JANUARY 2021

COMBINED HEAT AND POWER AND A CHANGING CLIMATE: REDUCING EMISSIONS AND IMPROVING RESILIENCE

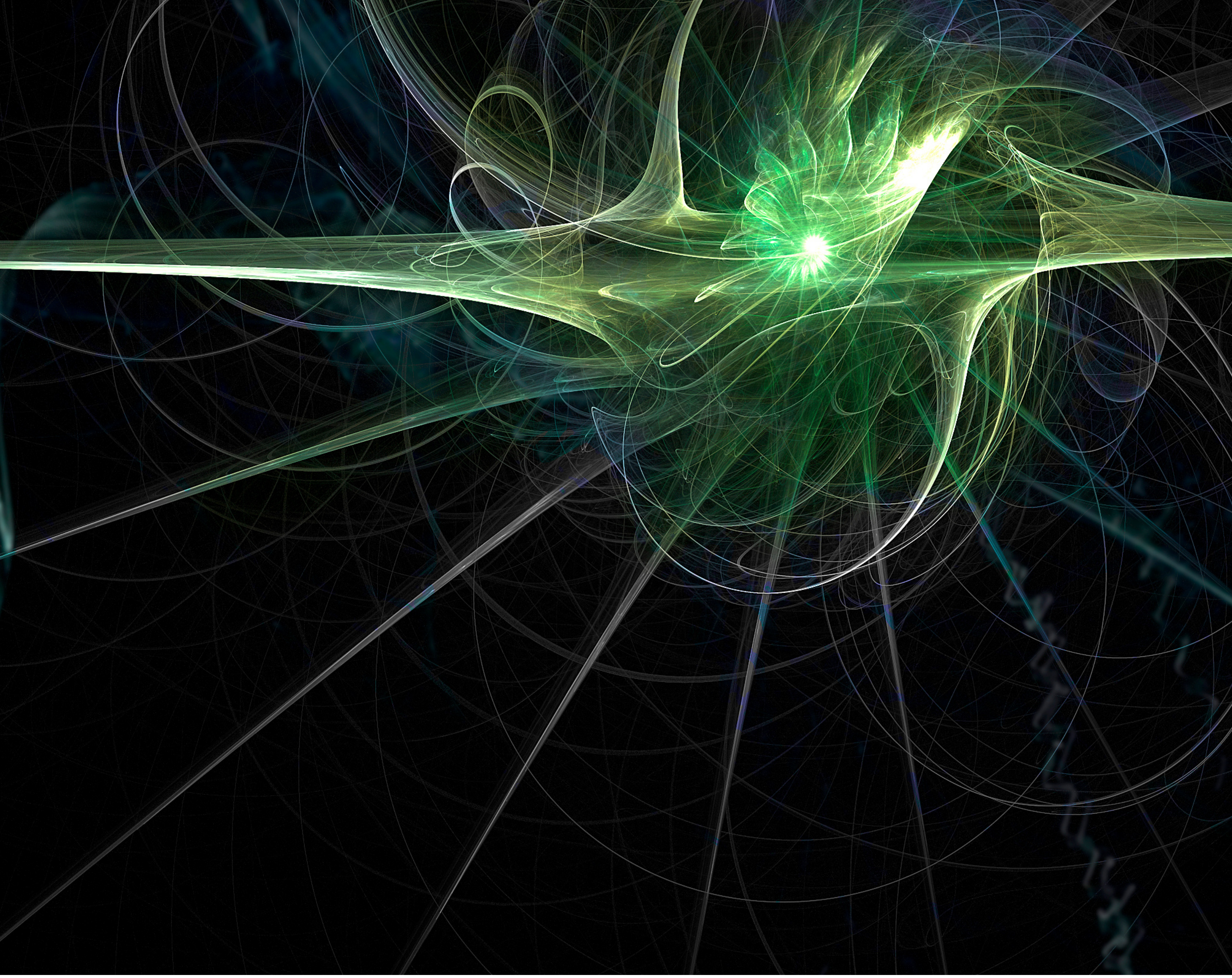

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Table of Contents

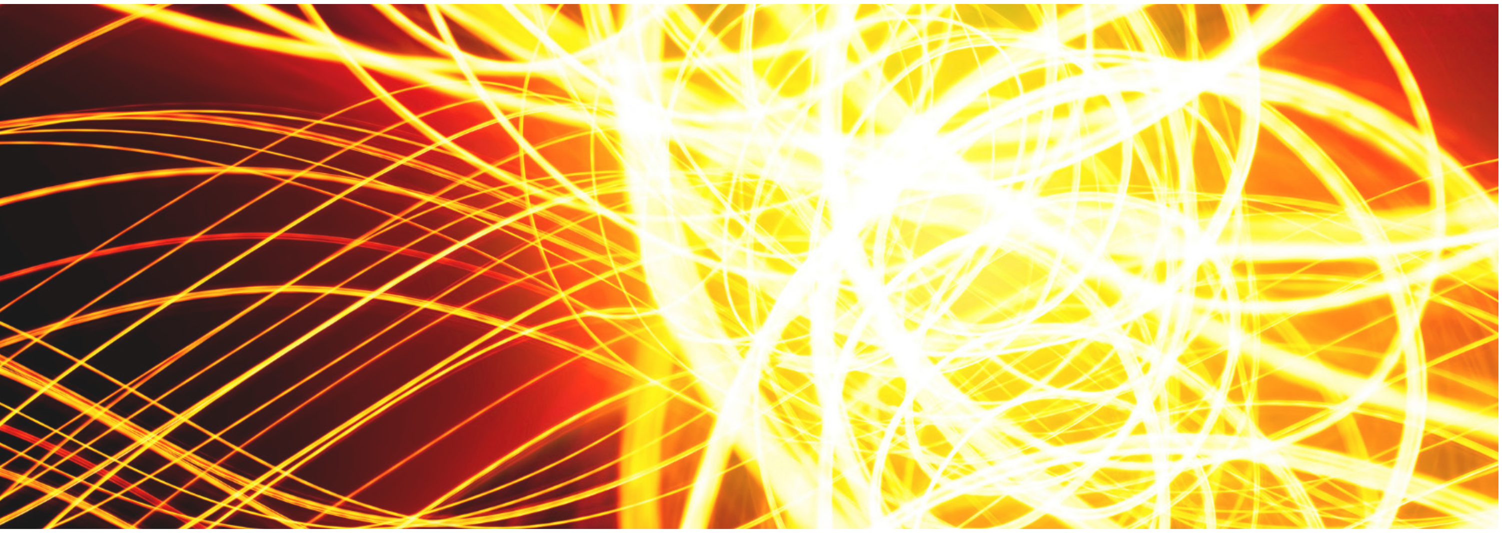
Section 01

Section 02

Section 03

Section 04

Section 05



Executive Summary

The global climate is changing, and many are working to reduce emissions and build up resiliency across sectors, including electricity generation, transportation, industry, and commercial and residential buildings. Combined heat and power (CHP) can help to confront climate change challenges on both fronts: as an electric and thermal energy generation resource with lower greenhouse gas (GHG) emissions than other generation options, and as a resilient asset that can keep the lights on during grid outages.

CHP can play a significant role in decarbonizing the electricity, buildings, and industrial sectors: in almost all regions of the U.S., **CHP systems installed through 2035 and operating through 2050 are expected to cause a net reduction in carbon emissions over their system life.** CHP systems require less fuel inputs for the same energy outputs, have a high capacity factor allowing them to displace high-emitting marginal grid resources, and can enable the addition of intermittent renewable resources to the grid by providing a consistent source of power. This net reduction does not include additional reductions that may be achieved by CHP units that use lower-carbon fuels.

CHP systems can utilize lower-carbon fuels to generate power and thermal energy. While the first wave of CHP technologies, "CHP 1.0," have historically relied on fossil fuels, **"CHP 2.0" units can be fueled by renewable or lower-carbon fuels** such as biogas, renewable natural gas (RNG) or biomethane, and hydrogen. Using these fuels allows CHP 2.0 systems to reduce emissions even further than CHP 1.0 systems. As governments, businesses, and the public look to reduce emissions, CHP is among the solutions that can lead to a decarbonized future.

Climate scientists say climate change will exacerbate extreme weather events, which are already disrupting the electric grid due to wildfire threats in California and hurricanes along the Gulf and Atlantic coastlines. As risks of grid disruption increase due to climate change, CHP can **reliably deliver power and thermal energy locally for critical infrastructure**, such as hospitals, military bases, and colleges and universities. CHP's reliability benefits become even more important as the transportation and buildings sectors are electrified to reduce carbon emissions.

This paper examines these key benefits of CHP systems and how CHP is a climate change solution because it can both reduce emissions and be a resilient energy resource, reliably providing electric and thermal energy even during severe weather events. The next two pages highlight and summarize key insights found throughout the paper.

See pages 6 and 7 for **key insights**.

Key Insights

Combined heat and power (CHP), also known as cogeneration, is a technology that has been utilized to generate electricity for more than 135 years, and continues to be relevant today as businesses, governments, and communities seek to reduce their impact on the environment while maintaining a reliable energy supply that supports health, safety, and the economy.

CHP can play a significant role in decarbonizing the electricity, buildings, and industrial sectors. In almost all regions of the U.S., **CHP systems installed through 2035 and operating through 2050 are expected to cause a net reduction in carbon emissions over their system life.**

While CHP 1.0 has historically relied on fossil fuels, **CHP 2.0 units can be fueled by renewable or lower-carbon fuels** such as biogas, renewable natural gas (RNG) or biomethane, and hydrogen, allowing CHP 2.0 systems to reduce emissions even further than CHP 1.0 systems. Moreover, CHP will utilize these fuels more efficiently than other types of generation units, achieving the same energy outputs with less fuel inputs. CHP 1.0 can deliver immediate and meaningful emission reductions, and CHP 2.0 offers the potential for large additional emissions reductions in electricity, buildings, and industry.

CHP systems are able to **economically reduce emissions** due to a variety of factors, as described below. The first three factors describe CHP 1.0, while the fourth describes CHP 2.0:

- CHP systems **require less fuel inputs for the same energy outputs**, reducing all types of emissions, including greenhouse gases such as carbon, criteria pollutants, and hazardous air pollutants. In some examples, CHP systems can have 50% less annual carbon emissions than conventional electricity generation.
- CHP's **high capacity factor allows CHP to displace high-emitting marginal grid resources** for more hours than would be possible for wind or solar. A CHP unit operating at a capacity factor of 95% can reduce more GHG emissions in about six or seven years as the same capacity of zero-carbon solar photovoltaic does in 35 years.
- CHP **enables renewable resources** to be further integrated into the fuel mix. CHP can enable renewables as part of a microgrid, and CHP systems provide 37% of the capacity in existing microgrids.
- CHP systems use **lower-carbon fuels** and could use higher volumes and additional fuel types in the future. Carbon capture technologies can reduce emissions that do occur from CHP systems. Existing CHP systems can also be retrofitted to use lower-carbon fuels such as hydrogen and biogas.

As risks of grid disruption increase due to climate change, CHP can reliably deliver power and thermal energy locally for critical infrastructure, such as hospitals, military bases, and colleges and universities. CHP's reliability benefits become even more important as the transportation and buildings sectors are electrified to reduce carbon emissions. Any sector with electric and thermal needs, as well as policy makers who may be concerned about the consequences of disruptions to these sectors, should make CHP an integral part of their climate resiliency plan.

