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Better Buildings®
U.S. DEPARTMENT OF ENERGY

Boosting Industrial and Manufacturing Efficiency and Resiliency with CHP

June 17, 2021
1:00 – 2:00 pm ET

U.S. DEPARTMENT OF ENERGY

Thomas Wenning

Oak Ridge National Lab

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Today's Presenters

Gavin Dillingham
U.S DOE Southcentral CHP TAP, Director

Bruce Hedman
Entropy Research, LLC

Agenda

1. CHP Overview
2. CHP and Resilience
3. Waste Heat to Power for Industry
4. Project Snapshots
5. Working with the CHP TAPs
6. Decarbonization and CHP
7. Q & A and Next Steps

CHP Overview

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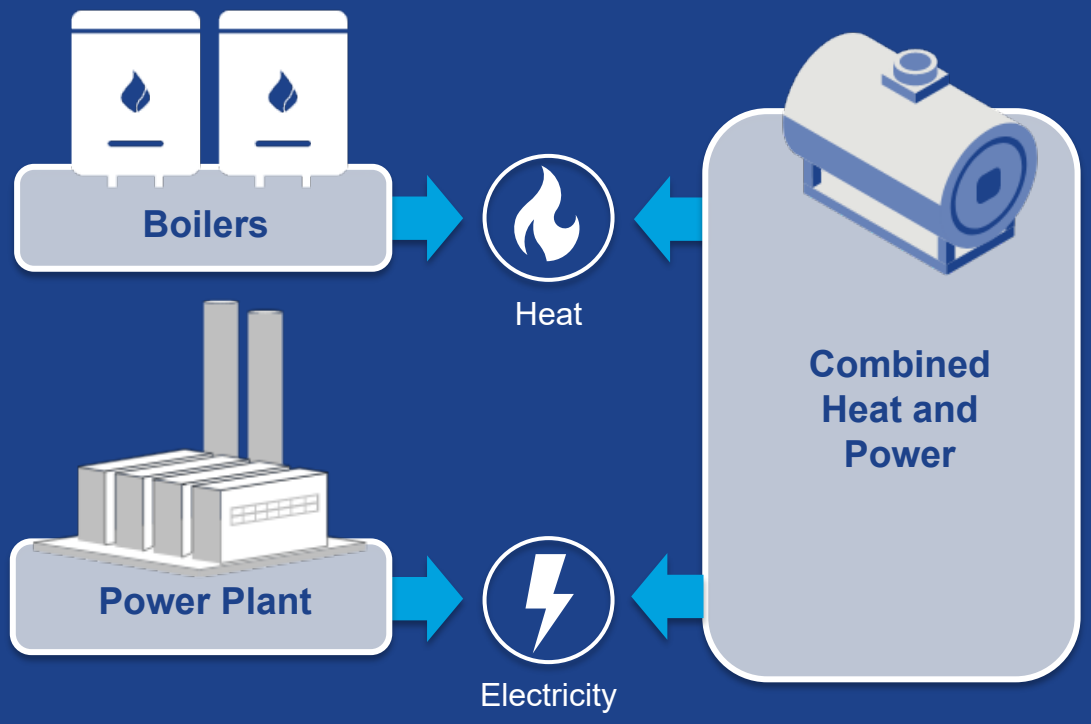
What is Combined Heat and Power (CHP)?

- **Form of distributed generation (DG)**
- **An integrated system**
- **Located at or near a building / facility**
- **Provides at least a portion of the electrical load and**
- **Uses thermal energy for:**
  - Space Heating / Cooling
  - Process Heating / Cooling
  - Dehumidification

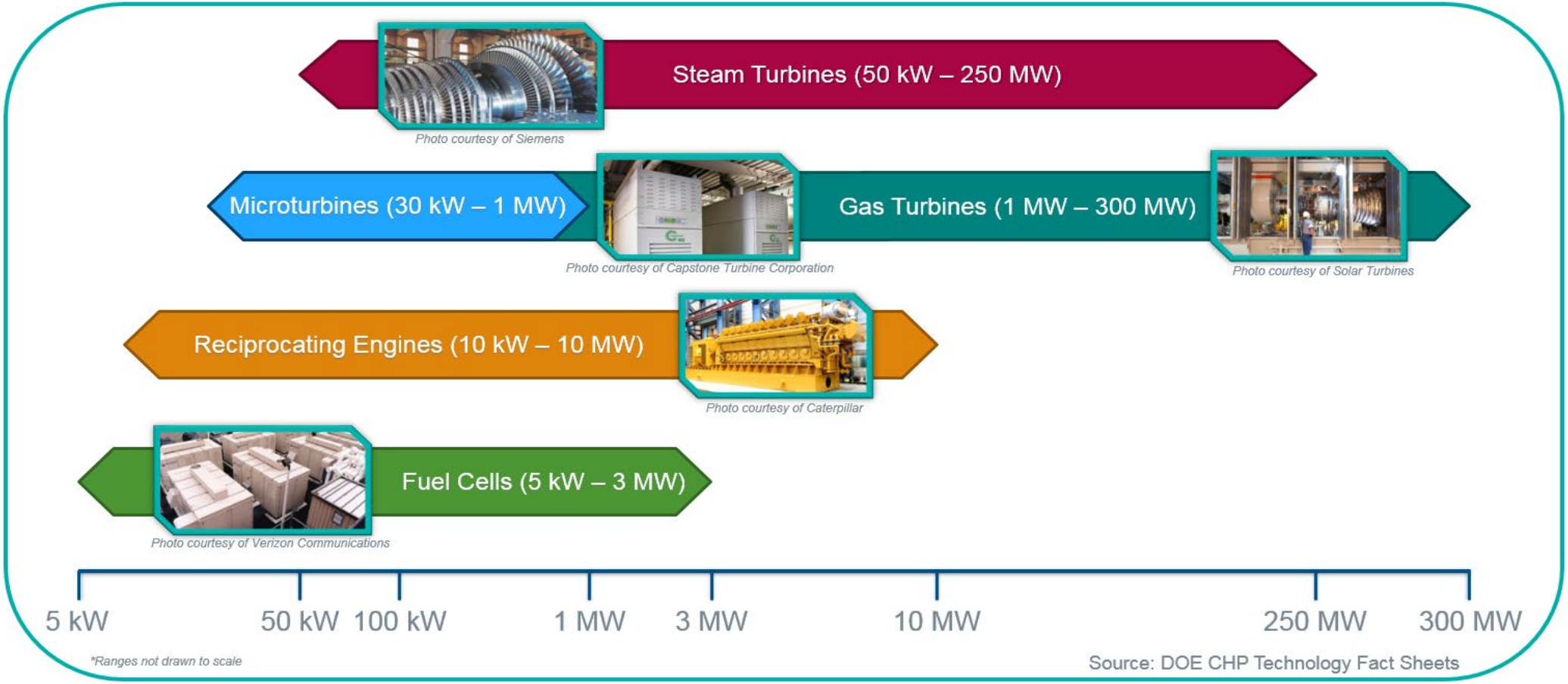
Did you know?

CHP results in **30% to 55% less** greenhouse gas emissions than traditional separate heat and power.

CHP provides efficient, clean, reliable, affordable energy – today and for the future



Common CHP Technologies and Capacity Ranges



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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)

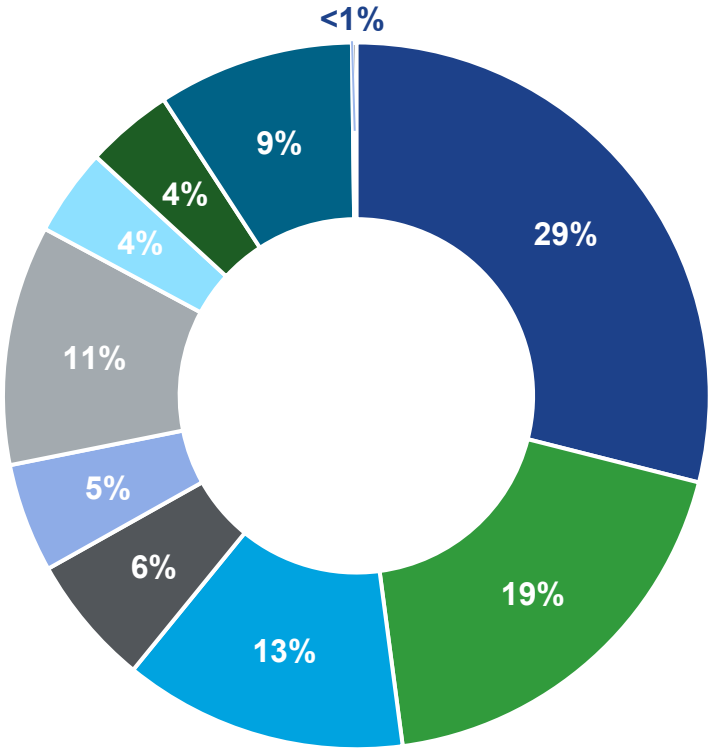
Higher efficiency reduces emissions of pollutants

CHP can also increase energy reliability and resiliency and enhance power quality

On-site electric generation can reduce grid congestion and avoid distribution costs.

