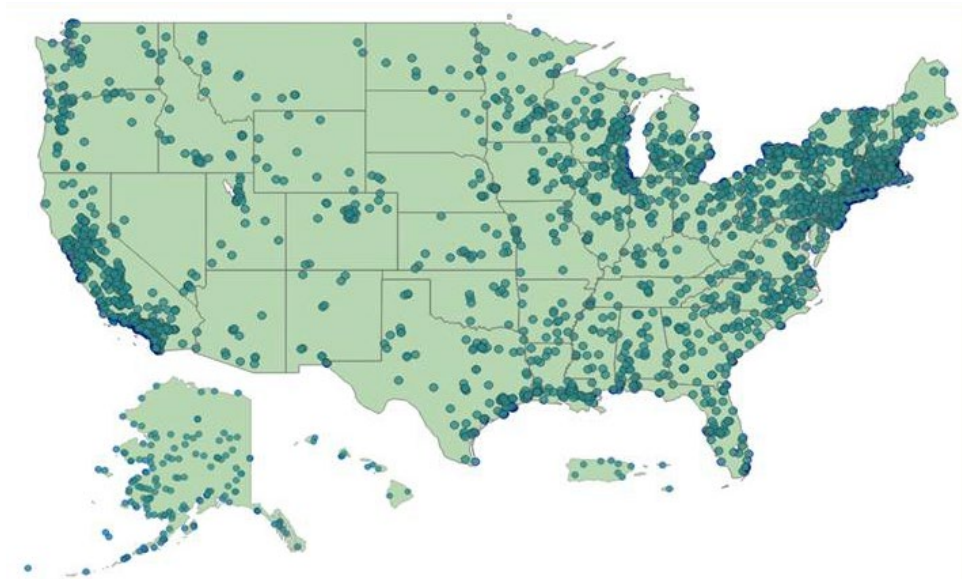
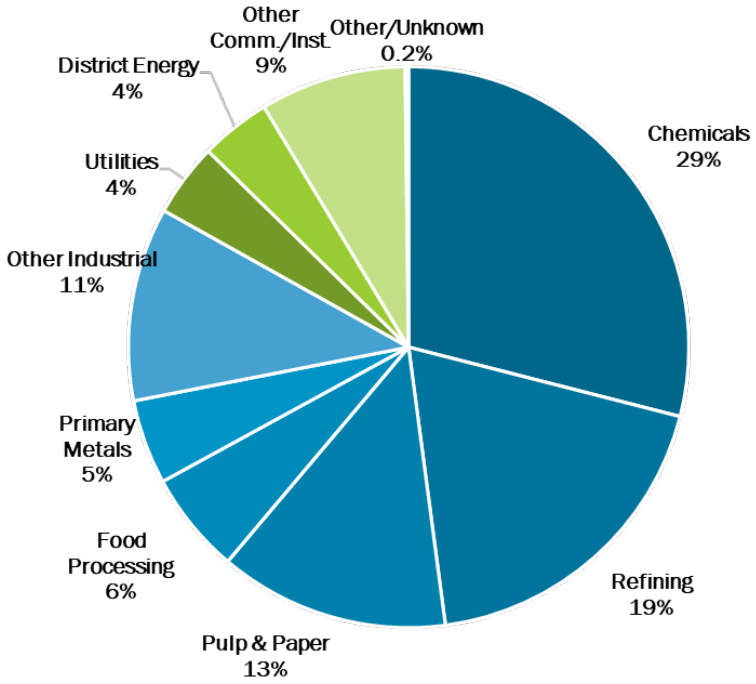
CHP TODAY IN THE UNITED STATES

CHP Installations in the U.S.



