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Beneficial CHP – Is that a Thing? Considering CHP in the Context of Beneficial Electrification

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ABSTRACT

For decades, combined heat and power (CHP) has been promoted and embraced as a cost-effective technology for meeting on-site thermal and electric needs more efficiently and with fewer emissions than separate procurement of those resources. But climate change concerns are leading to a reevaluation of CHP's benefits. Significantly, natural gas, the most common fuel for CHP and until recently regarded as an environmentally preferable "bridge fuel" in the energy transition to renewables, is increasingly being reexamined amid calls for deep decarbonization and emerging clean energy policies that limit the use of natural gas. Given this trend, electrification has gained traction as a net zero carbon energy strategy. With natural gas being a preferred fuel for CHP, policymakers and others are beginning to question CHP's role in a cleaner, more electrified future.

However, CHP fueled by low carbon fuels such as renewable natural gas and hydrogen may be a more viable path to decarbonizing industrial processes that are difficult to electrify due to technology limitations or cost, and for applications where energy resilience is a critical requirement. This paper seeks to add clarity to a complex issue. It offers a framework for assessing industrial applications where natural gas CHP will provide significant GHG reductions in the near term and provide a more economic and practical path to deep decarbonization in the long term through a transition to low carbon fuels.

INTRODUCTION

Combined heat and power (CHP), also referred to as cogeneration, is a technology-neutral and fuel-flexible practice that has long been used by industry to provide reliable heat and power with high efficiency and low emissions. On-site CHP systems recover the heat normally lost in power generation and provide this as useful thermal energy (steam, hot water, hot air and/or cooling) to the industrial process. Historically, the combined generation of electricity and thermal energy at the point of use has resulted in significant carbon dioxide (CO_2) emissions reductions by displacing fossil fuel emissions from central station generation, while enhancing energy efficiency and reliability for industrial and commercial users.

In a deeply decarbonized economy where grid emissions are greatly reduced, CHP systems can still retain an emissions and efficiency advantage through the use of low- to zero-carbon fuels such as renewable natural gas (RNG) and hydrogen[1]. As industrial needs for heat and power evolve on the path to a low-carbon future, the ways that CHP can support those needs will also evolve. The value provided by CHP will include reducing energy use and GHG

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[1] Hydrogen is often classified as grey (produced from natural gas reforming), blue (produced from natural gas with carbon capture), or green (produced from renewable resources). Blue hydrogen can be considered low-carbon and green hydrogen is a zero-carbon fuel.

emissions in the near term, supporting fuel flexibility and efficiency over the longer term, providing energy reliability and resilience to critical infrastructure, and serving as a flexible and efficient low- to no-carbon resource for future power and thermal needs.

Deep decarbonization of the economy is likely to rely on the combination of using low- to zero-carbon fuels and conversion of end-use applications to zero-carbon electricity. Electrification of end use sectors will require an unprecedented expansion of zero-carbon generation to replace both existing power generation and to power direct on-site energy uses now based on fossil fuels. The transition to deep decarbonization will also require large investments in expanded electric transmission and distribution capacity and in back-up and grid stabilizing support infrastructure to ensure operational reliability. Low- to zero-carbon fuels such as RNG and hydrogen can eventually be used to provide required grid regulation services, and CHP's high efficiency can deliver these same services using less fuel and extending the resource base of these emerging fuels. CHP based on low- and zero-carbon fuels can also support the integration of non-dispatchable renewable resources such as solar photovoltaics (PV) and wind by providing reliable, resilient power and long-duration back-up services to the grid and individual users.

Much of the current focus on end use electrification has been on the conversion of the residential, commercial and transportation sectors. Several studies have noted that electrifying the industrial sector will be more challenging and many industrial applications, particularly processes that require high pressure steam and high temperature direct heat, will be difficult and/or costly to electrify. Renewable and zero-carbon fuels such as RNG and hydrogen can be an alternative low carbon path for these thermally-based processes but will initially be limited in supply. High value will be placed on maximizing efficient utilization of these resources, and CHP is the most efficient way to provide required energy services with the least use of limited renewable fuel resources.

Renewable and low to no carbon fuels will include RNG, hydrogen and biogas/biomass (the latter already used in many CHP installations). RNG is biogas that has been upgraded to commercial natural gas specifications for injection into the existing natural gas pipeline infrastructure and is produced at landfills, through anaerobic digestion at wastewater treatment plants, agricultural operations, food processors and animal feed lots, and from gasification of biomass. As a renewable resource, RNG is considered carbon-neutral overall and can be used as a direct replacement of natural gas in current CHP equipment and systems. Hydrogen has long been used as a fuel for CHP either in natural gas/hydrogen mixtures or in pure gaseous form where available and is expected to be a key long term low to zero-carbon energy option. Most gas turbines and natural gas engines available today can operate on hydrogen mixtures ranging 10 to 40% depending on the manufacturer and model. All major turbine and engine manufacturers are on track to have 100% hydrogen compatible systems commercially available by 2030 or earlier.

Historically, the value of CHP to industrial and commercial users has been the economic value of efficiency and resilience. In the transition to a decarbonized grid, renewable-fueled CHP can be a cost-effective alternative to expensive process conversions to electric technologies, representing an economically viable path to zero-carbon that requires the least disturbance to existing operations. Renewable/hydrogen-fueled CHP can decarbonize thermal end-uses in industrial and commercial facilities that are difficult to electrify and critical operations that need dispatchable on-site power for long duration resilience and reliability. At the same time, CHP's inherent efficiency advantage serves to further extend the resource base of emerging renewable fuels.

CHP IN A BROADER CONTEXT

CHP has long been used by industry and commercial/institutional users to provide reliable heat and power with high efficiency and low emissions. The energy and GHG savings benefits of CHP are found in the aggregate reduction in overall energy consumption: CHP replaces both a separate on-site thermal system (e.g., furnace or boiler) and purchased electricity with a single, integrated system that efficiently produces both thermal energy and electricity at the point of use. Industrial CHP systems can provide needed energy services with overall energy efficiencies of 75% or more compared to separate production of heat and power, which collectively averages 45 to 55% system efficiency (DOE 2017). CHP also avoids the transmission and distribution (T&D) losses associated with electricity purchased via the grid, including power from utility-scale renewables.