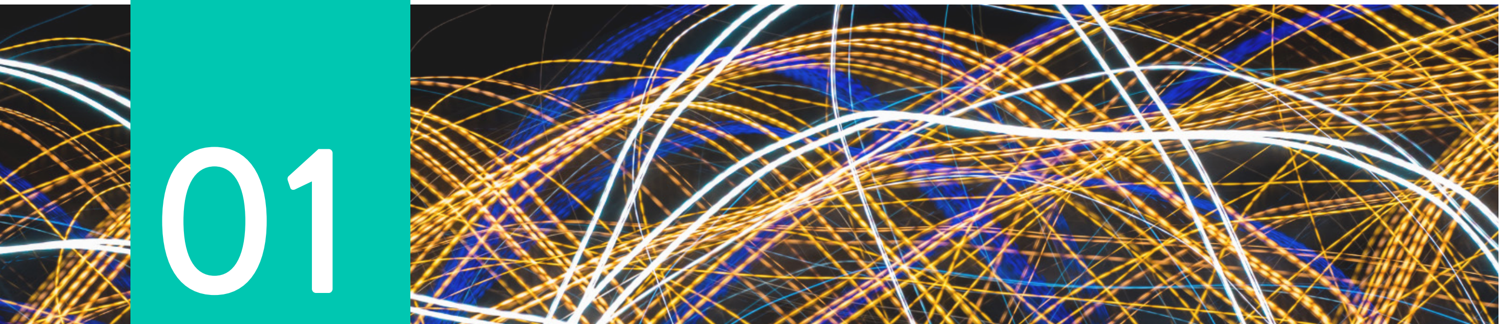
Numerous case studies demonstrate that **CHP's high level of resiliency** can help facilities maintain operations during severe weather events. In addition:

- CHP currently provides 37% of the capacity in existing **microgrids**.
- CHP systems support **critical infrastructure facilities**, providing them with electric and thermal energy during emergency situations and grid outages.
- CHP systems **support commercial, industrial, and manufacturing facilities** that are essential to the reliable supply of food and health and safety products.

While the emissions reduction and resiliency benefits of CHP are clear, **action is needed** to overcome barriers to increase deployment and ensure these benefits can be realized to their full potential. While there is 80.7 GW of installed CHP at more than 4,600 sites throughout the United States, the U.S. EPA estimates **there is more than 240 GW of technical potential at over 291,000 sites** across the country. This technical potential indicates that there is also significant potential for reduced emissions and increased resiliency at facilities throughout the nation.

- **Policymakers** can support policies that help to overcome economic and financial, regulatory, and informational barriers. Such policies include:
    - Investment tax credits,
    - Research and development of lower-carbon fuels,
    - Deployment of CHP at critical infrastructure facilities,
    - Utility ownership, and
    - Valuing carbon benefits.
- **Potential CHP hosts** can install CHP systems to realize their emissions and resiliency benefits, as well as cost savings.
- **Utilities** should consider CHP during their resource planning, valuing it not only as an electric generation resource, but also as a way to reduce transmission and distribution costs and line losses, and increase the reliability of electric supply.

In September 2020, the CHP Alliance hosted a three-day National CHP Summit on the role of CHP in a low-carbon future. At the Summit, climate experts such as Bob Perciasepe, President of the Center for Climate and Energy Solutions (C2ES), and Ana Unruh Cohen, Staff Director of the U.S. House Select Committee on the Climate Crisis, urged greater deployment of CHP in light of the increasing risks of climate-induced disruptions to the electric grid. This report is based on presentations and discussions from experts at the CHP Alliance's National CHP Summit, as well as on previous research and analysis conducted and gathered by the CHP Alliance.



01

Introduction

Combined heat and power (CHP), also known as cogeneration, is a technology that has been utilized to generate electricity for more than 135 years, but continues to be relevant today as businesses, governments, and communities seek to reduce their impact on the environment while maintaining a reliable energy supply that supports health, safety, and the economy.

The global climate is changing, and many are working to reduce emissions across sectors, including electricity generation, transportation, industry, and commercial and residential buildings. CHP has an important role to play in helping to achieve these goals: CHP can reduce near-term and long-term emissions in numerous sectors, including those that have been historically difficult to address. CHP can play a significant role in decarbonizing the electricity, buildings, and industrial sectors.

In addition to reducing emissions, CHP systems are highly reliable, increasing resilience against climate change impacts that are already occurring. Facilities that require consistent electric and thermal energy can deploy CHP to help them maintain operations during severe weather events or other grid outages.

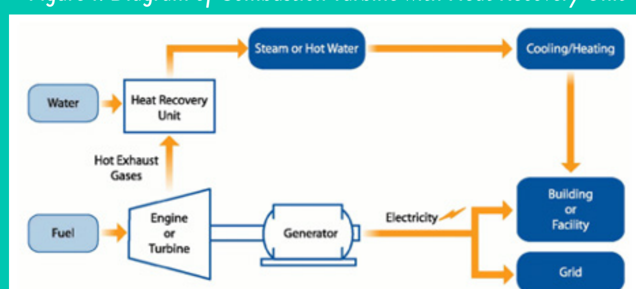
This paper will explain how CHP can reduce emissions in the near- and long-term, and how CHP is a reliable energy generation resource that can improve resilience against a changing climate. At the end, it will give a brief overview of the current state of the CHP market, as well as recommendations to overcome barriers and increase CHP deployment so that decreases in emissions and increases in resiliency can be realized.

What is CHP?

Combined heat and power (CHP), also known as cogeneration, is a technology that uses a single fuel source to generate both heat and electricity. CHP systems generate electricity and capture the heat that would otherwise be wasted to provide useful thermal energy, such as steam or hot water, that can be used for space heating, cooling, domestic hot water, and industrial processes. CHP systems can be located at an individual facility or building, or can be a utility resource or part of a district energy system.

CHP systems are typically located at facilities where both electricity and thermal energy are needed. CHP is used in over 4,400 facilities across the U.S.[*] There are a variety of types of CHP facilities, the diagram on the right provides one common example. Figure 1[**] demonstrates a combustion turbine with a heat recovery unit.

Figure 1: Diagram of Combustion Turbine with Heat Recovery Unit



[*] U.S. Environmental Protection Agency. "What is CHP?" https://www.epa.gov/chp/what-chp
[**] U.S. Environmental Protection Agency. "What is CHP?" https://www.epa.gov/chp/what-chp

CHP Reduces Emissions

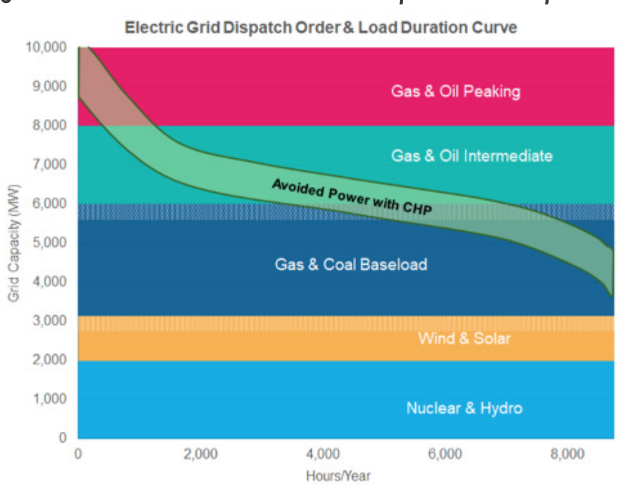
Numerous factors allow CHP systems to reduce emissions. Central to CHP's ability to reduce emissions is the fact that CHP systems are highly efficient, requiring less fuel inputs to achieve the same energy outputs as other systems. This section will explain how CHP systems are able to reduce emissions, even when using fuels such as natural gas. Emissions can be reduced even further when CHP systems are used to enable intermittent renewables such as wind and solar, CHP systems utilize renewable or lower-carbon fuels, or emissions that do occur are reduced through carbon capture or other technologies.

Reducing Grid Emissions

In almost all regions of the United States, CHP systems installed through 2035 and operating through 2050 are expected to cause a net reduction in carbon emissions over their system life.[1] For all states in the continental U.S., fossil fuel generators are used as marginal electric grid resources to serve incremental loads. But, when CHP is installed, grid requirements for these marginal resources are reduced. The emissions from the marginal resources are avoided, even with the CHP unit operating on natural gas.

CHP systems installed through 2035 and operating through 2050 are expected to cause a net reduction in carbon emissions over their system life in almost all regions of the U.S.

Figure 2: Avoided Power with CHP for an Example Utility



Source: ICF. "Combined Heat and Power Potential for Carbon Emission Reductions: National Assessment 2020-2050." July 2020, p. 7. http://consortia.myescenter.com/CHP/ESC_CHP_Emissions-Full_Study-ICF-071320.pdf

When additional power is needed, either to supply the electric grid when demand is high or to provide backup power during a grid outage, generation units fueled by coal, oil, or diesel are frequently brought into operation, increasing emissions. In the same circumstances, a CHP system fueled by natural gas can produce fewer emissions than these other types of generation units, avoiding the increased emissions from coal, oil, or diesel.[2]

On average across the U.S., ICF[a] estimates the rate of carbon reduction for CHP in 2020 ranges from approximately 800 to 1,000 pounds for each MWh of displaced grid electricity.[3] Looking ahead to 2050, the rate of carbon reduction decreases, but even in 2050, CHP is estimated to reduce carbon emissions by approximately 300 to 450 pounds for each MWh of displaced electricity.[4] ICF's analysis does not even take into consideration renewable or lower-carbon fuels that may be used in CHP systems, which could further reduce emissions.[5]

Some areas of the U.S. utilize a higher percentage of renewable or zero-carbon resources, including as marginal resources, impacting the grid emissions profile and narrowing the gap between carbon emissions from the grid and CHP.[6] ICF considered these regional differences, and their analysis showed that in every region except New York and California, two states with 100% clean energy mandates, CHP systems installed through 2035 and operating through 2050 are expected to cause a net reduction in carbon emissions over their system life.[7] However, even as regional grids approach 100% clean energy, it is likely that fossil fuel resources will still be used to serve marginal loads.[8] If this occurs, natural gas CHP could continue to reduce grid emission for a longer period of time in states like California and New York.[9]

We estimate that if CHP deployment were increased by 25%, this would reduce annual CO2 emissions by 24,468,750 short tons (equivalent to emissions from 5.7 coal-fired power plants),[10] save 137,891,250 MWh annual electricity, and save businesses more than $70 billion (2011$) cumulatively.[b11]

It is clear that CHP systems reduce emissions and will continue to do so into the future. The rest of this section will explain how CHP systems do this, and how they could have even lower emissions in the future by utilizing new and emerging fuels and technologies.

CHP Systems Are Highly Efficient

The average efficiency of fossil-fueled power plants in the U.S. is approximately 39 percent, with a range of anywhere from 31 to 37 percent efficient when accounting for transmission and distribution (T&D) losses.[c12] This means that over 60% of the energy used to produce electricity at most U.S. plants is wasted. When this electricity generation is combined with an on-site boiler for thermal energy needs, efficiency improves, but only to 50 percent.[13]

CHP systems require less fuel inputs for the same energy outputs, reducing all types of emissions, including greenhouse gases such as carbon, criteria pollutants, and hazardous air pollutants.