Existing CHP Capacity

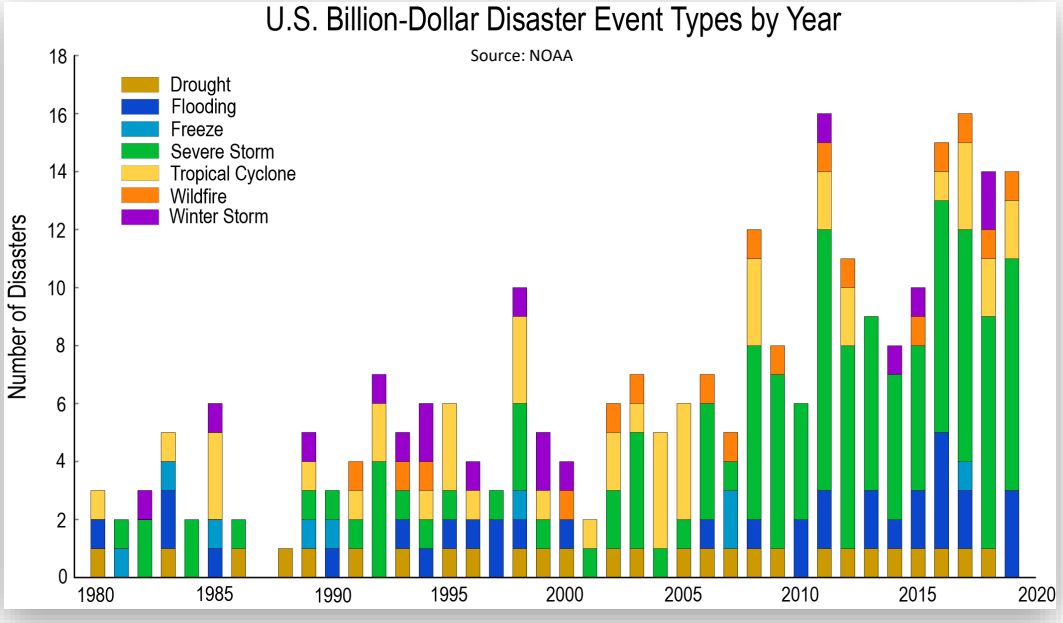


- 80.8 GW of installed CHP at more than 4,600 industrial and commercial facilities
- 7% of U.S. Electric Generating Capacity; 13% of Manufacturing
- 82% of existing CHP capacity is in industrial applications
- 72% natural gas fueled; 15% biomass, biogas, and municipal and process waste fueled

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

CHP PROVIDES RESILIENCE/RELIABILITY FOR CRITICAL INFRASTRUCTURE

- Higher reliability and power quality are needed to meet critical requirements
- Increased incidences of grid outages cause major 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



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*

https://betterbuildingsinitiative.energy.gov/accelerators/combined-heat-and-power-resiliency

