State of the CHP Industry and Market Trends

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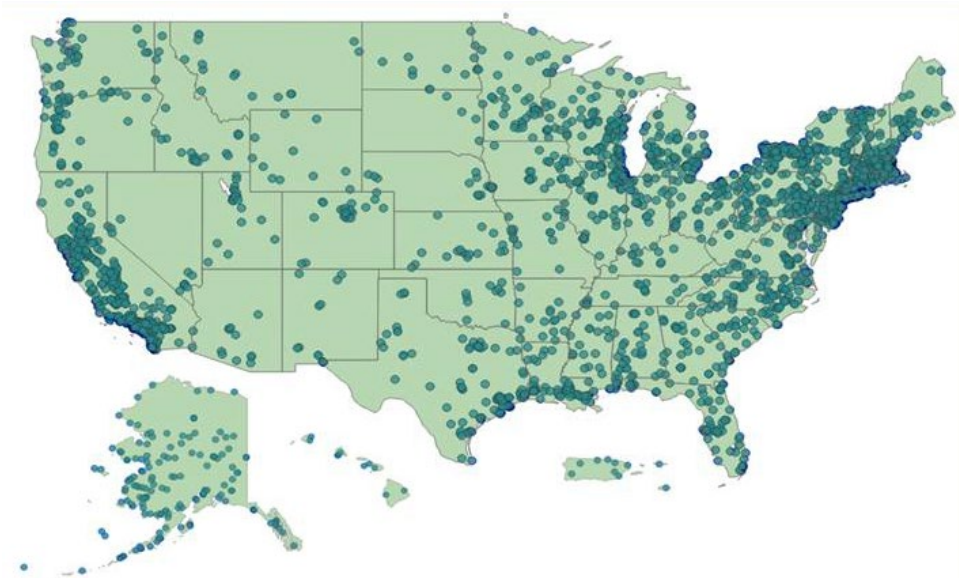
CHP Market Trends - Agenda

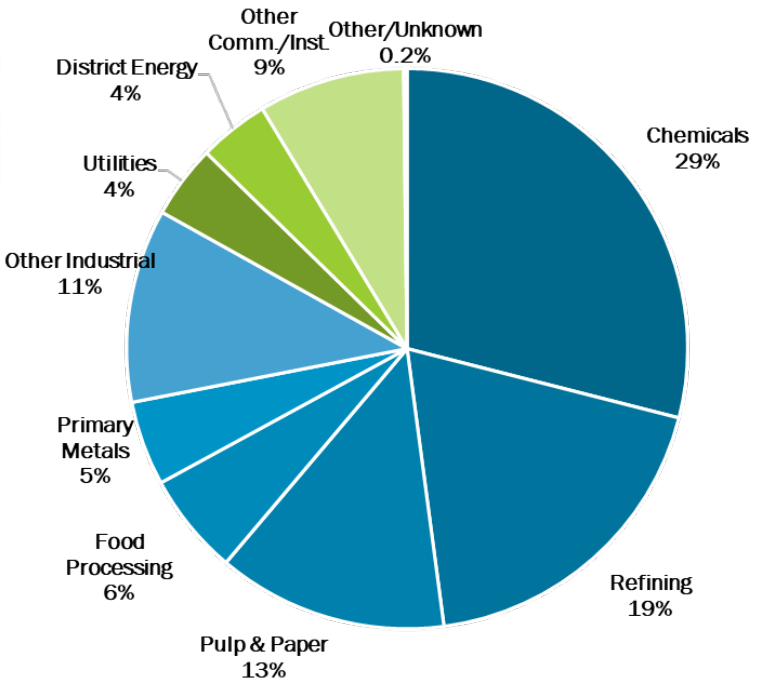
- Status of CHP today
- Growth of Non-traditional markets and packaged CHP systems
- Resilience as a driver for CHP
- CHP as an anchor for resilient microgrids
- Hybrid CHP
- Increased utility involvement in CHP
- Challenges

CHP Today in the United States

CHP Installations in the U.S.



Existing CHP Capacity

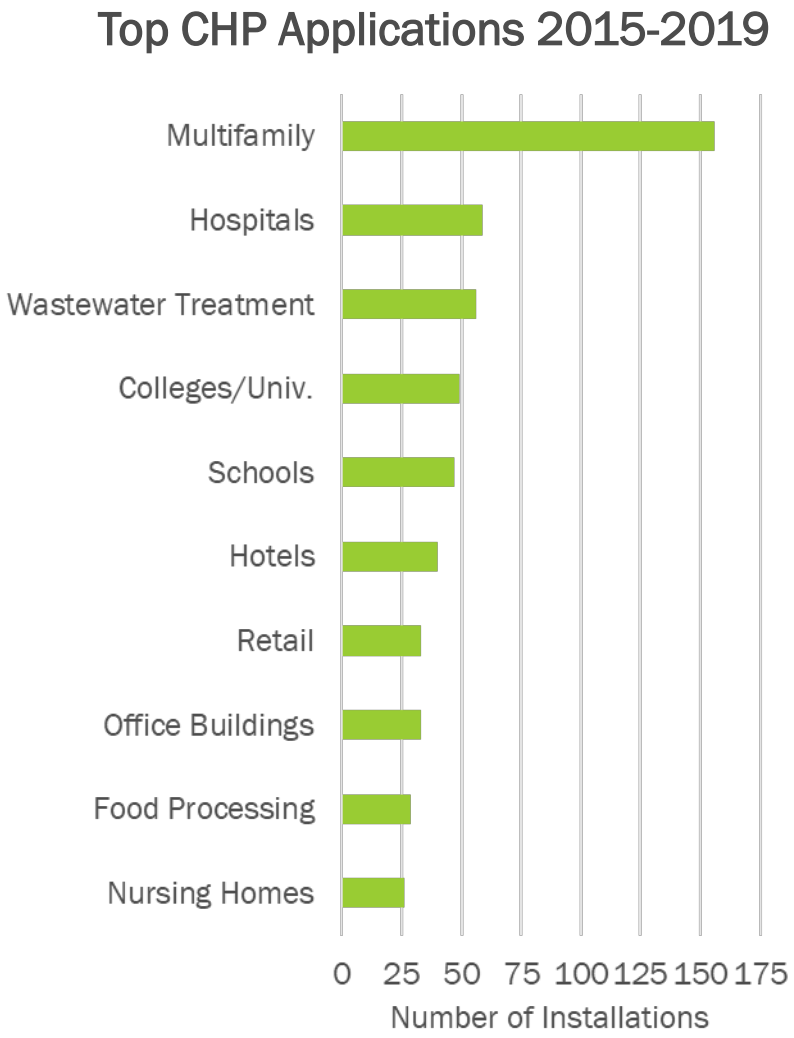


- 80.8 GW of installed CHP at more than 4,600 industrial and commercial facilities
- 7% of U.S. Electric Generating Capacity; 13% of Manufacturing
- 82% of existing CHP capacity is in industrial applications
- 72% natural gas fueled; 15% biomass, biogas, and municipal and process waste fueled

