine/Reciprocating Engine |
| **Fuel Type** | Natural Gas |
| **Thermal Use** | Heating and cooling |
| **Installation Year** | 2007 |

By using CHP, Shands hospital was able to achieve LEED Gold certification from the U.S. Green Building Council.

## Project Highlights:

The UF Health Shands HealthCare South Campus receives district heating and cooling as well as electricity from a CHP system owned by Gainesville Regional Utilities. The facility has a blackstart generator to ensure hospital operation during an outage.

## Project Testimonial

"The UF Health CHP system provides numerous benefits to our campus including the ability to operate in island mode, eliminating even momentary power drops during grid outages. Additionally, through our partnership with GRU, we benefit from the reliability and resilience attributes of the CHP system while allowing the hospital to concentrate on our core business."

- Bobby Baird, Director, Facility Operations, UF Health

# Fort Knox, Fort Knox, Kentucky

## Project Snapshot:
Reliability for Critical Infrastructure

| | |
|---|---|
| **Application** | Military |
| **Capacity** | 8.2 MW |
| **Prime Mover** | Reciprocating Engine |
| **Fuel Type** | Natural Gas |
| **Thermal Use** | Steam, Hot Water, and Chilled Water |
| **Installation Year** | 2014 |

**Project Highlights:**
Following a major ice storm that knocked out power for up to ten days in some buildings, CHP was installed at three locations on the base to provide resiliency for critical infrastructure facilities.


CHP enabled Fort Knox to reduce it NOx emissions by 90% and its CO emissions by 93%.

The Ireland Army Community hospital houses half of Fort Knox's CHP capacity. Pictured above are the two 2 MW reciprocating engines which provide heat, chilled water, and power to the hospital with full redundancy.

# Public Safety Headquarters, Gaithersburg, Maryland

## Project Snapshot: CHP Microgrid

| | |
|---|---|
| **Application** | Government Buildings |
| **Capacity** | 865 kW |
| **Prime Mover** | Reciprocating Engine |
| **Fuel Type** | Natural Gas |
| **Thermal Use** | Heating and hot water |
| **Installation Year** | 2018 |

The CHP system is accompanied with 2 MW of solar capacity. The combined solar and CHP capacity allows the facility to maintain an infinite backup capacity. *Photo courtesy of Montgomery County.*

**Project Highlights:**
Following a 2012 derecho which left buildings across Montgomery County without power for days, the county decided to invest in a CHP + solar microgrid to replace existing standby generators.

**Project Testimonial**
“On a typical operating day at the PSHQ advanced microgrid, the combined heat and power system can provide up to 70% of the site’s energy from CHP with the remainder from on-site solar with very little utility power.”
- Eric Coffman, Chief – Office of Energy and Sustainability, Montgomery County

# Questions?

# Kahoot and Q&A

Please use your phones to join our fun Kahoot game, testing your CHP Virtual Training Session #1 knowledge.

# Homework Questions: Due COB Monday 12/9

1. Which prime movers are better suited to provide high pressure steam?
2. Describe the Impact of run hours on payback on the investment.
3. In the DOE CHP eCatalog, list two of the four thermal outputs and three of the five prime movers available as search functions.
   DOE-CHP eCatalog | Welcome
4. What are four key configuration factors for CHP to provide uninterrupted operation during a grid outage.
5. CHP provides multiple attributes that increase energy resilience for manufacturers, utilities and communities. One such attribute is that CHP provides a continuous supply of electric and thermal energy. Which of the following additional attributes of CHP support energy resilience.
6. When compared to a back-up generation source, CHP systems typically have a higher initial capital cost but over time they represent a better capital investment. Why is that?

# Thank you!

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