CHP Today in the United States

Existing CHP Capacity



- Chemicals
- Refining
- Pulp & Paper
- Food Processing
- Primary Metals
- Other Industrial
- Utilities
- District Energy
- Other Comm/Industrial
- Unkown

Source: DOE CHP Installation Database (U.S. installations as of December 31, 2020)

Avoids more than **1.7 quadrillion Btus** of fuel consumption annually.

Avoids **232 million metric tons of CO_2** compared to separate production.

80.7 GW of installed CHP at more than **4,600** industrial and commercial facilities.

7% of U.S. electric generating capacity

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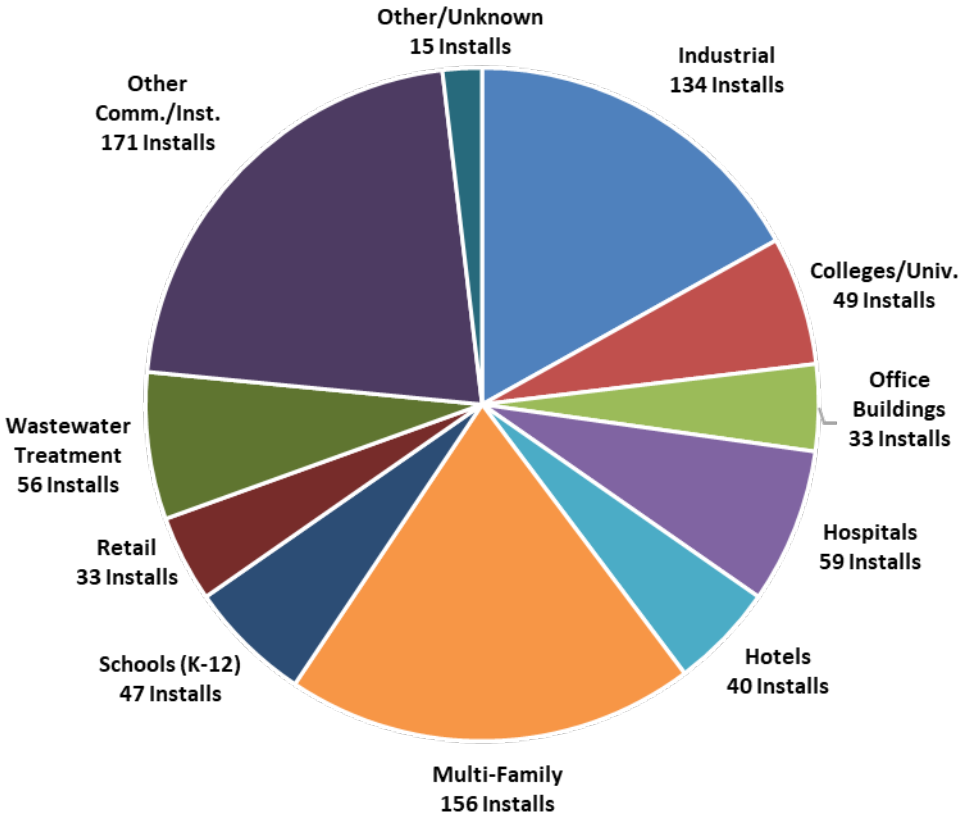
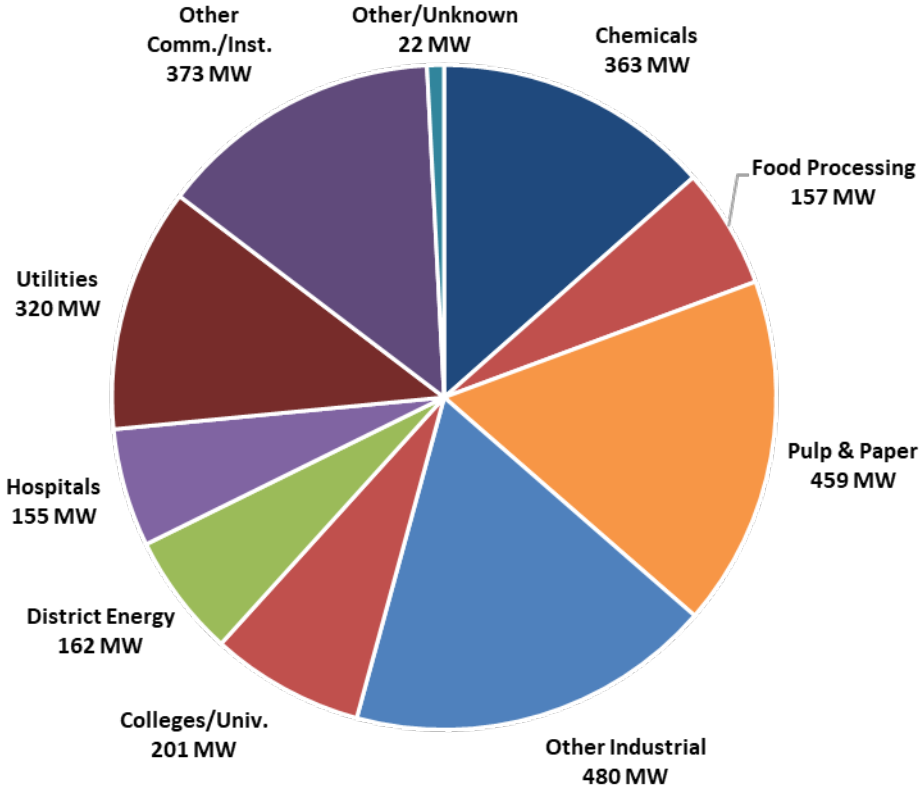
CHP Additions by Application (2015-2019)

By Installations – 793 Installs



By Capacity – 2.7 GW



Source: DOE CHP Installation Database (U.S. installations as of December 31, 2019)

Slide prepared on 7-31-20

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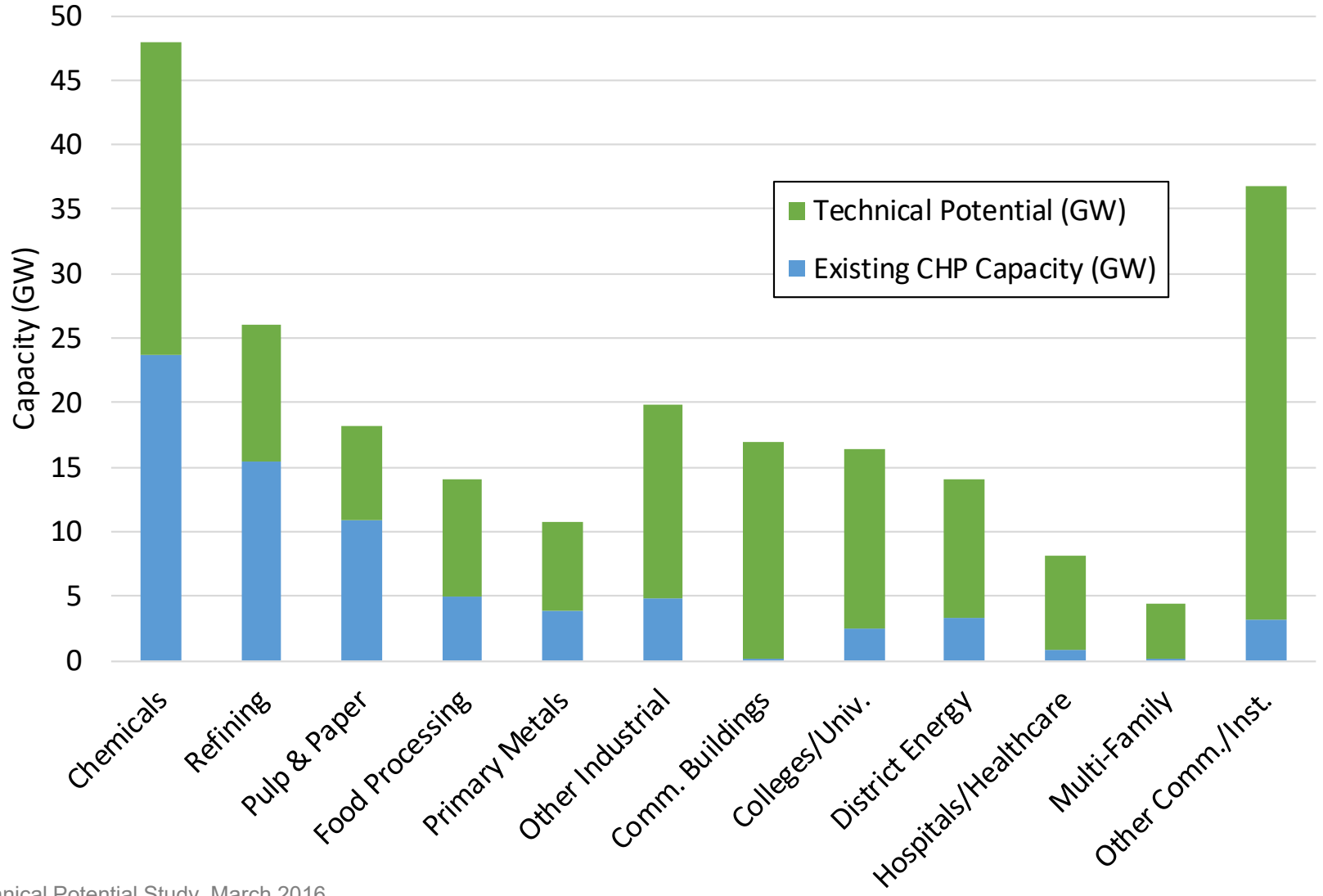
CHP Remains an Underutilized Resource



