Better Plants
U.S. DEPARTMENT OF ENERGY

# Combined Heat & Power
# Virtual INPLT Training & Assessment

Session 2
Thursday – Dec 1, 2022
10 am – 12:30 pm

U.S. DEPARTMENT OF ENERGY

# CHP Project Screening

## December 1, 2022

Tom Bourgeois, Director, NY/NJ CHP TAP

Dr. Beka Kosanovic, Asst. Director, NY/NJ CHP TAP

Gearoid Foley, Sr. Advisor, Mid Atlantic & NY/NJ CHP TAP

# Safety and Housekeeping

- You are welcome to ask questions at any time during the webinar
- When you are not asking a question, please MUTE your mic and this will provide the best sound quality for all participants
- We will be recording all these webinars and by staying on-line and attending the meeting you are giving your consent to be recorded
  - A link to the recorded webinars will be provided, afterwards

# Overview of Today's Presentation

Session 2: Part 1. Favorable conditions for CHP application

Gearoid Foley

Session 2: Part 2. The process and required data points for CHP project screening

Dr. Beka Kosanovic

Session 2: Part 3.What is next after project screening?

Tom Bourgeois

# Tom Bourgeois, NY/NJ CHP TAP

## Experience

### Thomas Bourgeois – Director Policy Research Pace University Land Use Law Center and Director NY/NJ CHP TAP (US DOE)

Director for Policy Research at the Pace Land Use Law Center for Sustainability and Director of New York/ New Jersey Combined Heat and Power (CHP) Technical Assistance Partnership.
Director NY/NJ CHP TAP 2018 to present
Deputy Director Pace Univ, Energy & Climate Center 2008-2022
Co-Director Northeast Combined Heat and Power Technical Assistance Partnership 2013 to 2017
Staff Economist and Research Director Pace Energy & Climate Center 1999-2007

# Dr. Beka Kosanovic, NY/NJ CHP TAP & UMass

## Experience

Dr. Beka Kosanovic – Assistant Research Professor in the UMass Amherst Department of Mechanical and Industrial Engineering

Dr. Kosanovic is Director of the Center for Energy Efficiency and Renewable Energy (CEERE), Director of the Industrial Assessment Center (IAC), Assistant Director of the New York-New Jersey Combined Heat and Power Technical Assistance Partnership (CHP TAP), Director of the Massachusetts Energy Efficiency Partnership (MAEEP),

Education: Ph.D. in Mechanical Engineering from UMass Amherst and a B.S. in Mechanical Engineering from the University of Belgrade.

# Gearoid Foley, DOE's NY/NJ CHP TAP

## Experience

- 30 years in energy plant design, on-site power integration, energy resilience and microgrid development. Currently managing installation of four 1.5 to 2.5 MW CHP plants at hospitals in NJ
- Senior Technical Advisor to NY/NJ and Mid-Atlantic CHP TAPs
- Clients include US Department of Energy, RWJBarnabas Health, Cooper UH, Mack-Cali RE, Dresser-Rand, Johnson Controls, BEA Systems, Lawrence Berkeley National Labs, Penn State University, Princeton University and the Electric Power Research Institute
- Collaborated with state agencies throughout the Northeast and Mid-Atlantic regions including the NJ BPU, NJ EDA, PA PUC, PA DCED, NYSERDA, NY DEC, MD MEA and DE DNREC, and has provided testimony and educated stakeholders in the development of energy efficiency, combined heat & power and resilience programs.
- Spoken at multiple State, regional and national events
- Voting member of ASHRAE TC1.10 and Chair of TC1.10 Programs Subcommittee

# Finding the Best Candidate
# Being the Best Candidate

# Part 1 – Favorable Conditions for CHP Application

- Being the Best Candidate
  - CHP Benefits & Drivers Overview
  - Basic Requirement & Being the Best
- Business Case
  - Energy Costs
  - ESG & IRR
- Market & Technology Segments
  - Industrial Decarbonization & Resilience

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

# 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

# Finding the Best Candidates

- High and constant thermal load
- Favorable spark spread
- Need for high reliability
- Concern over future electricity prices
- Interest in reducing environmental impact
- Existing central plant
- Planned facility expansion or new construction; or equipment replacement within the next 3-5 years

# Emerging National Drivers for CHP

Benefits of CHP recognized by policymakers

State Portfolio Standards (RPS, EEPS), Tax Incentives, Grants, standby rates, etc.

Favorable outlook for natural gas supply in North America

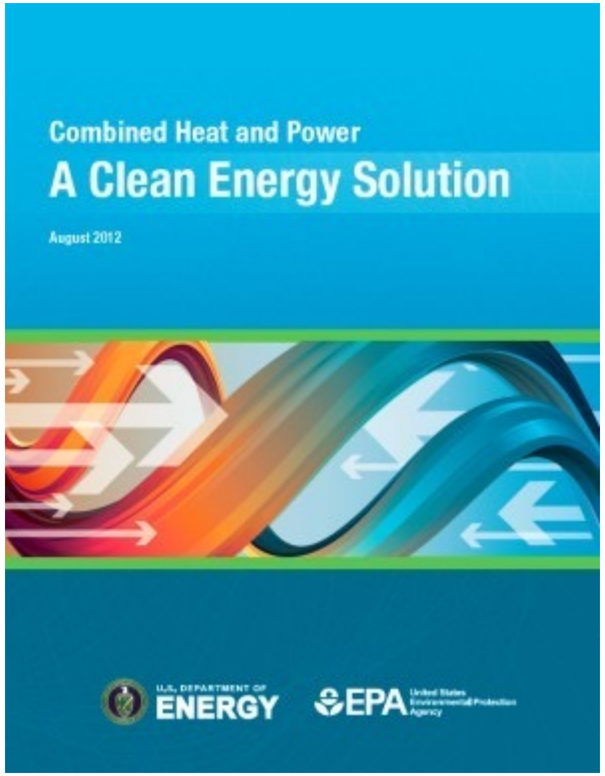
Opportunities created by environmental drivers

Utilities finding economic value (w/ industrial thermal host)

Energy resiliency and critical infrastructure

Interest in hybrid CHP systems

*DOE / EPA CHP Report (8/2012)*




http://www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_clean_energy_solution.pdf

# Being the Best Candidates

- High and constant thermal load
- **Constrained area** (Favorable spark spread)
- **Advanced manufacturing** (Need for high reliability)
- **Grid Policy** (Concern over future electricity prices)
- **Carbon Policy** (Interest in reducing environmental impact)
- Existing central plant
- **Fuel Flexible/Grid Smart** (Planned facility expansion)

# Polling Question 1

- What is your main concern on energy in the next 5 years?
  A. Cost of energy
  B. Availability of energy
  C. Cleanliness of energy (Environmental impact)

# Business Case

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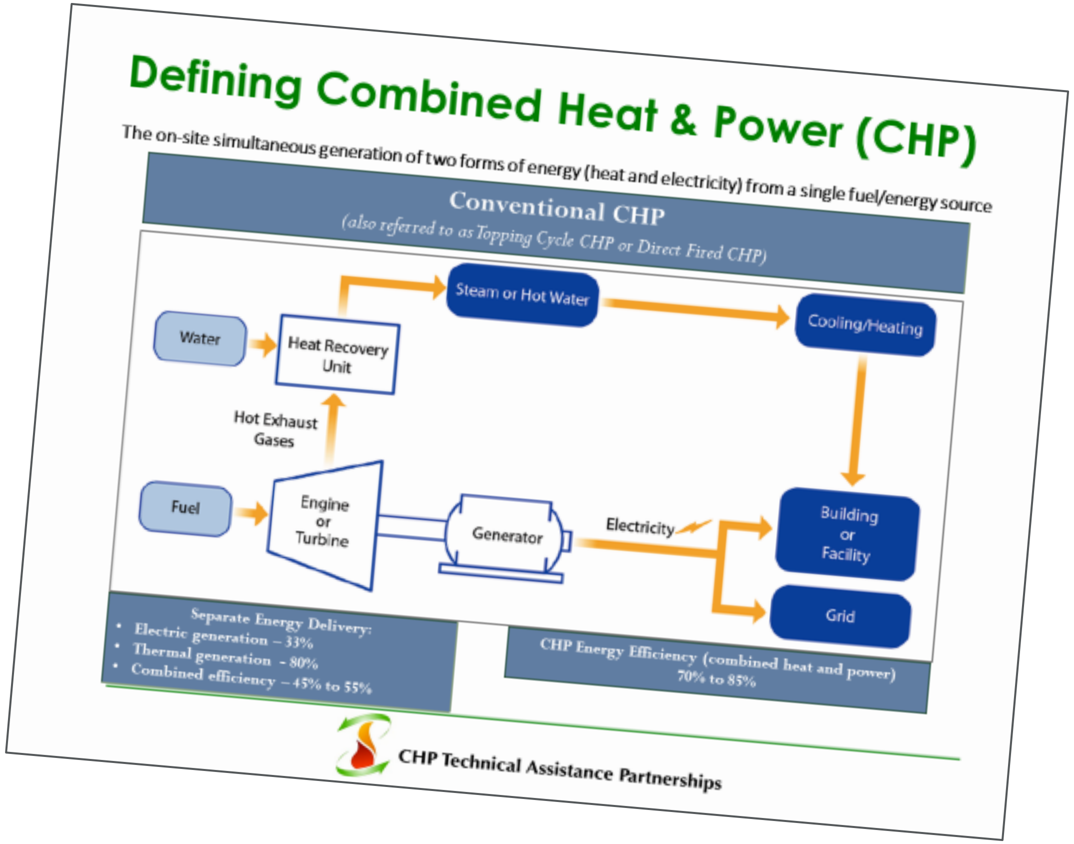
# Business Case – Thermal is a Prerequisite

- 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.