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

CHP Market Trends – The Last Five Years

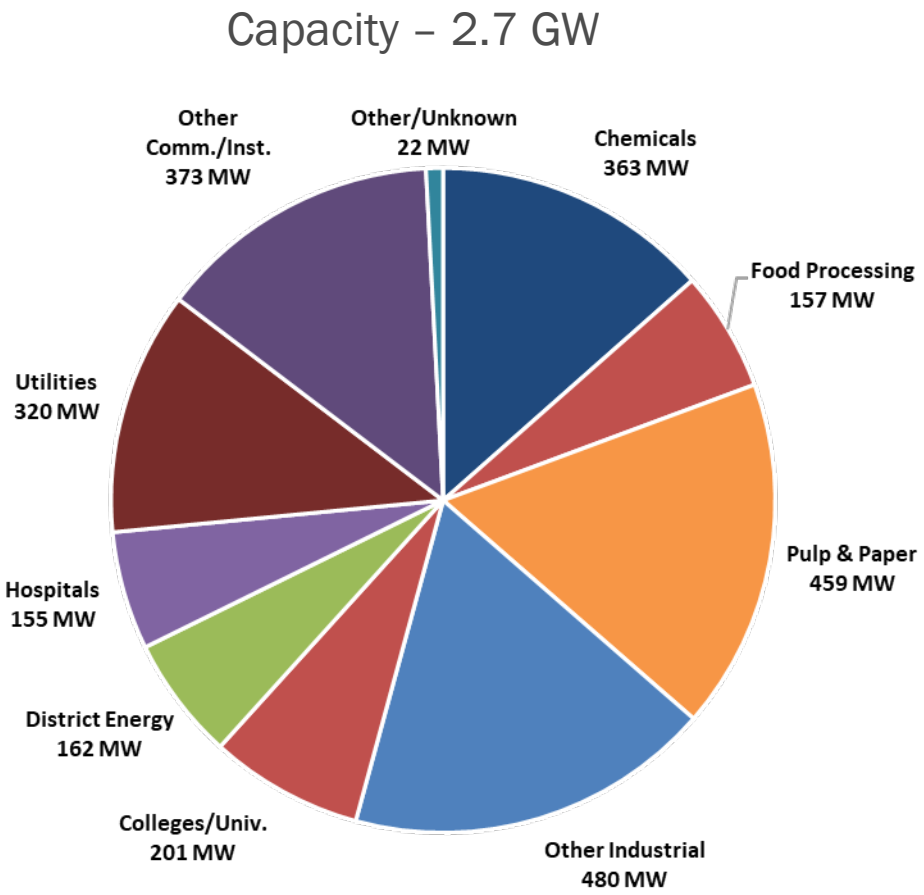
- Growing activity in non-traditional CHP markets (light industrial, commercial, institutional, multi-family) – 88% of installs
- Significant capacity continues to be installed in industrial applications – 55% of capacity
- Move toward smaller CHP installations - recip engines and microturbines make up 77% of installs
  - ✓ Increase in packaged CHP system offerings
- Natural gas continues to be the dominant fuel (77% of new capacity)
- Increasing interest in hybrid systems that integrated CHP with renewables and energy storage
- Prioritizing CHP for resilience with focus on critical infrastructure applications and microgrids



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

CHP Additions by Application (2015-2019)

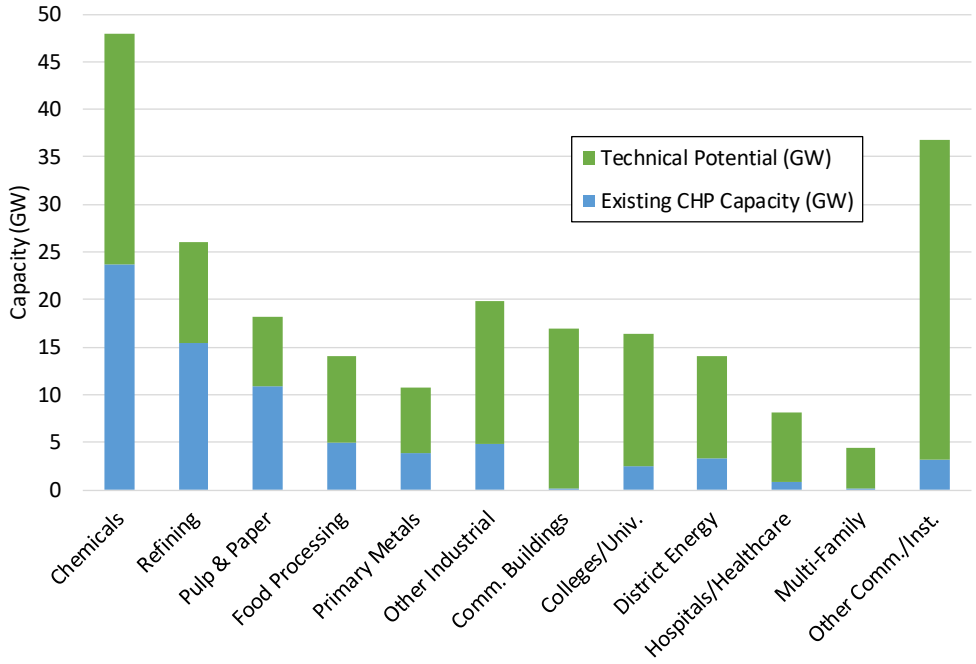
- Industrial applications accounted for 55% of installed capacity
  - 11 MW average project size
  - Gas turbines, recip engines
- Commercial/Institutional accounted for 45% of installed capacity
  - 1.8 MW average project size
  - Recip engines, microturbines, gas turbines



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

Packaged CHP System Markets are Growing

- Large CHP potential in small/midsized industrials, commercial, institutional, government and military applications
- Markets utilize smaller, packaged CHP systems (< 10 MW)
- Markets have limited CHP experience
- Users have limited technical resources
- History of issues with system performance and with CHP sales and service support