The 80.8 gigawatts (GW) of existing industrial CHP deployed at over 4,600 industrial plants and commercial businesses in the United States (U.S.) currently saves an estimated 1.7 Quads of fuel and 232 MMT of CO_2 emissions annually (DOE 2020). Industrial applications represent 86 percent of existing CHP capacity, employed in industries with high process thermal demands such as chemicals, refining, pulp and paper and food processing as shown in Figure 1 (DOE 2021). Use of CHP has been growing in commercial and institutional applications, and CHP is particularly valued for providing resilient heat and power to critical infrastructure such as hospitals, universities, military facilities and data centers.

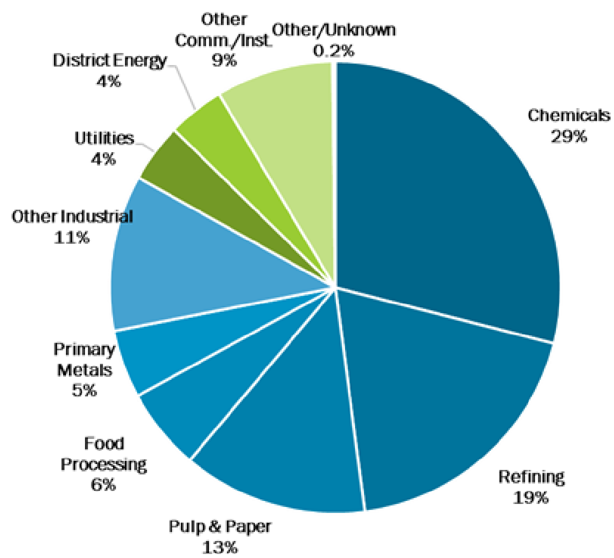


Figure 1. Existing CHP Capacity by Application, *Source:* DOE 2021

CHP IN THE INDUSTRIAL SECTOR

CHP is widely used at industrial facilities across the U.S. There are currently over 1,700 operational CHP systems at industrial sites across all 50 states, Washington, D.C., Puerto Rico, and the Virgin Islands, as seen in Figure 2. These installations provide 68 GW of electric capacity for the industrial sector. Much of this capacity comes from large power-exporting CHP installations at chemical plants, pulp and paper mills, and other large industrial sites. Figure 3 shows the breakdown of industrial CHP installations by application.

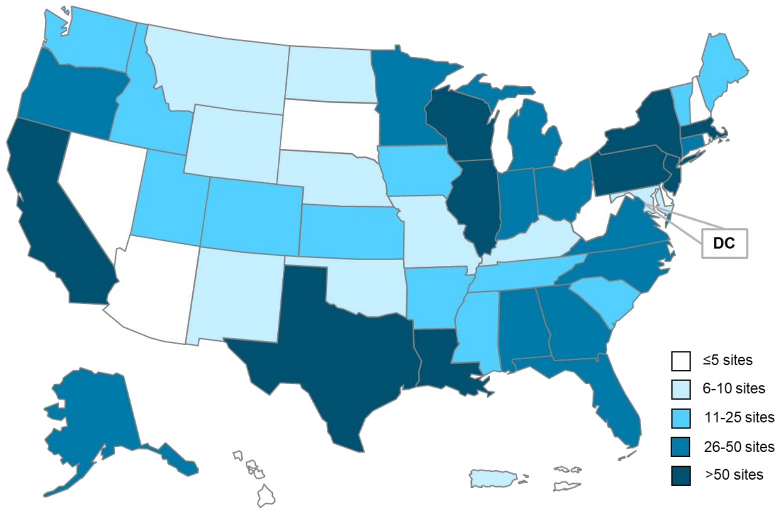


Figure 2. Industrial CHP installations by State. *Source:* DOE 2021

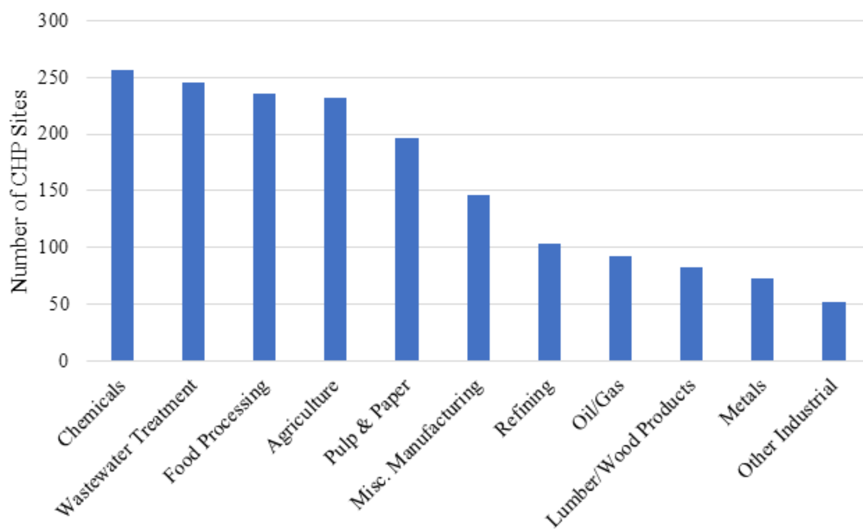


Figure 3. Industrial CHP installations by Application. *Source:* DOE 2021

Industrial CHP systems leverage a wide variety of fuels, as shown in Figure 4, and these fuel sources influence the level of emissions reduction benefits. Natural gas has historically been the dominant fuel source for CHP due to its availability, low emissions, ease of use and competitive price. CHP has been an efficient way to utilize other fossil fuels such as coal and fuel oil, but both have declined in use over the past decade. Industrial CHP systems have also long used alternative fuels such as biomass and wood, biogas and landfill gas, municipal and process wastes, waste gas streams from hydrocarbon processes and hydrogen mixtures where available. Although these non-fossil alternatives currently represent just 15% of installed industrial CHP capacity, they are used in over 44% of existing industrial CHP installations.

Biogas and landfill gas, in particular, are widely used renewable fuels, currently fueling 440 industrial CHP systems (26% of existing industrial CHP installations) (DOE 2021).

