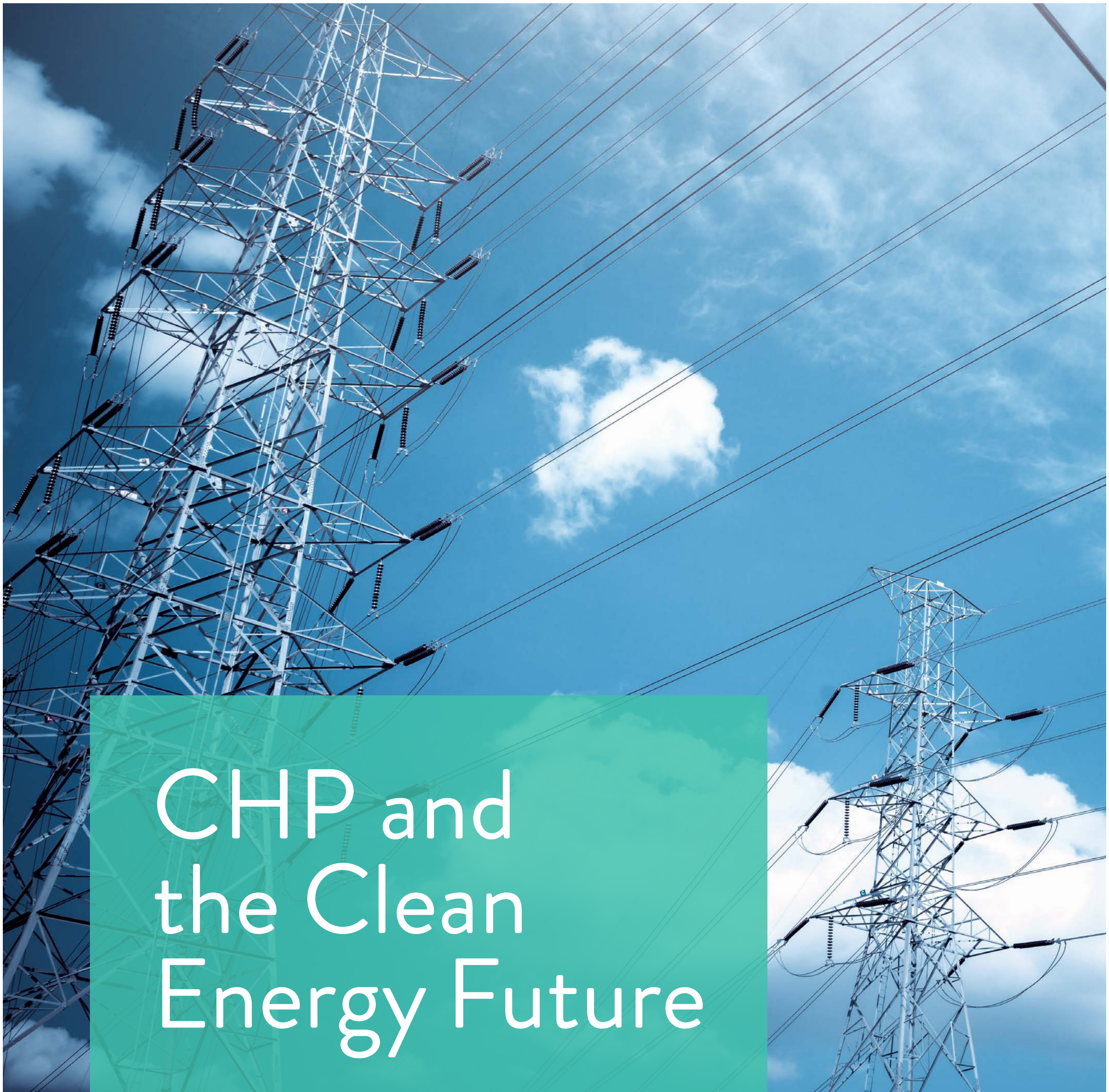

CHP and the Clean Energy Future

How CHP Fits into a Modern Electric Grid and a Green Gas System

NOVEMBER 2021

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Executive Summary

Combined heat and power (CHP) systems are an important part of our nation's energy future as we collectively seek energy resources that are cleaner, reliable, and more resilient.

The electric grid of the future will connect more distributed resources, will include more microgrids, and will be less carbon intensive. **CHP systems are an integral part of the grid of the future, providing energy close to where it is consumed, enhancing resiliency, and reducing emissions.**

The gas system of the future will be greener as well, incorporating more clean fuels such as renewable natural gas (RNG) and clean hydrogen. **CHP systems are an important part of this system too, as they can use these clean fuels efficiently, requiring less fuel inputs to achieve the same energy outputs.**

Attributes of CHP systems make this technology uniquely qualified to provide cleaner, reliable, and more resilient electric and thermal energy resources, including:

- 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.
- Properly designed CHP systems typically operate with an overall efficiency of 65-85 percent.
- CHP systems require less fuel inputs for the same energy outputs, saving money and reducing emissions.
- CHP can be integrated with other clean resources, including as part of a net-zero energy facility.
- CHP is the backbone of many microgrids, and used in 67% of continuously operating microgrids in the U.S.
- Flexible CHP systems can provide generating capacity to the utility electric grid when demand increases or intermittent renewable resources are not available.
- Renewable and lower-carbon fuel technologies such as RNG and hydrogen can serve as the primary fuel source for CHP systems.

This paper explores the current state of the electric grid and gas system in the U.S., the future of each, and examines how CHP will continue to work with these systems to provide cleaner, reliable energy that will support our communities and make them more resilient in the face of a changing climate.

01

Introduction

Combined heat and power (CHP) is a clean energy resource that can help governments, utilities, businesses, institutions, and communities meet their energy system goals by reducing emissions, saving money, maintaining energy reliability, and improving resiliency in the face of a changing climate.

The electric grid of the future will connect more distributed resources, include more microgrids, and be less carbon intensive. CHP systems are an integral part of the grid of the future, providing energy close to where it is consumed, enhancing resiliency, and reducing emissions. In addition, the gas system of the future will be greener as well, incorporating more clean fuels such as renewable natural gas (RNG) and clean hydrogen. CHP systems are an important part of this system too, as they can use these clean fuels efficiently, requiring less fuel inputs to achieve the same energy outputs.

This paper explores the current state of the electric grid and gas system in the U.S. as well as the future of each and examines how CHP will continue to work with these systems to provide cleaner, reliable energy that will support our communities.

02

The Clean Energy Future

A Modern Electric Grid

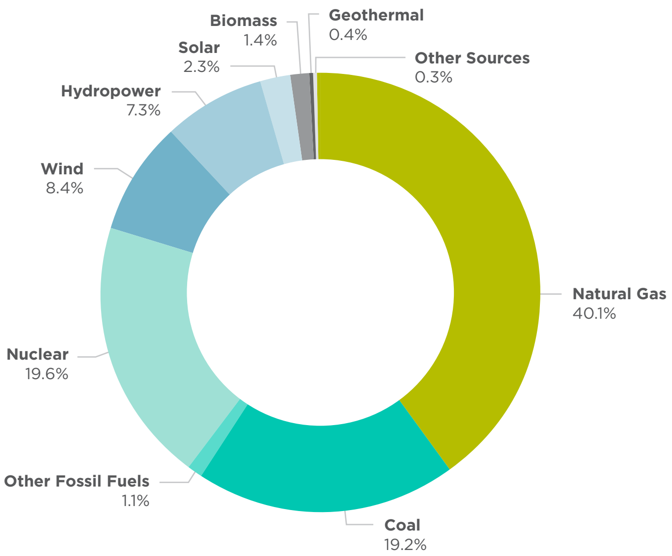
Current State of the Electric Grid

The U.S. electric grid is a complex system where electricity is generated at both centralized power plants and at decentralized units and is transported through a network of substations, transformers, and transmission lines to deliver electricity to end users.[1]

As of the end of 2019, there were 10,346 utility-scale electric power plants in the U.S.[2] The country's power system also includes nearly 160,000 miles of high-voltage power lines, and millions of low-voltage power lines and distribution transformers, connecting 145 million customers.[3]

In 2020, about 4,009 billion kilowatt-hours (kWh) of electricity were generated at utility-scale electricity generation facilities from a variety of resources and technologies.[4] As can be seen in Figure 1, about 60% of this electricity generation was from fossil fuels, about 20% was from nuclear energy, and about 20% was from renewable energy sources.[5]

FIGURE 1. *U.S. Utility-scale Electricity Generation by Source, 2020*[6]



1 "U.S. Electricity Grid & Markets," U.S. Environmental Protection Agency, accessed September 3, 2021, https://www.epa.gov/greenpower/us-electricity-grid-markets.

2 Utility-scale power plants have a total nameplate electricity generation capacity of at least one megawatt (MW). "How many power plants are there in the United States?," U.S. Energy Information Administration, last updated November 18, 2020, https://www.eia.gov/tools/faqs/faq.php?id=65&t=2.

3 "U.S. electric system is made up of interconnections and balancing authorities," U.S. Energy Information Administration, July 20, 2016, https://www.eia.gov/todayinenergy/detail.php?id=27152.

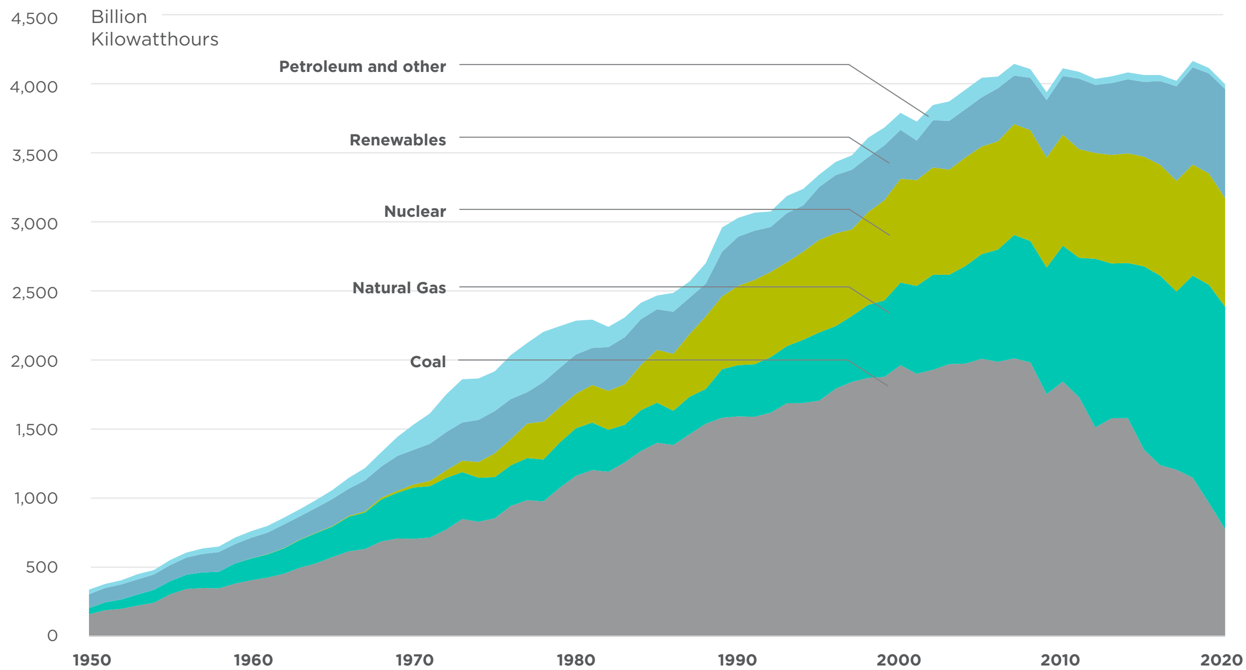
4 "What is U.S. electricity generation by energy source?" U.S. Energy Information Administration, last updated March 5, 2021, https://www.eia.gov/tools/faqs/faq.php?id=427&t=2.