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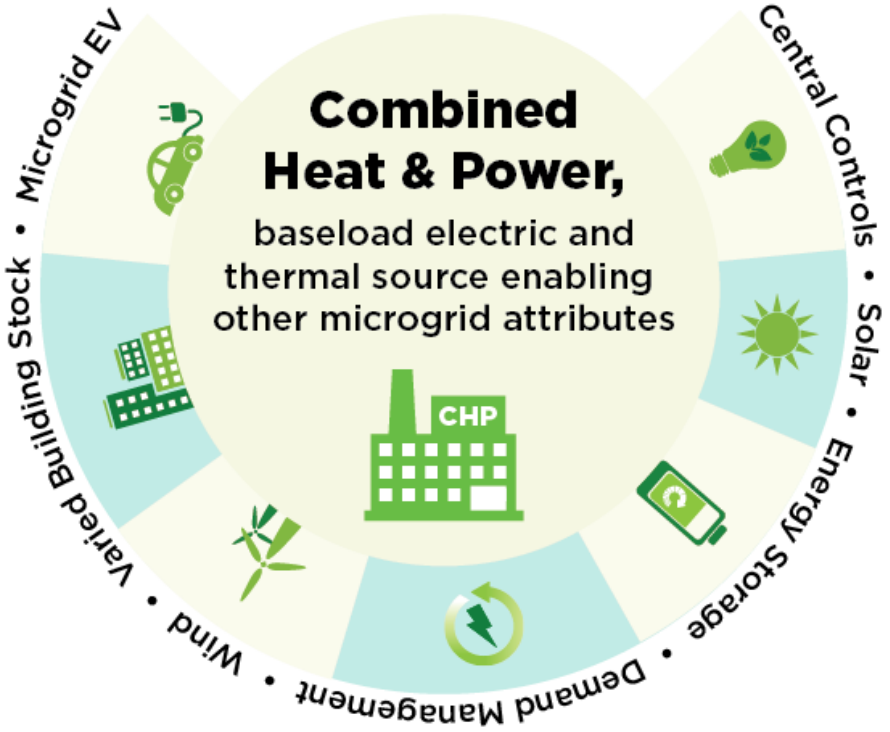
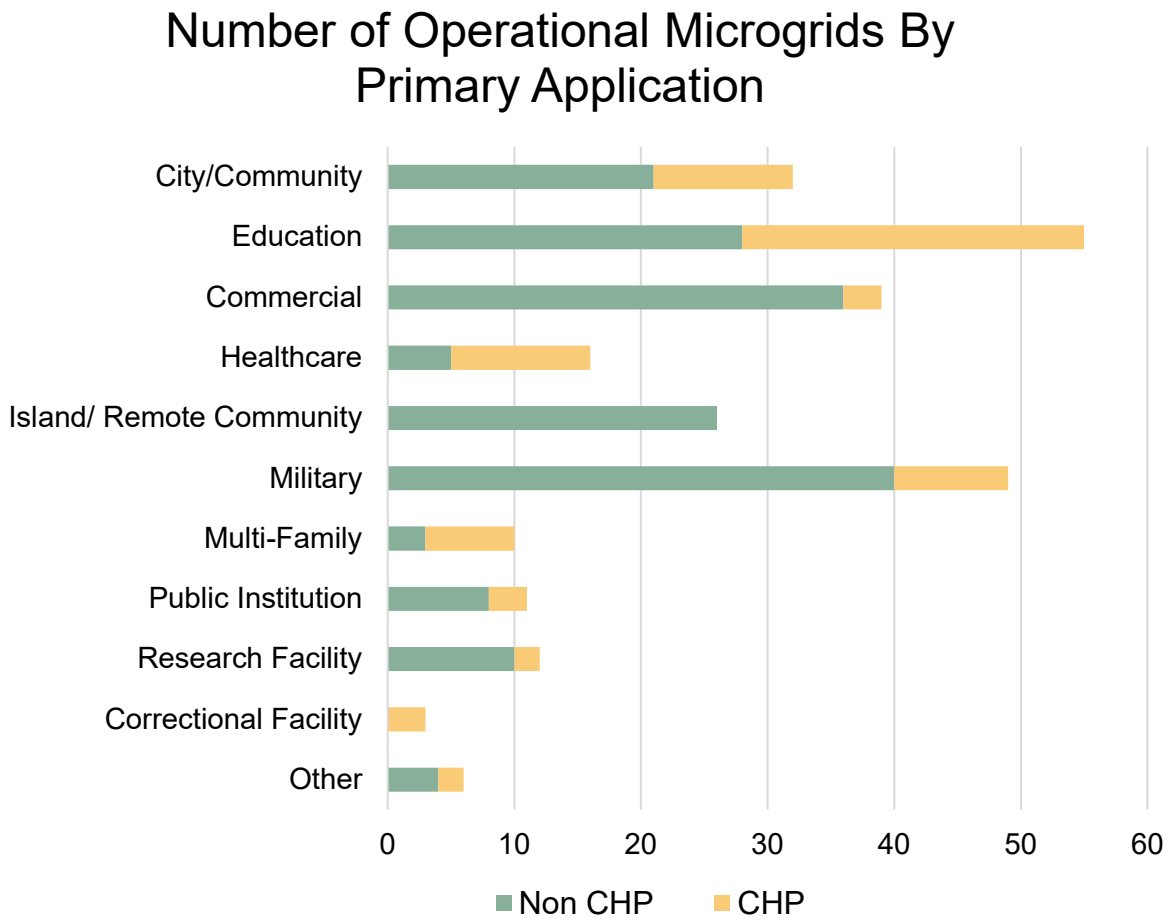
CHP AS A RESILIENT ANCHOR FOR CLEAN MICROGRIDS

- 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



OPERATIONAL MICROGRID INSTALLATIONS IN THE U.S.