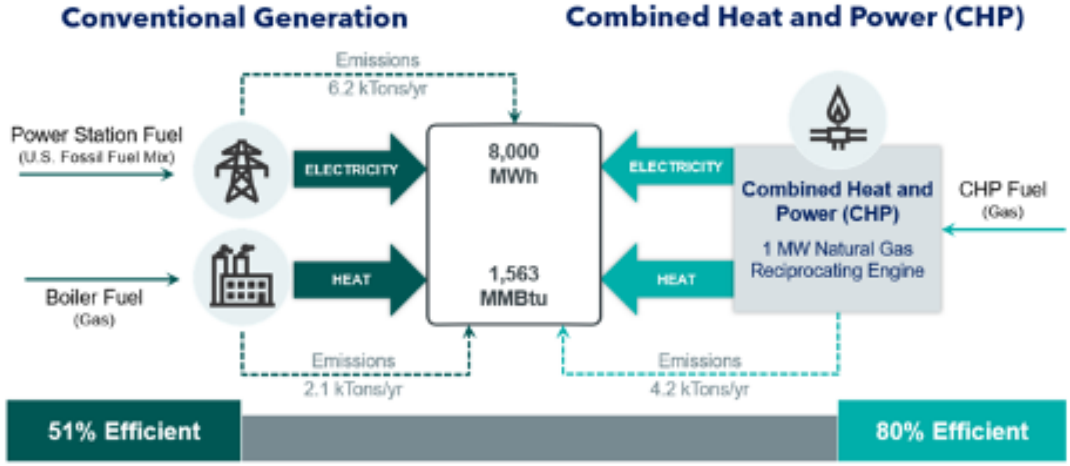
CHP systems are efficient electric and thermal energy generation units. Improvements in CHP technology over time have resulted in properly designed CHP systems typically operating with an overall efficiency of 65-85 percent,[14] with some approaching 90 percent.[15] This is compared to an overall efficiency of only 45-55 percent when electricity and thermal energy are provided separately.[16] CHP systems achieve these high efficiencies by recovering the waste heat by-product of electricity generation as useful thermal energy for heating and cooling.[17]

[a] ICF is a non-partisan, non-political global consulting services company providing services in a variety of sectors, including energy.

[b] Report calculated estimates for increase in deployment of 40 GW over 15 years. Adjusted for an increase in deployment of 20 GW (25% of 80 GW, see footnote 92), and for deployment and commensurate savings to occur over 10 years.

[c] Using eGRID 2018 summary data tables, the U.S. Energy Information Administration 2018 average operating heat rates for fossil-fuel energy sources we calculated that in 2018 the average efficiency for fossil-fuel generation (coal, petroleum, and natural gas) was 38.63%. EIA calculates operating heat rate for energy sources as a ratio of reported fuel consumption and electricity generation values located in EIA 923 data files. EIA notes in their October Electric Monthly Update that recent installments of natural-gas combined cycle (NGCC) gas plants have both higher capacity factors and lower heat rates, leading to increased efficiencies.Per eGRID 2018 summary tables data, average T&D grid losses for the U.S. were 4.87%. However, to account for variability of T&D losses from region to region, facility location and area density, as well as during peak and non-peak demand times, we used a range of 2 - 8% decrease in efficiency given T&D losses.

Figure 3: Energy and Emissions Savings Associated with CHP



Source: ICF. "Combined Heat and Power Potential for Carbon Emission Reductions: National Assessment 2020-2050." July 2020, p. 8. http://consortia.myescenter.com/CHP/ESC_CHP_Emissions-Full_Study-ICF-071320.pdf

When heat from CHP is recovered and utilized, it typically displaces steam or hot water from a boiler, which is usually fueled by natural gas.[18] Since the boiler is no longer fueled separately, emissions from the on-site boiler are reduced, lowering the net emissions impact of CHP when compared to separate heat from an onsite boiler and power generated from the grid.[19] Figure 3 (calculated using eGrid 2018 U.S. average emissions[20]) shows the energy and emissions savings associated with CHP.

Because they operate efficiently, CHP systems combust less fuel to provide the same energy services. This efficient generation of energy reduces all types of emissions, including greenhouse gases such as carbon, criteria pollutants, and hazardous air pollutants.

Since CHP systems are typically located close to where the electric and thermal energy will be used, savings are also achieved from reduced line losses, electricity that is typically lost during transmission and distribution from a central power plant to the end user. Within the five major power grids in the United States, average transmission and distribution losses vary from 4.23 percent to 5.35 percent, with a national average of 4.48 percent, and may be even higher when the grid is strained and temperatures are high.[21] By avoiding these transmission and distribution losses associated with conventional electricity supply, CHP further reduces fuel use, helps to avoid the need for new transmission and distribution infrastructure, and eases grid congestion when demand for electricity is high.[22]

Examples demonstrate that, compared to conventional electricity generation, CHP systems can use 32% less fuel and have 50% less annual carbon emissions.[23] Savings for individual systems will depend on a variety of factors, including the fuel use and emissions if heat and power were provided separately, the fuel use and emissions of the CHP system, and the grid emissions where the CHP system is located.

CHP Systems Have a High Capacity Factor

The capacity factor of an electric generation unit describes how often the generation unit operates during a specific period of time, using the ratio of the actual output to the maximum possible output during that period.[24] A generation unit may not run all the time due to maintenance or refueling or due to the intermittent nature of the resource, as is the case with renewable resources such as solar and wind. For example, utility-scale solar photovoltaic facilities

CHP's high capacity factor allows CHP to displace high-emitting marginal grid resources for more hours than would be possible for wind or solar.

had a capacity factor of 24.3% in 2019, while wind facilities had a capacity factor of 34.3%.[25]

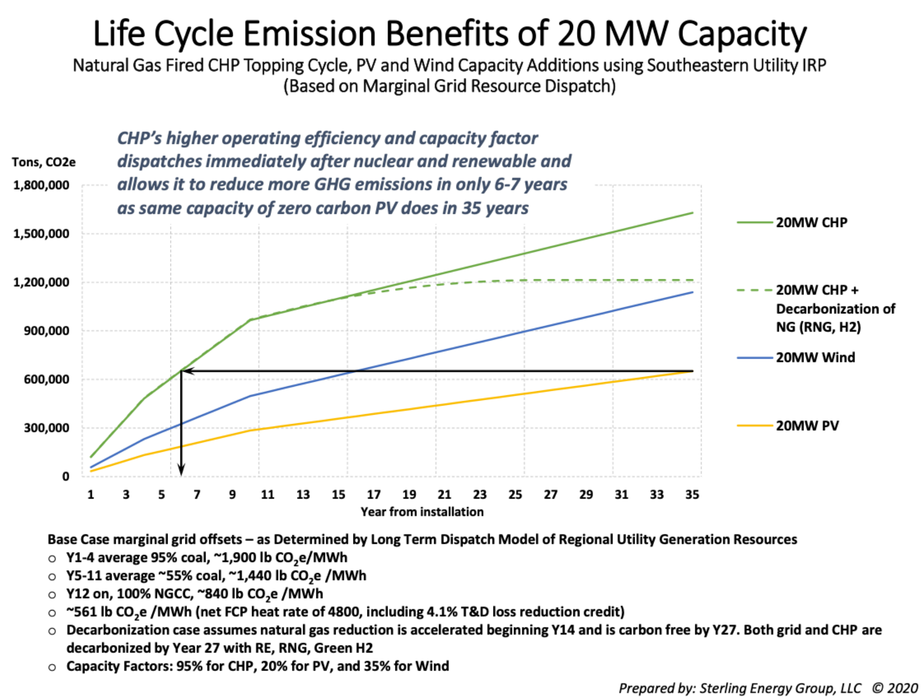
CHP systems typically operate at a high capacity, meaning that they often run nearly continuously close to the level of their maximum output. Well-applied CHP typically has an effective efficiency that is much higher than other fossil fueled resources such as natural gas combined cycle of goal generation, so CHP is generally dispatched at a very high capacity factor. The U.S. Environmental Protection Agency (U.S. EPA) has used a CHP capacity factor of 85% when examining how the benefits and costs of CHP compared to other clean energy technologies.[26] This capacity factor is much higher than those for solar and wind as described above.

This high capacity factor has impacts for CHP's ability to reduce emissions. Though electricity generated by CHP typically does have some emissions associated with it, it has lower emissions than many other resources, including many marginal grid resources as described above. While renewable resources such as wind and solar produce no emissions, they also have lower maximum capacity factors due to the intermittent nature of the resources. Any generation added to the grid is reducing what would be the marginal resource dispatched if the added generation were not dispatched. The high capacity factor of CHP means that when CHP displaces high-emitting marginal resources, it does so for many more hours than would be possible for wind or solar.

U.S. EPA's analysis shows that 10 MW of CHP installed capacity has a larger electricity and useful heat output than 10 MW of installed capacity of other technologies, and that 10 MW of CHP installed capacity also creates more annual energy savings and CO2 savings than 10 MW of installed capacity of other technologies.[27]

CHP combines its high efficiency with its high capacity factor to deliver greater emissions reductions than wind or solar for the equivalent installed capacity. Well-applied CHP systems can operate at capacity factors as high as 94-96%. As can be seen in the example Figure 4, CHP can reduce more GHG emissions in about six or seven years as the same capacity of zero-carbon solar photovoltaic does in 35 years.

Figure 4: Life Cycle Emission Benefits of 20 MW Capacity



Analysis conducted by Sterling Energy Group, LLC. 2020

As a distributed resource serving both electric and thermal loads at the point of production, CHP can also help to support intermittent renewable resources by reducing load on the regional grid and provide a baseload source of power to serve electric demand even when intermittent renewable resources are not generating power. CHP can help to enable more of these renewable resources, as explored further below.

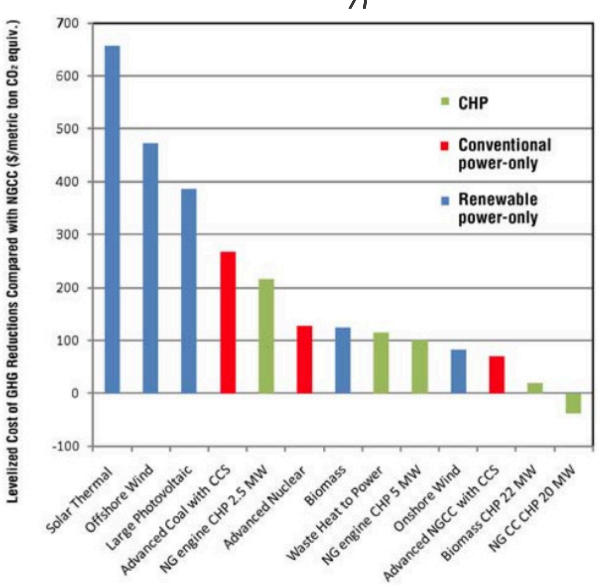
CHP Economically Reduces Emissions

The need to reduce emissions is significant and has the potential to be costly. Governments and organizations should strive to reduce emissions as much as possible for each dollar spent. During the CHP Alliance's National CHP Summit in September 2020, it was posited that in order to slow down the process of climate change, implementation of everything we can think of, particularly things that are cost-effective, will be needed.[28] CHP systems are cost-effective and can save on-site hosts and grid users money.

CHP is both a cost-effective method of reducing emissions when compared to other resources, and can save money for on-site hosts as well as utilities and their ratepayers.

CHP is an existing technology that can reduce emissions in a cost-effective way. CHP systems are commercially available and immediately deployable, providing a direct path to lower emissions through increased energy efficiency.[29] Well-sited and properly designed CHP systems can be a least cost resource, compared to other baseload resource options that are available.[30] As can be seen in Figure 5,[d] it costs less to reduce GHG emissions with CHP when compared to other generation resources.

Figure 5: Comparing Costs of Reducing GHG Emissions Across Resource Generation Type



International District Energy Association. "Combined Heat and Power (CHP): Essential for a Cost Effective Clean Energy Standard." March 2011. page 8. https://www.energy.gov/sites/prod/files/2013/11/f4/chp_clean_energy_std.pdf

[d] The levelized cost of greenhouse gas reduction for new generation resources comes from FVB Energy Inc. analysis consistent with methodology used in U.S. Energy Information Administration, Levelized Cost of New Generation Resources in Annual Energy Outlook 2011, December 2010, DOE-IEA-0383 (2010). Please note that chart reflects levelized cost of energy resources from 2010 data, and the levelized cost of energy resources, particularly renewables such as large photovoltaic solar, have reduced significantly in the last ten years.