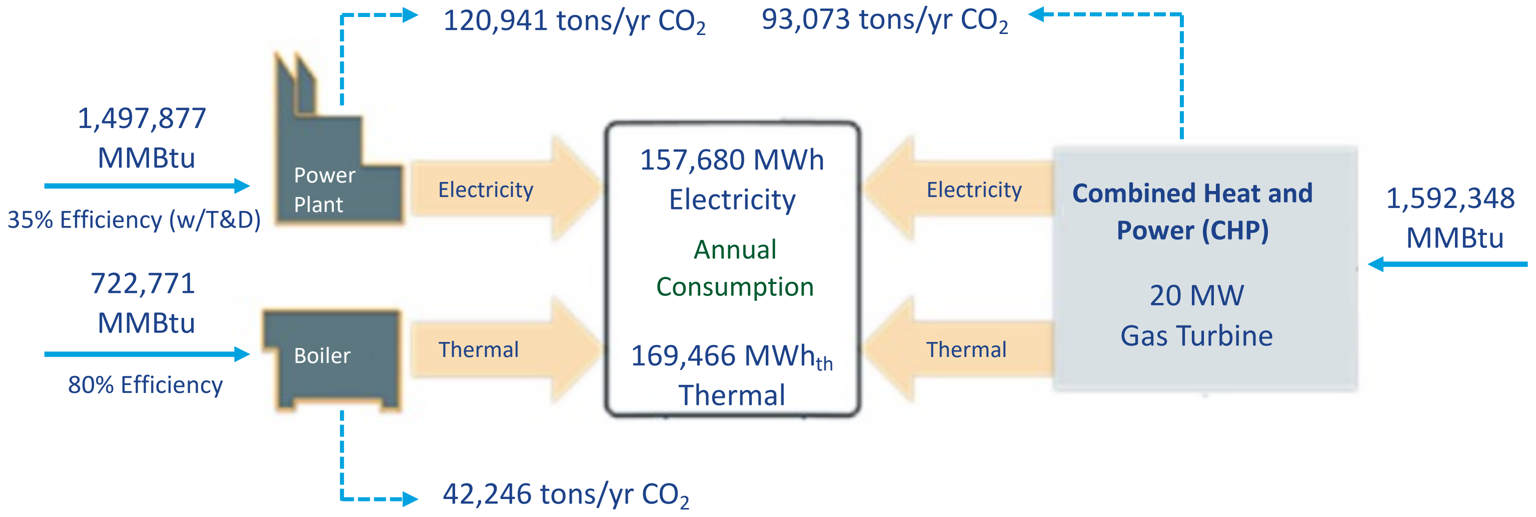


# CHP Provides both Energy and $CO_2$ Emissions Savings

## 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)

**Separate Heat and Power** | **Combined Heat and Power**




49% Total Efficiency

70% Total Efficiency

Energy savings: 628,300 MMBtu/yr

$CO_2$ Savings: 70,114 tons/yr

*Prepared by Entropy Research, LLC, 7/28/2022*

# 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 nat 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.

# Business Case – Electric Pricing

- PJM is similar to other open wholesale power markets.
- Capacity, transmission and energy are three separate markets that are combined in the wholesale cost of power.

Applicable to all large power users in ISO Region:

Wholesale Market – Getting Power to the 'Node'

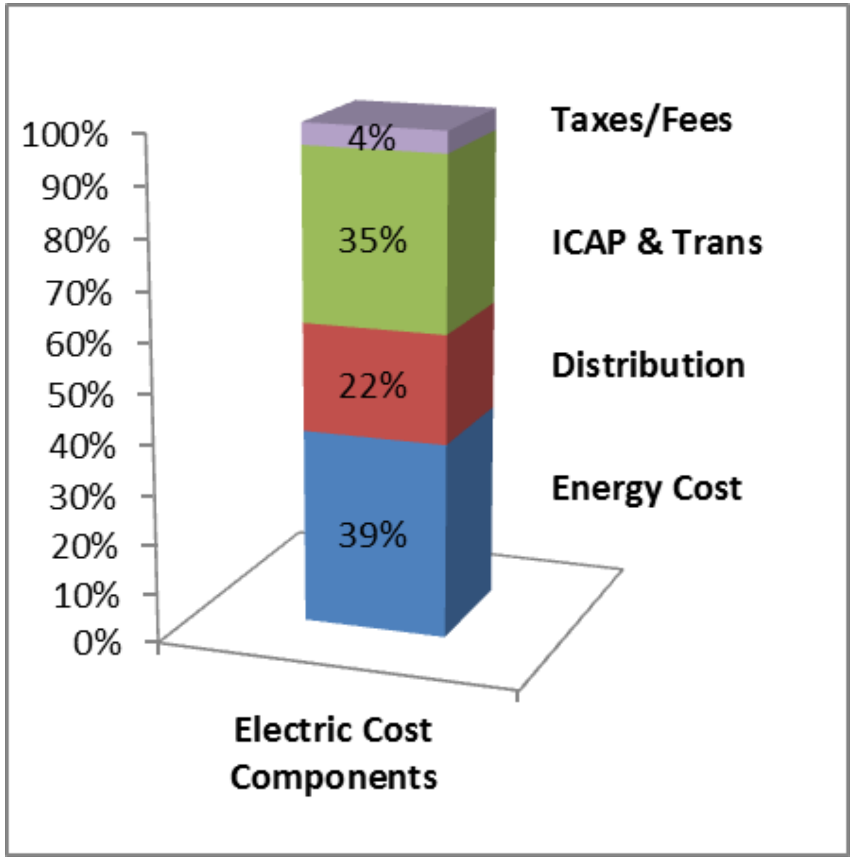
| | | |
|---|---|---|
| PJM Capacity Obligation Cost ($/MW-Day) | $$ | 75% |
| PJM Transmission Obligation Cost ($/MW-Day) | $$ | |
| Energy Generation Cost ($/MWh) | $$$ | |
| Ancillary Services & Losses | $ | |
| Portfolio Standard Costs, Taxes & Fees | $ | |

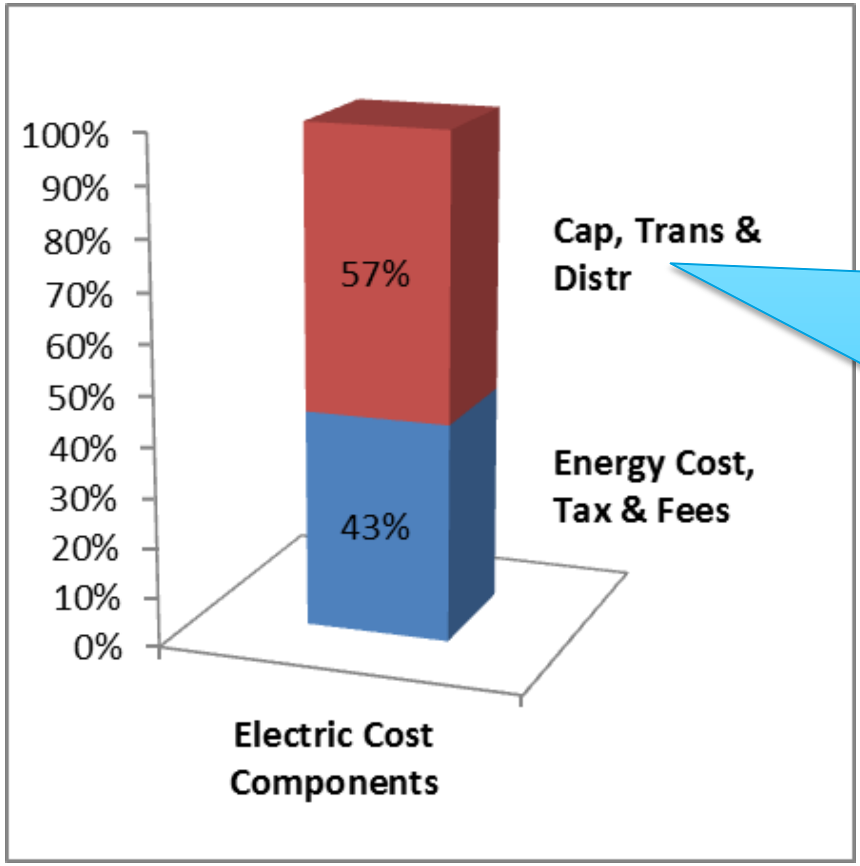
Distribution – Getting Power from Node to Facility

| | | |
|---|---|---|
| LDC Infrastructure Cost ($/kW) | $ | 25% |
| LDC Operations Cost ($/kWh) | $ | |
| Service Charge, Taxes & Fees | $ | |

# Business Case – Electric Pricing

## Identify and understand energy cost, not usage




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

# Business Case – Energy Pricing

- As CHP is an efficiency tool, it benefits from higher energy costs in general.
- Spark spread taking into account O&M of on-site generation should be in the order of 2 ₵ per kWh for reasonable rate of return on the capital investment.
  - $2,500/kW at 8,760 hrs x 95% available = $0.03/kWh in first year or $0.01/kWh in 3 years

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

# Business Case – Energy 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

# Polling Question 2

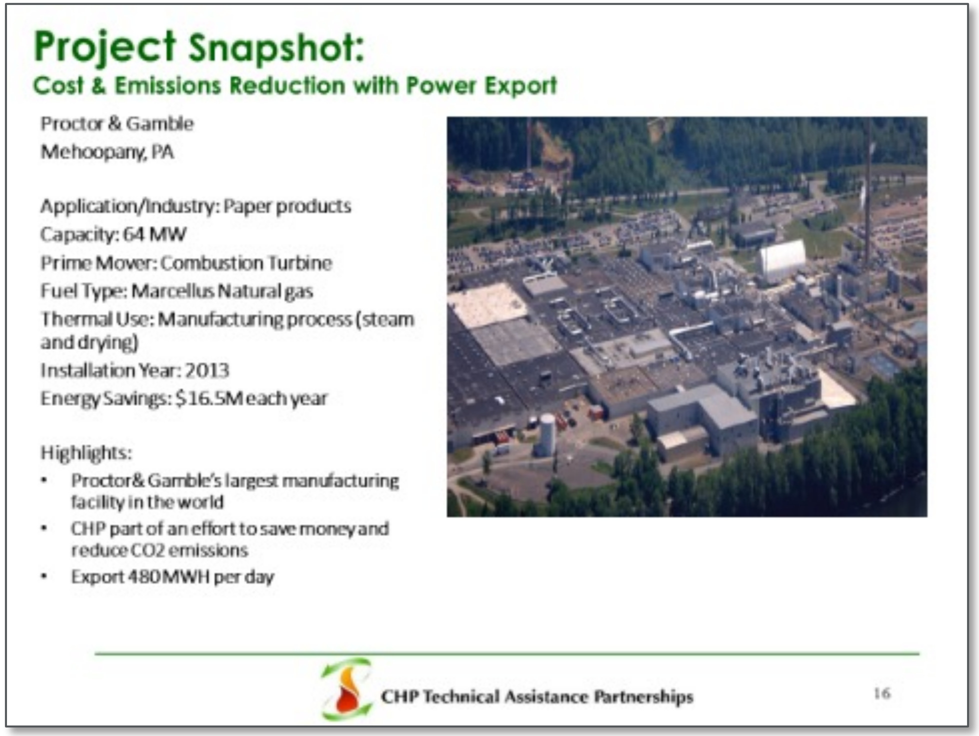
- What is Spark Spread?
  A. Cost of electric power
  B. Cost of natural gas in kW
  C. Difference between cost from utility and cost to self generate
  D. Difference between cost of natural gas and cost of electricity

# Business Case – Energy Resilience

- For end users:
  - 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

# 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 $CO_2e$ emissions per unit of production or throughput are important.