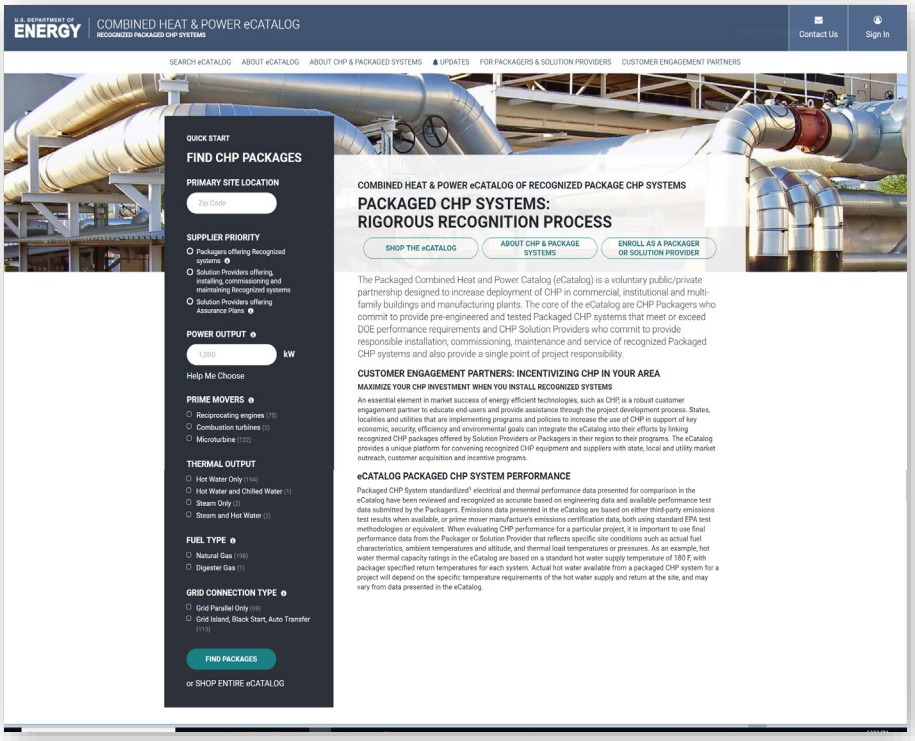


- Many perceived risks by both users and suppliers

Non-traditional markets represented 35% of the capacity and 70% of the projects installed since 2008

DOE Packaged CHP eCatalog

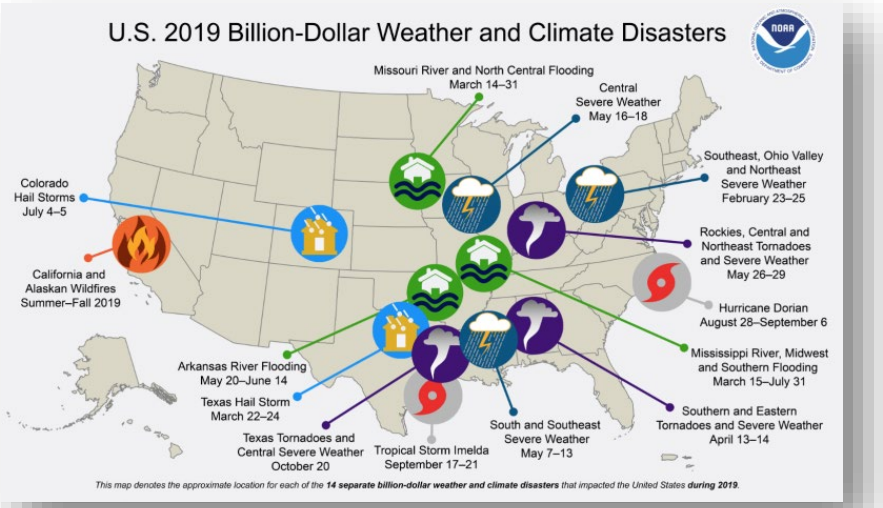
- A national web-based searchable catalog (*eCatalog*) of DOE-recognized packaged CHP systems and suppliers with the goal to **reduce risks for end-users and vendors** through partnerships with:
  - ***CHP Packagers and Solution Providers*** that assemble, install, commission and service packaged CHP systems
  - ***CHP Customer 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
- End-users and design engineers 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



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

CHP Provides Resilience/Reliability for Critical Infrastructure

- Higher reliability and power quality are needed to meet critical requirements
- Increased incidences of grid outages cause supply and production disruptions
- Consequences for health and safety of staff and clients, continuity of services, community support
- CHP can maintain power and heating/cooling during outages while providing financial benefits through operating savings every day



Source: NOAA

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	◓	○	◓	●	◓	○

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*

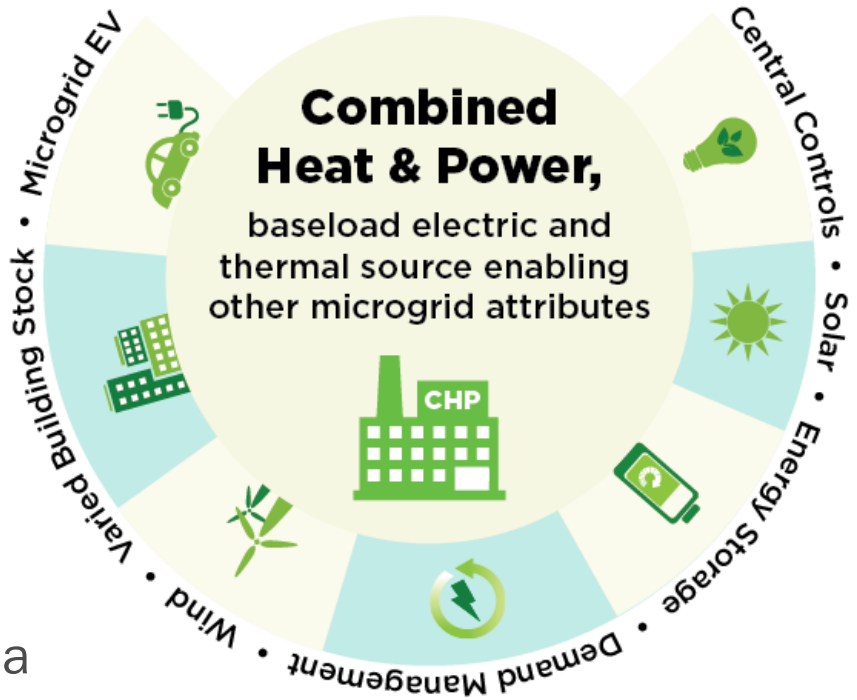
◓ *indicates the resource is likely to experience one, two, or three impacts*