Source: DOE CHP Technical Potential Study, March 2016

Growing Utility Participation

Utility-Owned CHP for Grid Generation

- Build, own, and operate CHP at customer sites as part of resource planning

CHP as a Distribution System Resource

- Encourage customers to install CHP as non-wires alternative to enhance grid stability, alleviate grid congestion, or defer investments

CHP in Utility Energy Efficiency Portfolio

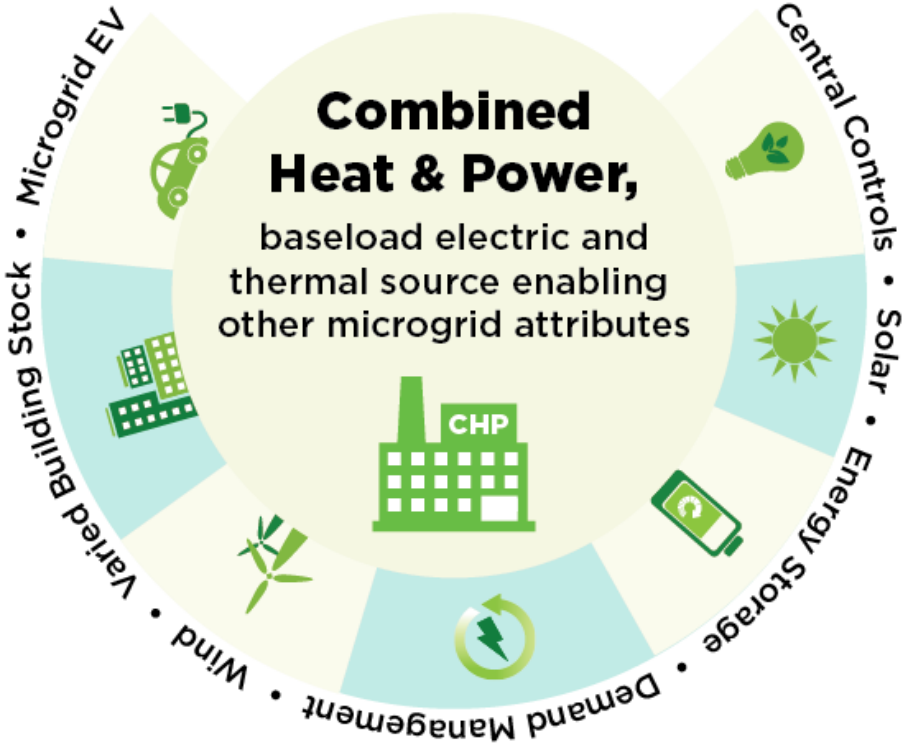
- Encourage customers to install CHP to gain low-cost energy savings

CHP and Microgrids

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

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

- With a CHP system providing reliable baseload electric and thermal energy, microgrids can add renewables and storage
- Increased focus on resilience for critical infrastructure
  - Universities, Hospitals, Military bases, Communities



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

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Packaged CHP eCatalog*

Launched Nov 8, 2019

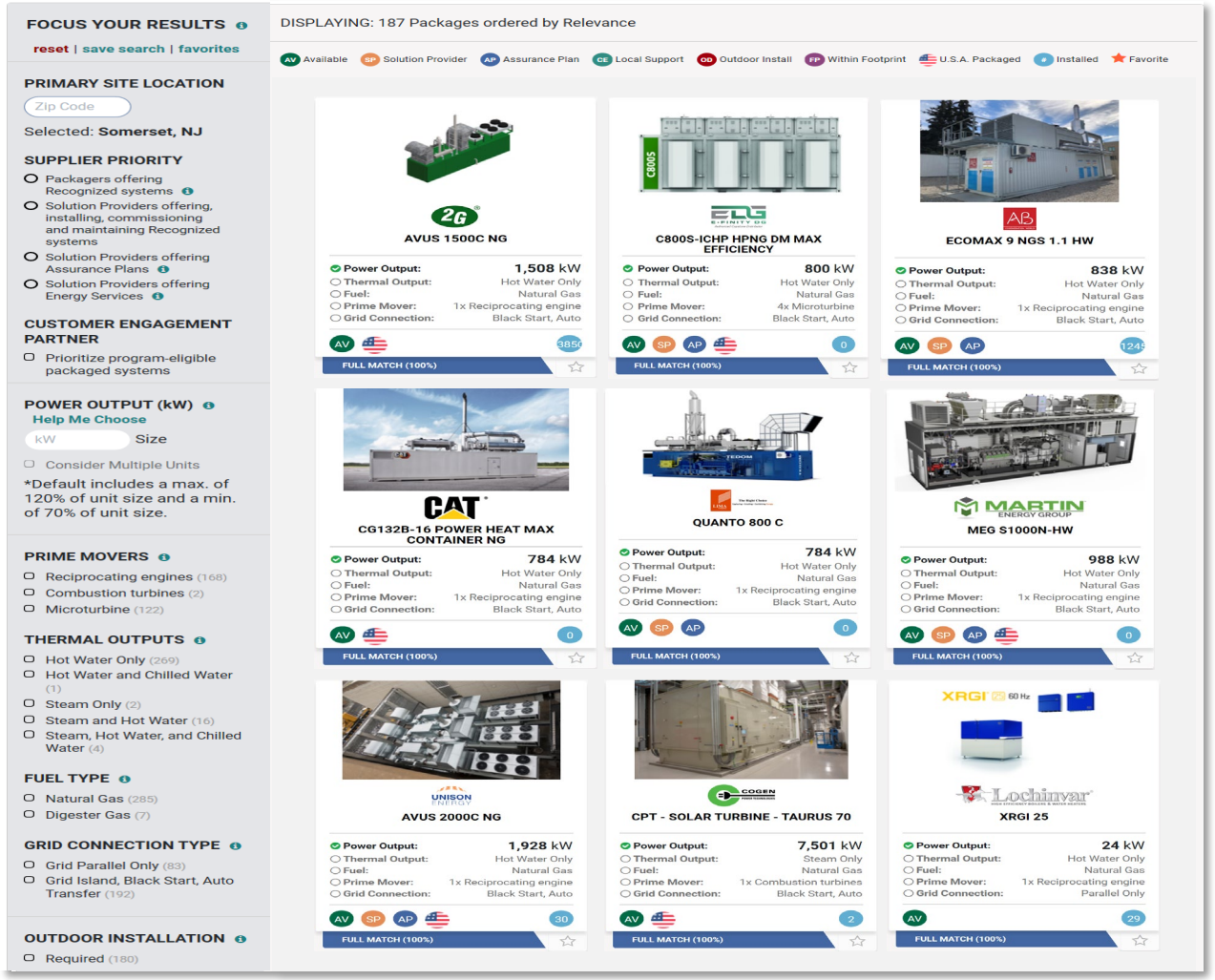
39 recognized Packagers

23 recognized Solution Providers

260 Package Offerings

- 193 reciprocating engine
- 74 microturbine
- 4 gas turbine
- 235 natural gas
- 35 digester gas
- 18 hydrogen blends
- 24 kW to 16.7 MW
- Multiple suppliers and packages in every zip code

10 Customer Engagement Partners



https://chp.ecatalog.lbl.gov//

*June 10, 2021 Status

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CHP and Resilience

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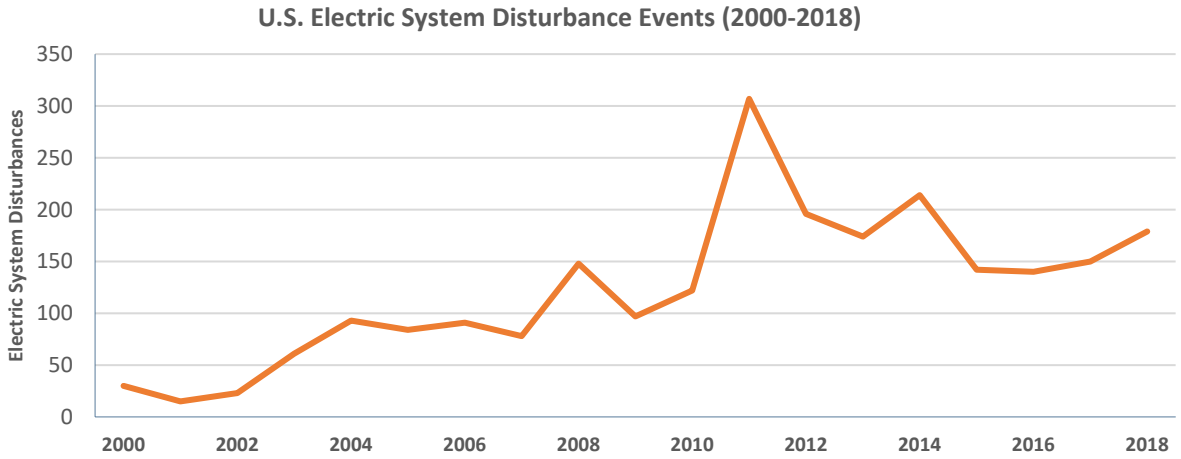
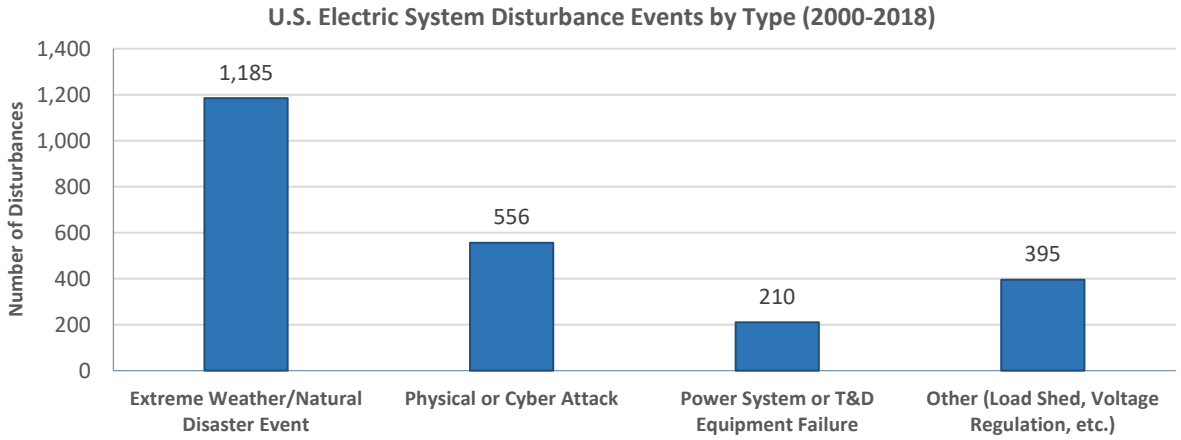
Electric System Disturbances