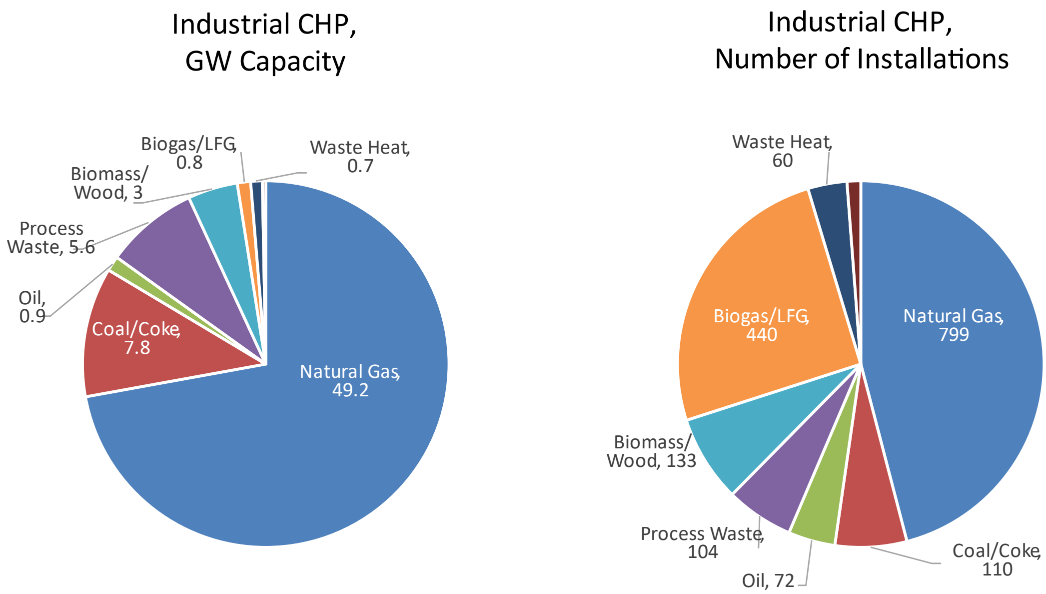


Figure 4. Industrial CHP Capacity and Installations by Fuel Type. *Source:* DOE 2021

Recent industrial CHP installations have trended strongly towards smaller systems and more diverse fuel types, especially renewable fuels. There has been a significant increase in CHP installations at wastewater treatment plants, food processing facilities and agriculture sites using anaerobic digester gas, with more than 250 installations in the last 10 years. Figure 5 shows the growth of the number of biogas CHP systems installed at industrial sites compared to all other fuels in 2000-2009 and 2010-2019. CHP technologies and systems are well positioned to use higher levels of biogas, biofuels, RNG and hydrogen as these resources become more available.

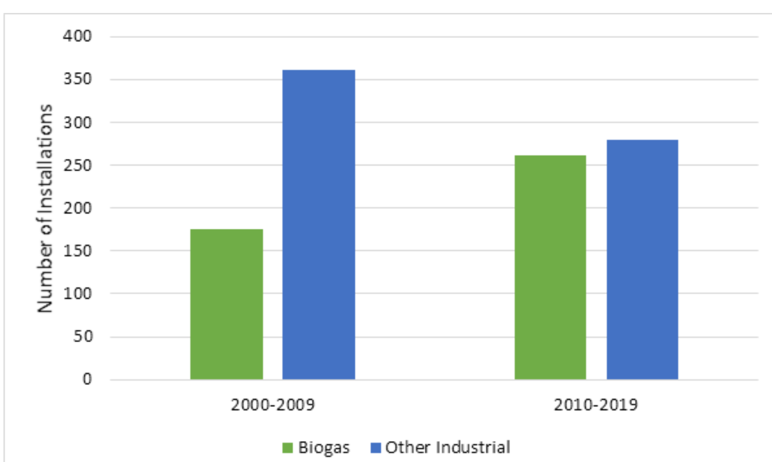


Figure 5. Growth in Biogas CHP Installations since 2000. *Source:* DOE 2021

In addition to providing high efficiency and lower energy costs, CHP also provides increased resilience and power reliability to industrial end-users. Specifically, critical infrastructure sectors, such as chemicals, refining and food processing require consistent and reliable electricity and thermal energy to maintain operations, with unexpected disruptions creating major unwanted costs. Industrial sites can utilize CHP to ensure that critical functions and processes remain operational during extended grid outages, maintaining business continuity and ensuring high product quality and employee safety.

CHP IN RESILIENT MICROGRIDS

CHP systems can also be used as an efficient, resilient baseload anchor technology in clean energy microgrids, providing baseload power and efficient thermal energy in conjunction with other technologies such as PV and energy storage. This not only provides additional resilience but increases operational flexibility and maximizes emissions reductions. Currently, there are 104 operational CHP microgrids across the U.S., 14 of which serve industrial facilities and provide 73.6 megawatt (MW) of electric capacity. CHP is most often paired with solar PV and battery storage in microgrid configurations (DOE 2021b).

Hybrid CHP systems with PV and storage can provide several benefits, allowing CHP to be sized smaller and operate more efficiently (and with reduced emissions) while PV and storage are used to fill peak daytime loads, potentially participate in utility markets, and provide additional resilience benefits during grid outages (Figure 5). For example, in partnership with DTE Energy, Ford Motor Company installed a CHP system to complement an existing 1.04 MW solar array, forming a campus-wide microgrid at its Dearborn, MI facilities. The 34 MW CHP system is paired with a heat recovery system, chilled water system, thermal energy storage tank. This system decreases the Dearborn campus' carbon footprint by 50%, providing 100% of the steam that the Dearborn campus needs for heating and cooling, while providing reliable electricity for both Ford's Dearborn campus and the wider electric grid for DTE (DOE 2021c).