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

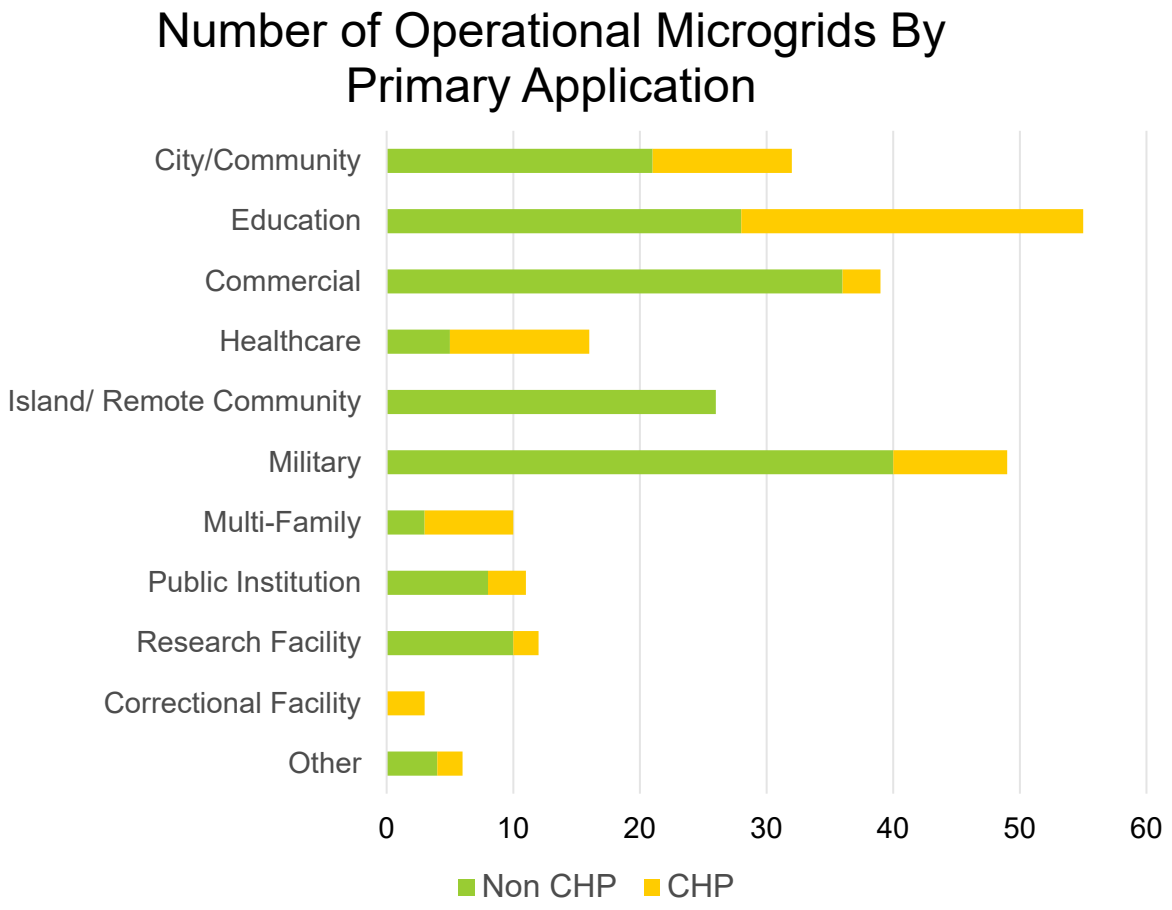
Source: https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/DER_Disaster_Impacts_Issue%20Brief.pdf

CHP as a Resilient Anchor for Clean Microgrids

- CHP provides efficient, resilient, baseload power and localized thermal energy
- CHP supports increased integration of renewable energy sources
- Storage adds additional flexibility and can help optimize CHP sizing and operation
- CHP supports the move toward a resilient, distributed, more renewable grid



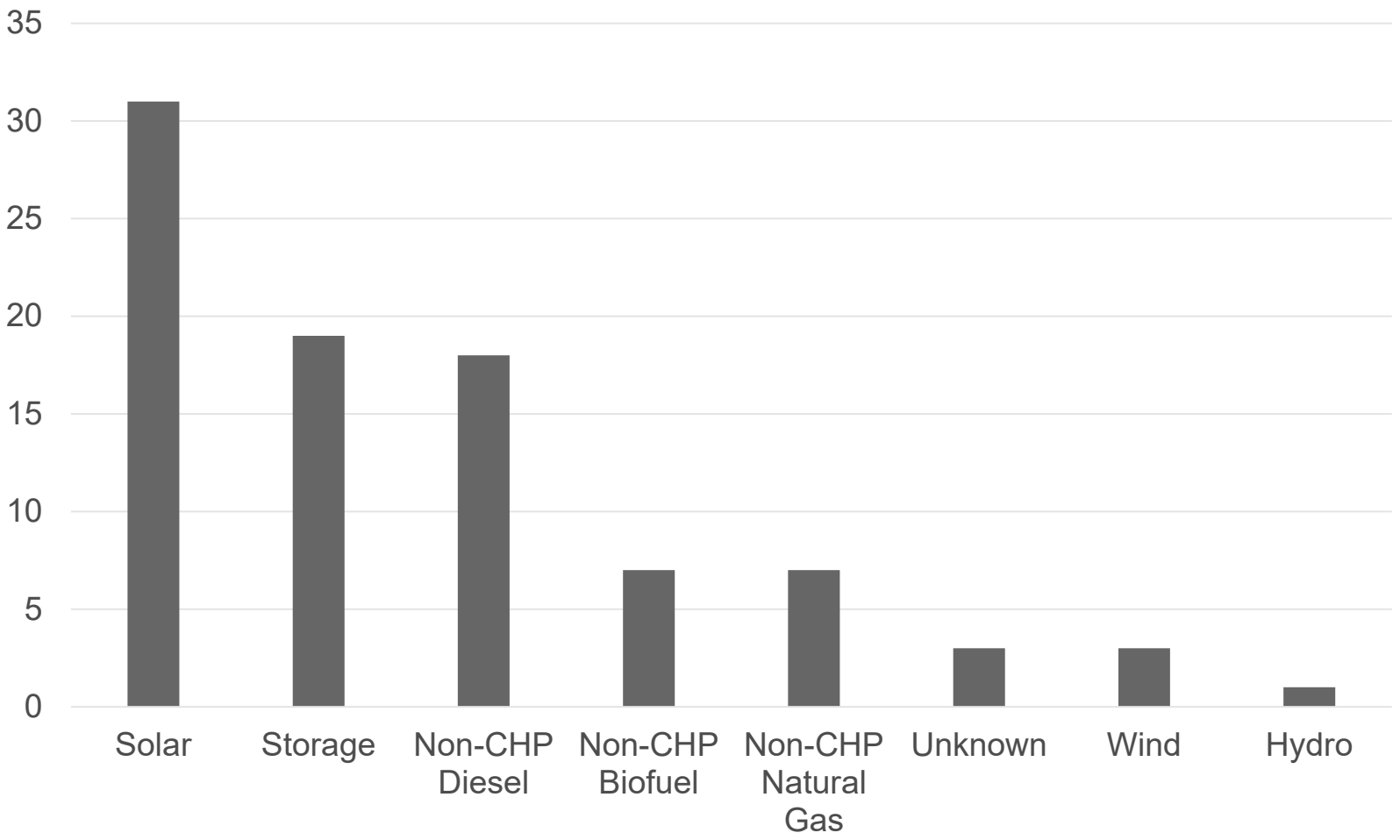
Number of U.S. Operational Microgrid Installations



- Currently **264** operating microgrid systems across the U.S.
- **84** operating microgrids are anchored with CHP systems
- Total operating microgrid capacity in the U.S. is **2.54** GW.