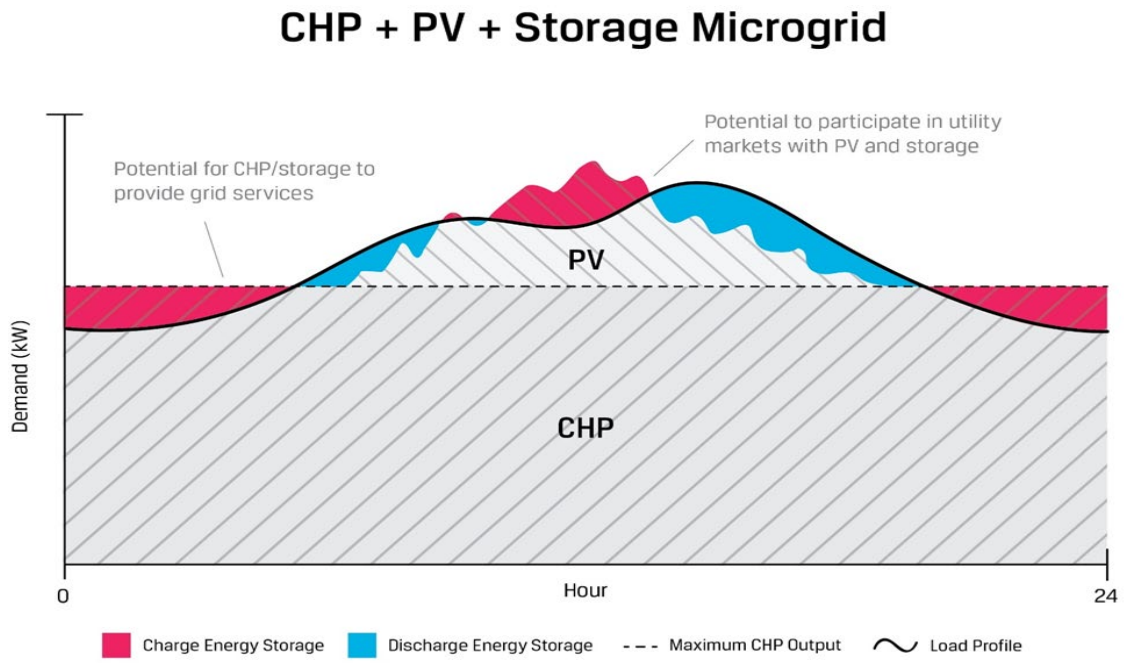


- Currently **264** operating microgrid systems across the U.S.
- **84** operating microgrids are anchored with CHP systems
- Total operating microgrid capacity in the U.S. is **2.54** GW

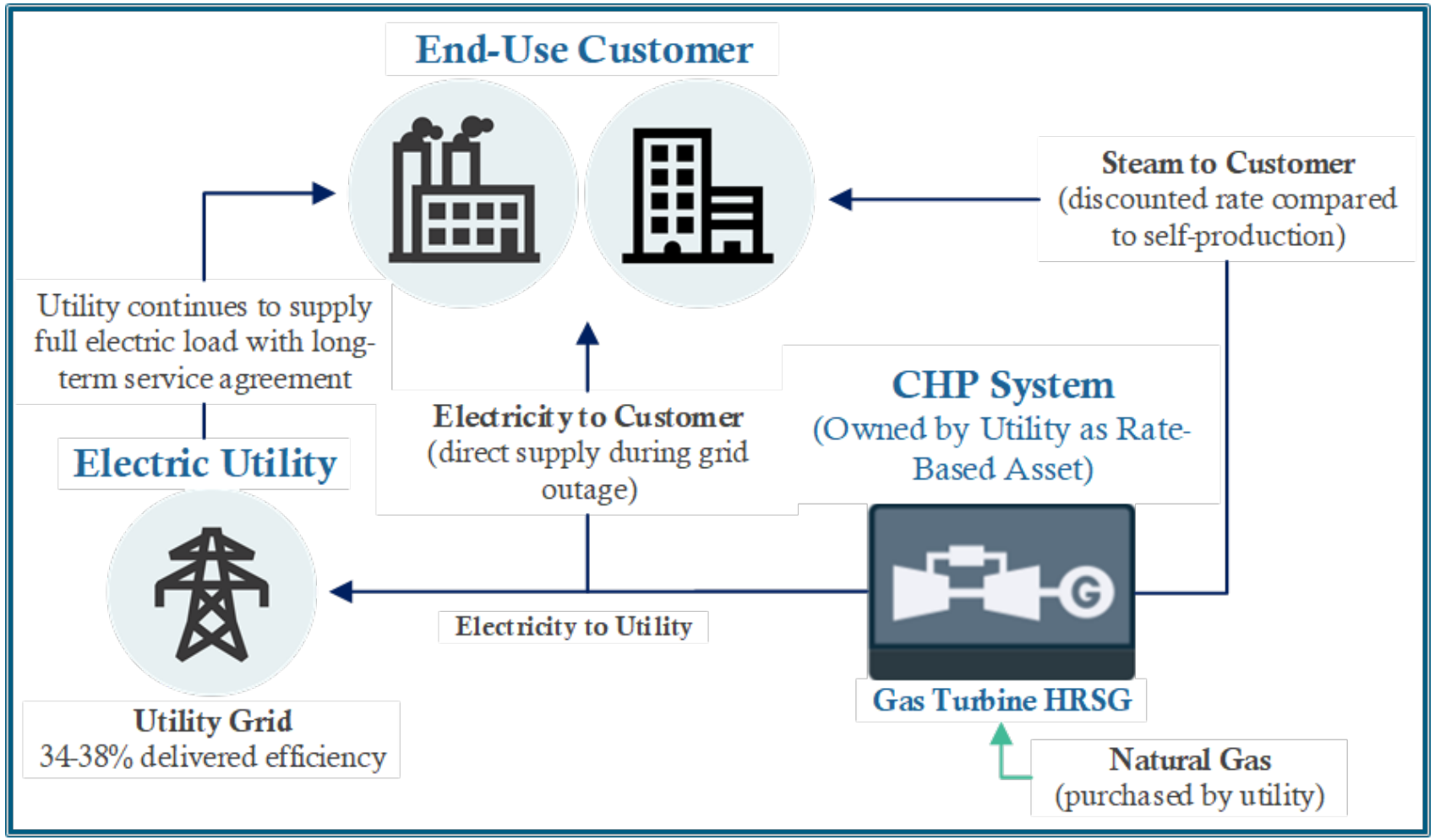
Source: ICF Microgrid Database (U.S. Installations as of August 28, 2020)