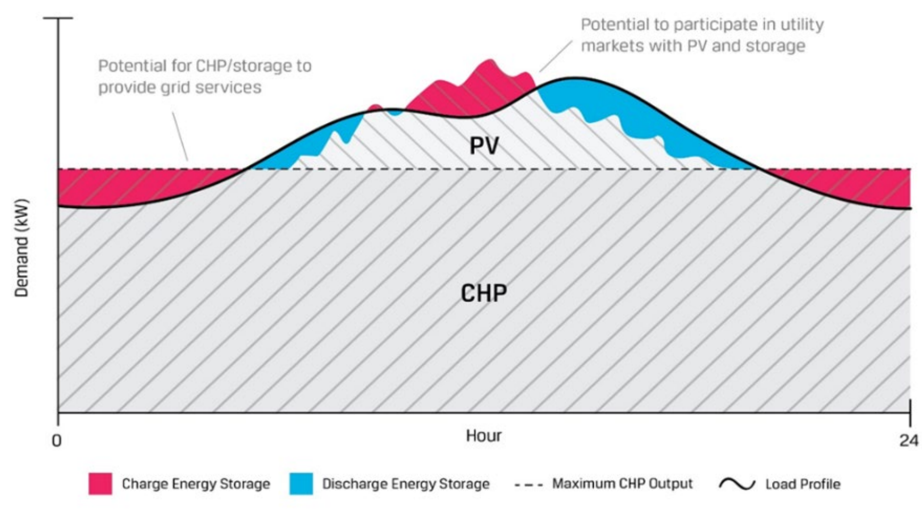


Figure 5. Example Load Profile for Hybrid CHP+PV+Storage Operation. *Source:* DOE 2020

THE CARBON REDUCTION BENEFITS OF CHP

The energy and emissions savings benefits of CHP are found in the aggregate reduction in overall energy consumption. A CHP system replaces both a separate on-site thermal system (furnace or boiler) and purchased power (typically electricity from a central station power plant) with a single, integrated system producing both thermal energy and power concurrently. The overall efficiency of a CHP system is calculated by dividing the total usable energy output (both electrical and thermal) by the total energy content of fuel inputs to the system. CHP systems can achieve overall energy efficiencies of 75% or more compared to separate production of heat and power, which collectively averages about 50% system efficiency.

Both outputs of the CHP system must be accounted for in order to accurately calculate the fuel or emissions avoided by a CHP system. The CHP system's thermal output displaces the fuel normally consumed by and emissions from on-site thermal generation in an existing boiler or heater, and the power output displaces the fuel consumed by and emissions from grid-connected power plants. CHP, which is normally located at the point of use, also avoids the T&D losses associated with electricity purchased via the grid, including power from utility-scale renewables.

CHP REDUCES CO_2 EMISSIONS TODAY

New CHP and renewable generation capacity generally displaces the marginal generation resource on the servicing grid (EPA 2018). Currently, with fossil fuel central station generation providing the bulk of marginal generation in most areas of the country, the high efficiency of CHP combined with the use of lower carbon fuels such as natural gas or biogas typically translates into reductions in both CO_2 and criteria emissions compared to separate heat and power. In fact, properly designed and operated natural gas CHP systems annually displace more grid generated CO_2 emissions on a per MW of capacity basis than comparably sized renewable resources such as solar PV and wind, primarily due to higher annual capacity factors for CHP.

Table 1 compares the annual energy, CO_2 emissions and nitrogen oxides (NO_x) emissions savings of a 20 MW gas turbine natural gas-fired industrial CHP system with utility scale solar PV and wind turbine systems. The emissions savings of each technology are based on using the EPA AVoided Emissions and geneRation Tool (AVERT) national Uniform Energy Efficiency central station generation emission factors as a first cut estimate of displaced marginal grid emissions and displacing an on-site natural gas boiler in the case of CHP. While one MWh of CHP power does not displace as much source energy or CO_2 emissions as one MWh of solar or wind power, CHP delivers an annual CO_2 emissions savings per MW of installed capacity that exceeds the per MW savings achieved through these renewable technologies because CHP systems operate with much higher load factors over the year. Baseload industrial CHP systems typically operate at capacity factors of 90% or higher compared to average annual capacity factors for utility-scale photovoltaic solar of 24.3% and wind facilities of 34.3% (EIA 2021). Table 1 shows that it takes 46.4 MW of solar PV capacity or 32.8 MW of wind capacity to generate the same CO_2 savings on annual basis as the 20 MW natural gas CHP system (76,500 tons of CO_2). Biogas or biomass CHP would generate significantly greater emissions savings.

Table 1. Industrial CHP Provides Energy and Emissions Savings Today[2] (Compared to Marginal Grid Generation), *Source:* Entropy Research 2021

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

Fossil fuel generators are currently used as marginal grid resources to serve incremental customer loads for all states in the continental U.S. As shown in Table 1, when CHP is installed, grid requirements for these marginal resources are reduced, and emissions are avoided, even when the CHP system is operating on natural gas. The emissions savings advantage of natural gas CHP installed today generally continues as long as fossil fuel generation remains on the margin, providing a significant amount of CO_2 savings over the life of the equipment. Figure 6 compares the cumulative CO_2 reductions from a 20 MW baseload natural gas industrial gas turbine CHP system to 20 MW of utility PV and wind capacity over a 35-year period based on a specific southeastern utility's long term resource plans. The displaced marginal generation was based on long term dispatch modeling of the regional generation resources as included in the utility's resource plan filed with the state public utility commission. The marginal generation is 95% coal in years one to four, 55% coal in years 5 to 11, and natural gas combined cycle generation from year 12 forward. The graph shows that based on the utility's resource plans, it

[2] Assumptions:

- CHP based on 20 MW Gas Turbine CHP – 34.1% electric efficiency, 68.7% total CHP efficiency, (DOE CHP Technology Fact Sheets)
- Annual capacity factors for Wind and PV based on 2019 national averages (DOE EIA Electric Power Annual, Tables 4.8.A and 4.8.B, Feb 2021)
- CHP, PV and Wind electricity displaces AVERT national Uniform Energy Efficiency central station generation emission factor (1,557 lbs CO2/MWh) as an estimate of displaced marginal grid emissions (EPA AVoided Emissions and geneRation Tool (AVERT), 2019 data)
- CHP thermal output displaces 80% efficient on-site natural gas boiler

would take 15 years for 20 MW of wind capacity and over 35 years for 20 MW of solar PV capacity to save the same amount of CO_2 emissions that 20 MW of CHP saves in the first 6 years of operation, CHP's savings would continue well beyond the 20-year economic life of the CHP system even as the marginal grid emissions decrease over time (CHP Alliance 2020).