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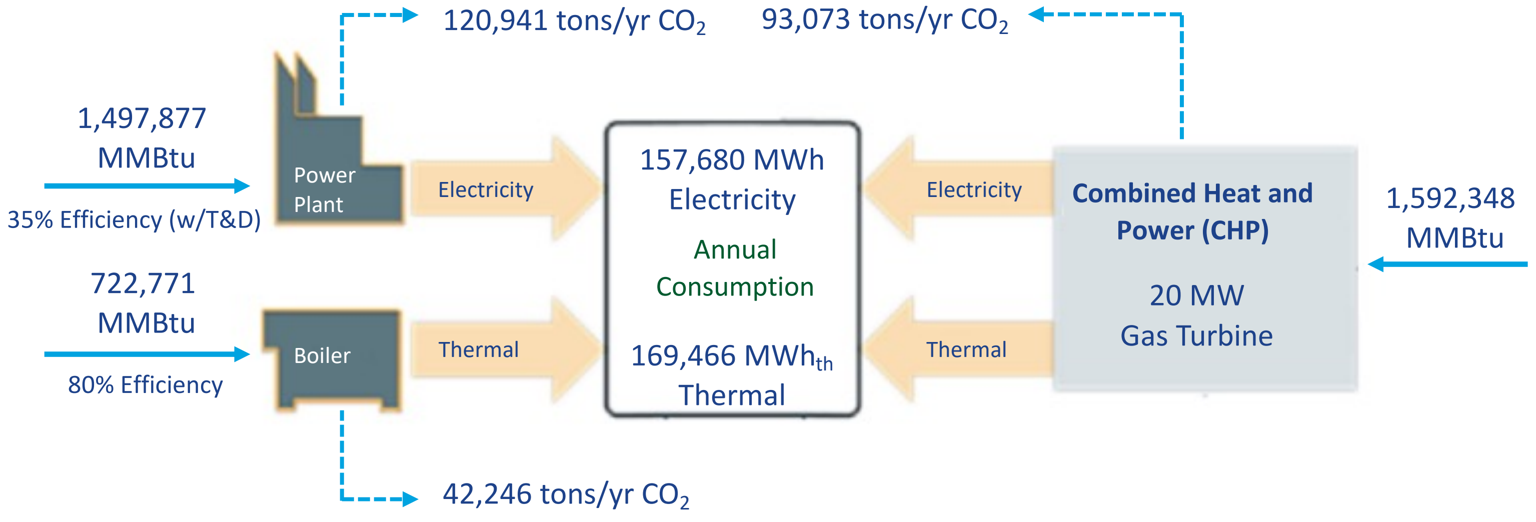


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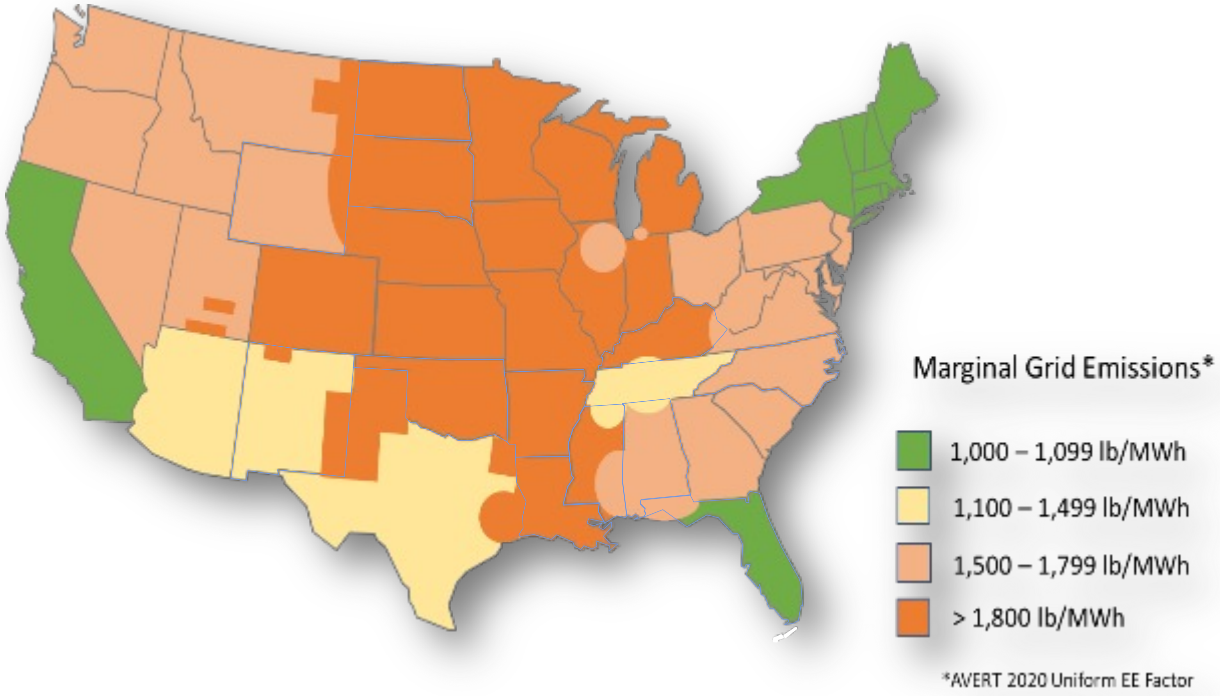
*Prepared by Entropy Research, LLC, 7/28/2022*

# CHP Reduces $CO_2$ Emissions in all Regions Today

- CHP and renewables displace marginal grid generation (including T&D losses)
- Marginal generation is currently a mix of coal and natural gas in most regions of the US
- CHP's high efficiency and high annual capacity factor currently results in significant annual energy and emissions savings
- *"Because emissions are cumulative and because we have a limited amount of time to reduce them, carbon reductions now have more value than carbon reductions in the future. The next couple of decades are critical."*

*Source: "Time Value of Carbon", Larry Strain, Carbon Leadership Forum, April 2020*

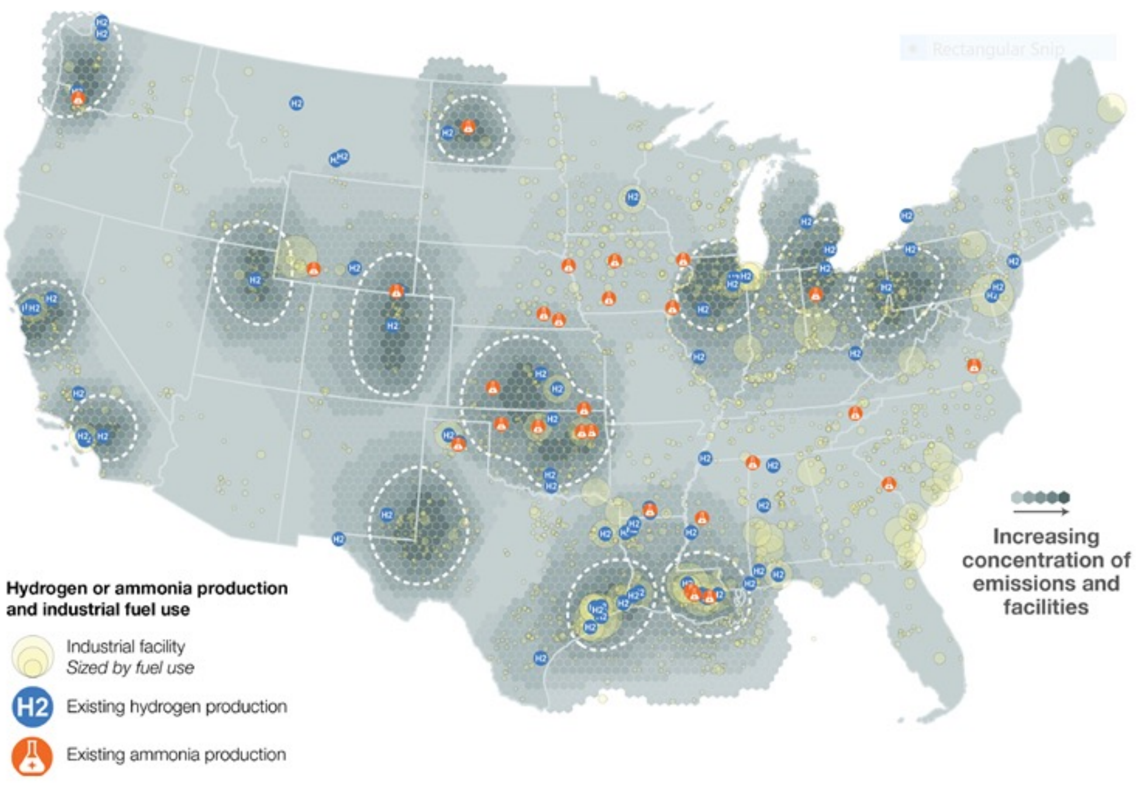
**Regional Marginal Grid Emissions Factors based on EPA AVERT 2021**



# Renewable and Net-Zero Fueled CHP

- Existing CHP systems can utilize biogas and biofuels.
- All natural gas-fueled CHP is compatible with renewable gas.
- Most existing turbines and engines can operate on hydrogen mixtures up to 10-40%.
- All major engine and gas turbine manufacturers are working on the capability to operate at high levels of hydrogen, targeting 2030 for 100% hydrogen prime movers.
- CHP systems can be changed out or modified in the field to 100% hydrogen-fuel blends