Electric system outages are increasingly frequent...



And outages are increasingly caused by natural disasters and storm events



Source: U.S. DOE Office of Cybersecurity, Energy Security, and Emergency Response, Electric Disturbance Events (OE-417) Annual Summaries

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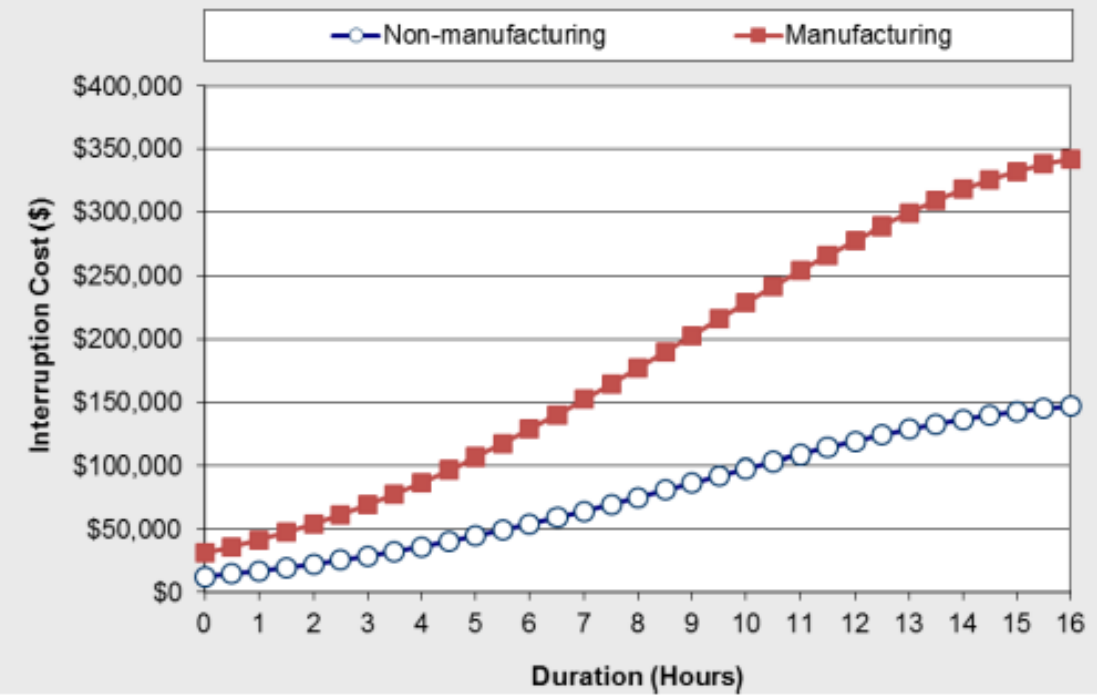
Reliability and Resilience: C&I Outage Costs by Sector



Cost figures in 2013$. Source: Sullivan, Schellenberg, Blundell 2015.

Sector	Momentary	30 min.	1 hour	4 hours	8 hours
Medium and large C&I					
Agriculture	$4,382	$6,044	$8,049	$25,628	$41,250
Mining	$9,874	$12,883	$16,366	$44,708	$70,281
Construction	$27,048	$36,097	$46,733	$135,383	$214,644
Manufacturing	$22,106	$29,098	$37,238	$104,019	$164,033
Telecommunications & utilities	$11,243	$15,249	$20,015	$60,663	$96,857
Trade & retail	$7,625	$10,113	$13,025	$37,112	$58,694
Finance, insurance, real estate	$17,451	$23,573	$30,834	$92,375	$147,219
Services	$8,283	$11,254	$14,793	$45,057	$71,997
Public administration	$9,360	$12,670	$16,601	$50,022	$79,793

Sector	Momentary	30 min.	1 hour	4 hours	8 hours
Small C&I					
Agriculture	$293	$434	$615	$2,521	$4,868
Mining	$935	$1,285	$1,707	$5,424	$9,465
Construction	$1,052	$1,436	$1,895	$5,881	$10,177
Manufacturing	$609	$836	$1,110	$3,515	$6,127
Telecommunications & utilities	$583	$810	$1,085	$3,560	$6,286
Trade & retail	$420	$575	$760	$2,383	$4,138
Finance, insurance, real estate	$597	$831	$1,115	$3,685	$6,525
Services	$333	$465	$625	$2,080	$3,691
Public administration	$230	$332	$461	$1,724	$3,205

Cost figures in 2008$. Source: Sullivan et al. 2009.

Manufacturing facilities generally experience higher outage costs than other Large C&I customer segments.

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CHP Increases 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

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	◒	○	◒	●	◒	○

Source: https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/DER_Disaster_Impacts_Issue%20Brief.pdf

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CHP vs. Status Quo

CHP vs. Backup Generation

Metric	CHP	Backup Generation
System Performance	• Designed and maintained to run continuously • Improved performance and reliability	• Only used during emergencies
Fuel Supply	• Natural gas infrastructure typically not impacted by severe weather	• Limited by on-site storage – finite fuel supply
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 • Thermal (heating, cooling, hot/chilled water)	• Electricity
Emissions	• Typically natural gas fueled • Achieve greater system efficiencies (80%) • Lower emissions	• Commonly burn diesel fuel

Source: DER Disaster Matrix, Issue Brief, U.S. DOE CHP for Resiliency Accelerator. 2018; Natural Gas Systems: Reliable & Resilient, The Natural Gas Council. 2017; Case Studies of Natural Gas Sector Resilience Following Four Climate-Related Disasters in 2017, ICF Prepared for SoCalGas. 2018.

Waste Heat to Power for Industry

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Benefits of Waste Heat to Power (WHP)

- Utilize heat from existing thermal processes, which would otherwise be wasted to produce electricity.
- Important resource for vastly increasing industrial energy efficiency.
- Improving the competitiveness of the U.S. industrial sector.
- Providing a source of pollution-free power.

Port Arthur Steam Energy/Oxbow Corp.

WHP Technical Potential by Application

Application	# of Sites	Potential (MW)
Mining	14	23
Oil/Gas Extraction	427	538
Food Processing	19	8
Beverage and Tobacco	2	0.3
Lumber and Wood	2	1
Paper	17	5
Chemicals	64	92
Petroleum Refining	176	3,593
Stone/Clay/Glass	255	1,173
Primary Metals	116	2,186
Machinery/Computer Equip.	2	4
Transportation Equip.	1	2
Other	10	0.3
Total	**1,105**	**7,624**

Source: “Combined Heat and Power (CHP) Technical Potential in the United States”, March 2016, energy.gov/chp-potential

Sources of Waste Heat

Waste Heat from a Thermal Process

Waste Heat from a Mechanical Drive

Waste heat from other systems

Port Arthur Steam Energy/Oxbow Corp, Texas

Northern Boarder Pipeline, North Dakota

Technical and Economic Factors to Consider

Technical

- Is the waste heat source a gas or a liquid stream?
- What is the availability of the waste heat—is it continuous, cyclic, or intermittent?
- What is the load factor of the waste heat source—are the annual operating hours sufficient to amortize the capital costs of the WHP system?
- Does the temperature of the waste stream vary over time?
- What is the flow rate of the waste stream, and does it vary?
- Is the waste stream at a positive or negative pressure, and does this vary?
- What is the composition of the waste stream?
- Are there contaminants that may corrode or erode the heat recovery equipment?