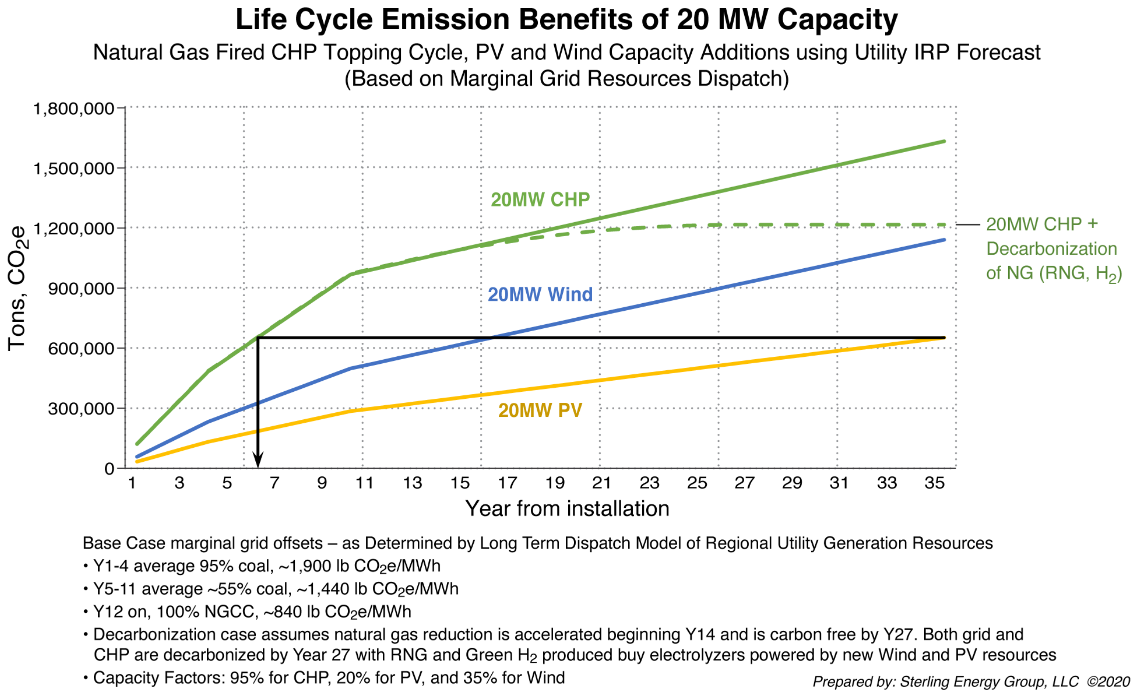


Figure 6. Industrial CHP Provides Significant Near- to Mid-Term Emissions Reductions.
Source: CHP Alliance 2020

CHP IS THE MOST EFFICIENT WAY TO GENERATE ELECTRICITY THROUGH COMBUSTION

As shown in Figure 7 below, well designed and operated natural gas CHP systems have a higher net electrical efficiency, and lower net carbon emissions per MWh than state-of-the-art natural gas combined cycle and simple cycle generation which increasingly represent the marginal grid generation resources in most states. The chart compares the net electrical efficiency (based on net power output divided by fuel chargeable to power) of various CHP systems to the electrical efficiency (including T&D losses) of new natural gas central station generation options, and shows that properly designed, and compensated, natural gas industrial CHP could meet marginal grid requirements more efficiently and with less carbon emissions than central station marginal natural gasgeneration. Furthermore, the efficiency and emissions advantages of using CHP as a marginal resource will remain as the natural gas infrastructure decarbonizes and renewable fuels such as RNG and hydrogen enter the market on both sides of the meter.

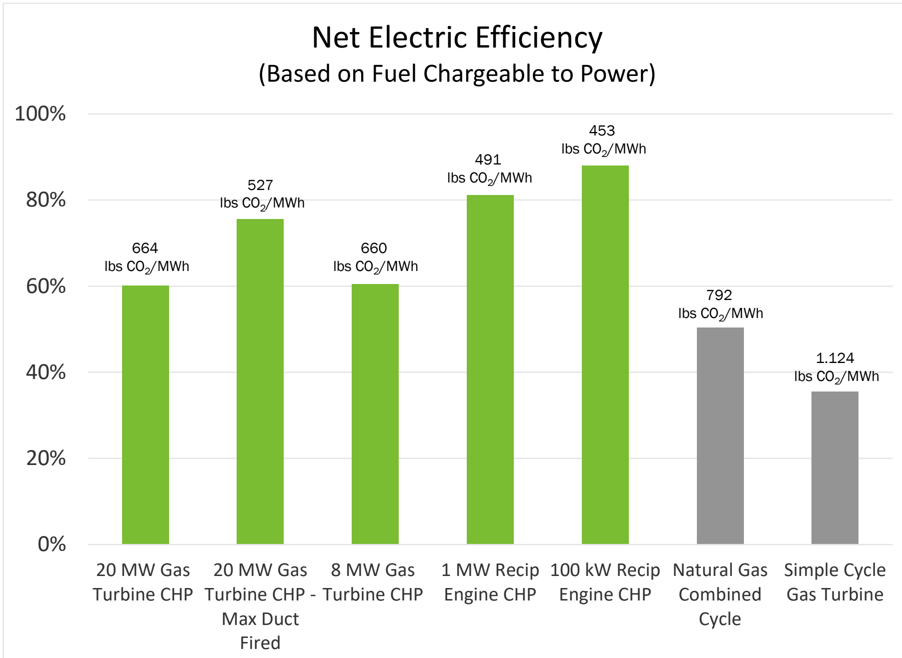


Figure 7. Natural Gas CHP Has Lower Net Emissions than State-of-the-Art Natural Gas Marginal Generation[3]
Source: Entropy Research, 2021

While economy-wide electrification and decarbonization of electricty generation is being pursued aggressively in many states and cities, fossil fuels, and natural gas specifically, are likely to remain as the marginal generation resource for the near and mid term, and may be necessary over the longer term to support the integration of greater amounts of intermittant renewable resources and provide grid regulation services. A 2020 study commissioned by the Energy Solutions Center evaluated the regional emissions reduction potential of natural gas CHP through 2050. The study modeled marginal grid fuel mix expectations in 2050 by eGRID subregion using state level economic forecasts and legislated mandates, such as zero grid emissions in New York in 2040 and California in 2045. As shown in Figure 8, natural gas fueled CHP installations reduced carbon emissions compared to the marginal grid emissions well over their system life in every region outside of New York and California.