Source: ICF Microgrid Database (U.S. Installations as of August 28, 2020)

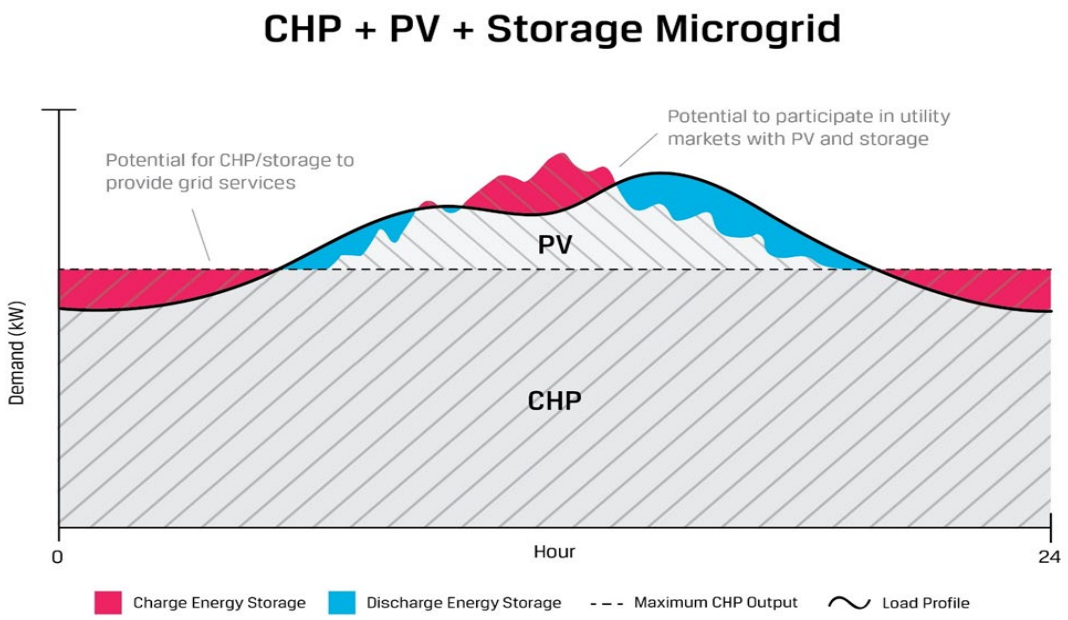
DER Technologies Paired with CHP in Microgrids



Source: ICF Microgrid Database (U.S. Installations as of August 28, 2020)

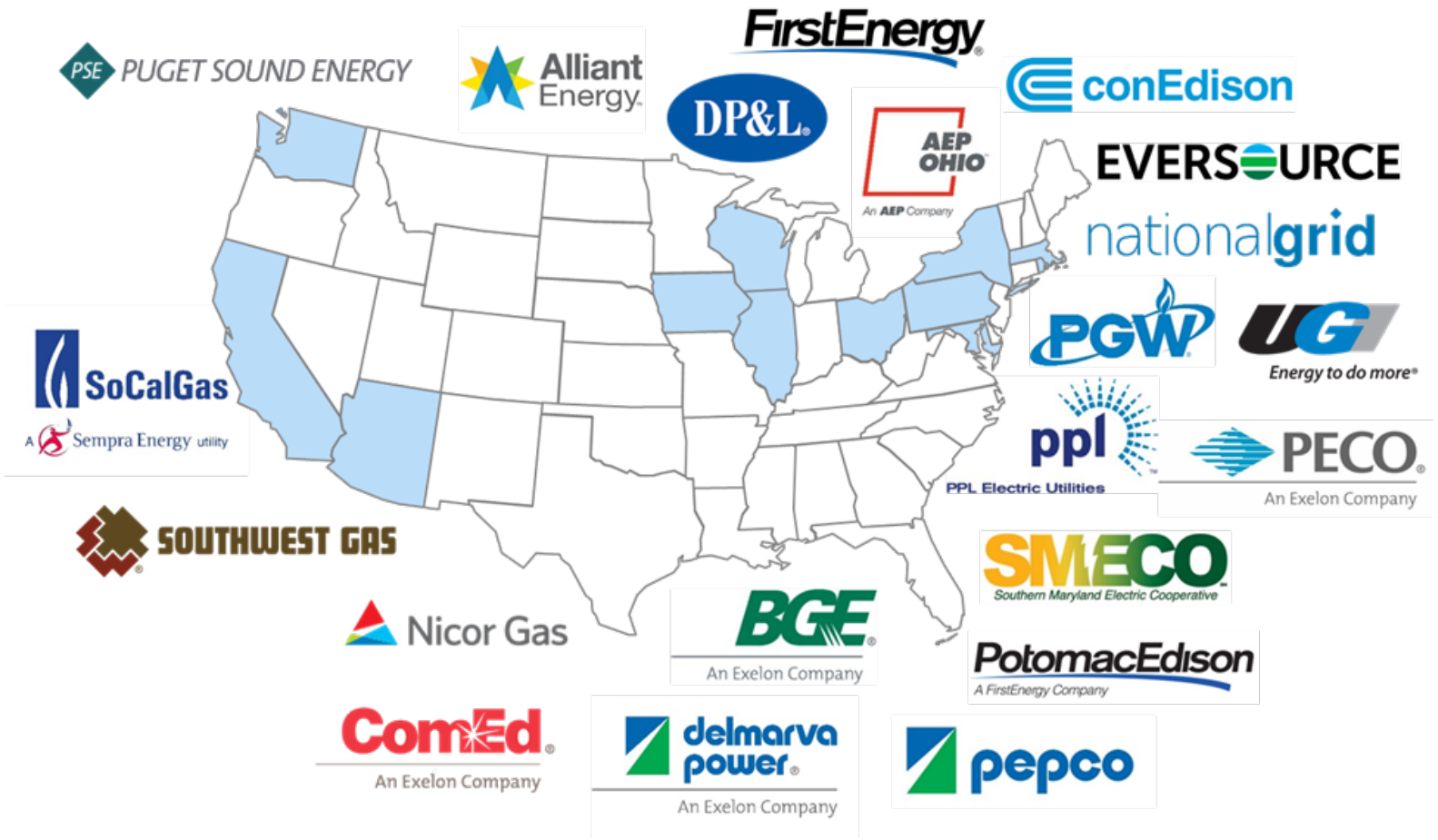
Hybrid solar + storage + CHP solutions

- An optimized combination of solar, storage, and CHP can provide long-duration, on-site energy for sites with high resilience needs with the least possible carbon emissions.
- Adding photovoltaic (PV) and storage lowers the required CHP size and further improves emissions compared to the grid.
- While CHP provides baseload power and thermal energy, PV can reduce grid demand and related emissions in peak hours, and storage can flexibly charge and discharge, helping to "firm" solar to meet peak site loads and avoid high demand or time-of-use charges.