5 U.S. EIA, "U.S. electricity generation by energy source."

6 U.S. EIA, "U.S. electricity generation by energy source."

Electricity generation from renewable resources has increased over time, as can be seen in Figure 2. In recent years, natural gas and renewable energy sources have accounted for an increasing share of U.S. electricity generation, and generation from renewable resources other than hydropower has steadily increased as well.[7] In 2020, 7% of total utility-scale electricity generation came from hydroelectric sources, while 13% came from non-hydroelectric renewable sources.[8]

FIGURE 2. *U.S. Electricity Generation by Major Energy Source, 1950-2020*[9]



The major factors that have contributed to changes in the generation mix in recent years include lower natural gas prices, state requirements to use more renewable sources, financial incentives for building new renewable capacity, federal air pollution emission regulations for power plants, and slowing electricity demand.[10]

Local grids are interconnected to create larger electricity networks and the network covering the lower 48 states is comprised of three major interconnections that function mostly independently of one another and have limited exchanges between them.[11] These three interconnections are the Eastern Interconnection, the Western Interconnection, and the Electric Reliability Council of Texas (ERCOT), as shown in Figure 3 on the following page.[12] Within each interconnection, regional balancing authorities manage grid operations to ensure that electricity supply constantly matches power demand in a balance that maintains electric service reliability.[13]

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7 "Electricity explained," U.S. Energy Information Administration, last updated March 18, 2021, https://www.eia.gov/energyexplained/electricity/electricity-in-the-us-generation-capacity-and-sales.php.

8 U.S. EIA, "Electricity explained."

9 Electricity generation from utility-scale facilities. U.S. EIA, "Electricity explained."

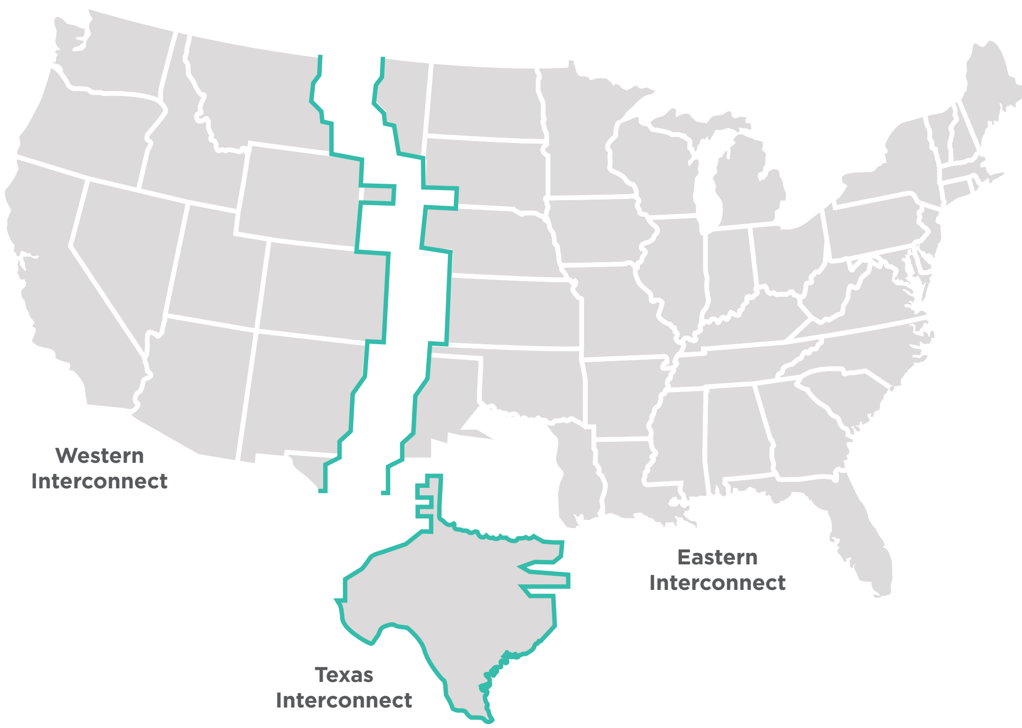
10 U.S. EIA, "Electricity explained."

11 U.S. EPA, "U.S. Electricity Grid & Markets."

12 U.S. EPA, "U.S. Electricity Grid & Markets."

13 U.S. EPA, "U.S. Electricity Grid & Markets."

FIGURE 3. *North American Electric Power Grids*[14]



The nation's electric grid is aging: major upgrades will be necessary to reliably incorporate new technologies and systems, changing market dynamics, and shifting consumer preferences.[15] While most electricity is still generated at large central power plants and transmitted through the grid system, the use of distributed generation units — technologies that generate electricity at or near the location where it will be used — in the U.S. has increased in recent years.[16] This increase is occurring for a variety of reasons, including:

- The cost-effectiveness of renewable technologies;
- State and local governments advancing policies to encourage greater deployment of renewable technologies;
- Use of distributed generation systems to provide electricity during power outages including those that occur after severe storms and during high energy demand days; and
- Grid operators relying on some businesses to operate their onsite emergency generators to maintain grid reliability during peak electricity use.[17]

Increased interest in renewables deployment and implementation of microgrids to improve resiliency can lead to further use and installation of distributed generation units.

States have found that the move to adopt new technologies and develop more distributed generation resources is outpacing regulatory policy: Policies are needed that promote cost-effective investment in the

14 U.S. EPA, "U.S. Electricity Grid & Markets."

15 "Modernizing the Electric Grid: State Role and Policy Options," National Conference of State Legislatures, April 5, 2021, https://www.ncsl.org/research/energy/modernizing-the-electric-grid-state-role-and-policy-options.aspx.

16 "Distributed Generation of Electricity and its Environmental Impacts," U.S. Environmental Protection Agency, accessed September 6, 2021, https://www.epa.gov/energy/distributed-generation-electricity-and-its-environmental-impacts.

17 U.S. EPA, "Distributed Generation."

electricity system while allowing for innovation and new energy management systems.[18] This will require state policymakers to adapt both existing policies and infrastructure that were designed for a centralized energy grid with one-way flows from central power plants to customers, to those that will allow for the smooth operation of a less centralized system that incorporates more distributed generation resources and multi-directional energy flows.[19]

The use of distributed generation units has increased in recent years and may continue to do so as more renewables and microgrids are deployed.

A Changing Climate Will Increase Grid Disruptions

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."[20] Weather events impact the electric grid: Extreme weather is the leading cause of electric power outages, especially for the most significant disruptions.[21] 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.[22] 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.[23] A 2020 analysis of national power outage data shows a 67% increase in major power outages from weather-related events since 2000.[24] 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.[25]

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.

There are myriad examples of severe weather causing devastating results throughout the country over the years, and 2021 has been no different. Early in the year, severe winter weather in Texas left nearly 4.5 million customers without electricity.[26] While wildfires are a natural part of California's landscape, the fire season in the state and across the West is starting earlier and ending later each year, as warmer spring and summer temperatures, reduced snowpack, and earlier spring snowmelt create longer and more intense dry seasons that make forests more susceptible to severe wildfire.[27] At the start of August, 91 wildfires were burning across

18 NCSL, "Modernizing the Electric Grid."

19 NCSL, "Modernizing the Electric Grid."

20 "Changes in Climate Extremes and their Impacts on the Natural Physical Environment," Intergovernmental Panel on Climate Change, 2018, p. 311, https://www.ipcc.ch/site/assets/uploads/2018/03/SREX-Chap3_FINAL-1.pdf.

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

22 "Power Failure: How Climate Change Puts Our Electricity at Risk—and What We Can Do," Union of Concerned Scientists, April 2014, p. 2-3, https://www.ucsusa.org/sites/default/files/2019-10/Power-Failure-How-Climate-Change-Puts-Our-Electricity-at-Risk-and-What-We-Can-Do.pdf.

23 "Climate change impacts and costs to U.S. electricity transmission and distribution infrastructure," Fant, et al., Energy, March 15, 2020, p. 1, https://www.sciencedirect.com/science/article/pii/S0360544220300062.

24 "Power OFF: Extreme Weather and Power Outages," Climate Central, September 30, 2020, https://medialibrary.climatecentral.org/resources/power-outages.

25 Oak Ridge National Laboratory, "Extreme Weather."

26 Ryan W. Miller, "'Massive failure:' Why are millions of people in Texas still without power?," USA TODAY, February 16, 2021, https://www.usatoday.com/in-depth/news/nation/2021/02/16/texas-weather-power-outage-rolling-blackouts-leave-millions-dark/6764764002/.

27 "2021 Incident Archive," CAL FIRE, last accessed September 16, 2021, https://www.fire.ca.gov/incidents/2021/.

the country.[28]

In late August, Hurricane Ida hit Louisiana knocking out power to all of New Orleans, leaving hundreds of thousands of people without air conditioning or refrigeration in the sweltering heat.[29] The storm did not stop there, but made its way to the Northeast where flash flooding killed at least 44 people in four states as roads and basements were submerged from torrential rain.[30]

These severe events have the potential to have an even greater impact as electrification of various sectors increases reliance and adds stress to the electric grid. 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.[31] 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.[32]

More sectors electrifying increases reliance on and places additional stress on the electric grid.