[3] Assumptions:

- CHP performance characteristics based on DOE CHP Technology Fact Sheets - 2017
- NGCC and Simple Cycle Gas Turbine marginal generation performance characteristics based on DOE EIA AEO 2018 - Cost and Performance Characteristics of New Generating Technologies
- 5.1% national average T&D losses based on EPA eGRID 2019 (2019 data)

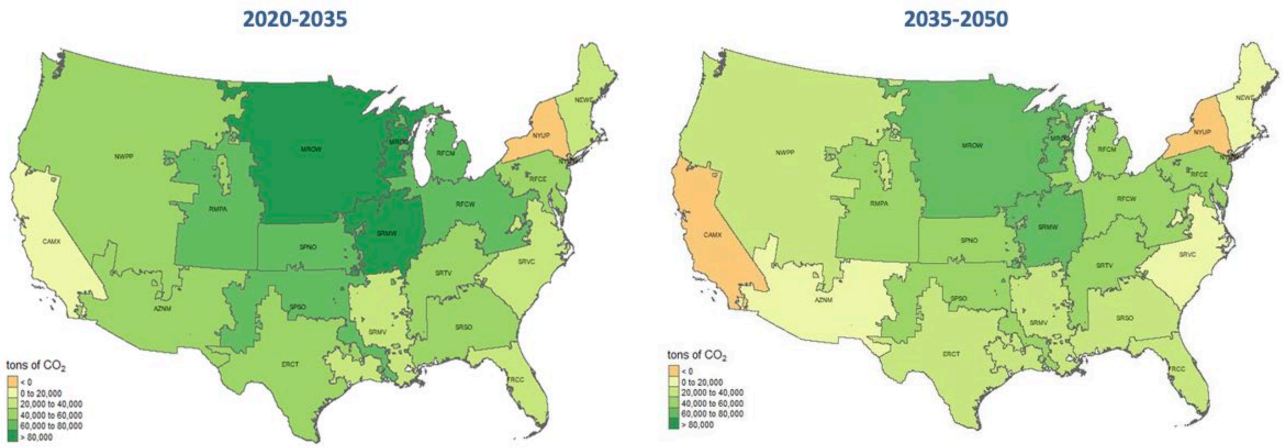


Figure 8. Lifetime Carbon Emission Reductions for Natural Gas CHP. *Source:* ESC 2020

THE ROLE FOR CHP IN INDUSTRIAL DECARBONIZATION

While natural gas CHP can have an immediate impact on carbon emissions, as coal powerplants are retired and utilities shift towards efficient combined cycle gas power plants and renewable generation the gap between carbon emissions from CHP and the grid will be narrowed in coming years. Converting the natural gas infrastructure over time RNG and hydrogen will further extend the emissions savings and reliability advantages of CHP (Figure 9). CHP has long used digester and biogas as fuel sources (DOE 2021)[4], and CHP systems deployed today can readily operate on increasing percentages of these fuels as pipeline RNG availability increases. In addition, engine and gas turbine manufacturers are currently testing and operating CHP systems on high percentage hydrogen fuels in preparation of increasing use of hydrogen in the future. RNG and hydrogen fueled CHP systems can be a long-term path to decarbonizing industrial thermal processes that are difficult to electrify because of technology or cost barriers, and for critical operations where dispatchable onsite power is needed for long-term resilience and reliability. The high efficiency of CHP can also serve to extend the resource base of emerging low carbon fuels. All major engine and gas turbine manufacturers are working on further improving performance with biogas and biofuels and developing the capability to operate efficiently and with low criteria emissions with high levels of hydrogen. Existing CHP systems will be able to utilize RNG from the pipeline without changes, and both engines and turbines can be changed out for 100% hydrogen capable models when needed. This can provide a means of transitioning the 3 million miles of natural gas pipeline capacity in the U.S. (EIA 2020) to high levels of RNG and hydrogen, using the benefits of CHP to utilize these low to no carbon fuels onsite with the highest efficiency and low net emissions.

[4] DOE (Department of Energy), CHP Installation Database lists 608 CHP systems with a total of 538 MW operating on digester gas and landfill gas utilizing reciprocating engines, gas turbines, microturbines and fuels cells