***The ultimate scale of renewable and hydrogen-fueled CHP deployment will depend on resource availability.***



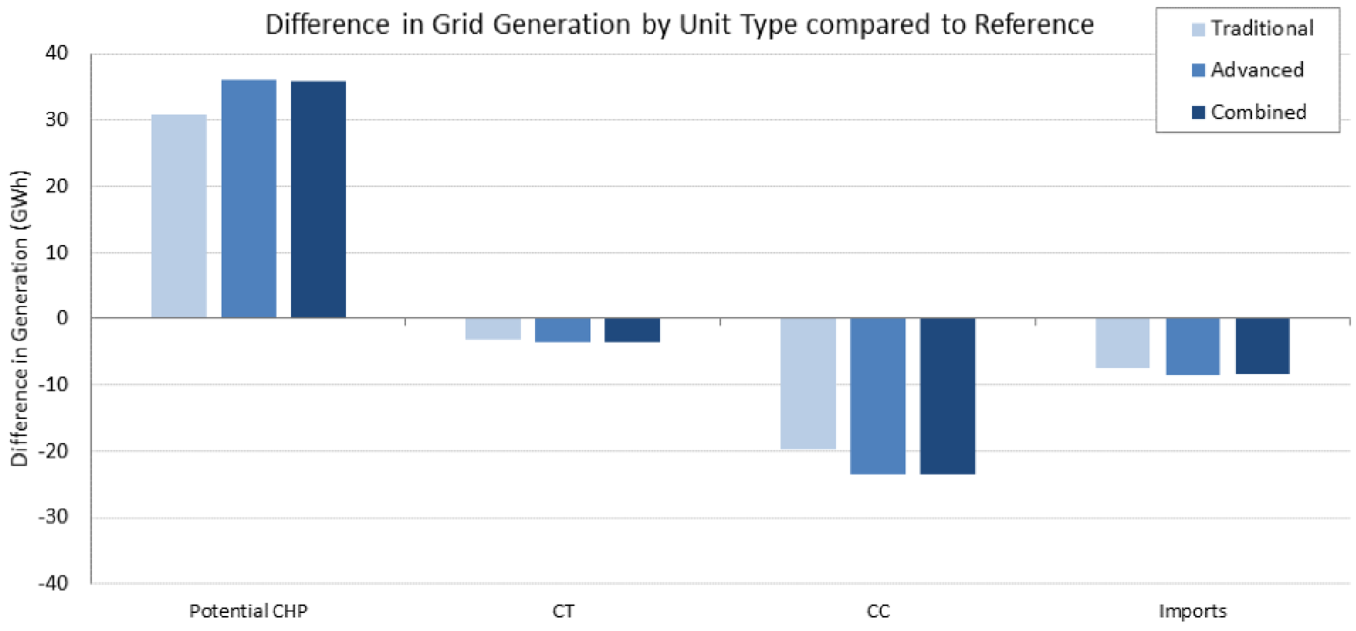

*Source: Atlas of Carbon and Hydrogen Hubs, Great Plains Institute, February 2022*

# Business Case – Grid Support

- Net-zero fueled CHP can accelerate independence from less efficient combustion resources as additional renewables come online.
- CHP can provide dispatchable net-zero generation and regulation support to support long-run resource adequacy
- To the extent that net-zero fuels are part of a decarbonized grid, CHP can be the most efficient way to use them.

*independent system operators (ISOs) | Utilities*

Modeling shows advanced CHP in California offsets combined cycle, combustion turbines, and imports, deepening emissions savings from renewables.




*Potential Impact of Flexible CHP on the Future Electric Grid in California, ORNL, Sept. 2021.*

# 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.

# Being the Best Candidate

- You have a thermal load
- Spark spread is favorable
- You have 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

# Polling Question 3

- How would a 10% reduction in energy cost impact you?
  A. Significant impact on bottom line
  B. Some impact on bottom line
  C. Minor impact on bottom line

# Market & Technology Segments

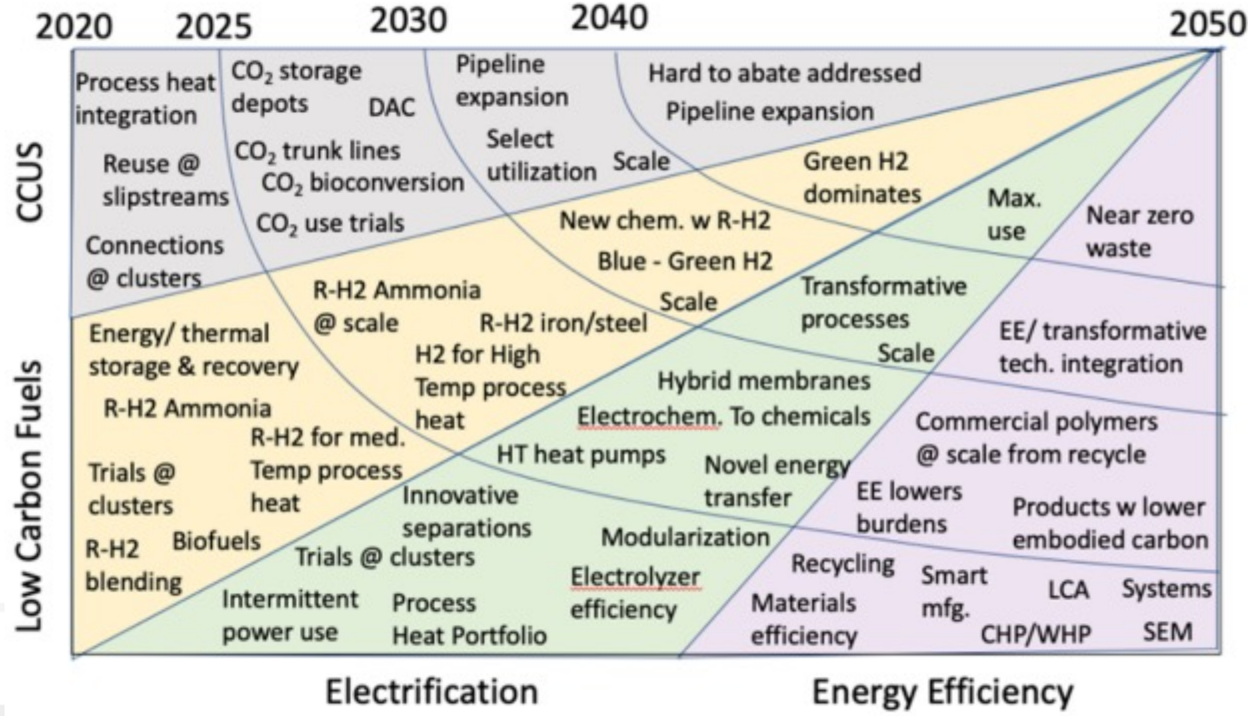
# CHP for Difficult to Decarbonize Industries

- CHP is well suited to address steam and process heating needs, 95% of which is currently fossil fueled.
- CHP enables three of the four pathways for industrial decarbonization (energy efficiency; low-carbon fuels; electrification) while mitigating the need for CCUS.
- Renewable and net-zero fueled CHP can decarbonize industrial thermal processes that are difficult or prohibitively expensive to electrify.

*Industrial facilities across the U.S. with challenging decarbonization pathways*

CHP supports decarbonization of the industrial sector while additional technologies reach maturity.

*Technology Pathways: Industrial Decarbonization*



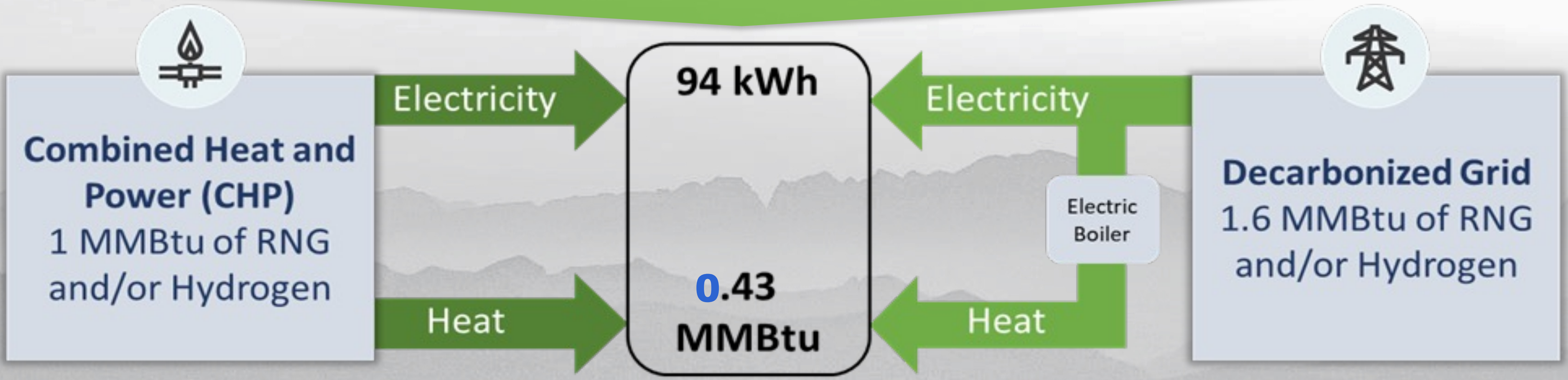

*Source: Industrial Decarbonization Roadmap, DOE, May 2022 Draft*

# CHP: Uniquely Suited for Decarbonizing the Industrial Sector

**CHP is uniquely positioned to accelerate industrial decarbonization by addressing the need for high pressure steam and high temperature direct heat.**

**The industrial sector is slated to require fuel well into the future.**

**CHP will remain the most efficient way to use net-zero fuels.**




***60% more RNG or hydrogen would be required to produce the same amount of electricity and heat with grid power and an electric boiler compared to CHP.***

*Source: Beneficial CHP – Is that a Thing? Considering CHP in the Context of Beneficial Electrification, ACEEE Summer Study, 2021*

# Food Processing

- Food processing often requires large volumes of thermal energy for heating, cooking, roasting, pasteurizing, cleaning, etc. Process cooling or refrigerated storage also provide thermal loads that can be supplied by CHP.
- Frito Lay’s CHP plant at its Killingly, CT processing plant provides over 90% of its electric demand and 80% of its steam demand while yielding over $1MM in cost savings annually.

https://www.energy.gov/sites/prod/files/2015/08/f26/PepsiCo%20Frito-Lay%20CHP%20Case%20Study_07.02.15.pdf

# Critical Processes

- CHP adds resilience to any facility and can be configured to black start and operate in grid island mode where the CHP unit, combined with other on-site generation and load management controls, can maintain services at near normal conditions during a long-term power grid outage.