The Grid of the Future

A more resilient grid system will help communities endure climate impacts. The grid of the future will connect more distributed resources to hedge against system-wide impacts, will include more microgrids to keep essential infrastructure and services online during grid outages, and will be less carbon intensive as businesses, governments, and individuals seek to decrease their emissions and prevent further climatic changes. CHP systems are an integral part of the grid of the future, providing energy close to where it is consumed, enhancing resiliency, and reducing emissions.

Distributed energy resources can contribute to overall electric grid reliability and energy security and can provide power to an individual facility or several as part of a microgrid.[33] This flexible CHP approach provides a distributed energy resource that the grid could call upon during times of high demand.

The grid of the future will connect more distributed resources, include more microgrids, and be less carbon intensive. CHP systems are an integral part of this future grid.

28 Amir Vera and Deanna Hackney, "91 wildfires are now burning across the US, with Oregon's Bootleg Fire growing to over 400,000 acres," CNN, August 1, 2021, https://www.cnn.com/2021/08/01/us/us-western-wildfires-sunday/index.html.

29 Rebecca Santana, Kevin McGill, and Jane McConnaughey, "Hurricane Ida lashes Louisiana, knocks out New Orleans power," AP, August 30, 2021, https://www.wrbl.com/news/national/powerful-hurricane-ida-closing-in-on-louisiana-landfall/.

30 Barbara Goldberg and Nathan Layne, "Ida's record rain floods New York-area homes, subways; at least 44 dead," Reuters, September 3, 2021, https://www.reuters.com/world/us/new-york-city-mayor-declares-state-emergency-after-record-breaking-rain-2021-09-02/.

31 David Ferris, "'Achilles' heel': How charging hobbles the electric truck," E&E News, October 16, 2020, https://www.eenews.net/stories/1063716351.

32 "The Road to Fleet Electrification," Ceres, 2020, p. 10, https://www.ceres.org/sites/default/files/reports/2020-05/The%20Road%20to%20Fleet%20Electrification.pdf.

33 "Distributed Energy Resources for Resilience," U.S. Department of Energy Federal Energy Management Program, last accessed September 11, 2021, https://www.energy.gov/eere/femp/distributed-energy-resources-resilience.

While much of our electricity is generated at central power plants and distributed through transmission and distribution systems, distributed generation allows electricity to be generated close to where it will be used, serving a single facility or as part of a microgrid. In addition, CHP owners could generate revenue from selling the excess electricity to partly offset the costs of owning and operating a CHP system.

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 mitigate these risks.[34]

Many businesses, governments, and institutions throughout the U.S. and around the world have made commitments to reduce their greenhouse gas (GHG) emissions to slow and eventually reverse climate change. This increases the demand for lower-carbon energy resources for both electric and thermal energy. No one clean energy resource will be able to reduce emissions sufficiently across sectors, rather we will need to deploy numerous clean energy resources and technologies to meet this increased demand for clean energy.

34 "Fourth National Climate Assessment Volume II: Impacts, Risks, and Adaptation in the United States," U.S. Global Change Research Program, November 23, 2018, https://nca2018.globalchange.gov/.

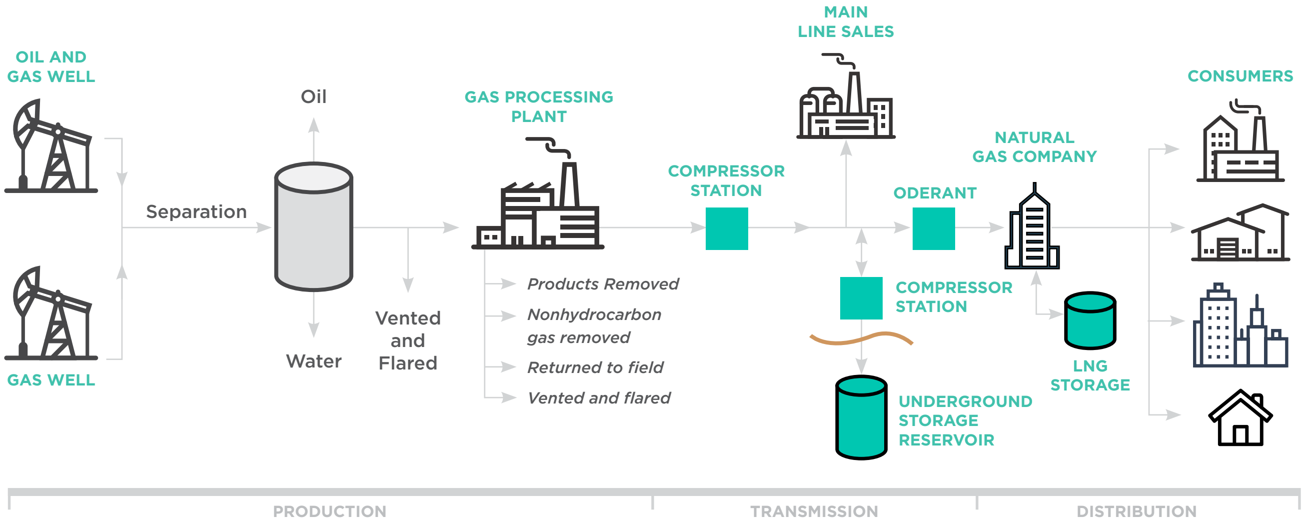
A Green Gas System

Current State of the Gas System

The natural gas pipeline system in the U.S. has about three million miles of mainline and other pipelines, and in 2019, this transportation network delivered about 28.3 trillion cubic feet of natural gas to about 76.9 million customers.[35] Gathering systems move raw natural gas from wellheads to processing plants that separate hydrocarbon gas liquids, nonhydrocarbon gases, and water from the natural gas before the natural gas is delivered into a mainline transmission system.[36] Interstate and intrastate transmission pipelines transport natural gas from areas where it is produced and processed to storage facilities and distribution centers, and local distribution companies deliver the natural gas to consumers through lower pressure service lines.[37]

> *The demand for clean energy is increasing and numerous clean energy resources and technologies will need to be deployed to meet this demand.*

FIGURE 4. *Natural Gas Production and Delivery*[38]



35 "Natural gas explained: Natural gas pipelines," U.S. Energy Information Administration, last updated December 3, 2020, https://www.eia.gov/energyexplained/natural-gas/natural-gas-pipelines.php.

36 U.S. EIA, "Natural gas pipelines."

37 U.S. EIA, "Natural gas pipelines."

38 "Natural gas explained: Delivery and storage of natural gas," U.S. Energy Information Administration, last updated December 3, 2020, https://www.eia.gov/energyexplained/natural-gas/delivery-and-storage.php.

Impacts to the Gas System from a Changing Climate

Gas pipelines can be affected by severe weather events, including impacts such as loss of power, flooding, and changes to surfaces and landscapes on which pipelines are installed.[39] However, since gas pipelines in many places are installed underground, gas-fueled CHP is less likely to experience impacts from a variety of disasters than other types of distributed generation, as can be seen in Figure 5, below.

Gas-fueled CHP is less likely to experience impacts from a variety of severe weather events than other types of distributed generation.

FIGURE 5. *Matrix of DER Vulnerability to Weather Events*[40]

Natural Disaster or Storm Events	Flooding	High Winds	Earthquakes	Wildfires	Snow/Ice	Extreme Temperature
Battery Storage	◒	○	◒	●	○	◒
Biomass/Biogas CHP	◒	◒	◒	●	○	○
Distributed Solar	○	◒	◒	●	◒	◒
Distrubuted Wind	○	◒	◒	◒	◒	◒
Natural Gas CHP	○	○	◒	◒	○	○
Standby Generators	◒	○	◒	●	◒	○

RANKING CRITERIA

Four basic criteria were used to estimate the vulnerability of a resource during each type of disaster event. They include the liklihood of experiencing:

1. A fuel supply interruption
2. Damage to equipment
3. Performance limitations
4. A planned forced shutdown

○ Resource is likley to experience any impacts

◒ Resource is likely to experience one, two or three impacts

● Resource is likley to experience all four impacts

The Gas System of the Future

The nation's gas system has the potential to become less carbon-intensive in the future by delivering higher quantities of lower-carbon and renewable fuels. Using or retrofitting existing pipeline and related infrastructure may be a low-cost option to deliver cleaner fuels.

The gas system of the future has the potential to be less carbon-intensive.

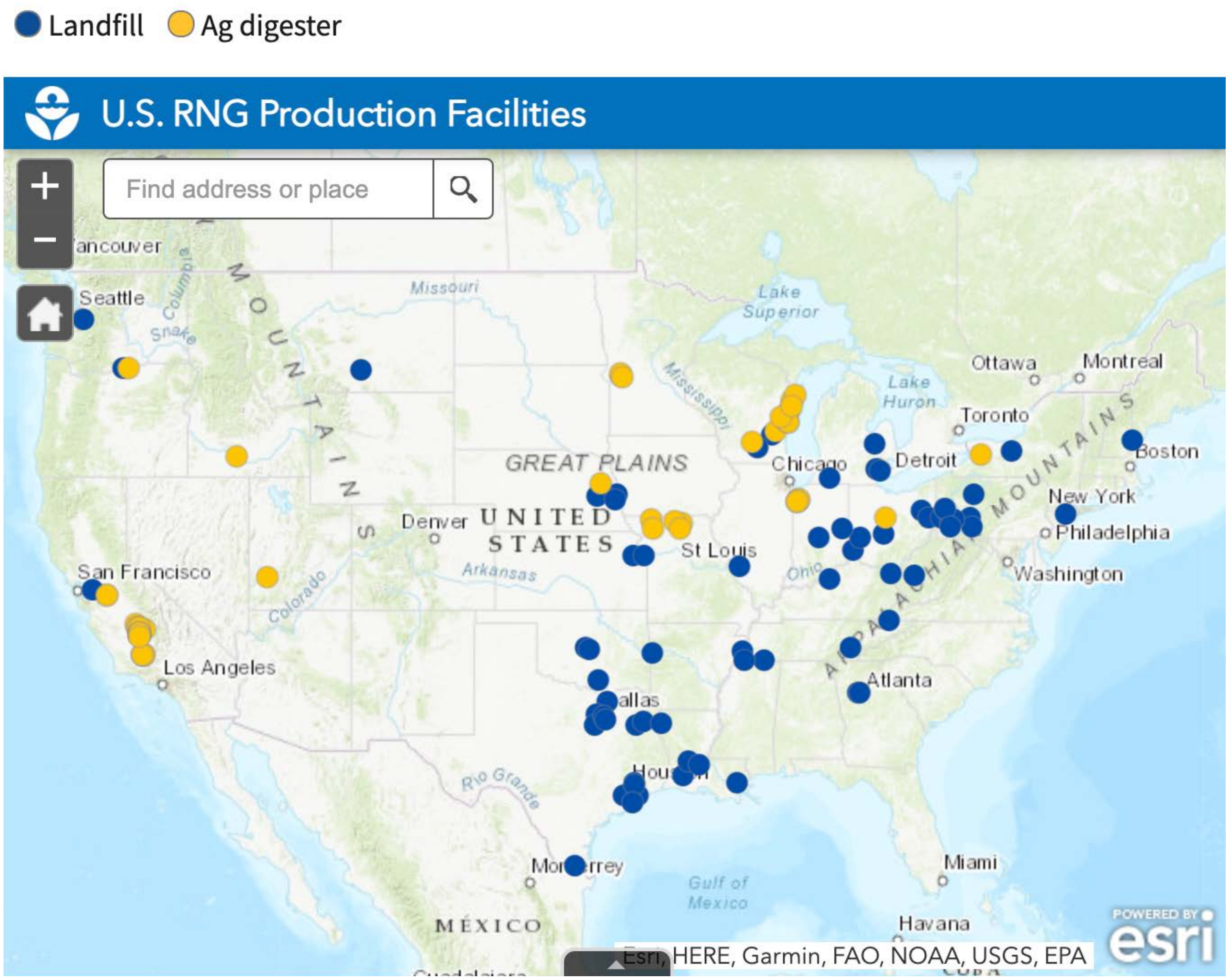
RNG, also known as biomethane, is most commonly produced from biogas that has been cleaned by removing CO_2 and other trace gases. RNG can also be generated from the direct gasification or pyrolysis of biomass. The high methane content of RNG allows for full compatibility within natural gas appliances and pipeline systems. CHP fleets that run on natural gas require minimal upgrades to be fueled by RNG and would produce immediate emission reductions by transitioning. According to an ICF study, RNG deployment could achieve as much as 235 MMT of GHG emissions reductions by 2040.[41] This is equivalent to 95% of the average GHG emissions attributable to natural gas consumption in the residential sector from 2009-2018.