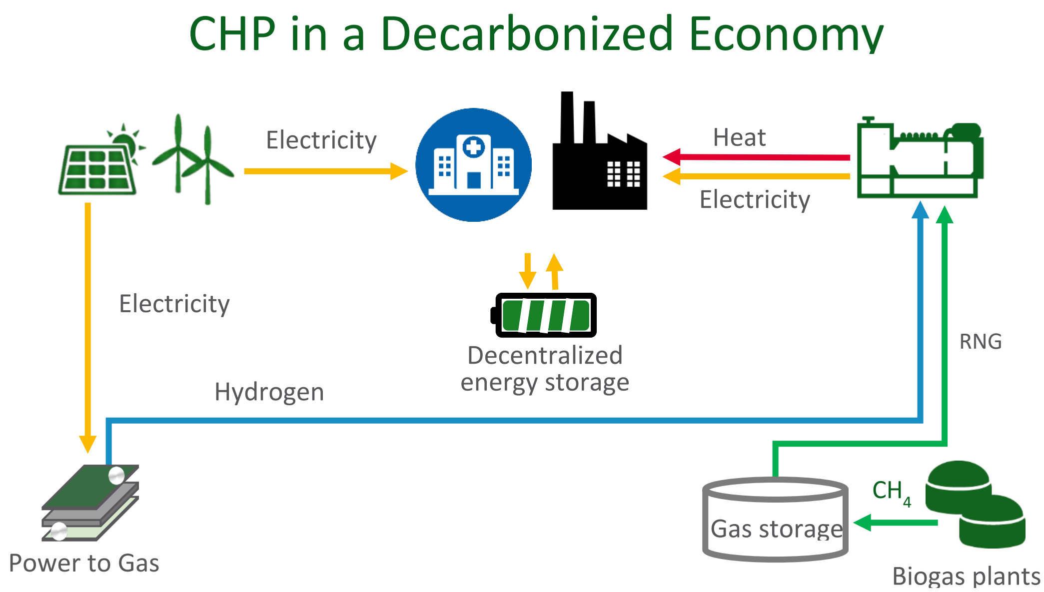


Figure 9. CHP in a Decarbonized Economy. *Source*: Based on 2G Energy, 2021

RESOURCE AVAILABILITY OF RENEWABLE NATURAL GAS

Renewable natural gas (RNG), also known as biomethane or upgraded biogas, is growing in prominence as a strategy to help achieve state climate, waste management, and other sustainability goals. Depending on how it is deployed, RNG has the potential to reduce methane emissions from organic wastes and provide fuel for applications that lack other low-carbon alternatives, such as industrial heat sources. Driven largely by recent state and federal mandates, RNG has risen to nearly 40 percent of fuel consumed by natural gas vehicles in the U.S. and is increasingly being considered as a low-carbon fuel option for stationary end uses (WRI 2020).

A 2019 American Gas Foundation report quantified the amount of renewable natural gas that could be produced from a variety of sources including energy crops, forest and agriculture residue, food waste, animal manure, landfill gas, water resource recovery facilities, and hydrogen methanation. The study considered three scenarios - low resource, high resource and technical potentials - and estimated that the total RNG resource production potential available in 2035/2040 at market competitive prices ranged from a low of 1,660 trillion Btu (tBtu) to a high of 4,510 tBtu (AGAF 2019). The high range estimate is about 60% of current annual industrial natural gas consumption (7,652 tBtu).

RESOURCE AVAILABILITY OF HYDROGEN

Most of the hydrogen production in the U.S. today comes from steam methane reformation (SMR), which uses steam to separate hydrogen from natural gas, leaving behind carbon dioxide which can be sequestered. Currently, about 1,350 tBtu of hydrogen is produced via this method. The full technical potential of hydrogen production by SMR is 2.4 million tBtus, an estimate based on the amount of technically recoverable natural gas reserves in the United States. The estimated production of hydrogen in 2050 via SMR based on current and future facilities is 3,717 tBtus, with most of this potential being centered in Texas, Louisiana, Oklahoma and Arkansas (NREL 2020).

A promising source of future hydrogen supplies is low temperature electrolysis where electricity is used to split water into hydrogen and oxygen. This technology can produce hydrogen without carbon emissions if the electricity comes from renewable or clean energy sources. The largest inhibitor to wide scale adoption of electrolysis for hydrogen is cost - electrolyzer costs are currently around $900/kW. The technical potential of hydrogen produced via electrolysis is only limited by the amount of electricity that can be generated and directed towards production. The growth of electrolysis for hydrogen production is therefore dependent on decreasing electrolyzer costs. A recent study by NREL estimated that roughly 2,693 tBtus of hydrogen could be economically produced via electrolysis by 2050 should electrolyzer costs reach $100/kW. This puts the estimated total availability of hydrogen at in 2050 at around 6,410 tBtus (NREL 2020).

RENEWABLE AND LOW CARBON FUELS CAN MAINTAIN CHP'S CARBON ADVANTAGE

Natural gas CHP systems that are installed today significantly reduce carbon emissions now and will continue to provide savings well into the midterm. Marginal grid resources today are primarily a mix of coal and natural gas generation in most regions of the country, and even as this shifts to more efficient natural gas combined cycle systems, CHP will continue to reduce emissions due to its ability to displace thermal energy requirements. CHP also has the capacity and flexibility to utilize low to no carbon fuels such as RNG and hydrogen. Figure 10 below illustrates how CHP decreases emissions in the short term, and how increasing levels of renewable and low to no carbon fuels can maintain the emissions advantage of CHP as the grid decarbonizes. The CHP net emissions rate credits the thermal output of CHP and subtracts those avoided emissions from the gross CHP emissions rate (the CHP emissions rate in Figure 10 assumes a thermal utilization rate of 80%).

A typical natural gas CHP net CO_2 emissions rate is shown in the figure by the horizontal black line, while the marginal grid emissions rate is represented by the orange line. Grid emissions decrease linearly from 1,557 lb/MWh (AVERT 2019 U.S. CO_2 Uniform Energy Efficiency emissions rate) (EPA 2019). The timeframe represented by the blue shaded region on the left represents the time that natural gas CHP provides emissions savings compared to the grid. As marginal grid emissions decrease below the natural gas CHP emissions rate, CHP can efficiently use renewable and other net zero carbon fuels to keep pace with declining grid emissions rates and maintain carbon neutrality with respect to the grid.