Pharma Production

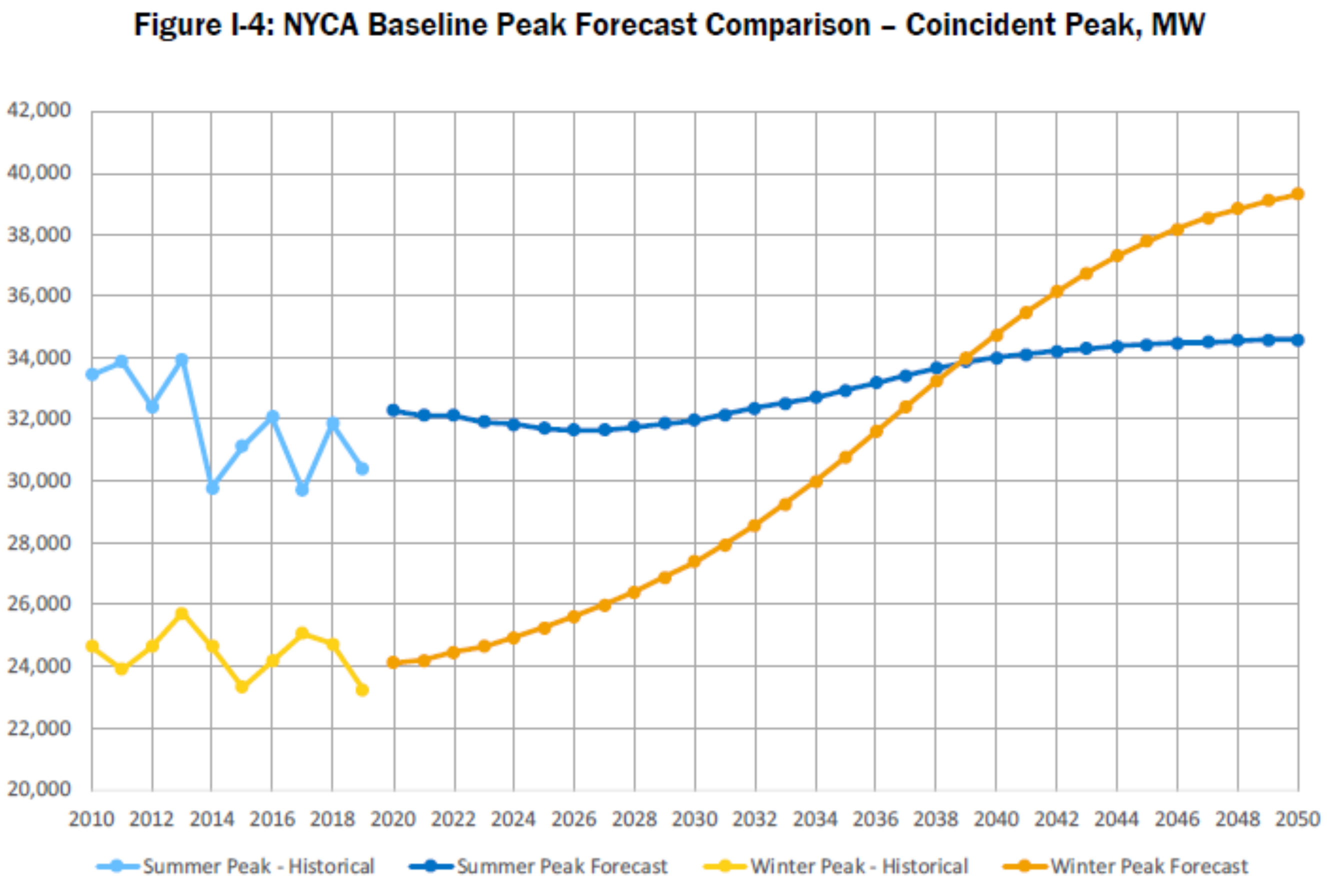
Food Processing & Storage

Plastics Forming

R&D, Labs

# CHP Assist Heat Pumps

- By providing both heat and power in mid winter when solar insolence in the northern hemisphere is at its lowest, CHP can provide a resilience component as well as offset oversizing of heat pumps and PV capacity to meet low duration cold weather events.

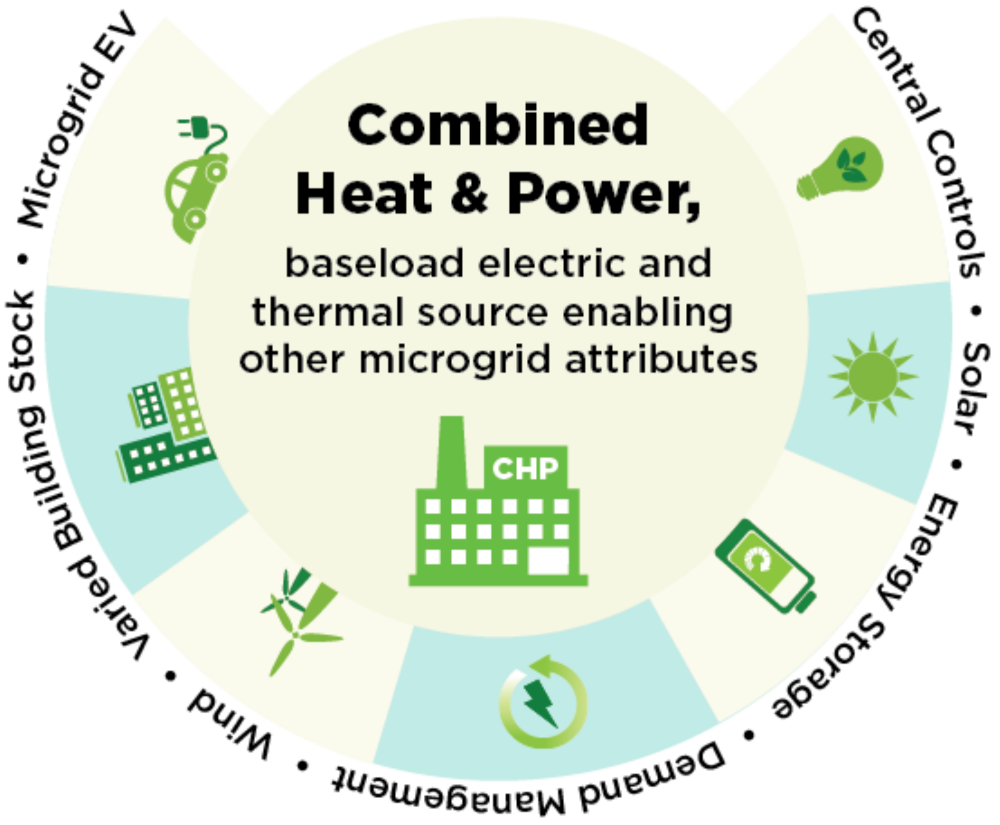



The 2020 NYISO forecast for summer and winter peak demands for the New York Control Area (NYCA) through 2050

# Controlled Environmental Agriculture

- CEA offers a unique fit with CHP that combined carbon capture and use as well as grid support.
- Greenhouses and vertical farms can be located in more remote areas where power supply may be an issue. Combined with hot water storage, CHP can provide the power required to operate the lighting, heat to maintain greenhouse set temperature or cooling to maintain vertical farm set humidity. The operating sequence can be altered to support the grid when necessary.
- The CEA CHP plant includes $CO_2$ removal and storage where it can store captured $CO_2$ and use it when CHP is off.

# CHP Can Enable Other Microgrid Technologies




- 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

# Pairing CHP with Renewables and Storage: Case Study

- CHP can be a resilient base load anchor for multi-technology microgrids, particiularly those incorporating renewable generation sources like solar PV or wind.
- CHP paired with renewable DERs optimizes overall emissions reductions and resilience.
- Net-zero fueled CHP can decarbonize critical facilities that need dispatchable on-site power for long duration resilience and operational reliability

*critical infrastructure, cities, and communities*

United States Marine Corps Recruit Depot (MCRD) Parris Island, SC, installed a hybrid microgrid including a 3.5 MW natural gas-fired CHP system plus 5.5 MW solar photovoltaic arrays to provide secure and resilient energy. The site also incorporated an 8 MWh battery-based energy storage system, all of which are controlled by a microgrid control system capable of fast load shedding.