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
- 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
- Adding photovoltaic (PV) and storage lowers the required CHP size and further improves emissions compared to the grid



BUSINESS MODEL FOR UTILITY-OWNED CHP

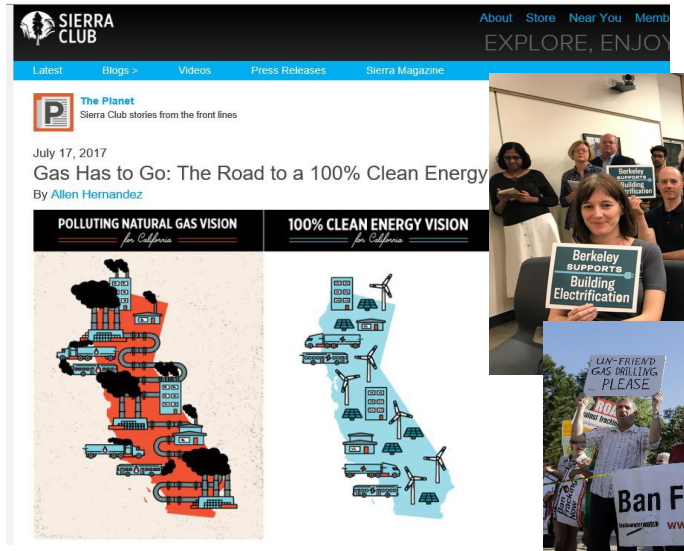


CHALLENGES

- Lack of awareness of CHP and benefits
- Project complexity and costs
- Interconnection/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

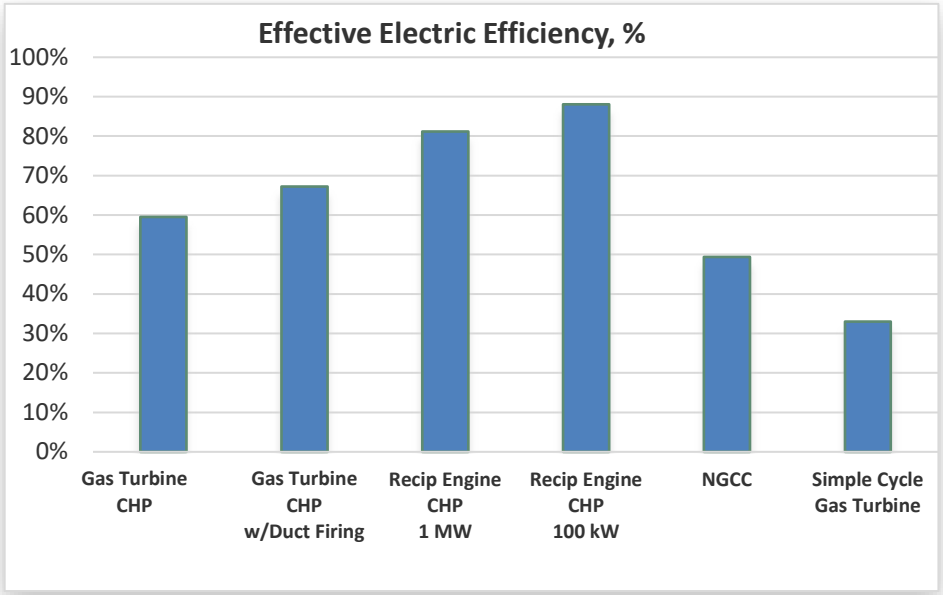
- CHP and renewables generally displace marginal grid generation (including T&D losses)
- Marginal generation is currently a mix of coal and natural gas in most regions of the country
- Natural gas CHP's high net electric efficiency and high annual capacity factor result in energy and emissions savings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