In addition to being cost-effective, CHP systems can save money, both for on-site CHP hosts and for electric grid users overall. Facilities that require electric and thermal energy loads for operations may be able to reduce operational costs by installing a CHP system to efficiently produce electric and thermal energy on-site. CHP systems can provide electric and thermal energy at a much lower cost to end users compared to grid electricity coupled with an onsite boiler.[31] CHP systems typically use natural gas, which is often lower cost than purchased electricity. For on-site systems, CHP output reduces electricity purchases, lowering electric bills.[32] As demonstrated in the case study of Fort Knox on page this page, these cost savings can be significant.

Electric utilities may also choose to install and own CHP generation units, potentially deriving savings for all of their customers. Utilities may own CHP units located on either side of the meter, and may also realize benefits from installations on-site at facilities. Utilities aware of the location of constrained grid assets can site CHP units accordingly: including CHP in transmission and distribution planning can help utilities to avoid certain investments and upgrades, reducing costs to the utility and their ratepayers.[33] Reduced demand on existing transmission and distribution infrastructure

CHP Saving Money at Fort Knox

Quick Facts:

- Location: Fort Knox, KY
- Facility: Army base facilities, including a gold vault, Army Human Resource Command Center, and a high school
- Emissions benefits: 90% removal of NO_x, 93% reduction of CO, 80% removal of formaldehyde
- Cost savings: Reduces energy costs by an estimated $5.5 to $6 million per year

A 2009 ice storm hit Fort Knox, severing the base's connection to the local utility and resulting in several buildings going without power for as long as 10 days. Energy security and reliability are a significant concern to military installations: Army Directive 2017-07 says "The Army will reduce risk to critical missions by being capable of providing necessary energy and water for a minimum of 14 days."[a]

In 2014, Fort Knox completed an energy project that provides the base with 44 MW of peak-load power. A CHP system constantly supplies power to the base, and there are also diesel generators primarily used for backup power. These units comprise a microgrid for the 109,000-acre base, providing power to about 2,000 facilities, including 1,500 homes. The CHP system provides power on a day-to-day basis, and also serves as reliable backup power in case of emergency

At the time of development, it was determined that CHP was the most effective way to provide Fort Knox both the energy security and energy savings it needs. In addition to providing energy security, the power system reduces the base's energy costs by an estimated $5.5 to $6 million per year.

During an emergency, Fort Knox can run independently from the larger electric grid for an indefinite amount of time. During a test of the system in the fall of 2018, the decentralized power system started powering up 14 minutes after all of the base's substations were shut down and the base was disconnected from the grid.

For additional information, see: http://bit.ly/CaterpillarCaseStudy. Photo Credit: Caterpillar, Inc.

[a] Secretary of the Army, "Army Directive 2017-07 (Installation Energy and Water Security Policy)," Feb. 23, 2017. https://www.asaie.army.mil/Public/ES/doc/Army_Directive_2017-07.pdf.

makes transmission and distribution capacity available to move power from remote renewable energy resources to load centers, avoiding costs associated with installing new transmission infrastructure as renewable resources are added to the grid.[34]

In addition to the supply side benefits, CHP can also provide benefits on the demand side, delivering electric and thermal savings that utilities need to meet energy efficiency targets or other demand management needs.[35] As utilities develop integrated resource plans (IRPs) or other plans for their future resources, they can evaluate CHP as a grid resource on the supply side, or as an energy efficiency resource on the demand side.[36]

CHP Enables Intermittent Renewable Generation Resources

CHP can also help to reduce emissions overall by providing a consistent source of power that allows more intermittent renewables to be added to the electric grid. CHP serves as an enabling technology to further integrate renewable energy into the fuel mix at the community level.[37] As noted above, CHP's high capacity factor can help to enable renewable resources such as wind and solar by providing a consistent source of power to smooth out the peaks and

Montgomery County (MD) Public Safety Headquarters CHP and Solar

Quick Facts:

- Location: Gaithersburg, MD
- Facility: Administrative facility for crucial public services
- Emissions benefits: Reduces GHG emissions by 5,900 metric tons annually, equivalent of taking more than 1,200 cars off the road
- The project includes multiple clean energy technologies, including the CHP system and solar photovoltaic canopies, that are integrated seamlessly as part of a microgrid.

The Montgomery County Public Safety Headquarters is the County's primary administrative hub for a range of critical public services, including transportation management resources, components of the County's Office of Emergency Management and Homeland Security, Fire and Rescue Service Headquarters, and the police station serving much of the central part of the County.

In 2012, a devastating storm left 250,000 Country residents and 71 County facilities without power for multiple days. In addition, the electrical infrastructure within Country buildings needed replacement due to age. The County pursued microgrids to meet its resiliency needs while providing upgrades to its systems.

The project includes multiple clean energy technologies that are integrated to operate seamlessly as part of a microgrid. The project includes 2 MW of solar photovoltaic canopies, a CHP system, and electric vehicle charging. The system can provide an estimated 90% of the facility's annual electricity consumption and nearly infinite backup capacity with minor adjustments to operations. If grid power is not available, the system can sustain itself in island mode.

The solar canopy provides shade to cars while powering the facility, and on a typical operating day, the CHP system can provide up to 70% of the site's energy, with the remainder from on-site solar, with very little utility power needed. The project is the first in the state to be certified under the Green Business Certification Inc's Performance Excellence in Energy Renewal rating system.

For additional information, see: http://bit.ly/2GCaseStudy. Photo Credit: 2G Energy Inc.

valleys of intermittent generation. As a marginal grid resource, electricity generated from CHP does not supplant renewable resources, but rather complements them by providing a consistent source of power.

CHP units can also enable renewable resources as part of a microgrid. As described further below, microgrids are "localized grids that can disconnect from the traditional grid to operate autonomously."[38] Similar to a centralized electric grid, a microgrid generates, distributes, and regulates the supply of electricity, but on a small scale.[39] Microgrids may have more than one source of electric generation and serve multiple buildings or loads.

CHP enables further integration of renewable resources into the fuel mix.

Sites with thermal demand that is met by an integrated CHP system may be able to establish a cost-effective microgrid that includes a renewable energy system.[40] Microgrids that combine CHP systems with renewable energy resources significantly reduce carbon emissions per unit of electricity consumed at the site by capturing and using the waste heat of combustion and minimizing transmission losses.[41] These emissions benefits can be significant, as demonstrated by the case study of the Montgomery County Public Safety Headquarters on page 15.

CHP Systems Can Use Lower-Carbon Fuels

Historically, CHP units have run on traditional fuels, and many today use natural gas. This use of CHP can be thought of as "CHP 1.0," the first wave of CHP technologies that relied on fossil fuels. However, CHP units can be fueled by renewable and lower-carbon fuels such as biogas, renewable natural gas (RNG) or biomethane, and hydrogen, or "CHP 2.0." Use of these lower-carbon fuels can allow CHP systems to reduce emissions even further than they do under CHP 1.0. Renewable and lower-carbon fuel technologies can serve as the primary fuel source for CHP systems and further reduce emissions across the industrial, commercial, and municipal sectors. Moreover, CHP systems will use these fuels efficiently, requiring less renewable and lower-carbon fuel inputs for the same energy outputs compared to other generation units.

Some CHP systems can currently use lower-carbon fuels, and work is being done to ensure that more systems can operate with higher volumes and new types of lower-carbon fuels in the future.

Fuels such as biogas and RNG are already being used in CHP systems, and additional existing systems could run on these fuels, providing a near-term solution for further emissions reductions. Generation equipment currently running on traditional fuels may be able to transition to lower-carbon fuels. In addition, using existing gas pipeline infrastructure can be a low-cost option for delivering these new fuels, and current research is examining how this existing infrastructure can accommodate the distribution of hydrogen gas.[42]

Work is also being done to increase the volume of hydrogen fuel that can be used in CHP systems. For example, gas turbine manufacturers are looking to provide equipment that can accommodate higher percentages of lower-carbon fuels: various companies in the U.S. and abroad are deploying or working on hydrogen-ready technology, and in 2019, a number of European companies committed to provide gas turbines that can handle 20% hydrogen content in fuel by 2020, and 100% by 2030.[43] Hydrogen fuel for CHP systems is not yet widespread but could see more extensive use in the future as technologies develop to produce hydrogen fuel and transport it as necessary. The remainder of this subsection will provide additional information about biogas, RNG, and hydrogen.

Biogas

Some CHP facilities already use biogas: gas that is captured from manure, wastewater treatment, or landfills.[44] As can be seen in the Tajiguas Landfill case study on page 17, one facility may be able to use biogas created from different sources in multiple CHP units, and for different purposes. Biogas that is captured and used on the same site reduces the need to transport gas, providing an additional layer of resiliency for a facility, as discussed further in the next section.

The World Biogas Association predicts that anaerobic digestion has the potential to reduce GHG emissions by 3,290 to 4,360 Mt CO2 eq., through renewable energy generation, avoided emissions management, crop burning, deforestation, landfill gas, and fertilizer manufacture emissions.[45]

RNG

Renewable natural gas (RNG), also known as biomethane, is processed biogas that has been cleaned and conditioned to become fully interchangeable with conventional natural gas and can be used in natural gas infrastructure.[46]

Using Biogas with CHP at the Tajiguas Landfill

Quick Facts:

- Location: Santa Barbara County, CA
- Facility: Tajiguas ReSource Center at Tajiguas Landfill
- Cost savings: ~ $1 million per year net electricity costs savings

CHP systems can provide resiliency ("grid back-up") and dispatchable ("on-demand") electricity. At the same time, CHP can make recovered thermal energy available for heating or drying processes and be powered by renewable fuels, further reducing emissions into the atmosphere.

The project at the landfill in Santa Barbara is designed to take advantage of all of these characteristics of CHP systems.

Two CHP units at the landfill are designed to use landfill gas - produced on a constant basis at the landfill, and utilized as fuel in lieu of natural gas - to generate electricity and power the electrical loads of a new on-site Material Recovery Facility (MRF). Utilizing the landfill gas avoids emissions from flaring the landfill gas and avoids emissions associated with using natural gas to generate the electricity required by the MRF. The selected CHPs, powered by internal combustion engines, can regulate output on demand and precisely follow on-site electrical loads in a controlled manner, but can also run constantly at maximum output and export surplus power to the grid.

In case of unplanned or planned power outages, which are occurring in multiple locations across the U.S., the CHP systems can run isolated from the grid and continue to power the MRF during the outage. Upon grid recovery, the CHPs can parallel automatically with the grid to resume normal operations.

In addition, thermal power available from the engines' cooling circuits and exhaust gases can be utilized at a paper drying facility located at the MRF, further offsetting the use of fossil fuels to otherwise generate the thermal power needed in the drying process.

In line with the objectives set out by California on organics diversion from landfills, the MRF's task is to separate incoming waste – which would be otherwise sent to the landfill in its entirety – into recyclable materials (paper, cardboard, glass, metals, plastics), organic waste, and landfill waste (the latter being only 40% of the total incoming waste). A new anaerobic digestion facility also located at the site is designed to receive the separated organic fraction of waste coming from the MRF and convert it into biogas through a dry fermentation process. Through California's feed-in-tariff for renewable generation, CHP units powered by this additional renewable fuel can export 100% of their electrical output into the grid at incentivized rates.