Economic

- Waste heat recovery options
  - Uses with other thermal processes or power generation?
- Cost of Grid Electricity
- Integration of WHP
  - Site Factors to Consider
- Availability of Financial Incentives

Source: Waste Heat to Power Systems – EPA 2012

Project Snapshots

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Project Snapshot 1:
Environmental Benefits

Shaw Industries
Columbia, SC

Application/Industry: Carpet fiber production

Capacity: 14 MW

Prime Mover: Combustion turbine

Fuel Type: Natural gas

Thermal Uses: Process heat, space cooling, and water heating

Installation Year: 2018

Emissions Savings: 26,000 metric tons annually

Testimonial: *"Shaw Industries has found incredible value in the CHP TAP, including the report, which demonstrated the viability of the project in measurable ways."*

- Kurt Kniss, Energy Manager, Shaw Industries

Source: https://chptap.lbl.gov/profile/201/ShawIndustries-Project_Profile.pdf

Slide prepared 5/2020

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Project Snapshot 2:

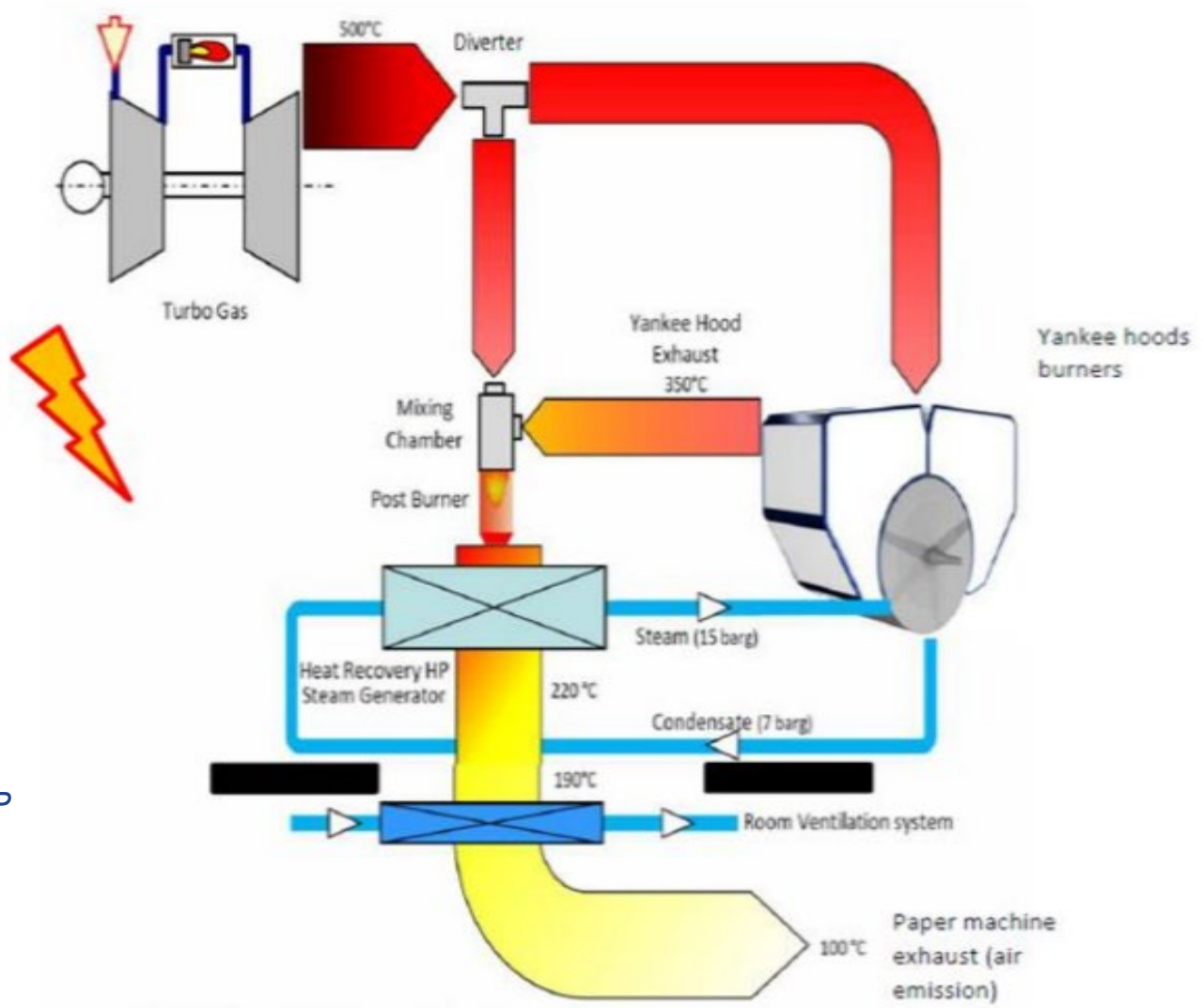
Partnership with a Local Utility

Sofidel Paper Manufacturing Facility

Circleville, OH

Application/Industry: Paper Manufacturing
Capacity: 16 MW
Prime Mover: Combustion turbine
Fuel Type: Natural gas
Thermal Use: Process heat
Installation Year: 2018

Testimonial: *"The Circleville, Ohio plant is one of Sofidel's most technologically and environmentally advanced tissue paper manufacturing plants in the world, with innovative machinery and a CHP system that increases both the quality of its products and the energy efficiency of its operations."*
- Antonio Cuccarese, Technical Machinery Manager, Sofidel America Corp.



Source: https://chptap.lbl.gov/profile/209/Sofidel-Project_Profile.pdf

Slide prepared 5/2020

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Project Snapshot 3:

Waste heat to power and process heat,

Port Arthur, TX

Application/Industry: Petroleum Refining
Capacity: 5 MW
Equipment: Waste heat recovery boilers; back pressure steam turbine
Fuel Type: Waste heat
Thermal Use: Steam and electricity generation
Installation Year: 2005
Environmental Benefits: CO2 emissions reduced by 159,000 tons/year

Testimonial: “Through the recovery of otherwise-wasted heat to produce high pressure steam for crude oil processing, Port Arthur Steam Energy LLP has demonstrated exceptional leadership in energy use and management.”
- U.S. Environmental Protection Agency, in giving the 2010 Energy Star Award

Working with CHP TAPs

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CHP Technical Assistance Partnerships (CHP TAPs)

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

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

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

Above: National Manufacturing Day 2019 at the University of Illinois at Chicago

CHP TAP Approach

The ten CHP TAPs are comprised of **regional CHP experts** who provide no-cost fact based, unbiased information on CHP, including technologies, project development, project financing, local electric and natural gas utility interfaces, and related state/local best practice policies. They are vendor, fuel, and technology-neutral.

CHP TAP ROLE IN TECHNICAL ASSISTANCE:

Screening and Preliminary Analysis	Feasibility Analysis	Investment Grade Analysis	Procurement, Operations, Maintenance, Commissioning
Quick screening questions with spreadsheet payback calculator; Advanced technical assistance to explore equipment or operational scenarios.	Perform 3rd party reviews of site feasibility assessments: Estimates on savings, installation costs, simple paybacks, equipment sizing, and type.	Perform 3rd party reviews of engineering analysis. Review equipment sizing and choices.	Review specifications and bids.

End-User & Stakeholder Engagements

- Workshops
- Webinars
- One-on-one Meetings
- Presentations
- Booths at conferences
- Project and Policy/Program Profiles
- Education – NOT Advocacy

Technical Services

- Screening Technical Assistance
- Advanced Technical Assistance
- Portfolio Reviews

CHP TAPs Provide Assistance Across the U.S. and Puerto Rico

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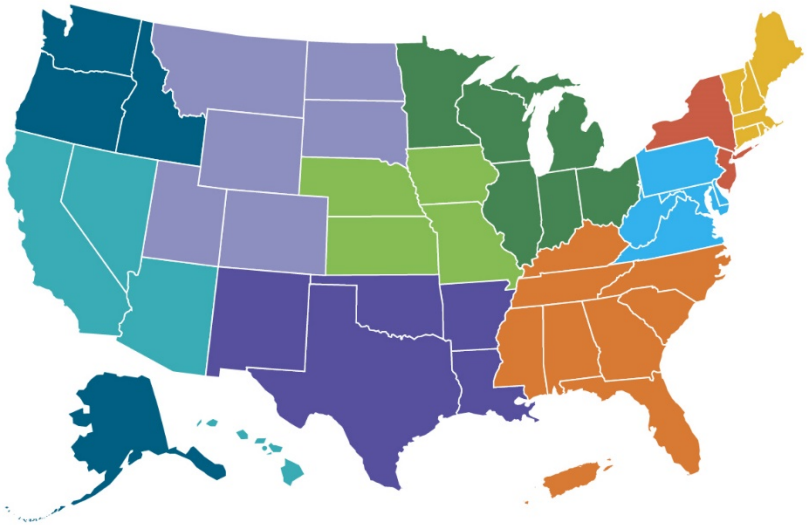