39 "Climate Change: Energy Infrastructure Risks and Adaptation Efforts," U.S. Government Accountability Office Report to Congressional Requesters, January 2014, https://www.gao.gov/assets/gao-14-74.pdf.

40 "Issue Brief: Distributed Energy Resources Disaster Matrix," U.S. Department of Energy Better Buildings, 2017, https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/DER_Disaster_Impacts_Issue%20Brief.pdf.

41 "Renewable Sources of Natural Gas: Supply and Emissions Reduction Assessment," An American Gas Foundation Study Prepared by ICF, December 2019, https://gasfoundation.org/wp-content/uploads/2019/12/AGF-2019-RNG-Study-Full-Report-FINAL-12-18-19.pdf.

FIGURE 6. *Existing RNG Production Sites*[42]



Biogas and RNG are viable low-carbon fuel alternatives, yet their deployment has been relatively lacking. The U.S. currently has more than 2,200 sites producing biogas with 860 of these locations using the biogas they produce.[43] However, the American Biogas Council estimates there are 13,500 sites with biogas production potential, primarily at animal farms and wastewater treatment facilities.[44] The majority of biogas deployment to date has been through landfill gas collection, which comprises nearly 90% of total production.[45] The livestock industry is responsible for one-third of total methane emissions in the U.S., and represents a significant untapped market for biogas production.

RNG is fully compatible within natural gas appliances and pipeline systems.

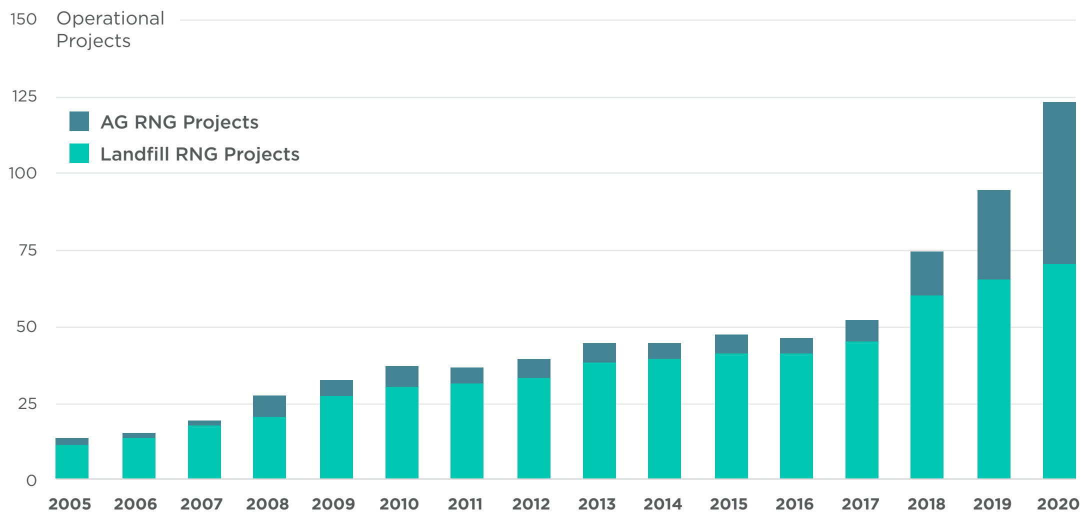
42 "RNG Project Map," U.S. Environmental Protection Agency, Landfill Methane Outreach Program (LMOP), last updated July 14, 2021, https://www.epa.gov/lmop/renewable-natural-gas#rngmap.

43 Anna Simet and Katie Fletcher, "Biogas Advances in the US," Biomass Magazine, January 27, 2017, http://biomassmagazine.com/articles/14135/biogas-advances-in-the-us.

44 "Why Biogas?," American Biogas Council, last accessed September 17, 2021, https://americanbiogascouncil.org/wp-content/uploads/2019/05/ABC-Handout-2019apr-vP3-1.pdf.

45 "Report extract: An introduction to biogas and biomethane," International Energy Agency, last accessed September 17, 2021, https://www.iea.org/reports/outlook-for-biogas-and-biomethane-prospects-for-organic-growth/an-introduction-to-biogas-and-biomethane.

FIGURE 7. *Landfill and Agriculture RNG Projects in the U.S. (2005-2020)*[46]



Hydrogen fuel is commonly produced through a thermal process known as natural gas reforming, or through electrolysis using domestic resources like nuclear power, biomass, solar, and wind.[47] 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.[48]

Using electricity from wind turbines and solar panels to power the electrolysis process and produce hydrogen is still under development, but has seen increased interest.[49]

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. 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. 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.

In a 2020 report, the Hydrogen Council estimated that hydrogen has the potential to achieve 18% of global end

46 "Landfill and Agriculture RNG Projects in the United States (2005-2020)," U.S. Environmental Protection Agency, Landfill Methane Outreach Program (LMOP), Last updated on July 14, 2021. https://www.epa.gov/lmop/renewable-natural-gas#basics.

47 "Hydrogen Fuel Basics," U.S. Department of Energy Office of Energy Efficiency & Renewable Energy, Hydrogen and Fuel Cell Technologies Office, last accessed September 12, 2021, https://www.energy.gov/eere/fuelcells/hydrogen-fuel-basics.

48 Noé van Hulst, "The clean hydrogen future has already begun," International Energy Agency, April 23, 2019, https://www.iea.org/commentaries/the-clean-hydrogen-future-has-already-begun.

49 "'Hydrogen Economy' Offers Promising Path to Decarbonization," BloombergNEF, March 30, 2020, https://about.bnef.com/blog/hydrogen-economy-offers-promising-path-to-decarbonization/.

energy demand by 2050.[50] 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 CO_2/year, more than the entire country of Germany.[51] 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.

Using lower-carbon hydrogen production options for both existing and added production can result in significant emissions reductions.

In June of 2021, Secretary of Energy Jennifer M. Granholm launched the DOE's Energy Earthshots Initiative to accelerate breakthroughs of more abundant, affordable, and reliable clean energy solutions within the decade.[52] The first Energy Earthshot is the Hydrogen Shot and seeks to reduce the cost of clean hydrogen by 80% to $1 per kilogram in the next decade.

Using existing gas pipeline infrastructure can be a low-cost option for delivering these new fuels. While RNG is interchangeable with natural gas, current research is examining how existing infrastructure can accommodate the distribution of hydrogen gas.[53]

Using existing gas pipeline infrastructure can be a low-cost option for delivering these new fuels.

50 "Path to hydrogen competitiveness: A cost perspective," Hydrogen Council, January 20, 2020, https://hydrogencouncil.com/wp-content/uploads/2020/01/Path-to-Hydrogen-Competitiveness_Full-Study-1.pdf.

51 "The future for green hydrogen," Wood Mackenzie, October 25, 2019, https://www.woodmac.com/news/editorial/the-future-for-green-hydrogen/.

52 "Secretary Granholm Launches Hydrogen Energy Earthshot to Accelerate Breakthroughs Toward a Net-Zero Economy," U.S. Department of Energy, June 7, 2021, https://www.energy.gov/articles/secretary-granholm-launches-hydrogen-energy-earthshot-accelerate-breakthroughs-toward-net.

53 "Hydrogen Pipelines," U.S. Department of Energy Office of Energy Efficiency & Renewable Energy, Hydrogen and Fuel Cell Technologies Office, last accessed November 24, 2020, https://www.energy.gov/eere/fuelcells/hydrogen-pipelines.