For additional information, see: http://bit.ly/ABCogenCaseStudy. Photo Credit: AB Energy

A study published by the American Gas Foundation prepared by ICF estimates that low and high resource potential scenarios will yield 1,910 tBtu/y and 4,510 tBtu/y respectively by 2040.[47] By comparison, the U.S. has consumed an average of 15,850 tBtu of natural gas annually from 2009-2018.[48] Through the same low and high resource scenarios, ICF estimates that RNG deployment could achieve 101 to 235 MMT of greenhouse gas emissions reductions by 2040. This is equivalent to 59-95% of the average greenhouse gas emissions attributable to natural gas consumption in the residential sector from 2009-2018.[49]

Hydrogen

In the future, more CHP systems could run on fuels with higher percentage concentration of hydrogen. Hydrogen fuel is commonly produced through a thermal process known as natural gas reforming,[50] or through electrolysis using domestic resources like nuclear power, biomass, solar, and wind.[51] There are different types of hydrogen that distinguish how it is produced, which has impacts on its overall emissions: grey hydrogen is produced industrially from natural gas, generating significant carbon emissions; blue hydrogen is also produced from natural gas, but its carbon emissions are captured and stored, or reused; and green hydrogen is generated though electrolysis of water by using renewable energy sources that do not produce carbon emissions.[52] Using electricity from wind turbines and solar panels to power the electrolysis process and produce hydrogen is still under development,[53,54] but has seen increased interest.[55]

Transportation and storage of hydrogen is another challenge to widespread adoption of hydrogen fuel in the near-term. The initial capital costs of new pipeline construction for hydrogen gas are a barrier to expanding hydrogen pipeline delivery infrastructure.[56] Transporting gaseous hydrogen through existing pipelines is a low-cost option for hydrogen delivery, though further research is needed, and being conducted, on the implications of transporting hydrogen through existing pipelines.[57] However, in the near-term, distributed generation technologies such as CHP can be deployed at the point of hydrogen production. This would allow the use of hydrogen fuel in CHP systems, and realization of the corresponding emissions benefits, while the development of hydrogen-ready pipelines is still underway.

The Hydrogen Council, an international coalition of energy, transport, and industrial companies interested in hydrogen propagation published a study entitled, "The Path to Hydrogen Competitiveness." In this report, they estimate that hydrogen has the potential to achieve 18% of global end energy demand by 2050.[58] The amount of emissions reductions that can be achieved by this increase in hydrogen use will depend on the source of the hydrogen fuel, as described above. Currently, 99% of global hydrogen is produced using fossil fuel sources, accounting for 830 Mt CO2/year, more than the entire country of Germany.[59] As the hydrogen economy grows, a switch towards lower-carbon hydrogen production options for both existing and added production could result in significant emissions reductions.

CHP Systems Can Further Reduce Emissions with Carbon Capture

Where a CHP system's use of fuels still results in carbon emissions, carbon capture and storage (CCS) can help to reduce system emissions. Carbon capture and utilization (CCU) can also be deployed to make use of the carbon that is captured as an input into other products or processes.

Carbon capture technologies can reduce emissions that do occur from CHP systems.

CCS is a process that captures and separates carbon dioxide from emissions created by power generation and industrial processes, compresses and transports the gas through pipelines, trucks, or ships, then injects the gas into geological formations that are typically one kilometer or more below the surface.[60]

CCU describes the many pathways where captured CO2, or in some cases carbon monoxide, can be used or "recycled" to produce economically valuable products or services.[61] While enhanced oil recovery (EOR) is the most widely practiced form of carbon utilization today, there are a wide array of carbon utilization options in diverse sectors including construction materials, fuels, plastics, chemicals, agriculture, and food.[62] For example, CHP units can supply commercial greenhouses with needed electric and thermal energy, while the CO2 byproduct from treated exhaust can be distributed at appropriate levels in the greenhouse.[63]

Carbon capture capacity is equal to 25 million metric tons across U.S. industries annually.[64] So far, captured carbon has been used mostly in EOR from existing, already-developed fields, geologically storing the carbon in the process. However, there is market interest and increased investment for other uses of captured carbon, such as concrete, chemicals, and fuels.[65] With appropriate incentives, the Global Carbon Initiative projects that by 2030 the overall CO2-based product industry could use seven billion metric tons of CO2 each year, or about 15 percent of our current global emissions.

03

CHP Provides Resilience in Response to a Changing Climate

In addition to reducing emissions, CHP is a climate change solution because it improves resilience to impacts that are already occurring due to a changing climate. This section will explain why additional resilience is needed, and how CHP can provide facility and community resilience.

A Changing Climate and Increased Electric Grid Disruptions

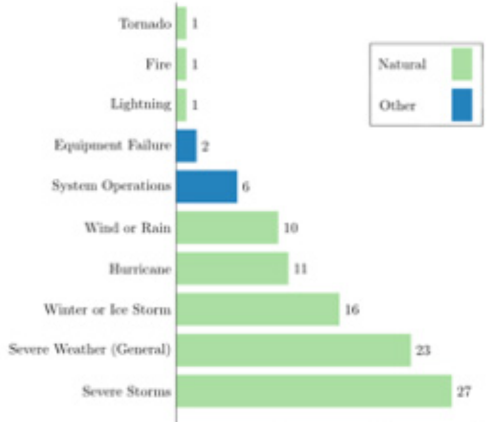
Increased reliance on the electric grid increases the impact grid disruptions have on businesses, industry, and communities.

We know from climate scientists that our climate is changing, and that "[a] changing climate leads to changes in the frequency, intensity, spatial extent, duration, and timing of weather and climate extremes, and can result in unprecedented extremes."[66] Weather events impact the electric grid: extreme weather is the leading cause of electric power outages, especially for the most significant disruptions.[67] Our electricity system was not designed to withstand many of the extreme weather events that occur today, and many parts of the grid are old, outdated, and in poor condition, making the grid even more vulnerable.[68] Weather-related events such as ice, high winds, flooding, and lightning strikes cause about 78% of the major power interruptions in the U.S. power distribution system.[69] This increased frequency and intensity of extreme weather events raises concerns about the resiliency of the electric grid to both present and future climate and weather events.[70]

These dangerous weather events are increasing in frequency across the U.S. and wreak havoc on communities and the economy. Violent storms, tornadoes, wildfires, hurricanes, and ice storms can all have significant and sometimes lasting impacts on communities. In April of 2020, at least 30 people were killed and approximately 750,000 customers were left without power across the South and Mid-Atlantic after a series of violent storms and tornadoes.[71] In October 2019, Pacific Gas & Electric Co. cut power to 730,000 California customers across 34 counties to reduce wildfire risks. While some had their power restored within 24 hours, nearly 600,000 customers waited multiple days before their electricity came back online.[72] This long-term outage forced a handful of colleges and universities to cancel classes, and also endangered many research laboratories and projects at The University of California, Berkeley.[73]

When Hurricane Harvey hit the Gulf Coast in in 2017, the number of reported outages exceeded 2.02 million customers, and in Houston, where flooding impacts were among the most severe, power was not restored until 15 days after the storm's landfall.[74] Also in 2017, Hurricane Maria knocked out 80% of Puerto Rico's electric grid, causing the largest blackout in U.S. history and taking almost 11 months for power to be restored.[75] In 2012, after Superstorm Sandy brought severe

Figure 6: Causes of Large U.S. Electric Disturbance Events Affecting at Least 50,000 Customers (% from 2000-2016)



Source: Oak Ridge National Laboratory. "Extreme Weather and Climate Vulnerabilities of the Electric Grid: A Summary of Environmental Sensitivity Quantification Methods." August 16, 2019, p. 5. https://www.energy.gov/sites/prod/files/2019/09/f67/Oak%20Ridge%20National%20Laboratory%20EIS%20Response.pdf

winds and flooding to the East Coast, over 8.2 million customers were without power, and New York was struck with lasting effects: over 632,000 Long Island customers were left without electricity for two weeks[76] and 818,000 New York City residents were without power for ten days.[77]

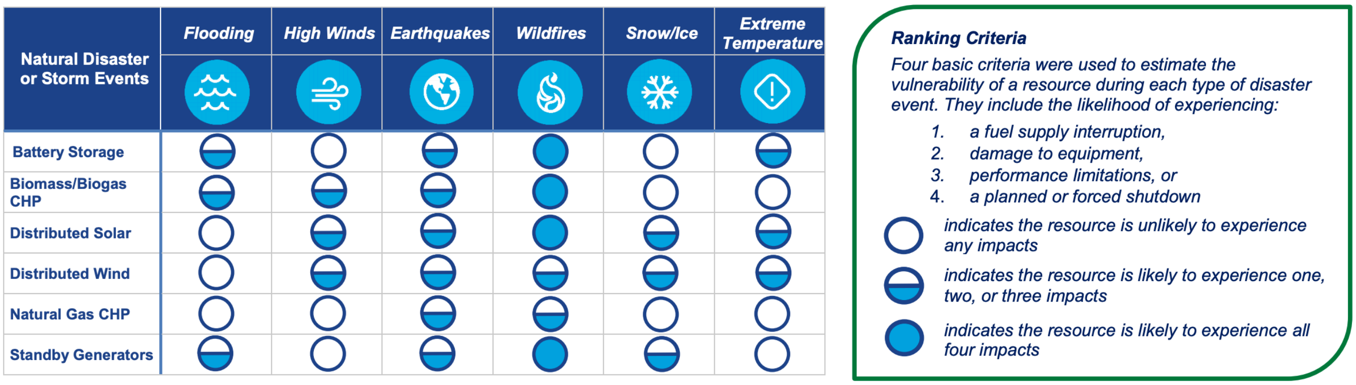
In October 2020, an "unseasonable" ice storm impacted large portions of Oklahoma, causing power outages for 373,000 households and businesses across the state.[78] A "freak" winter storm in October 2011 in the northeast cut power to an estimated 1.7 million homes along the Eastern Seaboard.[79] In one state alone, 700,000 homes and businesses were without power and at least 10 towns were completely without power for some period of time.[80]

More of our energy demand is becoming electrified with increased adoption of electric cars and trucks, commercial and industrial electric boilers, and other electrified industrial process heating applications. Increased reliance on electric energy and the electric grid also increases the impact grid disruptions have on businesses, industry, and communities.

As leading shipping companies including Walmart, UPS, and Amazon make aggressive pledges to expand their electric trucking fleets, the demand for a dependable electricity supply is increasing dramatically. Developing electric trucks has proved to be easy relative to expanding a large, reliable electricity infrastructure that can handle the increase of electricity demand from electric charging hubs.[81] According to a Ceres report, there are increasing concerns that vulnerabilities within the existing electric grid may lead to days-long outages, impacting electric vehicle fleets.[82]

At our National CHP Summit in September 2020, climate experts urged greater deployment of CHP in light of the increasing risks of climate-induced disruptions to the electric grid. CHP's resiliency in the face of natural disaster or storm events can help facilities, including critical infrastructure and essential manufacturing facilities, maintain operations and continue to support the communities they serve and the nation as a whole.[83]

Figure 7: Matrix of DER Vulnerability to Weather Events



Source: Better Buildings: U.S. Department of Energy. "Issue Brief: Distributed Energy Resources Disaster Matrix." https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/DER_Disaster_Impacts_Issue%20Brief.pdf

CHP is Highly Resilient

CHP is a distributed energy resource that is highly resilient to a variety of weather events, as can be seen in the chart in Figure 7. Natural gas fueled CHP is less likely to experience impacts from a variety of disasters than other types of distributed generation. During a grid outage, CHP systems can function in "island mode," automatically separating a host facility or microgrid from the utility grid and providing consistent power and thermal energy to the facility or facilities connected to the microgrid.

Numerous case studies demonstrate that CHP's high level of resiliency can help facilities maintain operations during severe weather events.

Gas infrastructure is less likely to be impacted by severe weather events than other infrastructure systems, as gas pipelines are predominantly underground and the system can continue to operate at high pressure with only half of the compression stations functioning.[84] As discussed above, this infrastructure may be used to transport lower-carbon fuels in the future. In addition, CHP systems that use fuels obtained on-site, such as biogas from a landfill or wastewater treatment plant, may be less reliant on gas infrastructure to maintain operations, adding another layer of resiliency.