# Part 2. The process and required data points for CHP project screening

DOE CHP TAP Screening Analysis

Screening Questions

Site Data Collection

Prime Mover CHP Performance Assumptions

CHP eCatalog

Finding the Best Candidates

Additional Considerations

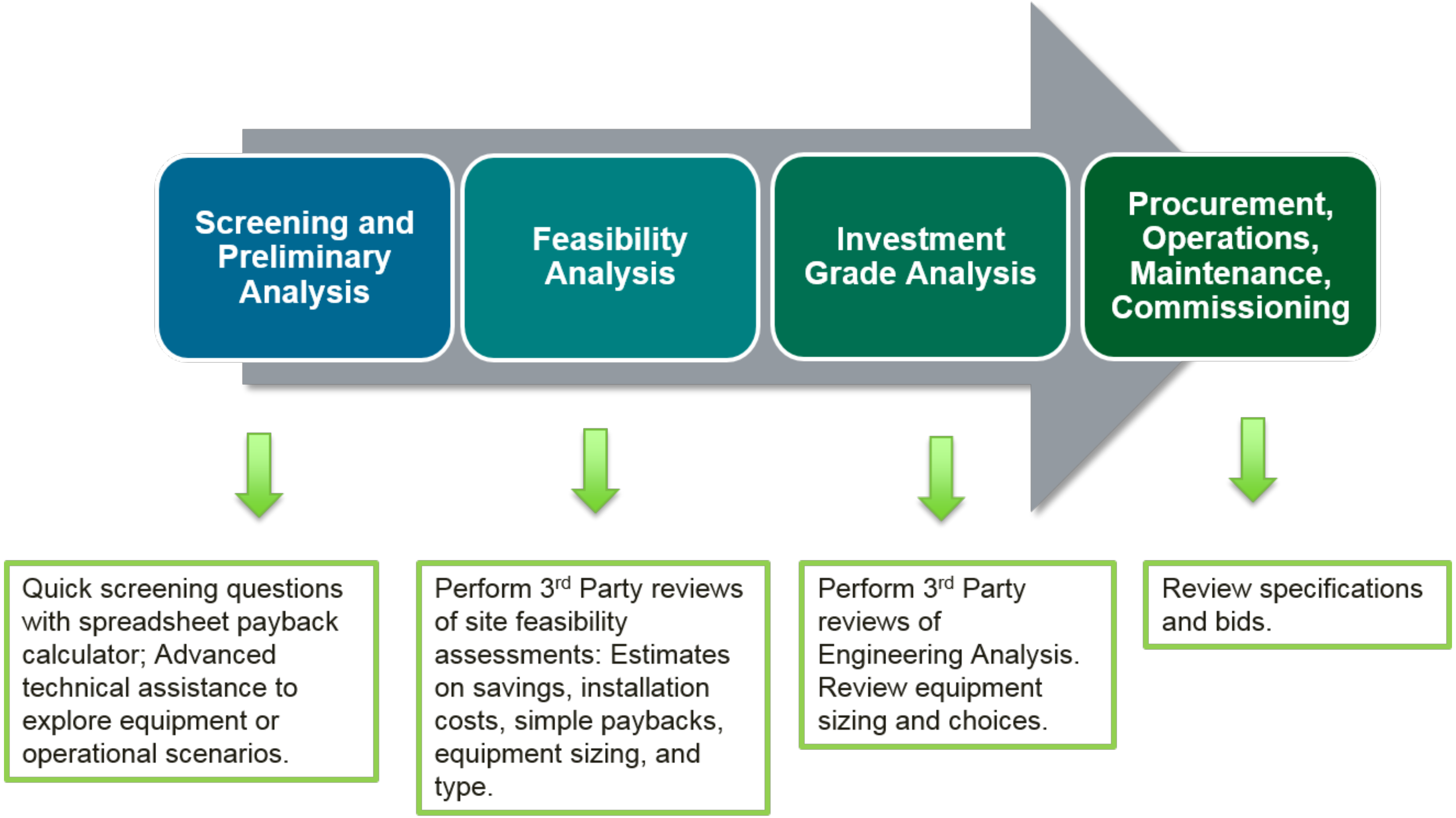
Operating Hours

Minimum Load

EPA Tools and Reopt - Renewable Energy Integration & Optimization

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

# CHP TAP Role: Technical Assistance



# 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

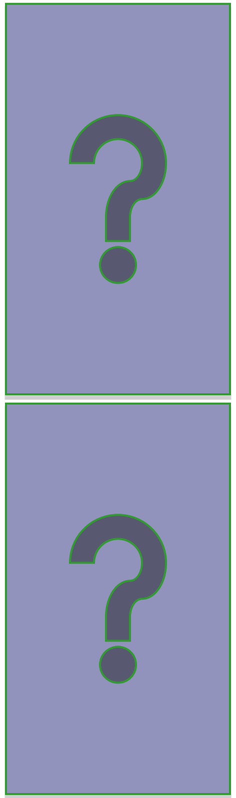
- Site Qualification Questions
- Site Data Collection
- Utility Bill Analysis
  - Utility Billing Data
  - Site Operating Schedule
  - Displaced thermal Equipment Information
  - CHP Operating Schedule
- CHP Screening Analysis
- Additional Considerations

# 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.)



# Site Data Collection

- How many hours per year does the facility operate? (hours)  or, operating schedule - day/week, hours/day
- What is average power demand during operation? (kW), or How much electricity do you use in a year, kWh?
- What is your facility's primary thermal load (i.e., DHW, steam/HW space heating, process steam, cooling, etc.)
- What is your average thermal demand? (MMBtu/hr), or
- How much fuel (gas/oil/etc) do you use in a year? (MMBtu/yr, Therms/yr, etc.)
- What is your current fuel price? ($/MMBtu)
- How much do you pay for fuel annually? (Dollars/yr)
- What are the CHP Fuel Costs? ($/MMBtu)
- What is your average electricity price? ($/kWh)
- How much do you pay for electricity annually? (Dollars/yr)
- What is the efficiency of your existing boiler(s)/thermal equipment? (%)
- What is the efficiency of your existing chillers? (kWh/ton)

# Site Data Collection

- Utility billing information
  - Electricity: On-peak, off-peak, shoulder, demand ratchet
    - $0.016 - $0.31/kWh
    - $3.60 - $28.00/kW (20% -80% of total)
  - Natural gas: Winter supply restrictions, demand considerations
    - $1.93 – 18.10/MMBtu
    - Demand ($/MMBtu-day)
    - Special rates for CHP/summer (uniform) use
  - Tax status
  - Incentives

# 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

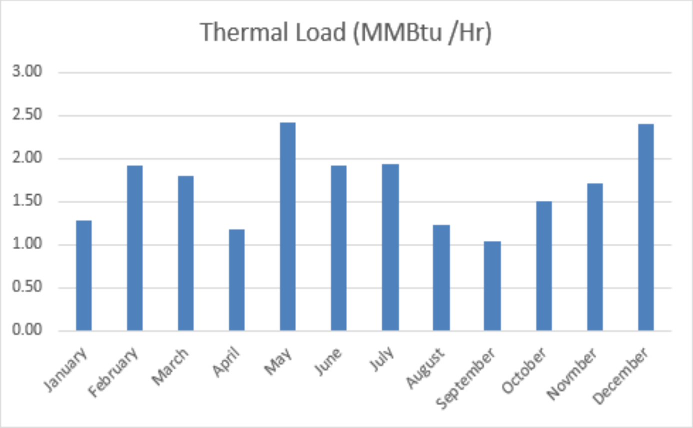
**Step 3 - Displaced Thermal Equipment Efficiency**

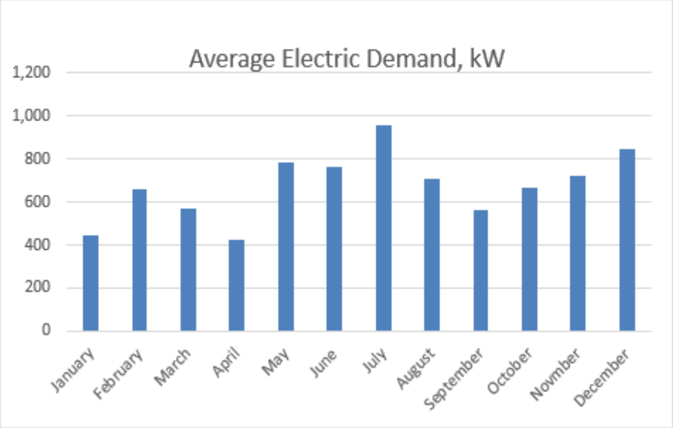
Displaced Thermal Efficiency: 85.0%

**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% | | | |

# CHP Screening Analysis




| **CHP Operating Schedule based on Thermal Loads** | **Winter/Shoulder** | | | **12 months** | | |
|---|---|---|---|---|---|---|
| Average Addressable Thermal Load (MMBtu/hr) / Thermal Load Factor (%) | 1.61 | MMBtu/hr* | 89.8% | 1.67 | MMBtu/hr** | 88.9% |
| Minimum Addressable Thermal Load (MMBtu/hr) / Thermal Load factor (%) | 1.04 | MMBtu/hr | 100% | 1.04 | MMBtu/hr | 100% |

**4a - Select CHP Operating Schedule:** 12 Months

**4b - Select Addressable Thermal Load:** 1.04 MMBtu/hr

Thermal Load Factor: 100.0%

*Average Addressable Load based on Shoulder Months;

Minimum Addressable Load based on Winter/Shoulder Months

**Average and Minimum Addressable Load based on 12 Months

# Prime Mover Driven CHP Performance Assumptions

| | Based on Recip Engines | | | | | Based on Gas Turbines | | | |
|---|---|---|---|---|---|---|---|---|---|
| Thermal Output, MMBtu/hr | 0.09 | 0.61 | 2.84 | 4.54 | 13.57 | 36.30 | 52.20 | 77.40 | 133.80 |
| Net Capacity, kW | 15 | 100 | 633 | 1,140 | 3,410 | 7,487 | 10,669 | 20,440 | 40,484 |
| System | A | B | C | D | E | F | G | H | I |
| Heat Rate, Btu/kWh | 11,630 | 11,540 | 9,896 | 9,089 | 9,089 | 11,700 | 12,185 | 10,313 | 9,609 |
| Net Electrical Efficiency, % | 29.3% | 29.6% | 34.5% | 37.5% | 37.5% | 29.2% | 28.0% | 33.1% | 35.5% |
| Thermal Output, Btu/kWh | 5,829 | 6,100 | 4,487 | 3,979 | 3,979 | 4,848 | 4,893 | 3,787 | 3,305 |
| Thermal Output, MMBtu/hr | 0.09 | 0.61 | 2.84 | 4.54 | 13.57 | 36.30 | 52.20 | 77.40 | 133.80 |
| Thermal Output for Cooling (single effect) | 80% | 80% | 85% | 85% | 85% | 100% | 100% | 100% | 100% |
| Thermal Output for Cooling (single effect) | 0.07 | 0.49 | 2.41 | 3.86 | 11.53 | 36.30 | 52.20 | 77.40 | 133.80 |
| Thermal Output for Cooling (double effect) | 50% | 50% | 50% | 50% | 50% | 90% | 90% | 90% | 90% |
| Thermal Output for Cooling (double effect) | 0.04 | 0.31 | 1.42 | 2.27 | 6.78 | 32.67 | 46.98 | 69.66 | 120.42 |
| Total Efficiency, % | 79% | 82% | 80% | 81% | 81% | 71% | 68% | 70% | 70% |
| Incremental O&M, $/kWh | $0.0240 | $0.0240 | $0.0210 | $0.0190 | $0.0190 | $0.0123 | $0.0120 | $0.0093 | $0.0092 |
| Total Installed Costs, $/kW | $3,300 | $2,900 | $2,840 | $2,370 | $2,100 | $2,017 | $1,798 | $1,474 | $1,276 |

Based on DOE CHP Technology Fact Sheets - 2017

35 kW based on Yanmar Spec Sheet for 35 kW system - 2018

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

# 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

# CHP e-Catalog

## 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 the 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 |

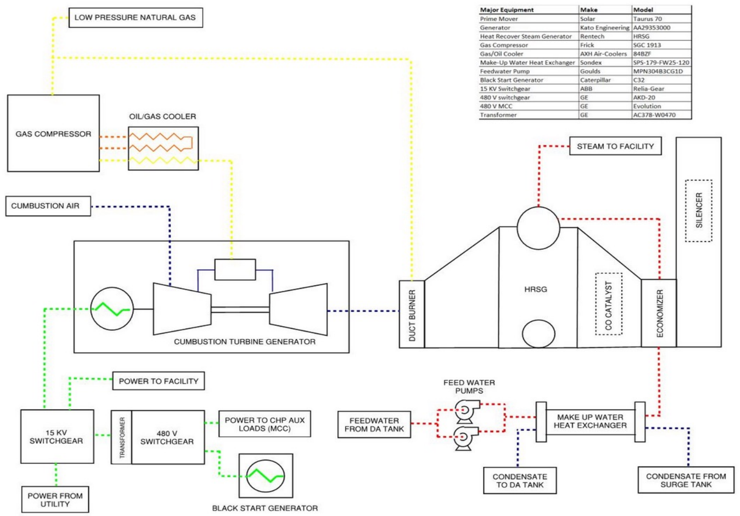
| | | | | | |
|---|---|---|---|---|---|
| **Fuel Gas Pressure to Packaged CHP System (psig)** | 1 | 25 | 50 | 100 | 300 |
| **Fuel Gas Booster Compressor Power Required (kW)** | 416 | 258 | 189 | 131 | 11 |