03

CHP Supports a Modern Electric Grid

Reducing Emissions

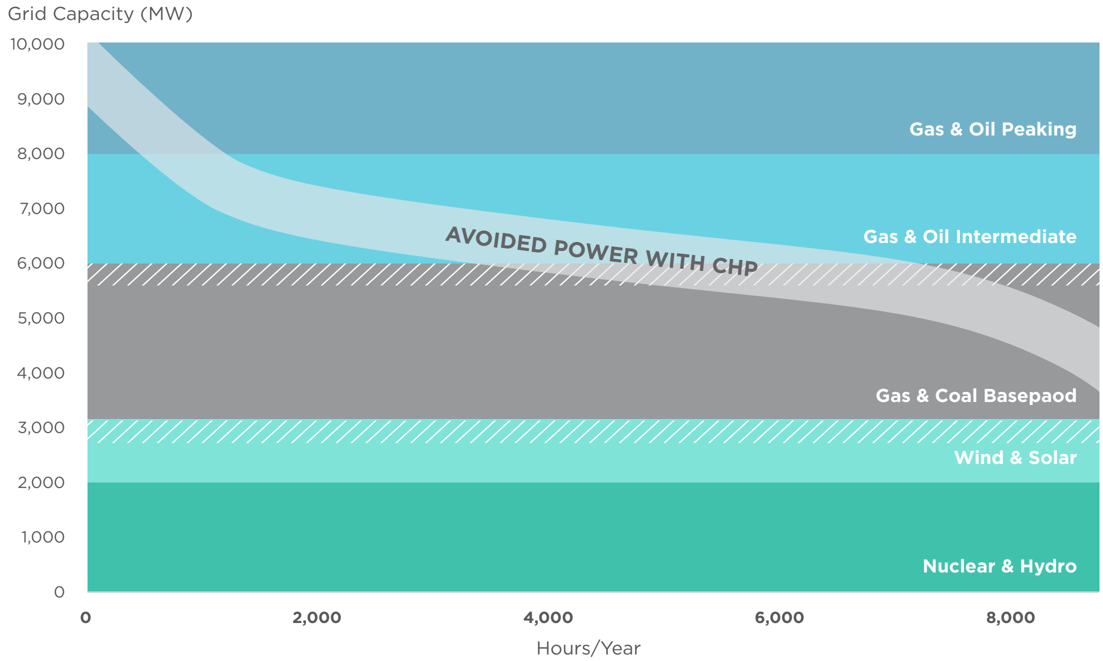
Numerous factors allow CHP systems to reduce emissions and this section will explain how this occurs, even when CHP systems use fuels such as natural gas. Central to CHP's ability to reduce emissions is the fact that CHP systems are highly efficient, requiring less fuel inputs to achieve the same energy outputs as other systems. 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.

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.[54] 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.

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.

54 In all regions except New York and California. "Combined Heat and Power Potential for Carbon Emission Reductions: National Assessment 2020-2050," ICF, July 2020, p. 4, http://consortia.myescenter.com/CHP/ESC_CHP_Emissions-Full_Study-ICF-071320.pdf.

FIGURE 8. *Avoided Power with CHP for an Example Utility*[55]



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.[56]

The average efficiency of fossil-fueled power plants in the U.S. is approximately 39%, with a range of anywhere from 31% to 37% efficient when accounting for transmission and distribution (T&D) losses.[57] This means

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55 ICF, "National Assessment," p. 7.

56 "Valuing the Reliability of Combined Heat and Power," U.S. Environmental Protection Agency, January 2007, p. 2, https://www.epa.gov/sites/production/files/2015-07/documents/valuing_the_reliability_of_combined_heat_and_power.pdf.

57 Using eGRID 2018 summary data tables, the U.S. Energy Information Administration 2018 average operating heat rates for fossil-fuel energy sources, and the equivalent Btu content of a kWh of electricity (3,412 Btu), 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 with a simple ratio of reported fuel consumption and electricity generation values located in EIA 923 data files. For example, in 2018, EIA found that the 10.5 quadrillion Btu's of natural gas consumption at non-CHP electric power sector plants yielded 1,358 TWh of natural gas-fired electric generation, giving a 7,732 Btu/kWh operating heat rate for natural gas resources. 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. The NGCC power blocks that were installed before 2000, which represent 21% of total capacity, have a relatively high heat rate (8,840 Btu/kWh) and a relatively low-capacity factor (44%). In contrast, the low 6,654 Btu/kWh heat rate of NGCC power blocks installed since 2015, which represent 11% of all NGCC capacity, helped drive the capacity factor of this group up to 63%. 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, as well as during peak and non-peak demand times, we used a range of 2 - 8% decrease in efficiency given T&D losses.

- "Emissions & Generation Resource Integrated Database (eGRID): Summary Tables 2018," U.S. Environmental Protection Agency, created March 9, 2020, https://www.epa.gov/sites/production/files/2020-01/ documents/egrid2018_summary_tables.pdf.
- "Table 8.1: Average Operating Heat Rate for Selected Energy Source, 2009 through 2019," U.S. Energy Information Administration, https://www.eia.gov/electricity/annual/html/epa_08_01.html.
- "What is the efficiency of different types of power plants?," U.S. Energy Information Administration FAQs, last updated August 17, 2020, https://www.eia.gov/tools/faqs/faq.php?id=107&t=3.
- "Form EIA-923," U.S. Energy Information Administration, last updated October 2021, https://www.eia.gov/electricity/data/eia923/.
- "Electricity Monthly Update," U.S. Energy Information Administration, October 2020, https://www.eia.gov/ electricity/monthly/update/archive/october2020/.

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%.[58]

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% to 85%, with some approaching 90%.[59] This is compared to an overall efficiency of only 45% to 55% when electricity and thermal energy are provided separately. CHP systems achieve these high efficiencies by recovering the waste heat byproduct of electricity generation as useful thermal energy for heating and cooling.[60]

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 GHGs such as carbon, criteria pollutants, and hazardous air pollutants.

Properly designed CHP systems typically operating with an overall efficiency of 65% to 85%.

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 U.S., average transmission and distribution losses vary from 5.1% to 5.5%, with a national average of 5.1%, and may be even higher when the grid is strained and temperatures are high.[61] By avoiding these transmission and distribution losses associated with conventional electricity supply, CHP further reduces fuel use, helps avoid the need for new transmission and distribution infrastructure, and eases grid congestion when demand for electricity is high.[62]

CHP systems typically operate at a high capacity, meaning that they often run nearly continuously close to the level of their maximum output. 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% to 96%. 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. 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.

CHP systems combust less fuel to provide the same energy services.

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58 "What is CHP?," U.S. Environmental Protection Agency Combined Heat and Power Partnership, last accessed October 12, 2021, https://www.epa.gov/chp/what-chp.

59 "Combined Heat and Power (CHP) Technical Potential in the United States," U.S. Department of Energy, March 2016, p. 3, https://www.energy.gov/sites/prod/files/2016/04/f30/CHP%20Technical%20Potential%20Study%203-31-2016%20Final.pdf; "CHP Benefits," U.S. Environmental Protection Agency Combined Heat and Power Partnership, last accessed October 12, 2021, https://www.epa.gov/chp/chp-benefits.

60 "Fuel and Carbon Dioxide Emissions Savings Calculation Methodology for Combined Heat and Power Systems," U.S. Environmental Protection Agency Combined Heat and Power Partnership, February 2015, p. 3, https://www.epa.gov/sites/production/files/2015-07/documents/fuel_and_carbon_dioxide_emissions_savings_calculation_methodology_for_combined_heat_and_power_systems.pdf.

61 "Emissions & Generation Resource Integrated Database (eGRID): Data Explorer," U.S. Environmental Protection Agency, last updated on May 20, 2021, https://www.epa.gov/egrid/data-explorer.

62 U.S. EPA CHP Partnership, "CHP Benefits."

Enabling Renewables

As a distributed resource serving both electric and thermal loads at the point of production, CHP can also help support intermittent renewable resources by reducing load on the regional grid and providing a baseload source of power to serve electric demand even when intermittent renewable resources are not generating power. As seen in the case study of Saint Peter's University Hospital on page 22, CHP can complement renewable resources such as solar and allow facilities to utilize these intermittent renewable resources while maintaining reliability.

CHP can be part of a net-zero energy facility.

CHP can be part of a net-zero energy facility, and net-zero energy facilities that use CHP offer myriad benefits, including improved energy security, reduced environmental impacts, lower operating and maintenance costs, and improved resilience.[63] A net-zero energy facility typically includes a combination of energy efficiency and on-site renewable resources such that the facility's net annual energy consumption equates to zero. In a 2018 report, the National Renewable Energy Laboratory (NREL) found that 64% of commercial buildings could achieve net-zero energy goals using technologies such as CHP.[64]

63 "CHP in Net-Zero Energy Facilities," Midwest CHP Technical Assistance Partnerships, March 2021, https://chptap.lbl.gov/profile/422/CHP_in_Net-Zero_Energy_Facilities.pdf.

64 Shanti Pless, Ben Polly, and Sarah Zaleski, "Communities of the Future: Accelerating Zero Energy District Master Planning," NREL, September 2018, https://www.nrel.gov/docs/fy18osti/71841.pdf.

CASE STUDY | Saint Peter's University Hospital

QUICK FACTS

LOCATION | New Brunswick, NJ
SECTOR | Healthcare
CHP SIZE | 2 MW
EQUIPMENT | Reciprocating engine
FUEL TYPE | Natural gas
COMBINED EFFICIENCY | 75% or greater
CONFIGURED FOR ISLAND MODE | Yes

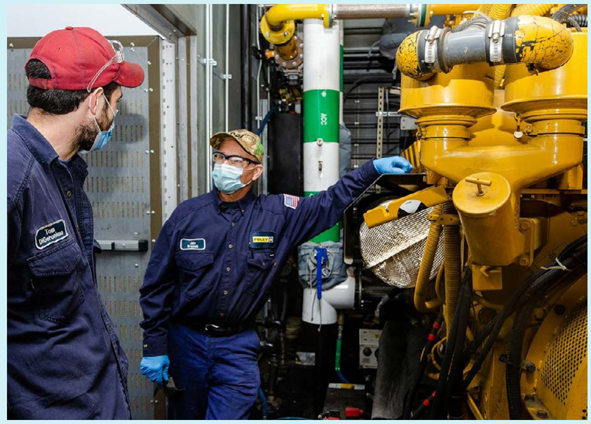


PHOTO CATERPILLAR INC.

This non-profit acute care hospital provides a full scope of adult medical and surgical services and specialized pediatric healthcare services for newborns and children. In 2011, the hospital began an energy-savings initiative that included the installation of LED lighting, and in 2012, more than 10,000 solar panels were installed to provide about 20% of the energy demand for the campus.

When Superstorm Sandy knocked out grid power in 2012, many people in the region came to Saint Peter's seeking shelter and treatment. With emergency generators providing backup power to only critical areas of the hospital, Saint Peter's was only able to provide emergency and inpatient care. But, since installing the CHP plant in late 2018, the hospital now can operate in island mode with full power in the event of a grid outage, increasing the facility's resiliency in the face of a severe weather event and allowing the hospital to be a refuge for their community during such an emergency.

By utilizing both solar energy and CHP, the hospital has low utility energy usage and avoids peak demand charges, saving $200,000 to $300,000 annually in energy costs. The existing CHP system could serve an even larger facility, allowing for future expansion of the hospital.