This high level of resiliency can help facilities to maintain operations during a severe weather event, as demonstrated by the case study of the University of Texas Medical Branch Galveston on page 21. There are numerous other examples of facilities utilizing CHP that were able to continue operations during major weather events, including Montefiore Medical Center in New York during the 2003 Northeast blackout and Hurricane Sandy,[85] Texas Medical Center during Hurricane Harvey,[86] Louisiana State University during Hurricane Katrina,[87] and New York University, Bergen County Utilities Wastewater Treatment Plant, and numerous other facilities during Superstorm Sandy.[88]

CHP for Resiliency at the University of Texas Medical Branch

Quick Facts:

- Location: Galveston, TX
- Facility: University and hospital
- Emissions benefits: Reduces CO_2 emissions by 16,476 tons per year (equal to removing the carbon emissions of 2,721 cars)
- Cost savings: Save approximately $3 million annually

The University of Texas Medical Branch Galveston (UTMB) includes seven hospitals, a network of specialty clinics, numerous centers and institutes devoted to advanced research, a medical library, and schools of nursing, health professions, and biomedical science, in addition to a medical school of 2,500 students and 1,000 faculty. The facility covers 85 acres with more than 45 buildings and over two million gross square feet, and is supported by 13,000 employees.

In 2008, Hurricane Ike flooded more than one million square feet of the UTMB campus buildings to depths of six feet. When replacing damaged systems, UTMB decided to improve site resilience, replacing critical infrastructure to 49 buildings, including supplementing outside electric utilities with on-site microgrid CHP.

The CHP system provides sufficient chilled water, heating water, and steam to maintain operations of critical buildings during the loss of electrical power from the local utility. The CHP system was tested during Hurricane Harvey in 2017 when the UTMB campus lost both of its electrical feeders as a result of the hurricane, which would have resulted in a complete blackout of the campus. However, the new CHP system continued to operate during and after the storm, allowing the hospital to maintain regular operations.

The systems performed as planned, allowing UTMB to continue patient care, and allowing the hospital to accept patients from surrounding hospitals that were impacted by the storm.

For additional information, see: http://bit.ly/SolarTurbineCaseStudy. Photo Credit: Affiliated Engineers, Inc.

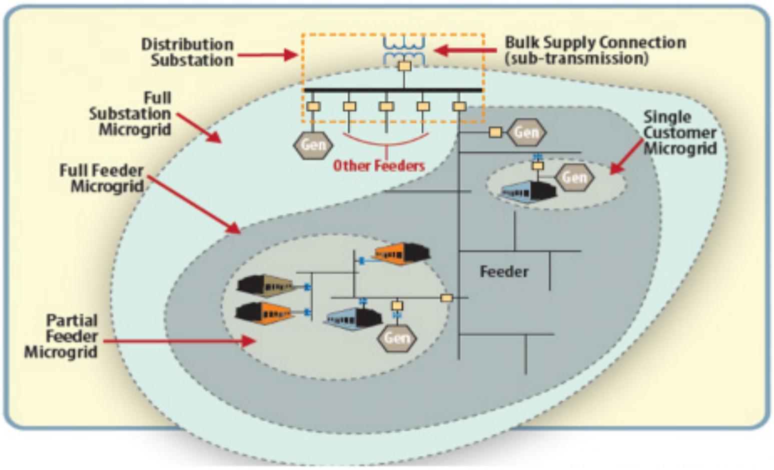
CHP in Microgrids

CHP provides 37% of the capacity for existing microgrids.

The nation's electric grid is a highly interconnected system: impacts to the grid in one location can affect communities far away. According to the latest National Climate Assessment, climate-related impacts increase risks for critical, interconnected systems, many of which span regional and national boundaries. Investing in smaller grid structures powered by clean energy sources, such as microgrids powered by CHP systems, can help to mitigate these risks.[89]

The U.S. Department of Energy (DOE) describes microgrids as "localized grids that can disconnect from the traditional grid to operate autonomously."[90] CHP systems can provide reliable power to a local community as part of a microgrid, allowing several buildings or facilities to keep the lights on during a grid outage.[91] Microgrids are used by universities, military installations, municipalities, and public institutions, helping to maintain the reliability of their electric and thermal energy supply and to improve their resiliency against extreme weather and power outages.[92] In some locations, a number of critical facilities such as hospitals, fire and police stations, emergency shelters, and gas stations can be connected and configured to operate in isolation from the larger utility grid, even during extended outages.

Figure 8: The Role Microgrids in Helping Advance the Nation's Energy System

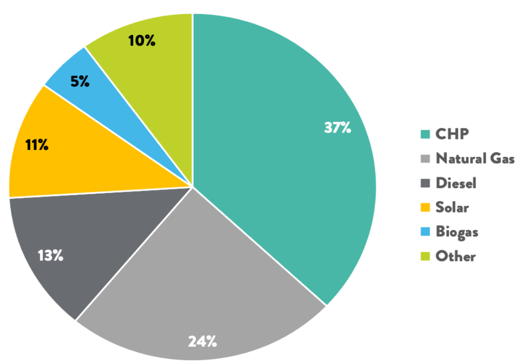


Source: U.S. Department of Energy. Office of Electricity. "The Role of Microgrids in Helping to Advance the Nation's Energy System." https://www.energy.gov/oe/activities/technology-development/grid-modernization-and-smart-grid/role-microgrids-helping

Microgrids strengthen grid resilience and mitigate grid disturbances for these users by localizing power generation close to critical services and providing faster system response and recovery.[93] As of 2016, CHP was the primary generation technology for existing microgrids and is expected to be implemented in future microgrid projects.[94]

CHP systems are more reliable than conventional backup generators because they supply continuous thermal and electric energy and they frequently utilize natural gas infrastructure, rather than relying on deliverable fuels.[95] This makes CHP-fueled microgrids a resilient solution to support critical infrastructure such as hospitals, colleges and universities, wastewater treatment plants, and airports.

Figure 9: Microgrids in the U.S. by Technology Type (% of Total Generating Capacity)



Consulted ICF Microgrid Database and determined CHP's capacity in operational microgrids.

Data Center Uses CHP Microgrid

Quick Facts:

- Location: Bloomington, MN
- Facility: OATI South Campus offices and mission critical datacenter
- CCHP is the backbone of the microgrid, which includes other distributed energy resources including solar panels, energy storage, and wind turbines.
- The customer can run in several modes: optimized for economic benefit, optimized for sustainability benefit, and isolated from the grid in emergency mode. Resiliency is the highest priority as this site is a critical data center for the utility industry.

A new, five-story, 110,000 square-foot office building housing a critical data center built a microgrid on site that can operate in "island mode," separate from the utility's electric grid.

The priority for this facility was ensuring reliable power for its mission-critical data center, ensuring resiliency that could not be provided by the utility. Traditional data centers rely on power from the utility and have banks of batteries to keep servers and equipment running during short power losses, with standby emergency generators typically used for longer outages. However, the system for this facility is configured for a CHP microturbine to provide power and thermal energy in stand-alone mode in the event of a grid failure.

In addition to the CHP unit that provides electricity and heating and cooling, the facility's microgrid includes other distributed energy resources including solar panels, wind turbines, energy storage capacity, and a backup diesel generator. Each of these separate power generation technologies is tied together by a smart microgrid controller with the ability to control and dispatch using advanced optimization models. The CHP unit provides the backbone of the system, operating constantly with its output adjusted by the microgrid controller to coordinate with the intermittent solar and wind power generation. The microgrid provides backup power to the critical facility, and also make economic sense for the customer.

For additional information, see: http://bit.ly/CapstoneTurbinesCaseStudy. Photo Credit: Capstone Turbine Corporation

CHP-powered microgrids are becoming more prevalent in community resilience planning with multiple stakeholders because of their ability to provide continuous power to critical infrastructure and limit the impact of outages by localizing power generation close to critical services.[96] CHP systems not only provide the benefit of essential energy services during catastrophic weather events and emergencies, but can also create cost savings, distribution capacity, power quality benefits, and environmental benefits for an entire community.

In addition to municipal applications, CHP-powered microgrids are an important component of energy reliability in a variety of sectors, as can be seen in the case study on page 25 of the Open Access Technology International (OATI) data center in Minnesota.

CHP Supports Critical Infrastructure

Critical infrastructure is defined as the "assets, systems, and networks that, if incapacitated, would have a substantial negative impact on national security, economic security, or public health and safety,"[97] and includes facilities such as hospitals, nursing homes, colleges and universities, military bases, multi-family buildings, schools, food processing facilities, wastewater treatment plants, lodging, police and fire stations, prisons, supermarkets, pharmaceutical facilities, airports, data centers, and food distribution centers.[98]

CHP systems produce reliable electric and thermal energy close to where it is consumed, improving the resiliency of facilities that utilize it. CHP systems are vital to critical infrastructure facilities because the systems can provide continuous power and thermal energy during emergency situations and grid outages.

CHP systems can support critical infrastructure facilities, providing them with electric and thermal energy during emergency situations and grid outages.

As noted above, CHP systems can be used in a variety of settings. At critical infrastructure facilities such as hospitals and nursing homes and colleges and universities, CHP systems can reduce energy costs, producing savings that can then be used to further their core mission, all while helping these facilities reduce their greenhouse gas and other emissions.

Resiliency and reliability benefits of CHP are of paramount importance to hospitals and universities, especially where healthcare procedures or critical research could be compromised by a loss of power or thermal energy, as was discussed by speakers at our CHP National CHP Summit in September 2020.[99] Resilient medical facilities are essential at any time, and the current COVID-19 pandemic highlights the importance of emergency preparedness in hospitals and nursing

CHP System Supports Municipal Infrastructure

Quick Facts:

- Location: Holland, Michigan
- Facility: Community-owned power supplier
- Emissions benefits: 66% reduction in NOx, 50% reduction in CO2 emissions
- Used a sustainable return on investment (SROI) model where they looked at not only the financial, but also at the societal benefits and costs.

When planning for a new power station to replace an aging coal-fired plant, the Holland Board of Public Works (HBPW), a community-owned power supplier, took into account environmental, health, and social implications. The existing plant could not meet the city's future energy demand, and was a significant source of emissions and subject to public scrutiny. The HBPW engaged the local community in its process, and considered coal, natural gas, renewables, and buying power from the grid. Most of the HBPW's customers – 82% – are commercial or industrial.

The priority of the project was to supply the community with reliable, clean, and affordable energy. The project allows the HBPW to offer an extended snowmelt system, and eventually district heating. The higher thermal efficiency of the plant, combined with reduced fuel costs, provides substantial economic benefits to the City of Holland, City residents, and local businesses.

About 11.5 acres of the streets and pavement in downtown Holland are serviced by an underground snowmelt system that uses the waste heat generated by the power plant's circulating water system. The snowmelt system can melt around one inch of snow per hour in temperatures of 15° to 20°F. The City has the largest snowmelt system in North America, as well as the capability to support a system five times larger.

Clear sidewalks, streets, and parking areas have been a major factor in attracting businesses and customers to the downtown commercial district year-round since the system was first installed.

For additional information, see: http://bit.ly/SiemensEnergyCaseStudy. Photo Credit: Siemens Energy, Inc.

homes. In order to continuously provide lifesaving services, these facilities require reliable and affordable energy resources.

Municipalities can also use CHP systems to support their communities, as can be seen in the case study about Holland, Michigan's Energy Park on page 25.

CHP Supports Industry and Manufacturing

CHP systems can support industrial and manufacturing facilities that are essential to the reliable supply of food and health and safety products.