Utility Interest in CHP is Growing

Location of utility CHP programs, 2020



Utility Ownership of CHP

The Ford Engineering & Research Center

Source: Ford Motor Company

Clemson University

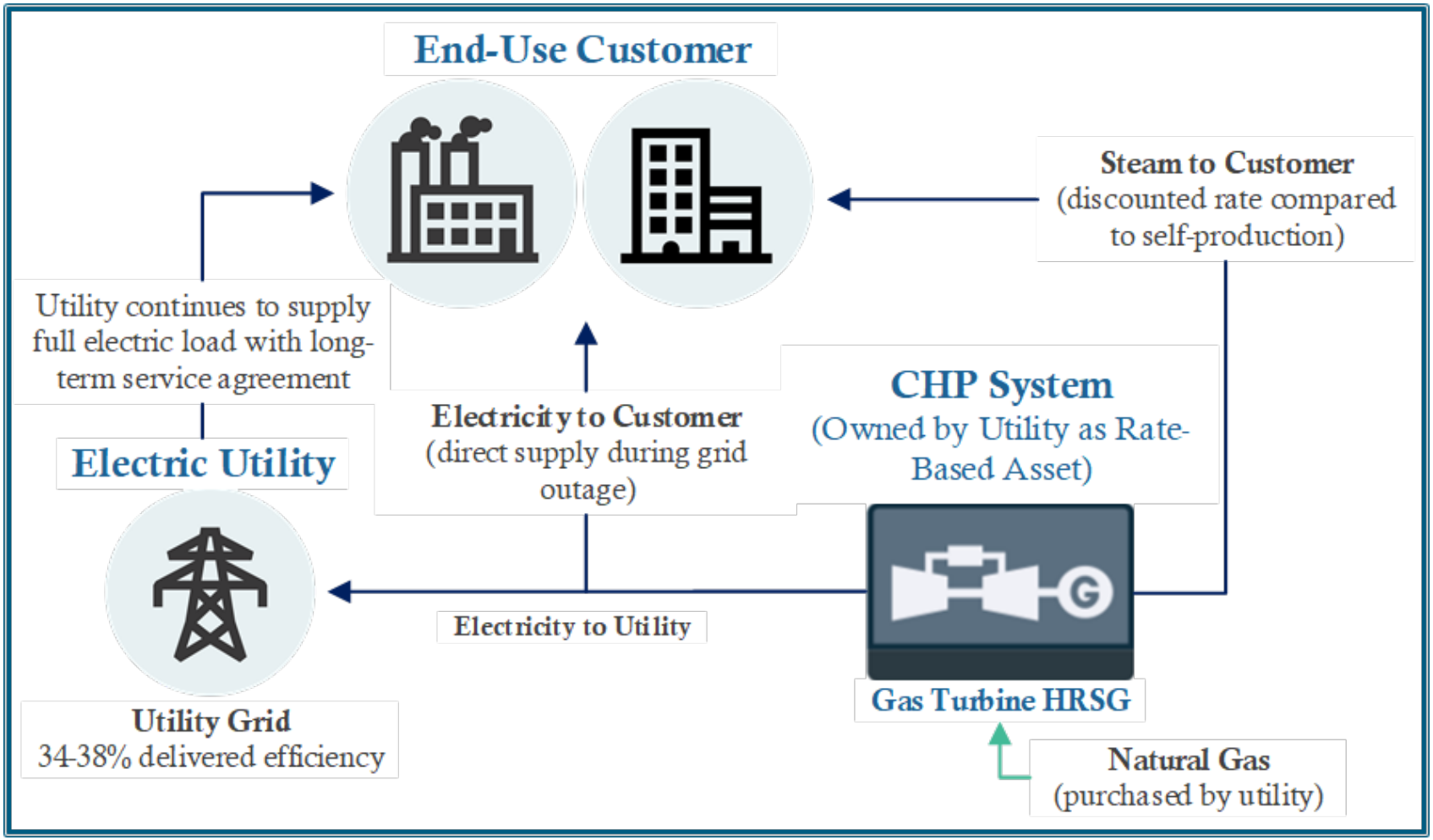
Source: Duke Energy

Purdue University

Source: Purdue University

	Dearborn, MI	Clemson, SC	West Lafayette, IN
Utility	DTE	Duke Energy	Duke Energy
Year	2019	2019	2022
Size	34 MW	15 MW	16 MW
Host Type	Research Campus	Campus/University	Campus/University
Host Name	Ford Motor Company	Clemson University	Purdue University
Term of agreement	30 years	35 years	35 years
Main drivers	Grid congestion, campus reliability and resilience	Campus energy system reliability and resilience	Campus energy system reliability and resilience
Regulatory oversight	Request for cost recovery approved	Cost recovery for thermal PPA approved	CPCN granted; request for cost recovery approved

Business Model Framework for Utility-Owned CHP

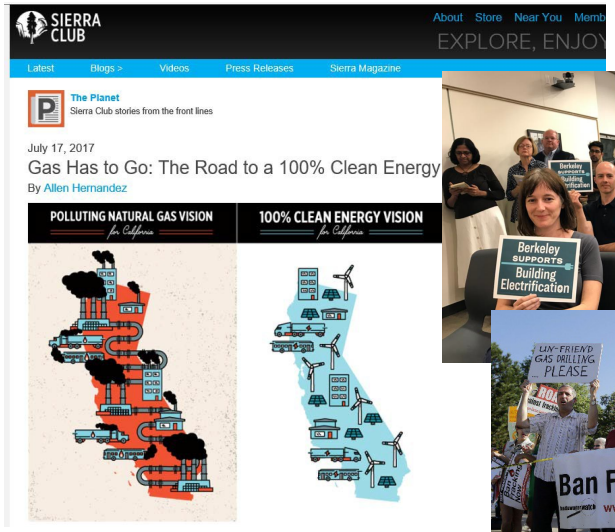


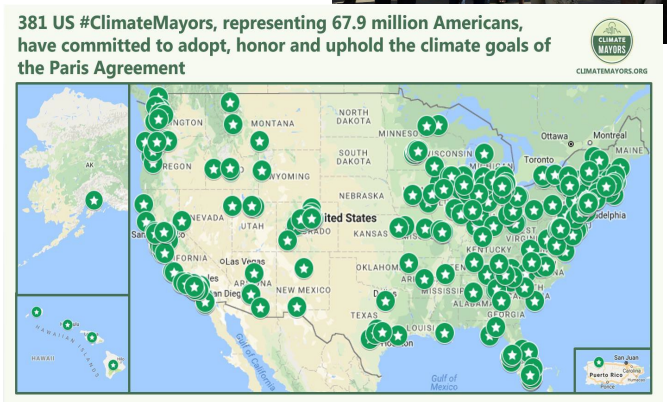
Challenges to CHP

- Lack of user awareness of CHP and benefits
- Project complexity and costs
- Integration with the grid
- Monetizing value of resilience
- Monetizing value of grid support
- What is the role of CHP in a decarbonized future