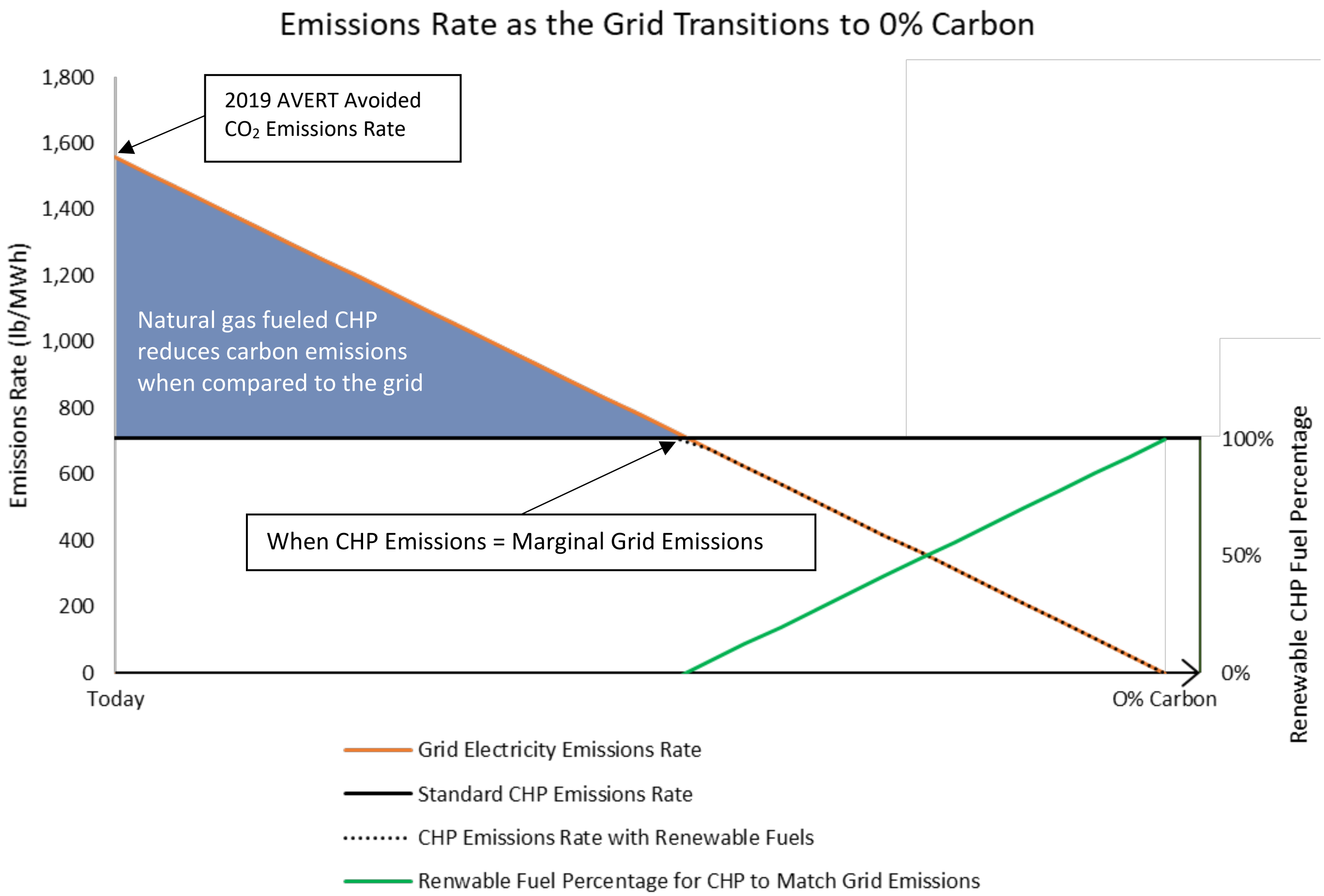
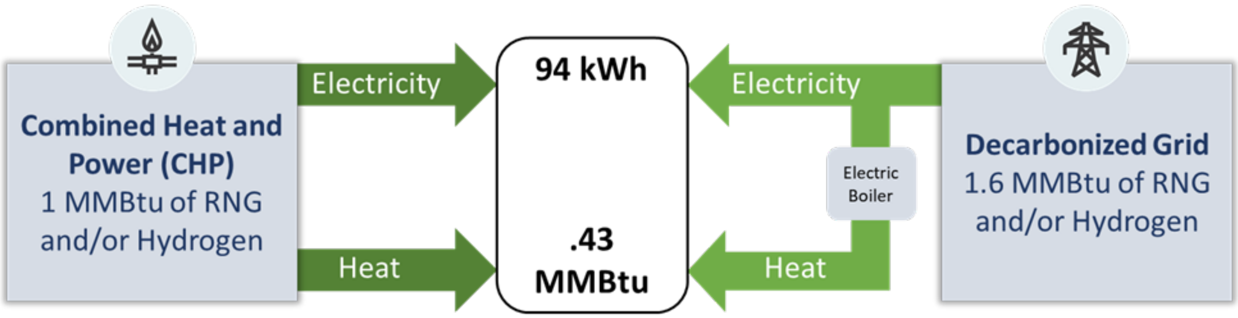


Figure 10. CHP Emissions as the Grid Decarbonizes. *Source:* ICF 2021

CHP is not the only potential use for RNG or hydrogen – these fuels could be used directly in industrial boilers and heaters or for generating carbon free electricity. However, the supply of RNG and hydrogen will likely be limited, and there is a compelling case that the use of these renewable fuels should be prioritized for high efficiency applications such as CHP.

Using RNG and hydrogen in onsite CHP to provide needed thermal energy and electricity ensures that these fuels are used most efficiently. For example, installing electric boilers and relying on grid electricity would cause industrial facilities to increase their overall electricity consumption, increasing the need for additional grid generation and distribution capacity. While electric boilers operate at an end-use efficiency up to 99%, the electricity is still produced by the grid with associated efficiency and T&D losses. In addition, these facilities forego the reliability and resilience benefits that CHP can provide, becoming entirely dependent on grid electricity for all energy requirements. As shown in Figure 11, CHP would use about one third less renewable fuel to supply power and thermal energy to the site than central station renewable generation and an onsite electric boiler or heater.



System Specifications				
CHP Electric Efficiency	CHP Total Efficiency	Grid Combined Cycle Efficiency	Electric Boiler Efficiency	Transmission & Distribution Losses
32%	75%	50%	99%	5.1%

Figure 11. CHP in a Decarbonized Economy. *Source:* ICF 2021

CONCLUSION

CHP is the most efficient way to generate power and thermal energy and can reduce CO_2 emissions now and in the future. The role of CHP is changing to accommodate the needs of transitioning to net-zero industrial carbon emissions. CHP can serve as a flexible and efficient resource for current and future energy and thermal needs, providing optionality and resilience. CHP using RNG and hydrogen is a way of decarbonizing industrial processes where the thermal requirements are difficult to electrify due to technology limits or cost constraints and offers an economic alternative to expensive process changes. Renewably fueled CHP can serve as a low carbon source of on-site dispatchable power and thermal energy for critical infrastructure and industrial operations where energy reliability and resilience is a critical requirement. CHP is a highly efficient way of using emerging low- to zero-carbon fuels such as RNG and hydrogen, extending the availability of these resources which will initially be limited in supply and high in cost. Advanced thermal storage will further increase the efficiency of CHP systems, providing increased flexibility for CHP systems to address non-coincident thermal and electricity loads and enhancing the ability of CHP to provide critical services to the surrounding grid.

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