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Decarbonization and CHP

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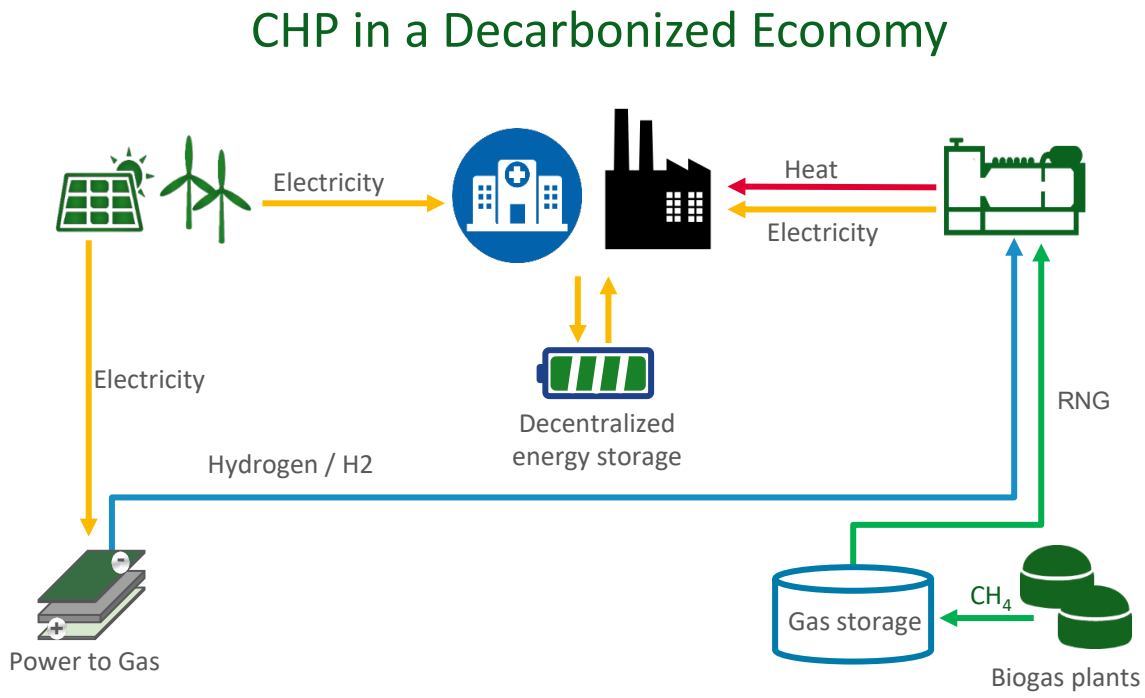
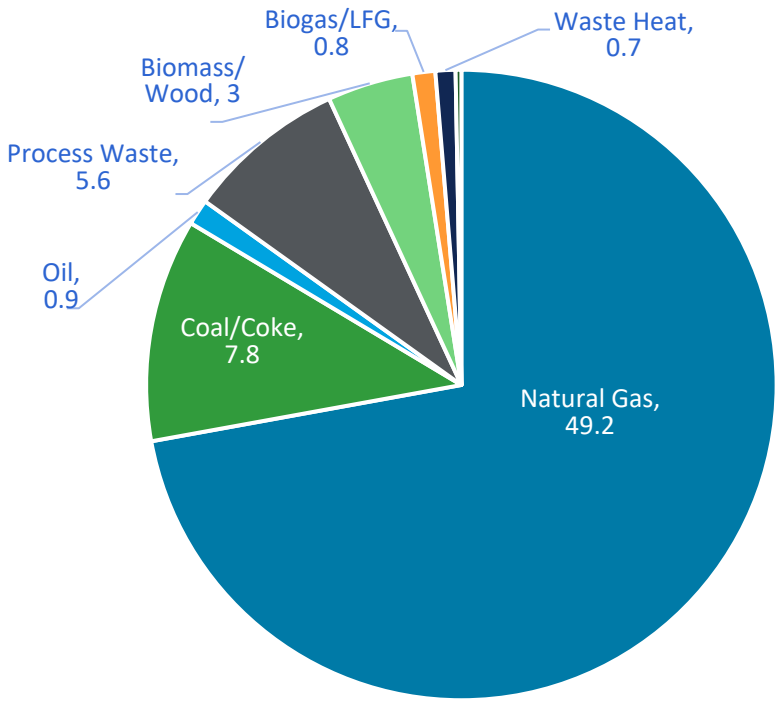
CHP and Decarbonization

- CHP is fuel flexible - CHP currently uses renewable fuels, low carbon waste fuels, and hydrogen where available, and **will be ready to use higher levels of biogas, renewable natural gas (RNG) and hydrogen in the future**
- CHP is the **most efficient way to generate power and thermal energy**, and can reduce CO_2 emissions now and in the future
- Renewable/hydrogen fueled CHP can **decarbonize thermal end-uses in industrial and commercial facilities that are difficult to electrify**
- Renewable/hydrogen fueled CHP can **decarbonize critical facilities that need on-site power for long duration resilience and operational reliability**
- CHP's high efficiency **can extend the supply of renewable, low carbon and hydrogen fuels**

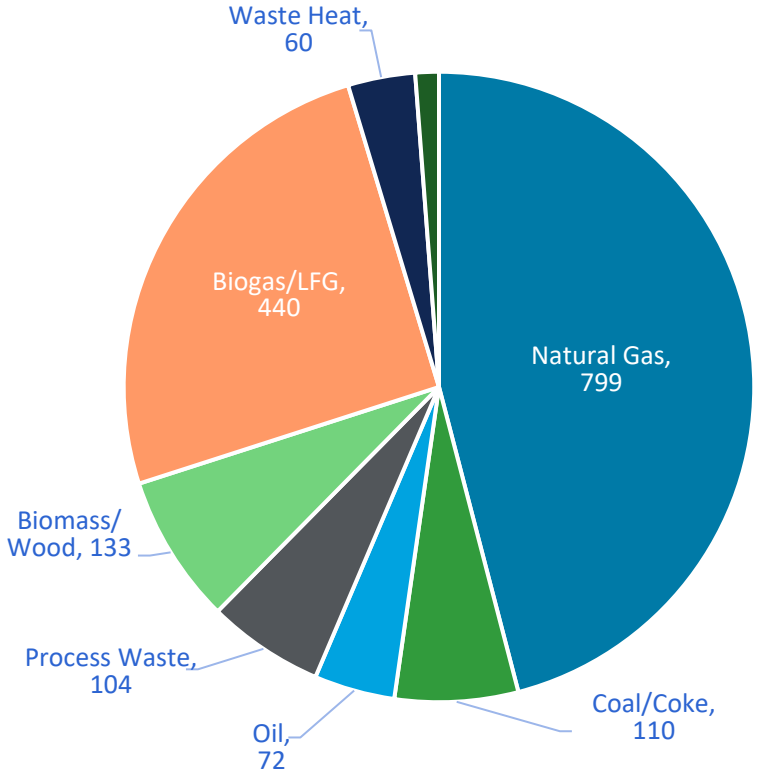


Industrial CHP is Fuel Flexible

Industrial CHP,
GW Capacity



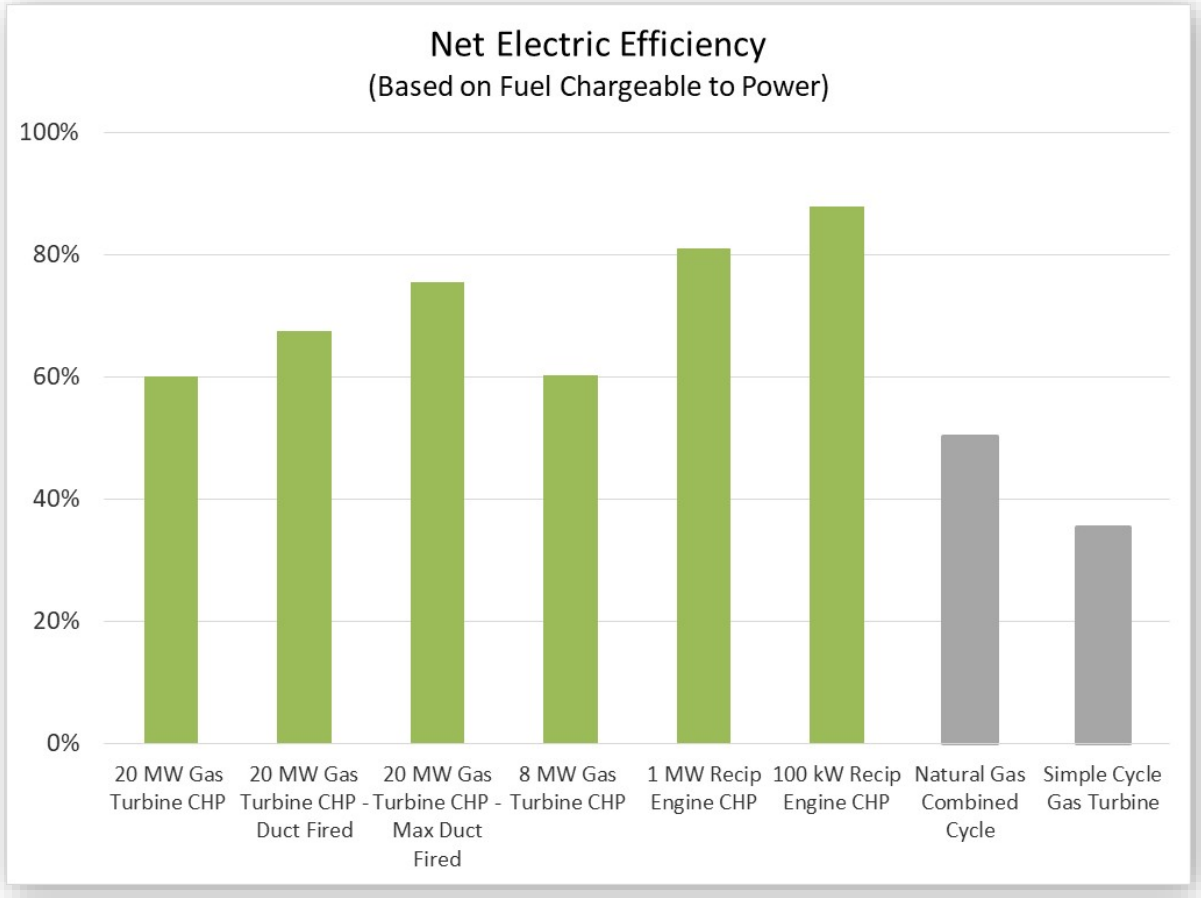
Industrial CHP,
Number of Installations



Source: DOE CHP Installation Database (U.S. installations as of December 31, 2020)