CHP, Natural Gas, and Decarbonization

- Decarbonization is a major policy topic in many states and cities
  - Aggressive CO_2/greenhouse (GHG) reductions - 40% by 2030 and 80% by 2050
  - Focus on economy-wide electrification to get to net zero carbon
- Major push against natural gas in some areas
  - 20 cities in California and others in the Northeast have banned natural gas in new construction
  - Efforts to stop investment in natural gas infrastructure
    - Pipelines
    - Natural gas CHP





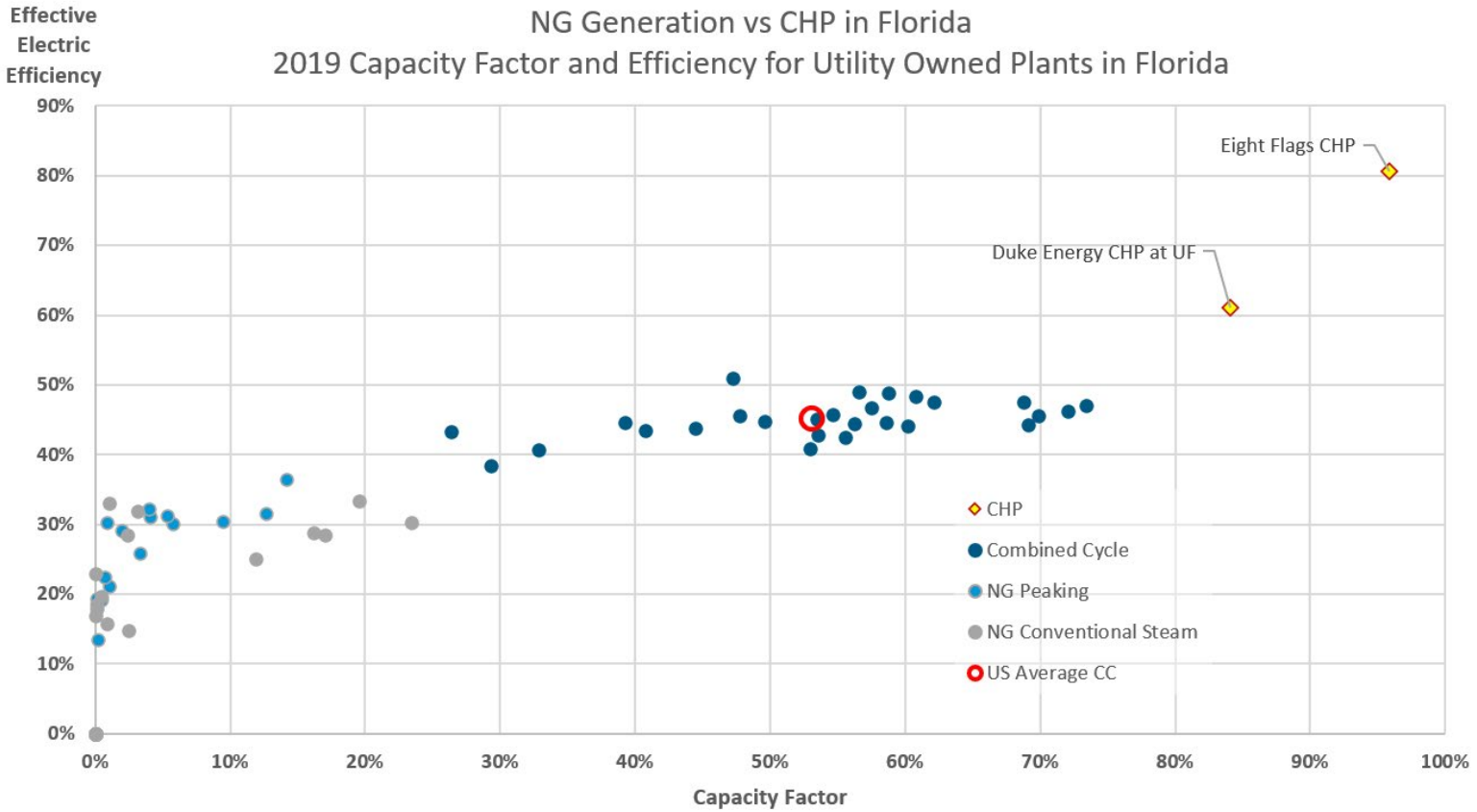
CHP's High Efficiency Provides Savings Today

- CHP and renewables generally displace marginal grid generation (including T&D losses)
- Marginal generation is currently a mix of coal and natural gas in most regions of the country
- Natural gas CHP's high efficiency and high annual capacity factor results in energy and emissions savings on par with PV and wind

Category	10 MW CHP	10 MW PV	10 MW Wind	10 MW NGCC
Annual Capacity Factor	85%	26.1%	37.4%	57.6%
Annual Electricity, MWh	74,460	22,864	32,762	50,458
Annual Useful Heat Provided, MWh_{th}	97,505	None	None	None
Annual Energy Savings, MMBtu	**265,086**	**203,042**	**290,950**	**115,074**
Annual CO_2 Savings, Tons	**33,533**	**17,159**	**24,501**	**18,403**
Annual NOx Savings, Tons	38.5	12.5	17.9	26.0

Savings based on EPA eGRID Non-Baseload Generation as a first level estimate of displaced marginal generation