Serving as the Backbone of Many Microgrids

The U.S. Department of Energy (DOE) describes microgrids as "localized grids that can disconnect from the traditional grid to operate autonomously."[65] 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.[66] Microgrids

65 "Distributed Generation (DG) for Resilience Planning Guide," U.S. Department of Energy Better Buildings Initiative, January 2019, p. 51, https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/DG%20for%20Resilience%20Planning%20Guide%20-%20report%20format.pdf.

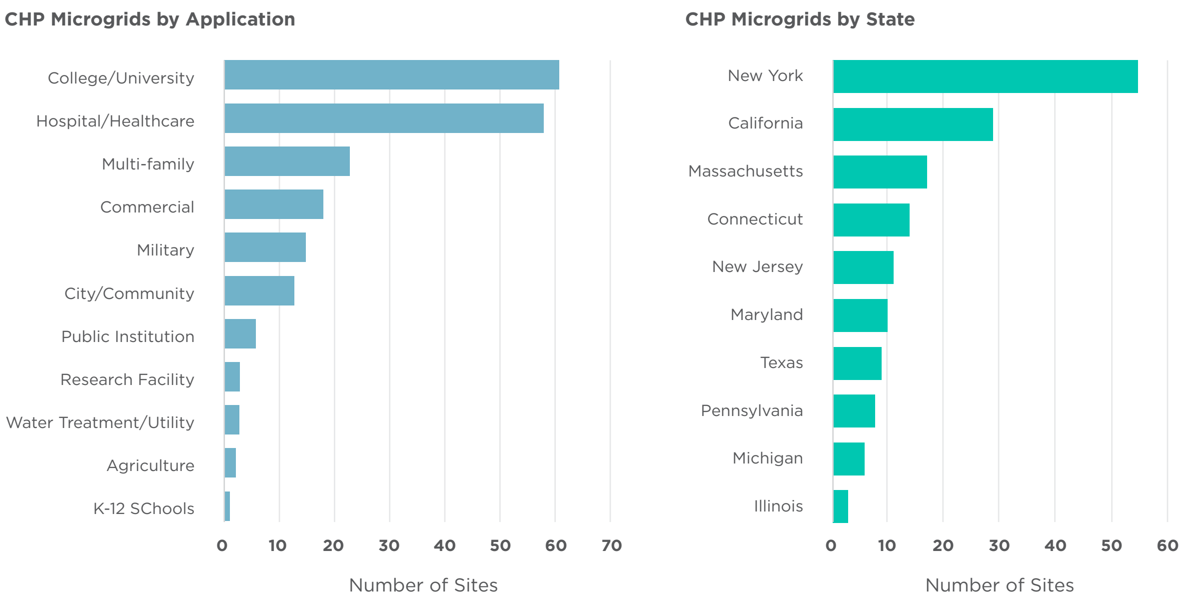
66 "CHP for Resiliency in Critical Infrastructure," U.S. Department of Energy Office of Energy Efficiency & Renewable Energy, May 2018, https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/CHP_Resiliency.pdf.

are used by universities, military installations, municipalities, and public institutions, helping maintain the reliability of their electric and thermal energy supply and to improve their resiliency against extreme weather and power outages.[67] 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.

CHP can be part of a net-zero energy facility.

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.[68] As of 2016, CHP was the primary generation technology for existing microgrids and is expected to be implemented in future microgrid projects.[69] Over 200 microgrids in the U.S. use CHP, equivalent to 35% of all the nation's microgrids. Moreover, CHP is used in 67% of those microgrids that operate continuously.[70]

FIGURE 9. *CHP Microgrids by Application and State*[71]



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. CHP systems not only provide the benefit of essential energy services during catastrophic weather events and emergencies, but also can create cost savings, distribution capacity, power quality benefits, and environmental benefits for an entire community. The Hudson Yards case study on page 25 demonstrates how a single CHP system can serve a large multi-use

67 Olivia Chen, "US Microgrid Growth Beats Estimates: 2020 Capacity Forecast Now Exceeds 3.7 Gigawatts," Greentech Media, June 1, 2016, https://www.greentechmedia.com/articles/read/u-s-microgrid-growth-beats-analyst-estimates-revised-2020-capacity-project#gs.fmnot7GL.

68 "The Role of Microgrids in Helping to Advance the Nation's Energy System," U.S. Department of Energy Office of Electricity, last accessed November 2, 2021, https://www.energy.gov/oe/activities/technology-development/grid-modernization-and-smart-grid/role-microgrids-helping.

69 U.S. DOE Better Buildings Initiative, "Distributed Generation."

70 "Microgrid Installations," U.S. Department of Energy, data current as of July 31, 2021, https://doe.icfwebservices.com/microgrid.

71 David Jones, ICF, "CHP State of the Market," National Summit on CHP, State of the Market panel, September 13, 2021.

building complex.

In general, CHP can play a significant role in decarbonizing the electricity, buildings, and industrial sectors. As discussed above, 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.[72] CHP systems require less fuel inputs for the same energy outputs and have a high capacity factor allowing them to displace high-emitting marginal grid resources.[73]

In addition, CHP can help 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.

Microgrids powered by CHP units can also enable renewable resources as part of the microgrid. Similar to a centralized electric grid, a microgrid generates, distributes, and regulates the supply of electricity, but on a small scale. Microgrids may have more than one source of electric generation and serve multiple buildings or loads.

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. 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

72 ICF, "National Assessment," p. 4.

73 "Fuel and Carbon Dioxide Emissions Savings Calculation Methodology for Combined Heat and Power Systems," U.S. Environmental Protection Agency Combined Heat and Power Partnership, June 2021, https://www.epa.gov/sites/default/files/2015-07/documents/fuel_and_carbon_dioxide_emissions_savings_calculation_methodology_for_combined_heat_and_power_systems.pdf; "Combined Heat and Power: Frequently Asked Questions," U.S. Environmental Protection Agency Combined Heat and Power Partnership, last accessed September 11, 2021, https://www.epa.gov/sites/default/files/2015-07/documents/combined_heat_and_power_frequently_asked_questions.pdf.

CASE STUDY | Hudson Yards

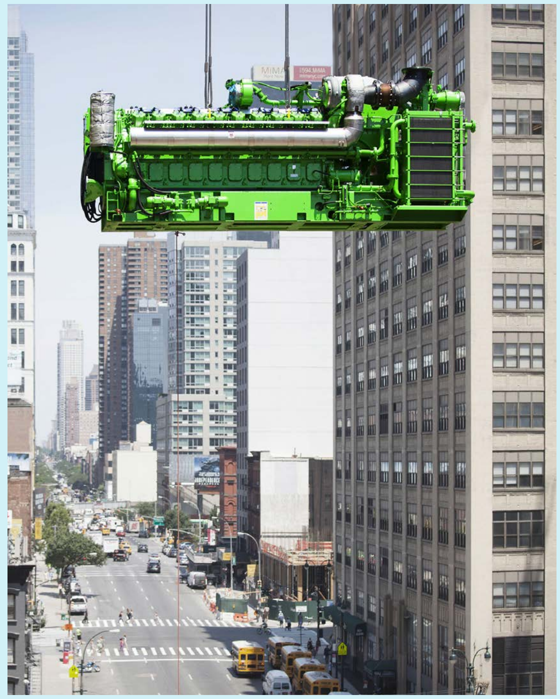


PHOTO NORTHEAST-WESTERN ENERGY SYSTEMS

QUICK FACTS

LOCATION | New York City, NY

SECTOR | Commercial and residential building

CHP SIZE | 14.4 MW

EQUIPMENT | 13.2 MW reciprocating engines and 1.2 MW microturbines

FUEL TYPE | Natural gas

COMBINED EFFICIENCY | Greater than 80%

CONFIGURED FOR ISLAND MODE | Yes

Hudson Yards is the largest construction project in New York City since Rockefeller Center and the largest private real estate development in the country by area with 18 million square feet of commercial and residential space. The complex includes a retail tower with shops and residences, offices, a performing arts center, and a staircase sculpture, the Vessel. In an effort to mitigate the city's high utility rates to make the complex more attractive to retailers and companies, the project was designed with the first true microgrid in the city.

The backbone of the microgrid is a CHP system and includes microturbines and diesel generation. The CHP unit provides electricity as well as heat and refrigeration to the complex's tenants. In the event of a loss of utility power, Hudson Yards can island itself from the utility grid and the system can provide base load power and chilling, keeping the buildings operational.

Consolidating the power and thermal demands of the numerous buildings that comprise the complex and connecting them with a microgrid and a thermal loop capitalized on the mixed-use nature of Hudson Yards, as different types of facilities have peak energy needs at different times.

In 2012, Hurricane Sandy had devastating impacts on New York City and highlighted the need for resilient infrastructure. The CHP plant at Hudson Yards is located on the tenth and eleventh floors of the retail building and is supplied by fuel from underground piping, allowing the site to maintain power in the event of a utility grid outage.

For additional information, see: **Utility Dive** and **McKinsey**

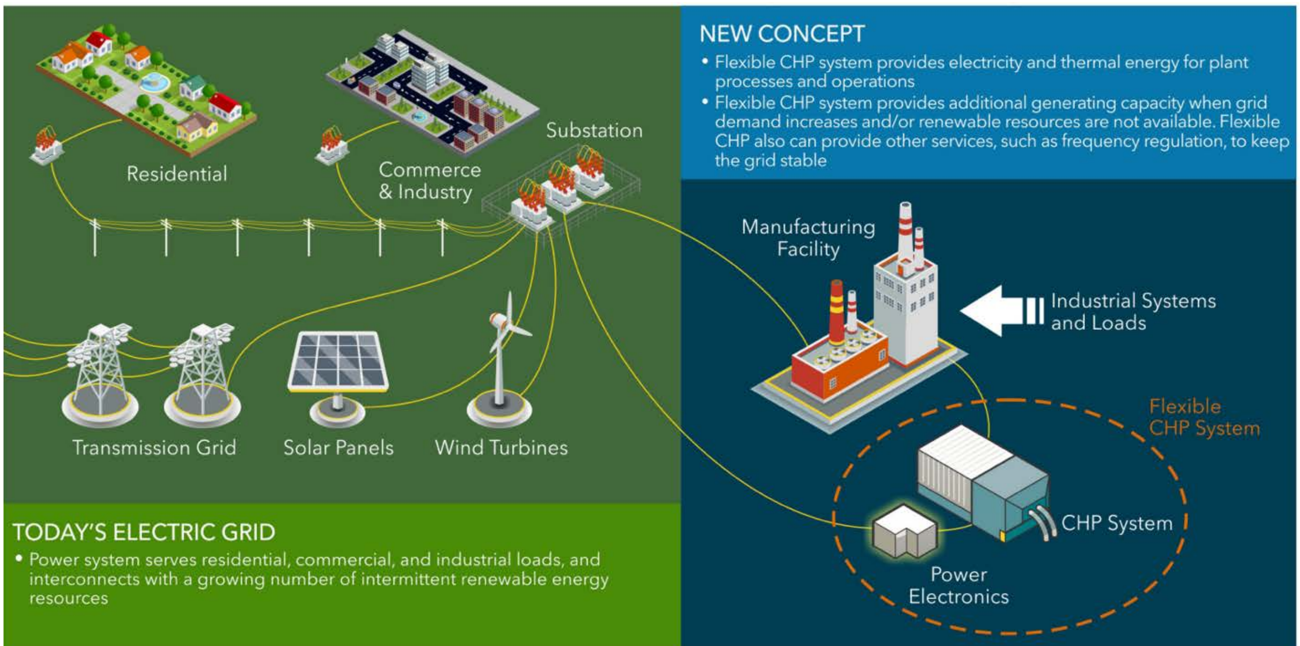
74 Jim Freihaut, et al., "CHP-Enabled Renewable Energy Microgrids in Pennsylvania: A Guidance Document for Conceiving Feasible Systems," Pennsylvania Department of Environmental Protection, September 20, 2018, https://marcellusdrilling.com/wp-content/uploads/2018/12/CHP-Enabled-Renewable-Energy-Microgrid-Guide.pdf.