CHP Is the most Efficient Way to Generate Power and Thermal Energy

- CHP has higher net electric efficiency than state-of-the-art marginal natural gas generation (combined cycle)
- CHP systems have lower net GHG emissions than marginal natural gas generation
- Natural gas CHP can meet marginal grid loads more efficiently and with less CO_2 emissions
- CHP's efficiency and emissions advantages will remain as the natural gas infrastructure decarbonizes



Prepared by: Entropy Research, LLC, 3/29/21

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CHP's High Efficiency Saves CO_2 Emissions 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
- Natural gas CHP's high net electric efficiency and high annual capacity factor currently results in higher energy and emissions savings than PV and wind on a per MW basis
- *"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"*

Source: "Time Value of Money", Larry Stein, Carbon Leadership Forum, April 2020

Category	Industrial CHP	Utility Solar PV	Utility Wind
Capacity, MW	**20.0**	**46.4**	**32.8**
Annual Capacity Factor	90%	24.3%	34.3%
Annual Electricity, MWh	157,680	98,771	98,554
Annual Thermal Provided, MWh_{th}	160,061	None	None
Annual Energy Savings, MMBtu	**556,152**	**862,690**	**860,792**
Annual CO_2 Savings, Tons	**76,452**	**76,547**	**76,379**
Annual NOx Savings, Tons	51.9	42.0	41.9

Savings based on EPA AVERT Uniform EE Emissions Factors as a first level estimate of displaced marginal generation

Prepared by: Entropy Research, LLC, 3/29/21

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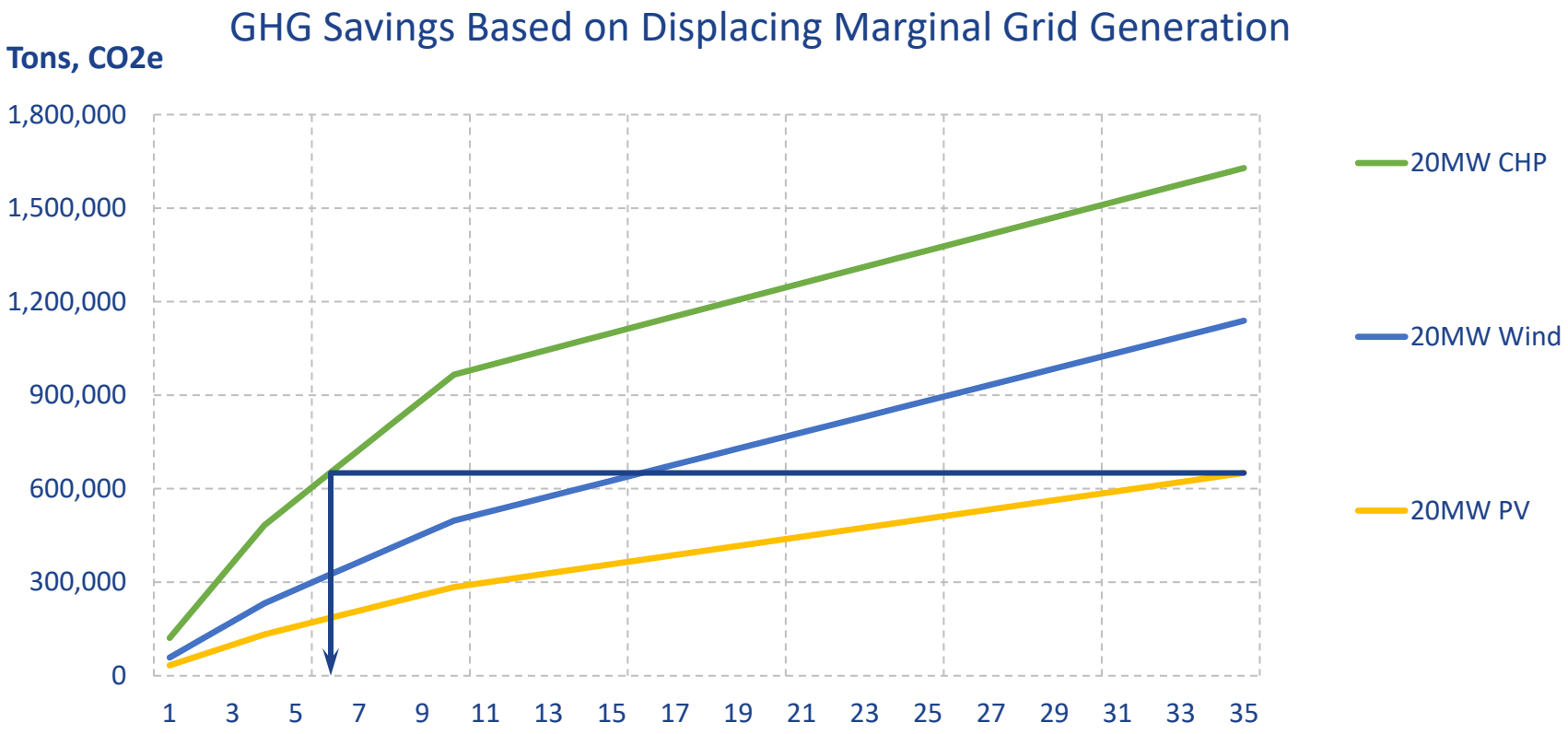
CHP Reduces Emissions as long as Fossil Fuel is on the Margin



Base Case marginal grid offsets based on Long Term Dispatch Modeling of Regional Utility Generation Resources

- Y1-4 average 95% coal, ~1,900 lb CO_2e/MWh
- Y5-11 average ~55% coal, ~1,440 lb CO_2e /MWh
- Y12 on, 100% NGCC, ~840 lb CO_2e /MWh
- ~561 lb CO_2e /MWh (net FCP heat rate of 4800, including 4.1% T&D loss reduction credit)
- Capacity Factors: 95% for CHP, 20% for PV, and 35% for Wind

CHP saves more GHG emissions in 6 years as the same capacity of solar PV does in 35 years

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CHP and Long Term Decarbonization

- Current CHP products routinely operate on biogas and hydrogen blends, and **all major manufacturers are introducing 100% hydrogen capability**
- Renewable/hydrogen fueled CHP can **decarbonize thermal end-uses in industrial and commercial facilities that are difficult to electrify**
- Renewable/hydrogen fueled CHP can **decarbonize critical facilities that need on-site power for long duration resilience and operational reliability**
- CHP's high efficiency **can extend the supply of renewable and low carbon fuels**

Low/Zero Carbon Fuel Feedstocks

- *Food Waste*
- *Animal manure*
- *Wastewater Treatment (WWTP)*
- *Landfill gas (LFG)*

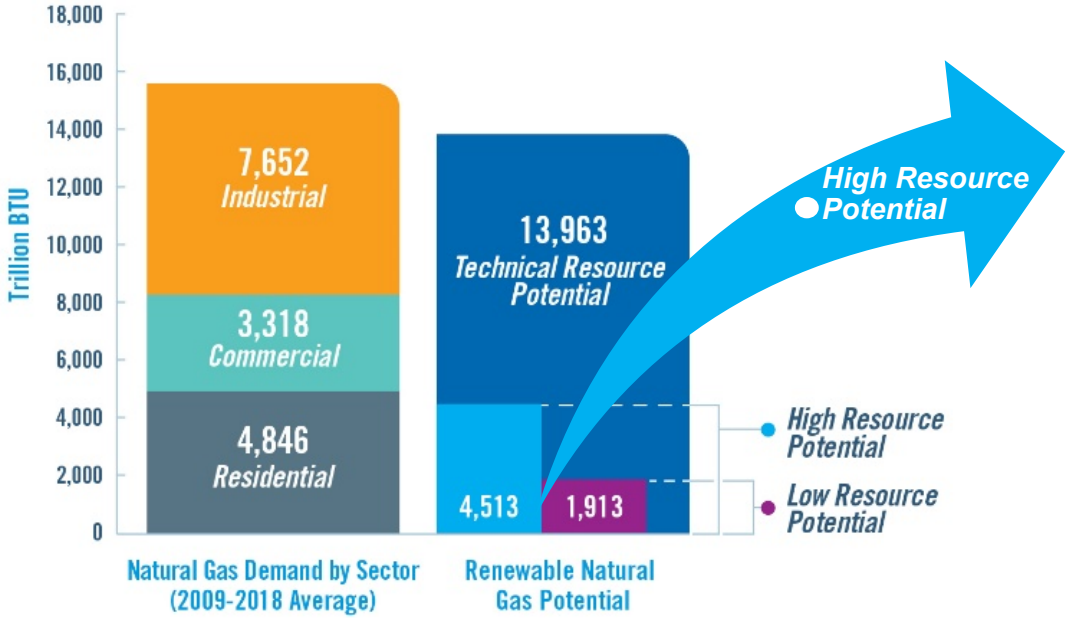
- *Agricultural residue*
- *Forestry and forest product residue*
- *Energy crops*
- *Municipal solid waste (MSW)*