CHP's Efficiency Advantage over Central Station Generation



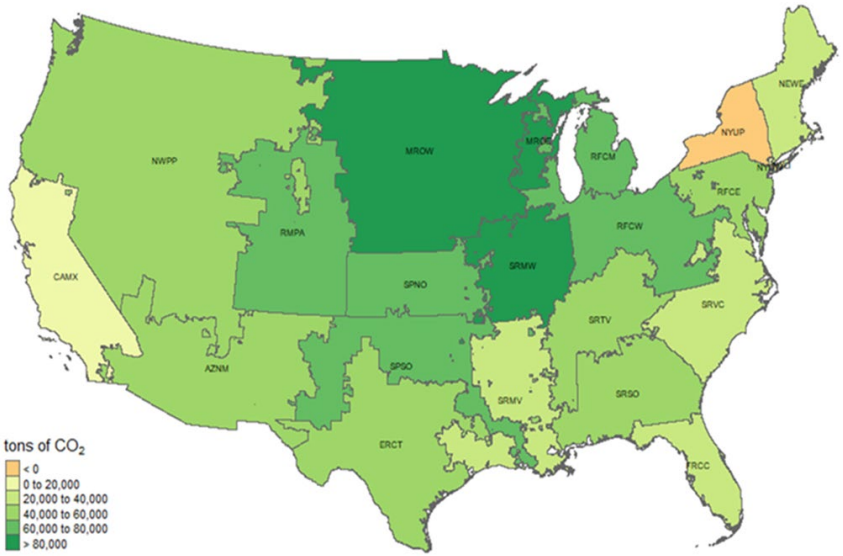
Notes:

- All combined cycle data based on reports DOE EIA-960 and EIA-923 for 2019. All data and efficiency calculations based on HHV.
- Duke Energy owned 45 MW CHP at UF capacity factor based on EIA-960 and EIA-923, and verified by 2018 operating data. The LM6000 driven plant installed in 1992, still utilizes steam injection for N0x control which impacts overall efficiency
- Capacity factor and efficiency for Eight Flags CHP based on actual operating data provided for calendar year 2019. Unit was also uprated during Feb 2019 outage to 21.5 MW net.
- Effective electric efficiency accounts for grid losses and includes a credit for the displaced thermal fuel for CHP.
- Per EPA eGRID 2020 (2018 data), total grid losses for central station plants in FL is 4.88%, US average is 4.87%. Losses associated with CHP of 2.44% due to proximity of generation to point of consumption.

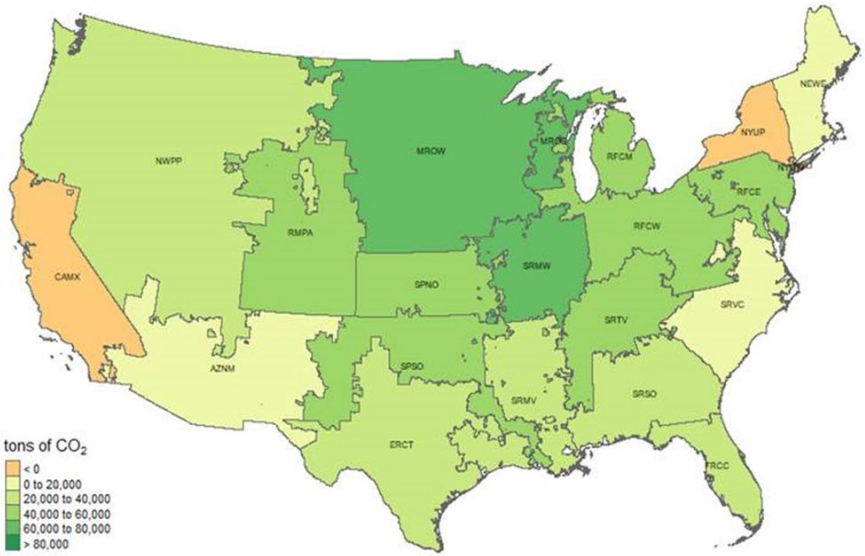
Compiled by: Sterling Energy Group, LLC

Lifetime Carbon Emission Reductions for CHP Systems

2020-2035



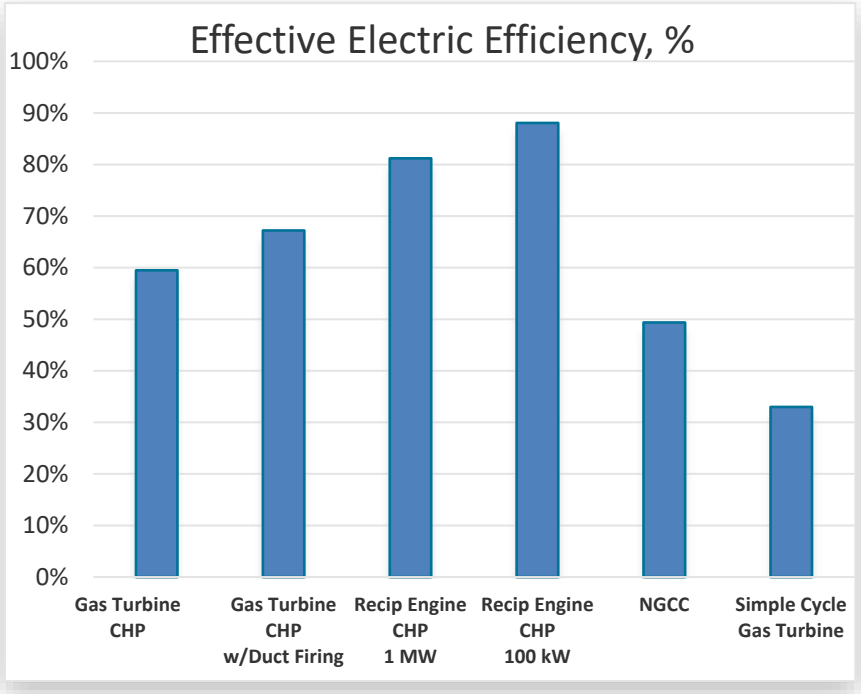
2035-2050



- CHP will continue to reduce emissions in most U.S. locations through 2050
- Emission reduction potential depends on location and timing
- For states with 100% clean/renewable energy mandates, CHP will become a net emitter as the grid goes green, but *timing is uncertain*
- CHP can play a strong role in decarbonization efforts across most of the country while also providing resilience benefits

CHP as a Path to a Long Term Solution?

- CHP is the most efficient way to generate power with a fuel. CHP has higher efficiency and lower net GHG emissions than marginal natural gas generation. As the electric grid decarbonizes, marginal generation will continue to be served by natural gas in the near to mid-term
- CHP technologies currently use renewable fuels, low carbon waste fuels, and hydrogen mixtures where available, and will be ready to use higher levels of renewable natural gas (RNG) and hydrogen as the natural gas infrastructure decarbonizes
- Distributed, dispatchable CHP can help support greater integration of renewables in the distribution grid, microgrids, and individual facilities, while enhancing energy resilience and security
- RNG/hydrogen fueled CHP can decarbonize facilities that need dispatchable on-site generation for resilience and industrial processes that will be difficult to electrify



Source: DOE CHP Deployment Program

Questions

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