Supporting Utilities with Flexible CHP

CHP systems are typically located at facilities where both electricity and thermal energy are needed and designed to produce onsite, baseload electric and thermal energy for a facility. However, flexible CHP systems can also provide generating capacity to the grid when demand increases or intermittent renewable resources are not available.[75]

Flexible CHP systems can provide generating capacity to the utility electric grid when demand increases or intermittent renewable resources are not available.

FIGURE 10. *Flexible Combined Heat and Power Systems — The Concept*[76]



The Flexible CHP System concept provides benefits to both the electric grid and the manufacturing facility hosting the system.
Graphic credit U.S. Department of Energy

This flexible CHP approach provides a distributed energy resource that the grid could call upon during times of high demand. While much of our electricity is generated at central power plants and distributed through transmission and distribution systems, distributed generation allows electricity to be generated close to where it will be used, serving a single facility or as part of a microgrid. Distributed energy resources can contribute to overall electric grid reliability and energy security and can provide power to an individual facility or several as part of a microgrid. In addition, CHP owners could generate revenue from selling the excess electricity to partly offset the costs of owning and operating a CHP system.

75 "Flexible Combined Heat and Power (CHP) Systems," U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, January 2018, https://www.energy.gov/sites/prod/files/2018/01/f47/Flexible%20CHP%20Comms_01.18.18_compliant.pdf.

76 U.S. DOE, "Flexible Combined Heat and Power (CHP) Systems."

A recent analysis by Oak Ridge National Laboratory shows that the availability of CHP can provide significant value to the grid through the provision of energy, as well as contingency and regulation ancillary services.[77] The report noted that some of the ways that CHP can help the grid are difficult to monetize, such as a reduction in grid stress hours.

In addition to providing electric reliability for the host facility and increasing reliability for the surrounding utility grid by reducing congestion, CHP systems can also provide essential grid services through frequency response, voltage control, and ramping capabilities.[78] Increasing the use of CHP to serve offsite loads and support the electric grid could provide system-wide benefits, such as lower wholesale energy costs, decreased transmission congestion, and improved grid stability.[79]

Flexible CHP systems can also support renewable energy resource deployment by facilitating the integration of intermittent renewables, such as wind and solar, while providing locational value to utilities. An ICF paper noted that models in Europe show that flexible gas-fired CHP systems may be the most affordable and practical option to balance the increase of renewable loads with variable output.[80]

At their fall 2020 CHP workshop, the U.S. Department of Energy's Advanced Manufacturing Office (DOE AMO) noted that while many of the technologies required for flexible CHP systems are currently available, additional research and development will be needed to ensure that CHP systems can be integrated into complete CHP packages that can interface seamlessly with the grid while remaining affordable for system owners.[81] DOE AMO's CHP research and development project portfolio aims to enable private-sector development of flexible CHP systems that can play a role in stabilizing the electric grid and improving its resilience. As climate-related impacts increase risks for critical, interconnected systems, resulting in grid outages, CHP's high level of resiliency can help facilities to maintain operations, either individually or as part of a microgrid.

Flexible CHP systems can provide a variety of benefits to CHP site hosts and their communities, utilities, and the grid system as a whole, including electric reliability, resiliency in the face of severe weather or other grid outage events, reduced emissions, integration of intermittent renewable resources, and cost savings. Additional research and analysis to further integrate flexible CHP systems into the electric grid can help to achieve the realization of these benefits.

Creating Resilient Communities

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.[82] 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.

77 Jal Desai et al., "Potential Impact of Flexible CHP on the Future Electric Grid in California," Oak Ridge National Laboratory, August 2020, https://info.ornl.gov/sites/publications/Files/Pub129588.pdf.

78 David Jones and Meegan Kelly, "Supporting grid modernization with flexible CHP systems," ICF, 2017, https://www.icf.com/insights/energy/supporting-grid-modernization-with-flexible-chp-systems.

79 Desai et al., "Potential Impact of Flexible CHP."

80 Jones and Kelly, "Supporting grid modernization."

81 "Fall 2020 Combined Heat and Power (CHP) Virtual Workshop: Workshop Report," U.S. Department of Energy Office of Energy Efficiency & Renewable Energy Advanced Manufacturing Office, September 8-10, 2020, https://www.energy.gov/sites/prod/files/2021/02/f82/CHPWorkshopReportSeptember2020_compliant.pdf.

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

Facilities seeking to maintain operations during a severe weather event may install CHP for its high level of resiliency, as demonstrated by the case study of the CC1 Coca-Cola Bottlers in Puerto Rico on this page. There are numerous other examples of facilities utilizing CHP that were able to continue operations during major weather events, including the University of Texas at Austin during the 2021 freeze in Texas, Montefiore Medical Center in New York during the 2003 Northeast blackout and Hurricane Sandy, the Texas Medical Center during Hurricane Harvey, Louisiana State University during Hurricane Katrina, and New York University, Bergen County Utilities Wastewater Treatment Plant, and numerous other facilities during Superstorm Sandy.[83]

CASE STUDY | CC1 Coca-Cola Bottlers

QUICK FACTS

LOCATION | Cayey, Puerto Rico

SECTOR | Food and processing

CHP SIZE | 6.7 MW

EQUIPMENT | Reciprocating engines

FUEL TYPE | Propane

COMBINED EFFICIENCY | 82% total efficiency at high heating value (HHV)

CONFIGURED FOR ISLAND MODE | Yes

PHOTO MARTIN ENERGY GROUP

In 2017, Hurricanes Maria and Irma had devastating effects on Puerto Rico, severely damaging the islands infrastructure, including electric infrastructure. In the immediate aftermath of the storms, CC1 was able to provide liquids to residents of the island. But, in the event of another severe weather event, CC1 sought an energy solution that could support their manufacturing process.

The facility's CHP system will allow it to not only maintain operations and be resilient in the face of another storm, but also improve the efficiency of the manufacturing process. The facility currently operates separately from the grid in island mode. If the facility were to be connected to the utility grid in the future, it is configured to seamlessly transition to island mode in the event of a utility grid loss of power. The configuration allows for remote operation with full automation and remote monitoring.

83 Juan M. Ontiveros, "UT Austin's Microgrid Performance During Winter Storm URI," National Summit on CHP, Resilient Communities Spotlight panel, September 14, 2021; "CHP for Hospitals: Superior Energy for Superior Patient Care," U.S. Environmental Protection Agency, https://www.epa.gov/chp/chp-hospitals-superior-energy-superior-patient-care; "CHP Installation Keeps Hospital Running During Hurricane Harvey," U.S. Department of Energy Office of Energy Efficiency & Renewable Energy, September 8, 2017, https://www.energy.gov/eere/amo/articles/chp-installation-keeps-hospital-running-during-hurricane-harvey; Anne Hampson, et al., "Combined Heat and Power: Enabling Resilient Energy Infrastructure for Critical Facilities," ICF, March 2013, p. 24, https://www.energy.gov/sites/prod/files/2013/11/f4/chp_critical_facilities.pdf; U.S. DOE Better Buildings, "Distributed Generation (DG) for Resilience Planning Guide."

Utilizing Fuels of the Future with CHP 2.0

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, 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.

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. How CHP fits into a green gas system and uses these fuels is explored further in the next section.

04

CHP Can be Integrated into a Green Gas System

Greening the Gas System

While CHP systems can run on RNG and some can already run on 100% hydrogen fuel, challenges remain in obtaining sufficient quantities and transporting these fuels. Using existing gas pipeline infrastructure to transport and deliver these fuels and "green" the entire gas system has the potential to be a low-cost option.

While RNG is compatible with current infrastructure and is a viable low-carbon fuel alternative, its deployment has been relatively lacking, as discussed above. Transporting large volumes of hydrogen poses additional challenges given its different properties as compared to natural gas and RNG, and current research is examining how this existing infrastructure can accommodate the distribution of hydrogen gas.[84]

In June 2021, the U.S. Department of Energy's Office of Fossil Energy and Carbon Management announced a research project with Oak Ridge National Laboratory to perform a geographical assessment of natural gas pipelines and related infrastructure materials for the transport of gas blends and an investigate the compatibility of those materials with hydrogen, ammonia, and carbon dioxide.[85] This assessment will inform both policy makers and energy markets about the ability to leverage existing natural gas infrastructure to advance the clean hydrogen economy.[86]

84 U.S. DOE Office of Energy Efficiency and Renewable Energy, "Hydrogen Pipelines."

85 "DOE's Oak Ridge National Laboratory to Conduct Geographical Assessment of Natural Gas Infrastructure and Pipeline Materials for Blended Gas Transport," U.S. Department of Energy Office of Fossil Energy and Carbon Management, June 17, 2021, https://www.energy.gov/fe/articles/does-oak-ridge-national-laboratory-conduct-geographical-assessment-natural-gas.

86 U.S. DOE Office of Fossil Energy and Carbon Management, "Oak Ridge National Laboratory to Conduct Geographical Assessment."

Using Lower-Carbon and Renewable Fuels

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, including biogas, RNG, and hydrogen. In addition, using existing gas pipeline infrastructure can be a low-cost option for delivering these new fuels.[87]

Some CHP units can already operate on 100% hydrogen fuel, and work is 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.[88] 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.