- *Green Hydrogen from renewable electricity*
- *Blue Hydrogen from natural gas with carbon capture*

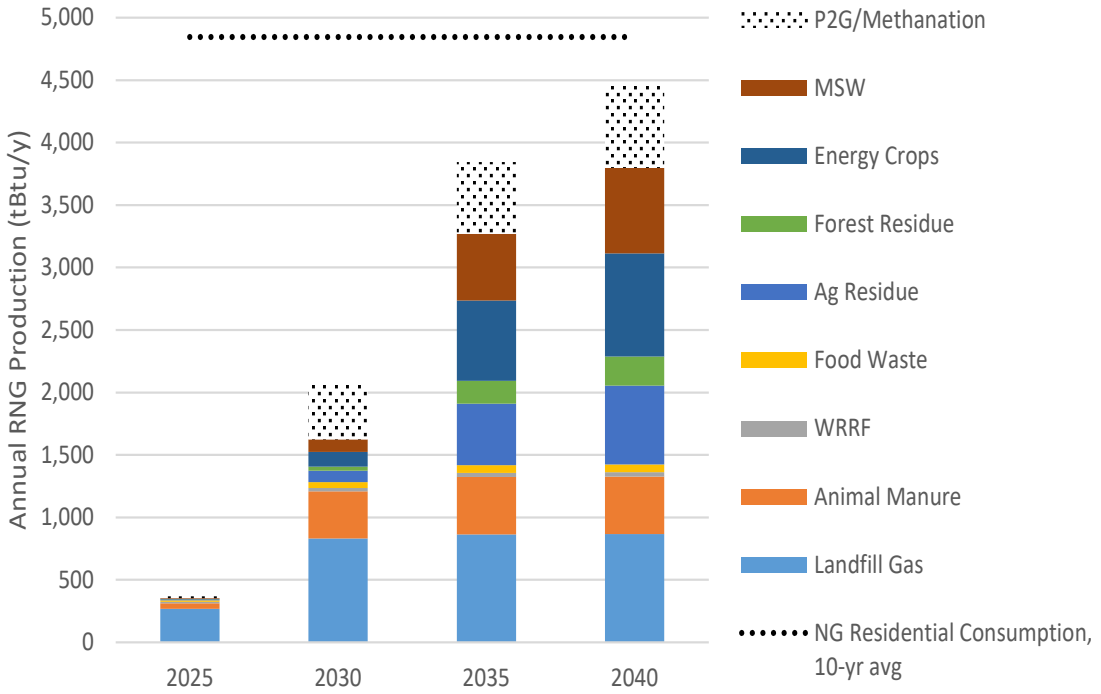
Source: AGA Foundation, Renewable Sources of Natural Gas: Supply and Emissions Reduction Assessment, 2019

RNG Resource Potential

- High resource case: 4.5 Tcf of RNG by 2040
- Represents 60% of current industrial natural gas use
- Cost competitive with other emission reduction strategies, $55-300/ton of GHG emission reductions

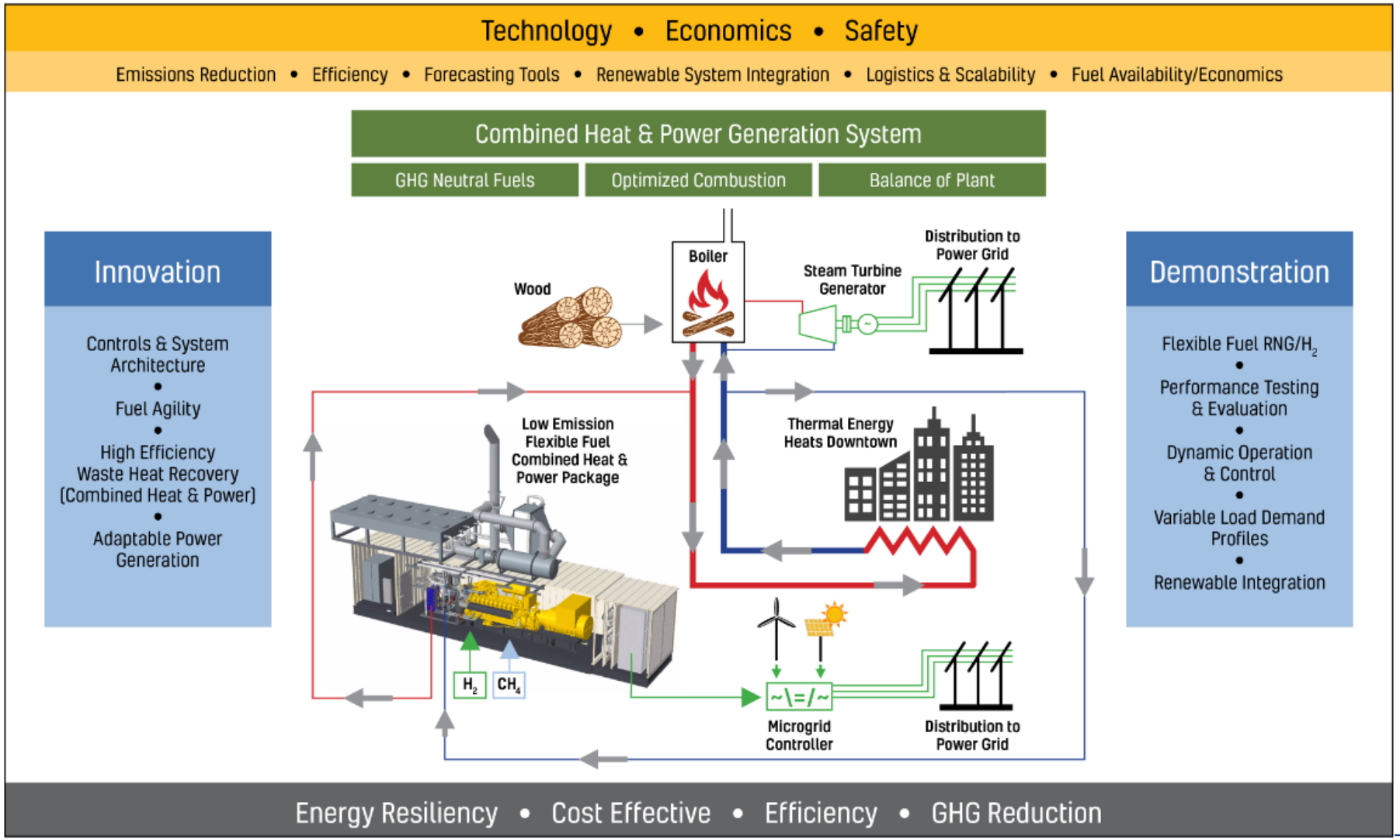


Estimated Annual Production



Source: AGA Foundation, Renewable Sources of Natural Gas: Supply and Emissions Reduction Assessment, 2019

CHP R&D Example: Hydrogen Blending



Project Summary

Caterpillar Inc., the National Renewable Energy Laboratory, and District Energy St. Paul will demonstrate a **2MW flexible natural gas/hydrogen combined heat and power (CHP) system** at a municipal generating station.

Technology Impact

This project will seed effort in adding natural gas/hydrogen flexible fuel CHP systems to the wide options space for stationary power applications.

Next Steps

Submit Questions
www.slido.com event code **#DOE**

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Summary

- CHP and WHP get the most out of energy, enabling
  - Higher overall utilization efficiencies
  - Reduced environmental footprint
  - Reduced operating costs
- CHP and WHP can be used in different strategies, including critical infrastructure resiliency and emergency planning
- Proven technologies are commercially available and cover a full range of sizes and applications
- CHP and WHP can be a key path to decarbonization

Next Steps

- Resources are available to assist in developing CHP Projects.

Contact your regional CHP TAP to:

- Perform CHP and WHP Qualification Screening for a particular facility
- Advanced Technical Assistance
- Identify existing CHP sites for Project Profiles
- ***SIGN UP for the July 1st Webinar to See How CHP TAPs Can Support your Work***

Q & A

Submit Questions
www.slido.com event code **#DOE**

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Part 2 of CHP Webinar Series

HOW TO IDENTIFY CHP PROJECTS THAT FIT YOUR GOALS

Thurs, July 1, 2021 | 1:00 – 2:00 PM ET

REGISTER TODAY

DOE experts will share how to identify candidate CHP projects opportunities, provide an overview of the CHP project development process, and complete a step-by-step screening analysis for CHP – a no-cost service provided to end-users through the DOE CHP Technical Assistance Partnerships (TAP) program. The webinar will also highlight the benefits CHP can provide your facility, from reducing operating costs and meeting decarbonization and sustainability goals to increasing your on-site resiliency.

Additional Questions?

Please Contact Us

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