| | | |
|---|---|---|
| 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



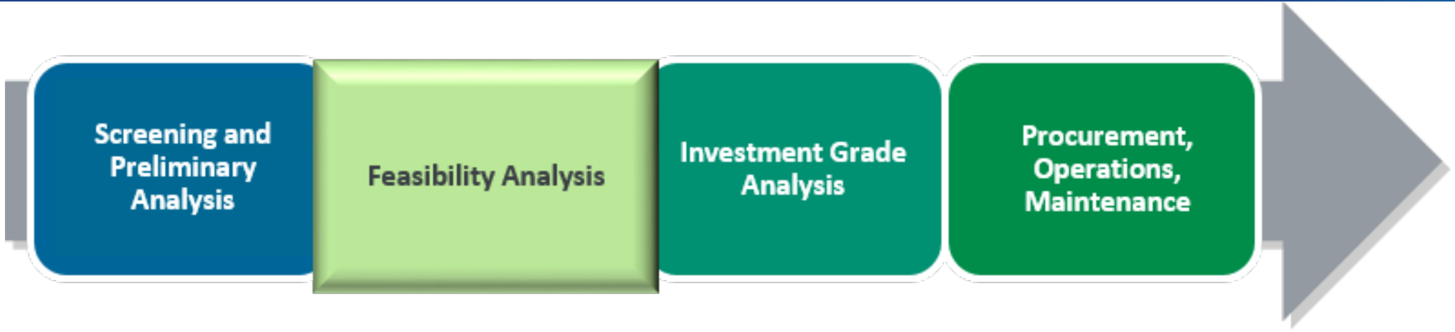

| Major Equipment | Make | Model |
|---|---|---|
| Prime Mover | Solar | Taurus 70 |
| Generator | Kato Engineering | AA29353000 |
| Heat Recover Steam Generator | Rentech | HRSG |
| Gas Compressor | Frick | SGC 1913 |
| Gas/Oil Cooler | AXH Air-Coolers | 84BZF |
| Make-Up Water Heat Exchanger | Sondex | SPS-179-FW25-120 |
| Feedwater Pump | Goulds | MPN304B3CG1D |
| Black Start Generator | Caterpillar | C32 |
| 15 KV Switchgear | ABB | Relia-Gear |
| 480 V switchgear | GE | AKD-20 |
| 480 V MCC | GE | Evolution |
| Transformer | GE | AC378-W0470 |

https://chp.ecatalog.ornl.gov

# Polling Question 4

- What is the heat rate?
  A. It is the amount of heat released during the combustion of a specified amount of fuel.
  B. It is an affordable way to heat your facility by receiving a credit per kWh for the electricity generated by CHP.
  C. It is a quantity that reflects the amount of fuel required to generate one unit of electrical energy.
  D. Is an index product that allows a CHP owner to decouple future electricity costs from energy markets and tie them to the natural gas market so they can buy natural gas when advantageous market opportunities exist.

# A Feasibility Analysis Typically Involves:




- Electrical load profiling
- Thermal load profiling
- Unit sizing
- Thermal use determination (what to do with the heat)
- Installation cost estimations
- Financial calculations (simple payback, ROI, etc.)
- Cost/savings information compared to what your facility would pay if the CHP system were not installed

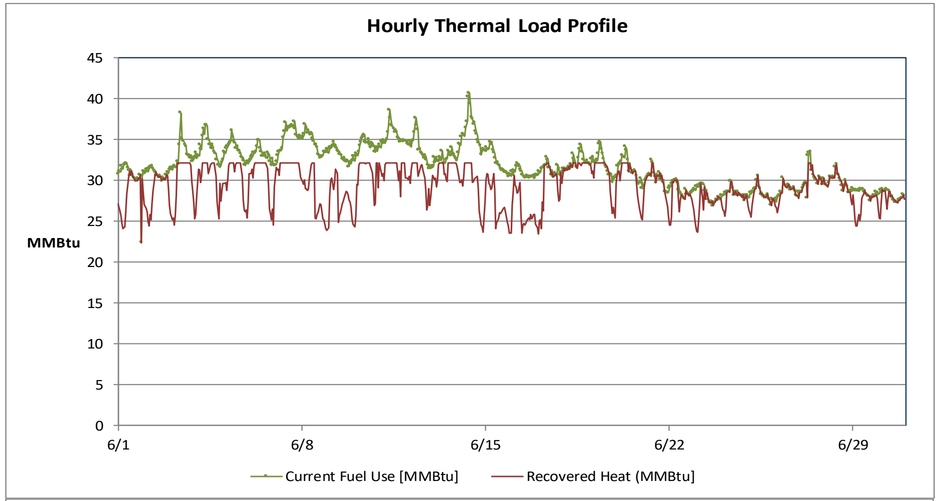
# Finding the Best Candidates: Some of All of These Characteristics

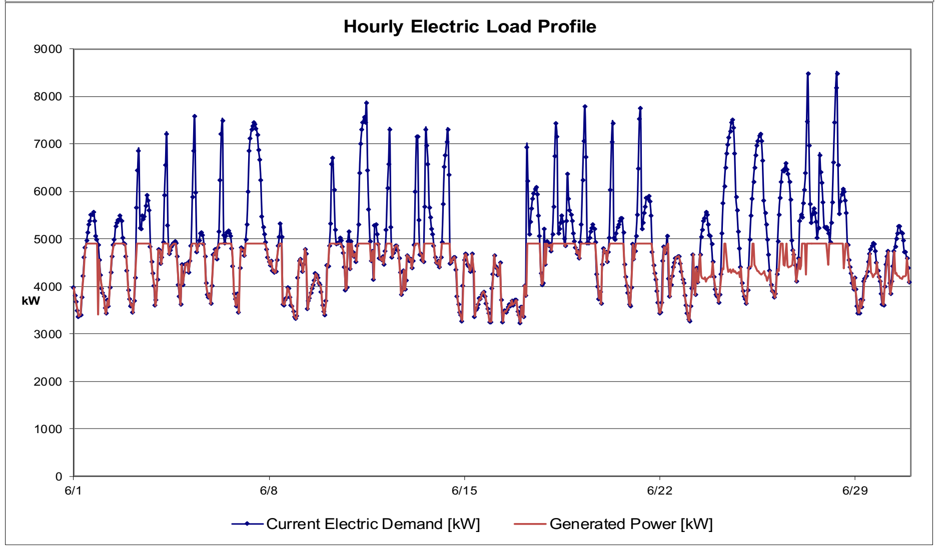
- High and constant thermal load
- Favorable spark spread
- Need for high reliability
- Concern over future electricity prices
- Interest in reducing environmental impact
- Existing central plant
- Planned facility expansion or new construction; or equipment replacement within the next 3-5 years

# Additional Considerations

- Operating hours
- CHP minimum load allowed
- CHP engine size
- CHP heat rate

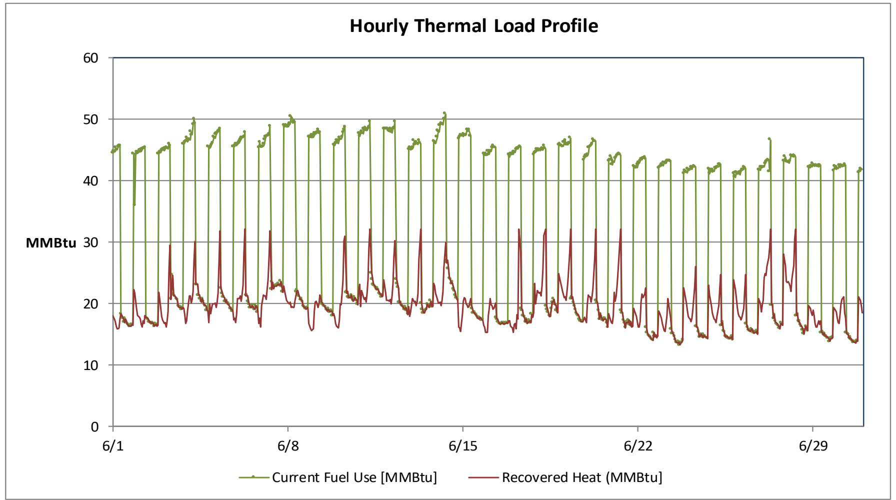
# Operating Hours (8,760 (24/7))

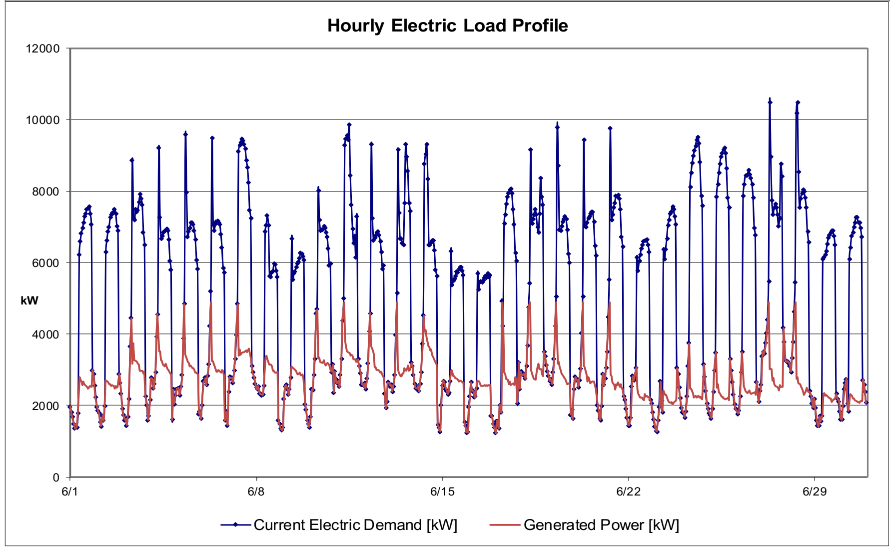



| | | |
|---|---|---|
| Averge load | 4,897 | kW |
| Maximum load | 8,485 | kW |
| Minimum load: | 3,227 | kW |
| Total Electricity Usage | 3,526,104 | kWh |
| Actual Electricity Generated | 3,192,811 | kWh |
| Actual Electricity Generated | 90.5% | |
| System Efficiency | 77% | |
| CHP Operating Hours | 720 | hr |
| Operating hours % | 100% | |
| CHP system size | 4,897 | kW |
| Heat rate: | 12,793 | Btu/kWh |
| Number of units | 1 | |
| Minimum engine load allowed: | 50% | |