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

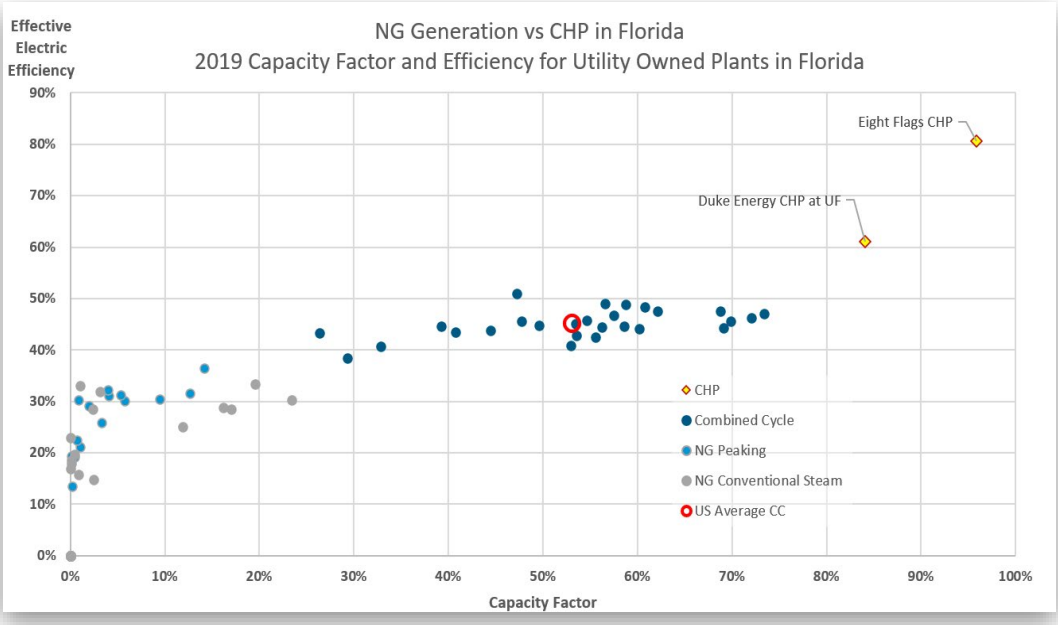
Savings based on EPA eGRID Non-Baseload Generation as a first level estimate of displaced marginal generation

CHP IS THE MOST EFFICIENT USE OF NATURAL GAS

CHP systems have higher effective generation efficiency than marginal natural gas generation due to thermal energy recovery and elimination of T&D losses



Source: DOE CHP Deployment Program



Source: Sterling Energy LLC

CHP's higher annual capacity factors generates additional energy and emissions savings compared to central station marginal generation

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CHP CAN BE PART OF THE LONG-TERM SOLUTION

- As the electric grid decarbonizes, marginal generation will continue to be served by natural gas in most areas of the country. CHP is the most efficient way to generate power with natural gas.
- 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 in the future.
- CHP can support the transition to a low carbon economy by enabling greater integration of renewables in the distribution grid, microgrids, and individual facilities, while helping businesses adapt to changing conditions by enhancing energy resilience and security
- CHP's efficiency, emissions, flexibility and resilience advantages will remain as the natural gas infrastructure decarbonizes
- CHP can ultimately be carbon free by using RNG/hydrogen and/or carbon capture - CHP can decarbonize thermally based industrial processes and facilities that rely on on-site generation for resilience