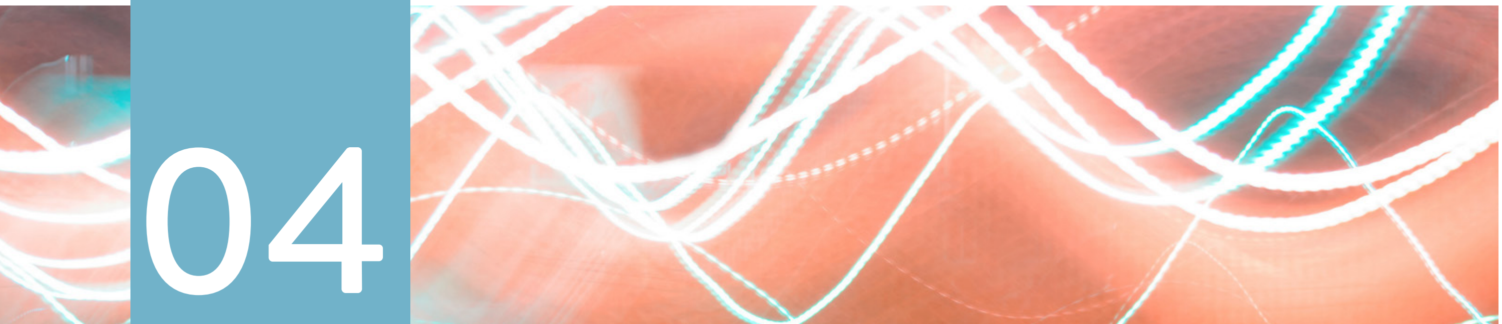
Access to food supplies as well as essential health and safety products is essential. CHP systems can help manufacturing, food processing, greenhouses, and other industrial facilities be resilient in the face of a changing climate, helping to supply food and health and safety products.

As the current COVID-19 pandemic has highlighted, consistent access to food supply chains, including growing, processing, warehousing, transporting, and retailing; pharmaceutical products; and critical manufactured goods including personal protective equipment, ventilators and other medical products, and personal hygiene and cleaning supplies is essential for health and safety.

At manufacturing and other industrial facilities, CHP systems can help to make these plants cost competitive by reducing their energy costs, while helping companies to achieve their environmental and emissions reduction goals.[100]

At present, there are 80.7 GW of installed CHP at more than 4,600 sites throughout the U.S.[101] Of this capacity, 70% is fueled by natural gas, and 16% is fueled by renewable sources (biomass, waste, or wood).[102] CHP currently comprises about 7% of U.S. utility-scale electric generating capacity,[103] but the U.S. Department of Energy estimates there is more than 240 GW of technical potential at over 291,000 sites across the country.

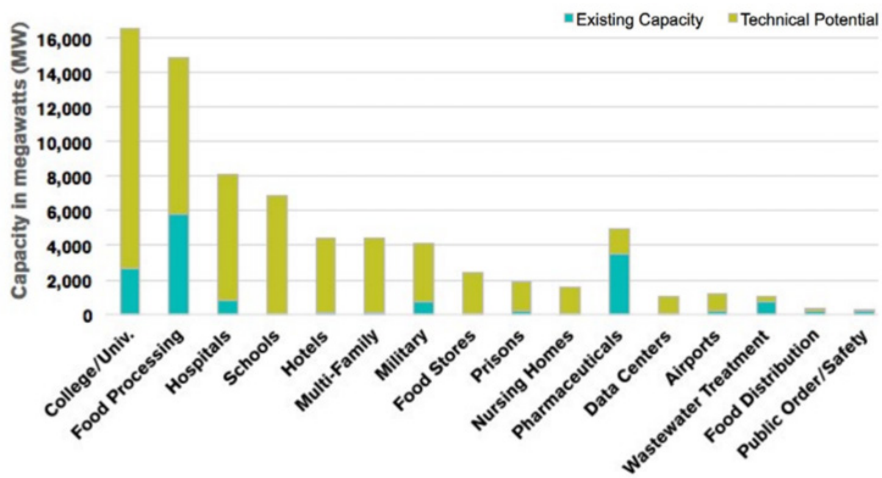
04



The State of the Market

Various market drivers contribute to the continued deployment of CHP technologies, including reduced operating costs, environmental benefits, resiliency, and operational flexibility. However, as discussed further in the next section, there are barriers in the market that inhibit increased deployment, thereby constraining the emissions and resiliency benefits that could be achieved with increased CHP deployment.

Figure 10: Existing Capacity and Technical Potential for CHP Across Individual Critical Infrastructure Sectors in the U.S.

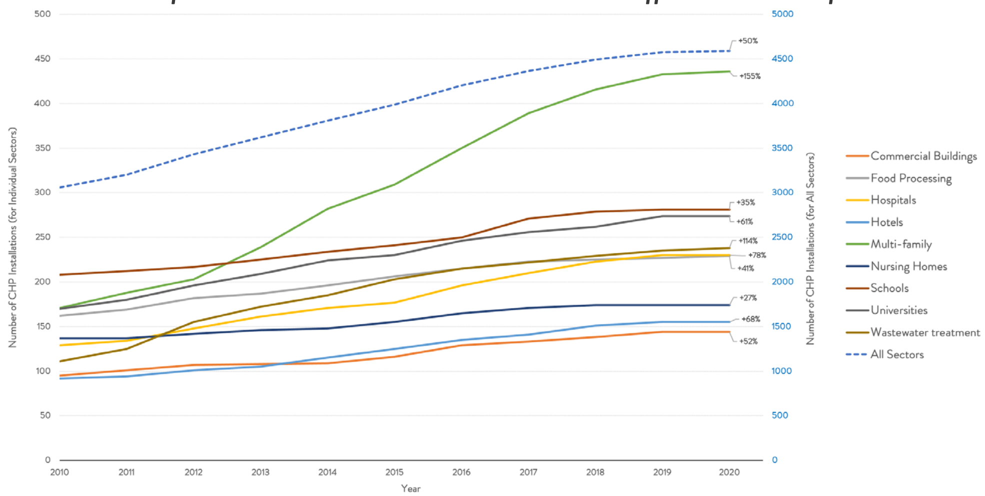


Data provided by ICF, adapted from the Department of Energy CHP Installation Database and CHP Technical Potential in the United States report.

There is growing activity in non-traditional CHP markets, including multi-family buildings, light industrial, commercial, and institutional settings, as evidenced by installations of CHP units since 2015.[104] As can be seen in Figure 11,[e] there has been significant growth in the number of CHP installations at multi-family buildings, wastewater treatment plants, hospitals, hotels, universities, commercial buildings, and other light industrial, commercial, and institutional locations.

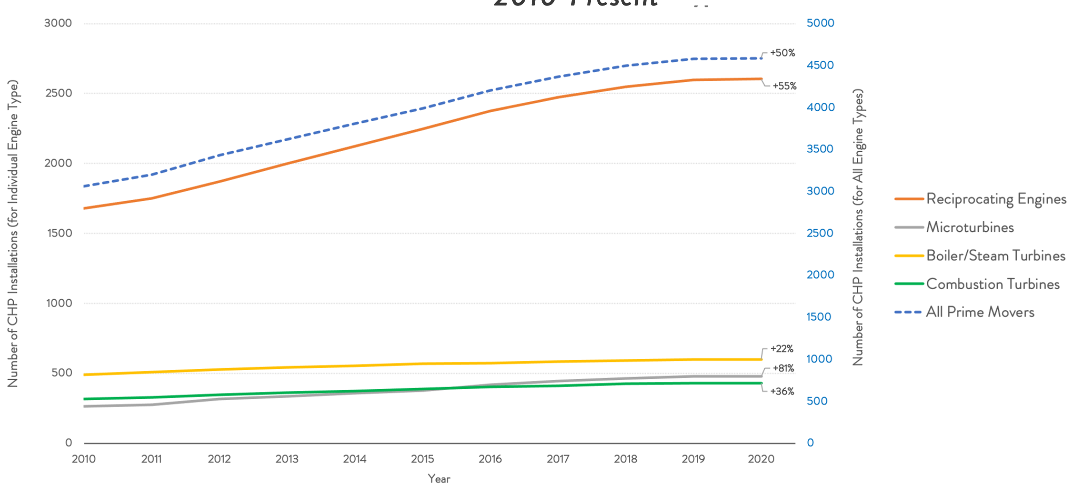
[e] Data retrieved from the Department of Energy Combined Heat and Power Installation Database, last updated August 31, 2020. 54 entries were excluded from the dataset due to lack of latest installation date information. Refer to the y-axis on the right-hand side of the graph for the "all sectors" trendline. Refer to the y-axis on the left-hand side of the graph for individual sector trendlines.

Figure 11: Number of CHP Installations in the US Across Different Sectors from 2010-Present



There is also a trend towards smaller CHP installations, including reciprocating engines and microturbines, and natural gas remains the dominant fuel for newly installed CHP systems.[105] Figure 12[f] shows that the largest increases since 2010 have been in the number of CHP installations using microturbines and reciprocating engines.

Figure 12: Number of CHP Installations in the US Powered by Renewable Fuel Types from 2010-Present



New installations are also trending towards "packaged" CHP systems: systems that are standardized and pre-engineered.[106] These systems reduce the time and expense required to install a CHP system compared to systems that involve custom engineering and design.[107]

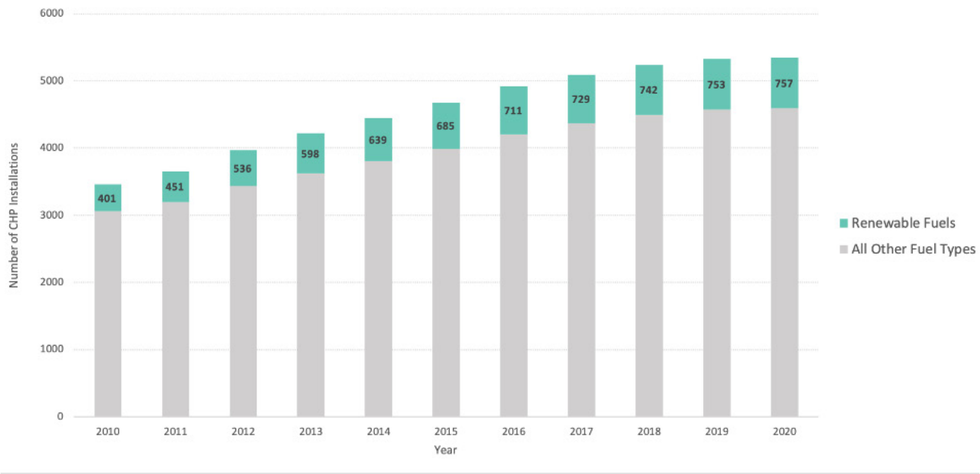
Growing markets for CHP include hybrid installations and microgrids where CHP can ramp up and down to balance variable generation from renewable resources, either as part of a facility's on-site microgrid or to support the local distribution grid.[108] These configurations integrate CHP with other distributed energy resources, increasing a facility's or

[f] Data retrieved from the Department of Energy Combined Heat and Power Installation Database, last updated August 31, 2020. 54 entries were excluded from the dataset due to lack of latest installation date information. Refer to the y-axis on the right-hand side of the graph for the "all engine types" trendline. Refer to the y-axis on the left-hand side of the graph for the individual engine type trendlines.

grid's capacity to accommodate additional intermittent renewable energy.[109]

A review of the CHP Installation Database also shows an increase in the number of CHP installations powered by renewable fuels, defined as agricultural biomass, digester gas, landfill gas, liquid biofuel, solid biomass, or wood, as can be seen in Figure 13.[g]

Figure 13: Number of CHP Installations in the US Powered by Renewable Fuel Types from 2010-Present



In addition, interest in carbon capture and storage (CCS) and carbon capture and utilization (CCU) may lead to CHP installations that include these additional technologies. Results have been promising for biomass-fueled CHP with CCS, and there are examples of CHP units being combined with CCU technologies in applications such as commercial greenhouses.[110]

Remarks by speakers at our National CHP Summit in September 2020 echoed these market trends, including a move towards smaller CHP installations in "non-traditional" CHP applications and packaged CHP systems, the value of resilience as a driver for CHP, CHP as an anchor for resilient microgrids, hybrid CHP systems, micro CHP systems, and a growing interest in CHP by utilities.[111]

g Data retrieved from the Department of Energy Combined Heat and Power Installation Database, last updated August 31, 2020. 54 entries were excluded from the dataset due to lack of latest installation date information. Renewable fuel includes: agricultural biomass, digester gas, landfill gas, liquid biofuel, solid biomass, or wood.