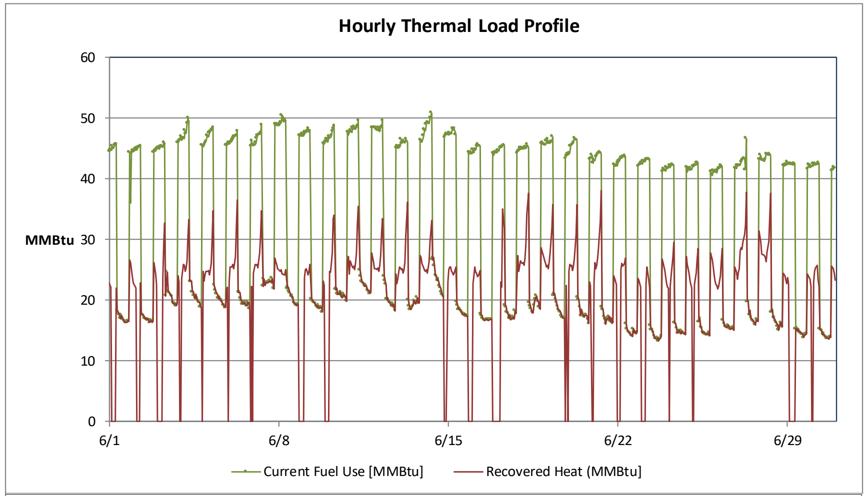
# Operating Hours (5,824 (16/7))

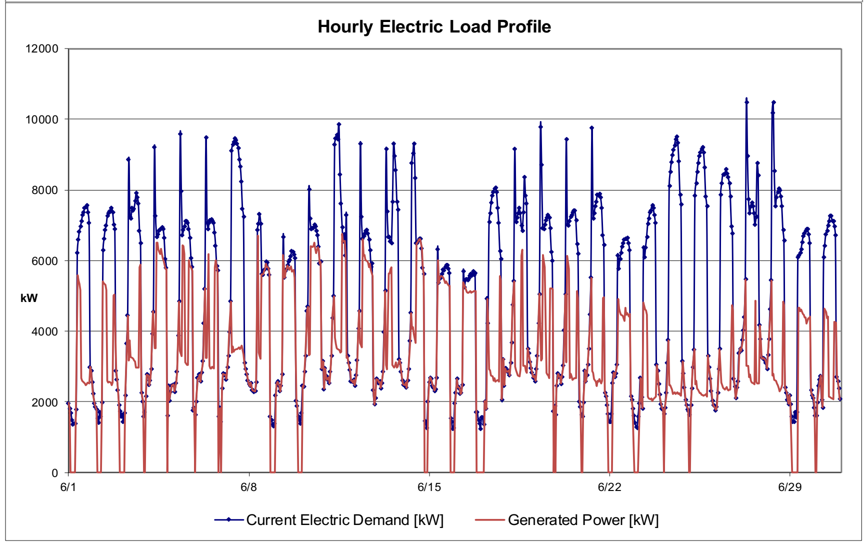



| | | |
|---|---|---|
| Averge load | 4,897 | kW |
| Maximum load | 10,485 | kW |
| Minimum load: | 1,227 | kW |
| Total Electricity Usage | 3,526,104 | kWh |
| Actual Electricity Generated | 1,919,866 | kWh |
| Actual Electricity Generated | 54.4% | |
| System Efficiency | 72% | |
| Operating Hours | 720 | hr |
| Operating hours % | 100% | |
| CHP system size | 4,897 | kW |
| Heat rate: | 12,793 | Btu/kWh |
| Number of units | 1 | |
| Minimum engine load allowed: | 10% | |

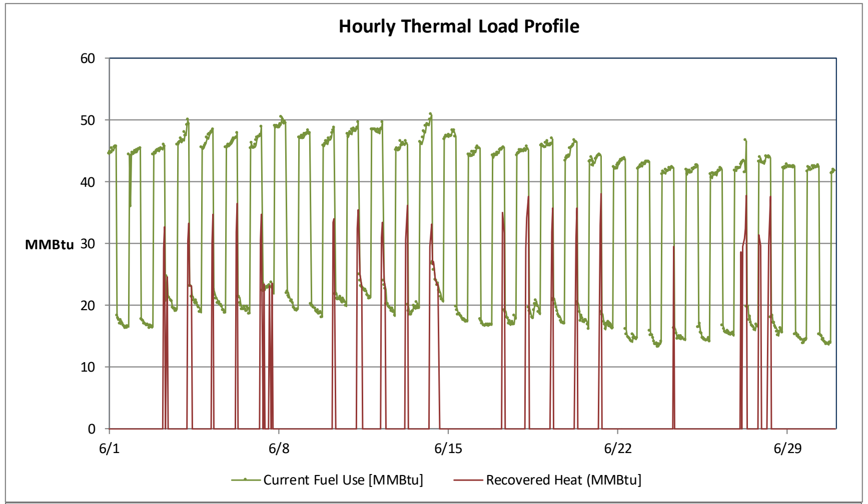
# Minimum Load (2 prime movers)

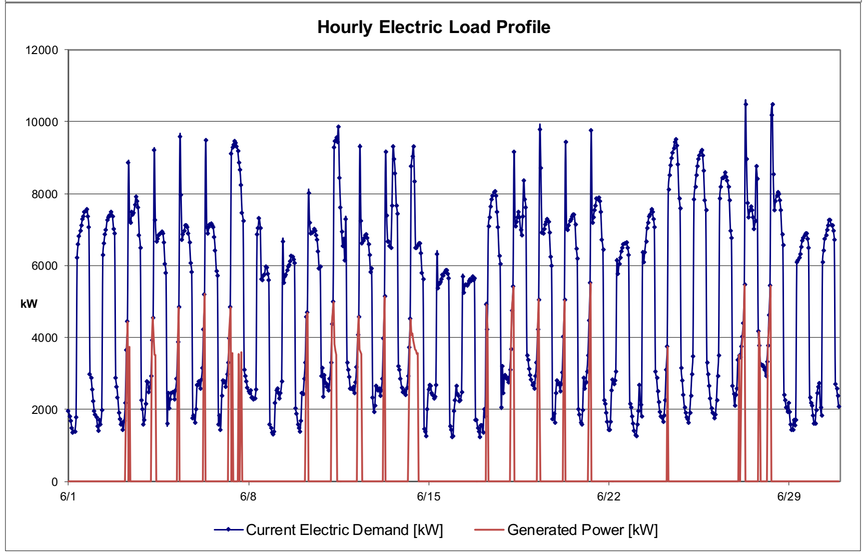



| | | |
|---|---|---|
| Averge load | 4,897 | kW |
| Maximum load | 10,485 | kW |
| Minimum load: | 1,227 | kW |
| Total Electricity Usage | 3,526,104 | kWh |
| Actual Electricity Generated | 2,284,351 | kWh |
| Actual Electricity Generated | 64.8% | |
| System Efficiency | 62% | |
| CHP Operating Hours | 652 | hr |
| Operating hours % | 91% | |
| CHP system size | 7,030 | kW |
| Heat rate: | 12,793 | Btu/kWh |
| Number of units | 2 | |
| Minimum engine load allowed: | 50% | |

# Minimum Load (1 prime mover)




| | | |
|---|---|---|
| Averge load | 4,897 | kW |
| Maximum load | 10,485 | kW |
| Minimum load: | 1,227 | kW |
| Total Electricity Usage | 3,526,104 | kWh |
| Actual Electricity Generated | 252,493 | kWh |
| Actual Electricity Generated | 7.2% | |
| System Efficiency | 74% | |
| CHP Operating Hours | 60 | hr |
| Operating hours % | 8% | |
| CHP system size | 7,030 | kW |
| Heat rate: | 12,793 | Btu/kWh |
| Number of units | 1 | |
| Minimum engine load allowed: | 50% | |

# EPA CHP Tool

- CHP Energy and Emissions Savings Calculator
  - Microsoft Excel–based tool that calculates and compares the estimated fuel consumption and air pollutant emissions ($CO_2e$, $SO_2$, and $NO_X$) of a CHP system and comparable separate heat and power system (e.g., grid power and a boiler system)
  - https://www.epa.gov/chp/chp-energy-and-emissions-savings-calculator

# REopt: Renewable Energy Integration & Optimization

- **The REopt® web tool allows users to:**
  - Evaluate the economic viability of distributed PV, wind, battery storage, combined heat and power (CHP), and thermal energy storage
  - Identify system sizes and dispatch strategies to minimize energy costs
  - Estimate how long a system can sustain critical load during a grid outage.
  - https://reopt.nrel.gov/tool

# What is the next after project screening?

The purpose of this screening tool is to determine if a feasibility analysis should be undertaken. The system performance and financial data is based on rules of thumb and estimates of addressable thermal demand (heating/DHW) only during site operating hours. These results are not to be used for financial and/or project decisions other than whether to proceed to a more detailed feasibility analysis.

# Ascertaining Degree of Interest

## The Enterprise / Organization’s Mission – Capital Plan

- Understanding project drivers
  - Economic return, competitive position
  - Resiliency, reliability, power quality
  - ESG- Environmental, Social, Governance
- This Investment’s Place in Capital Stack Ranking

# Passing the Initial Threshold

## Deeper Scrutiny: Economic Return, Competitive Position

- Beyond simple spark spread analysis
- Address limited site information (e.g., average electric demand, average thermal demand), and average utility rates.
- operating costs (fuel, incremental O&M, credit for displaced thermal energy is estimated assuming performance characteristics of a typical CHP system
- Assess future energy/ fuel cost assumptions for the site location

# Enterprise / Organization's Mission

## Corporate Priorities and Influential Project drivers

- The Importance of Resiliency, reliability, power quality at this site

- Significance of ESG- Environmental, Social, Governance:  Stakeholders (Investors, Shareholders, Customers) are increasingly applying these non-financial factors as part of their analysis.

# This Investment's Place in Capital Stack Ranking

- Does This Warrant an Advanced Financial Analysis?
  - Yields a return, all factors (economic and non) considered that exceed the organization's hurdle rate?
  - Is sufficiently aligned with the mission, goals, objectives of the core business
  - It's effect on risk, cost of capital, debt and equity
  - Availability, at present or with probability of future availability of state, federal, utility, grid operator incentives

# Next Steps

## Contact your Regional CHP TAP for assistance if:

- You are interested in having a "no-cost" Qualification Screening performed to determine if there is an opportunity for CHP on-site.
- If you have an existing CHP plant and are interested in expanding the plant.
- If you need an unbiased 3rd Party Review of a CHP proposal.

# Homework Questions

- Is there a difference in electric efficiency between reciprocating engines and gas turbines in the same size range?
- Use e-catalog to compare characteristics of gas turbines and reciprocating engines for a 5000-kW system
- Which prime movers are better suited to provide high pressure steam?
- Briefly describe how important is the number of units and the minimum load allowed for CHP system operating continuously

# Thank You

# Questions?

**New York New Jersey CHP TAP:**

**Tom Bourgeois (914) 422-4013**

**Tbourgeois@law.pace.edu**

**Beka Kosanovic (413) 545-0684**

**kosanovic@umass.edu**

*For more information about the CHP TAPs*:
https://betterbuildingssolutioncenter.energy.gov/chp/chp-taps