05

Recommendations

It is clear that CHP is a climate change solution because it can both reduce emissions and be a resilient energy resource, reliably providing electric and thermal energy even during severe weather events. However, a number of barriers prevent CHP deployment, and thus reduce the impact CHP can have on reducing emissions and providing resiliency benefits. A theme that was heard from various speakers at our National CHP Summit in September 2020 is the significance of the problem of climate change, and that there is no single solution to the problem.[112] Rather, it will take numerous smaller solutions to contribute to the solution of the bigger problem. CHP is one of those solutions. This section provides an overview of these barriers, and includes recommendations that will allow additional CHP deployment, resulting in reduced emissions and increased resilience.

Barriers to Increased CHP Deployment

CHP faces economic and financial, regulatory, and informational barriers to deployment.[113] These barriers inhibit CHP adoption, thereby limiting the scope of the emissions reductions and resiliency benefits that could be realized with additional CHP deployment.

Economic and Financial Barriers

The key economic and financial barriers to the accelerated adoption of CHP include internal competition for capital, the "split-incentive" between capital improvement and operation and management budgets, securing low-cost financing due to financial risks, and lack of financing instruments such as Master Limited Partnerships.[114]

Installation of CHP systems typically requires a significant upfront investment which can eclipse long-term benefits. Insufficient capital and internal competition for capital prevent many facilities from installing CHP systems, even when such a system has an attractive financial return.[115] A company may also be hesitant to make investments outside of its core business and may require an even higher rate of return compared to other, more familiar capital investments.[116] Internal accounting practices that separate plant operation and maintenance budgets from capital improvements, resulting in costs and savings accruing to different budgets, can also make it difficult to demonstrate the financial benefits of a system.[117] Facilities may also have a hard time finding favorable financing for a long-term investment in the facility upgrade.[118]

Regulatory Barriers

Regulatory barriers include utility business models that often fail to value the efficiency and other benefits that CHP delivers. This may result in rate designs that do not appropriately recognize the value of the services the CHP systems provide to the grid; inconsistent interconnection requirements and failure to recognize all of the benefits of CHP systems were also acknowledged as barriers by DOE.[119]

In addition to financial and tax barriers, regulatory barriers that impact project economics can also restrict capital outlays for CHP systems. Though many CHP systems can operate independently from the electric grid, many facilities that install such systems still interconnect with the electric grid to provide backup power during scheduled or unscheduled outages. A lack of uniform interconnection rules and inconsistent standby rate structures across jurisdictions can also make CHP installation more difficult.

Informational Barriers

The lack of information regarding CHP systems creates another barrier to additional deployment. Potential users of these systems may not be aware of the benefits in energy efficiency and reduced carbon and GHG emissions that could be realized. Even when benefits are known, a lack of information may make it difficult to demonstrate internally that a CHP system is a wise investment. In addition, financial institutions that could provide financing may be unfamiliar with CHP systems and deny needed capital or increase the cost of capital to mitigate their own risk.

Recommendations for Policymakers

Additional CHP deployment could be supported by policies that help to overcome these barriers. Economic and financial barriers could be lowered by the federal investment tax credit and valuing carbon, regulatory barriers could be lowered by utility ownership, and informational barriers could be lowered by research and development (R&D). Incorporating CHP into critical infrastructure planning, including infrastructure that receives government support, could help to save facilities money and improve their resiliency, as well as provide examples of projects and information about specific types of applications.

Investment Tax Credit

The federal Investment Tax Credit (ITC) has played, and continues to play, a critical role in driving energy innovation and technological leadership in the United States. The federal ITC has helped to create thousands of jobs, lower electricity prices for families and businesses, reduce carbon emissions, and maintain the country's competitive edge in emerging energy technologies. Section 48 and Section 25D of the ITC provide tax credits that cover renewable energy technologies such as CHP, micro-turbines, solar energy, geothermal, fuel cells, and distributed wind energy. Increasing, or at the very least maintaining, this tax credit will continue to allow businesses to realize energy and cost savings, support clean energy jobs, and reduce carbon and other GHG emissions.

R&D of Lower-Carbon Fuels

While many CHP units currently run on natural gas, they have the potential to use lower-carbon fuels in higher volumes. Resources such as biogas and RNG or biomethane are currently in use in CHP systems, and could also benefit from additional research and development that would support more commercially available products in the mid-term. Hydrogen fuel is receiving increased attention and interest, however additional research and development is required to overcome technical and informational barriers and realize wide deployment in the long-term.

Deployment in Critical Infrastructure

Ensuring the resilience of critical infrastructure facilities is crucial to community health and safety, and these facilities can be supported by CHP systems. Deployment of CHP at critical infrastructure facilities can reduce a facility's emissions, increase the facility's resiliency, and save the facility money, allowing more resources to be dedicated to the core mission.

Utility Ownership

As discussed above, strategically deployed CHP can help utilities to reduce costs associated with transmission and distribution, saving them and their ratepayers money. Including CHP in utility resource planning and integrated resource plans (IRPs) can help utilities to consider where grid constraints may be eased, and resilience can be improved, with CHP installations.

Valuing Carbon

While they are not zero-carbon resources, CHP systems can help to reduce emissions, and these reductions should be recognized in any system or program that values carbon. Reductions associated with CHP systems that run on lower-carbon fuels, and thus have even lower emissions, should also be recognized.

Valuing Resiliency

CHP systems are highly resilient to a variety of severe weather events. CHP's resiliency in the face of natural disasters or storm events can help facilities, including critical infrastructure and essential manufacturing facilities, maintain operations and continue to support the communities they serve and the nation as a whole.

As important as these resiliency benefits are, they are not always valued when policy or investments decisions are made. Resiliency benefits should be valued appropriately by policymakers, especially when considering investments in critical infrastructure facilities.

Recommendations for Potential Hosts

Potential hosts of CHP systems can realize numerous benefits by deploying CHP. Host facilities can reduce their emissions, improve their resilience, and save money. While many facilities have seen these benefits firsthand, there is still much more potential that has not yet been realized across industries and across the country.

Accessing information that is available to learn about CHP applications and benefits can help potential host facilities to see how installation of CHP systems can help them to meet their economic, environmental, and resiliency goals.

Recommendations for Utilities

Electric and gas utilities should consider CHP during their resource planning for potential application on either side of the meter. CHP is an electric generation resource, but also has value where it can reduce transmission and distribution costs, reduce line losses, and increase the reliability of the electric supply. Including CHP in utility resource planning and integrated resource plans (IRPs) can help utilities to consider where grid constraints may be eased, avoid costs associated with infrastructure buildout, and improve resilience with CHP installations.

In addition to utility ownership of CHP, utilities can support customers that are interested in installing CHP units themselves by working with these customers and developing rate structures that promote, rather than inhibit, CHP adoption.

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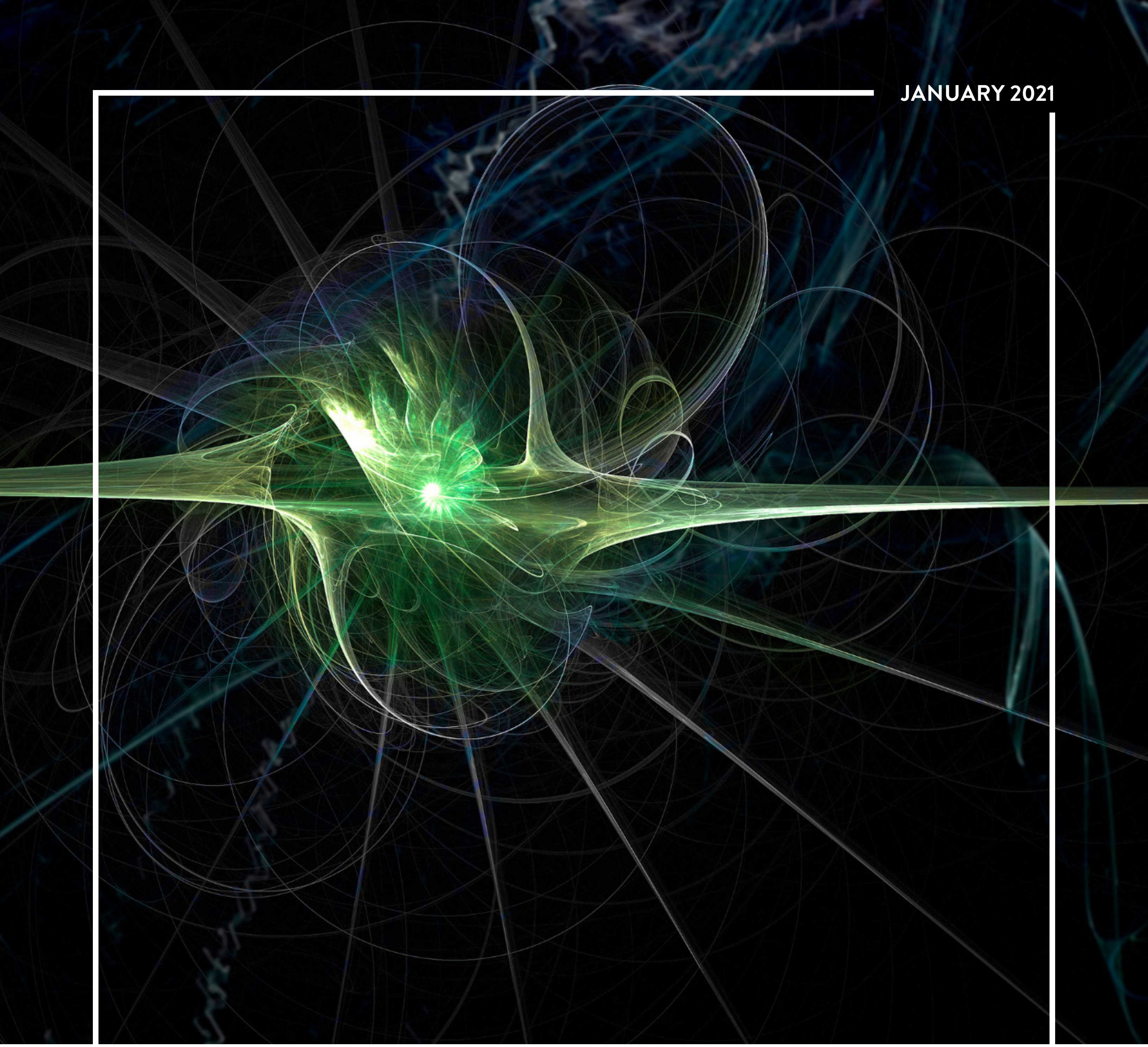

The Combined Heat and Power Alliance (CHP Alliance) is the leading national voice for the deployment of Combined Heat and Power (CHP) and Waste Heat to Power (WHP). We are a coalition of business, labor, contractor, non-profit organizations, and educational institutions with the common purpose to educate all Americans about CHP and WHP, and how CHP and WHP can make America's manufacturers and other businesses more competitive, reduce energy costs, enhance grid reliability, and reduce emissions.

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