Using lower-carbon fuels such as hydrogen in CHP units, or CHP 2.0, can allow CHP systems to reduce emissions even further across the industrial, commercial, and municipal sectors. CHP systems will use these fuels efficiently, requiring less lower-carbon fuel inputs for the same energy outputs compared to other generation units.

CHP systems will use fuels such as RNG and hydrogen efficiently, requiring less of these fuel inputs for the same energy outputs compared to other generation units.

Hydrogen fuel 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 hydrogen fuel efficiently, requiring less hydrogen fuel inputs for the same energy outputs. Given the high cost of creating hydrogen fuel, using hydrogen fuel efficiently in CHP systems will help keep costs low and enable GHG reductions. Efficient use of hydrogen fuel should be central to any hydrogen and climate strategy, and CHP helps meet this goal.

87 U.S. DOE Office of Energy Efficiency and Renewable Energy, “Hydrogen Pipelines.”

88 Sonal Patel, “High-Volume Hydrogen Gas Turbines Take Share,” POWER, May 1, 2019, https://www.powermag.com/high-volume-hydrogen-gas-turbines-take-shape/.

Integrating Technologies

CHP, Hydrogen, Renewables, and Storage

While CHP systems fueled by natural gas can already reduce emissions significantly, numerous CHP manufacturers and developers continue to seek ways to reduce energy-related emissions even further. Additional emissions reductions can be achieved by using lower-carbon or renewable fuels, as well as integrating CHP systems with intermittent renewable resources and energy storage systems.

PHOTO SIEMENS ENERGY INC.

The Zero Emission Hydrogen Turbine Center in Sweden is an example of a facility that is helping bring these clean energy elements together. This demonstration plant at a gas turbine test facility produces hydrogen in an electrolyzer, which is powered by solar panels and excess energy in gas turbine testing. The hydrogen is then compressed and stored, and surplus energy can also be stored in batteries, increasing the operational flexibility of the system and demonstrating different possibilities for storing energy. The compressed hydrogen can then be used to continue research and development for the optimization of hydrogen fuel use in gas turbines with the goal of running gas turbines on 100% hydrogen fuel by 2030.

While the main fuel used in the gas turbine testing facility is natural gas, biogas was added in 2020 to reduce the environmental impact of the facility. The more that clean fuels such as biogas and hydrogen are blended into the fuel source, the less carbon dioxide is emitted into the air.

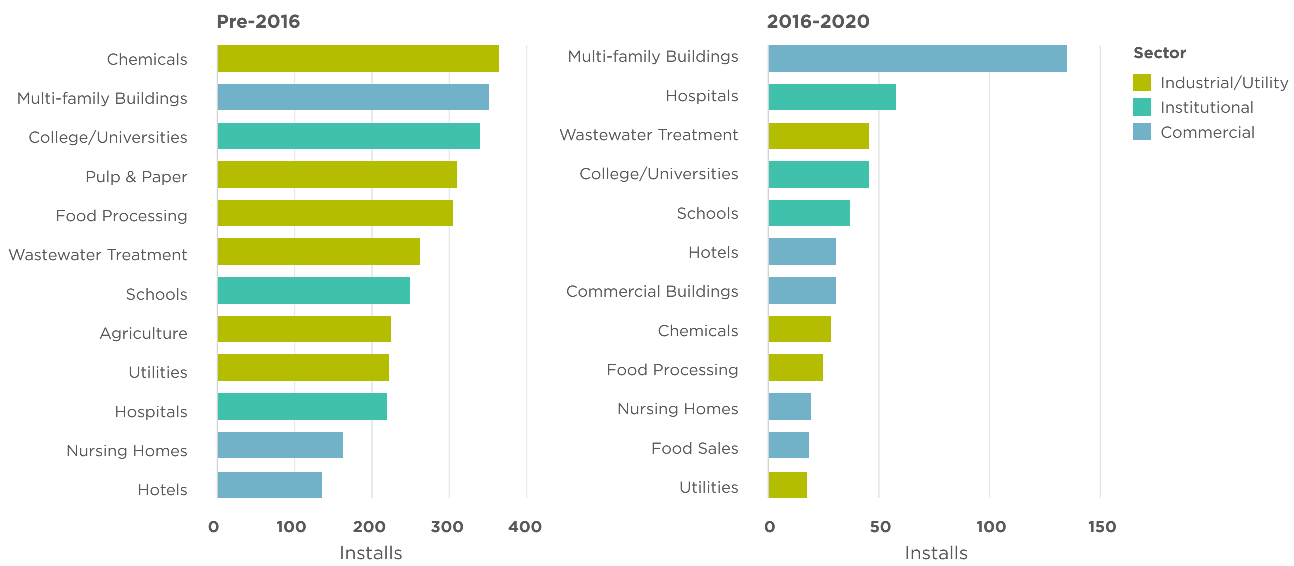
For additional information, see **Siemens Energy**.

05

Future CHP Technology Developments

Several current trends in the CHP market may continue as more entities seek to maintain energy reliability while reducing their emissions. There has been growing activity in non-traditional CHP markets, including light industrial, commercial, institutional, and multi-family locations, as can be seen in Figure 11.

FIGURE 11. *Top Market Sectors for CHP – Pre-2016 vs. 2016-2020 (Installs)*[89]



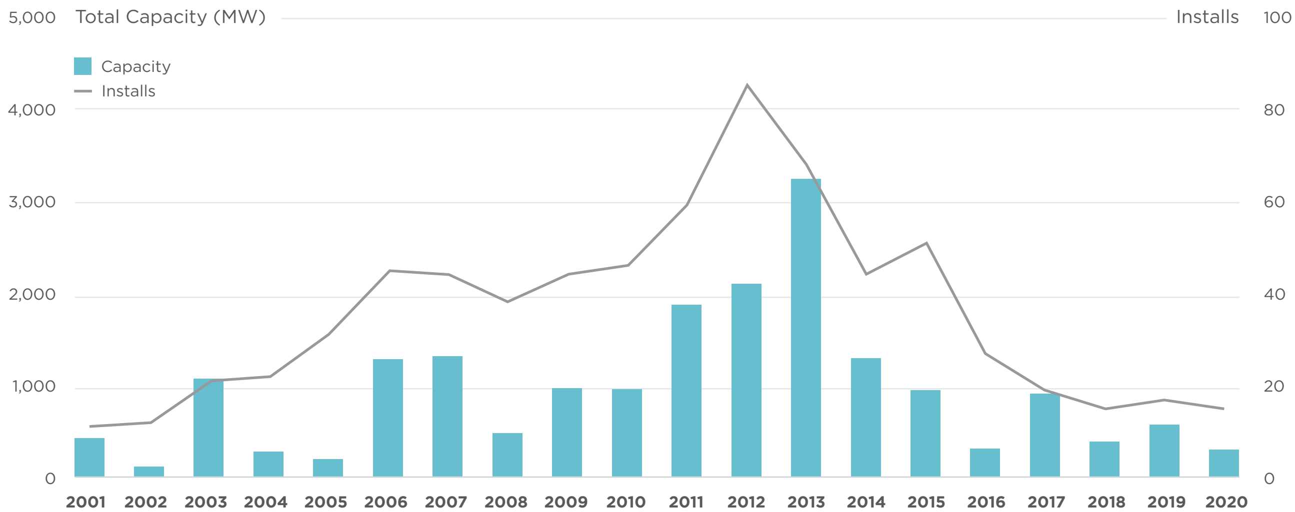
89 Jones, "CHP State of the Market."

While larger CHP systems are still being installed, there has also been a move toward smaller CHP installations and packaged CHP system offerings, and almost all installations in multi-family buildings, nursing homes, commercial buildings, and K-12 schools are less than 1 MW in size.[90] Resiliency, especially for critical infrastructure facilities and those installing microgrids, has emerged as a key driver of installations and there is increasing interest in hybrid systems that integrate CHP with renewable resources and energy storage.

Utilities are also increasingly interested in CHP for generation for the grid, as a distributed resource that is a non-wires alternative to enhance grid stability, to alleviate grid congestion or to defer investments, and to improve energy efficiency and gain low-cost savings.

While natural gas is still the dominant fuel for CHP, renewable fuels are also used in some systems. Installations utilizing renewable fuels peaked in 2012 with large numbers of biogas installations, as can be seen in Figure 12.

FIGURE 12. *Trends in Renewable CHP Installations: 2001-2020*[91]



Further efforts to green the gas system with fuels such as RNG and clean hydrogen will also play an important role in the future of CHP: CHP units will be able to use higher quantities of these fuels, reducing emissions further while still maintaining resiliency. As the entire gas system becomes less carbon-intensive, CHP units connected to the system will be able to use higher quantities of cleaner fuels.

90 Jones, "CHP State of the Market."

91 Jones, "CHP State of the Market."

06

Recommendations

CHP is an integral component of both the electric grid of the future and a future greener gas system. CHP is a clean, reliable, and resilient energy resource that can help governments, utilities, businesses, institutions, and communities meet their energy system goals, including reducing emissions, saving money, maintain energy reliability, and improving resiliency in the face of a changing climate.

However, various hurdles prevent more widespread CHP deployment, limiting the ability of CHP to contribute to our clean energy future. This section provides recommendations that would allow additional CHP deployment to support the energy and resiliency needs of our communities now and for years to come.

For Policy Makers

Additional CHP deployment could be supported by policies that help overcome economic and financial, regulatory, and informational barriers. Incorporating CHP into infrastructure planning can help to save facilities money and improve their resiliency in the face of a changing climate.

Providing support for CHP deployment can help support the clean energy and resiliency goals of our communities. Policy makers could:

- Support clean distributed generation resources such as CHP to increase reliability of energy services and the resiliency of communities.
- Ensure that all communities, especially those that have been historically and continue to be disproportionately impacted by pollution and climate change, have access to clean, efficient, resilient CHP energy resources.
- Support clean energy jobs of the future, through education and training, including those jobs involved in the manufacture, installation, and maintenance of CHP units.

Greening the gas system with high volumes of clean hydrogen fuel can allow CHP systems to use these clean fuels efficiently. CHP manufacturers are working to increase the volume of hydrogen fuel that can be used in CHP units, and some units can already use 100% clean hydrogen fuel. However, the cost, transportation, and delivery of this fuel remains a challenge. Policy makers could:

- Support research, development, and deployment of clean hydrogen and a green gas system, with the following considerations:

- Transportation: The existing gas pipeline system may provide a cost-effective way to transport clean hydrogen, but additional research is required to determine what quantities of hydrogen can safely be transported or what retrofits may be required.
- Distributed generation: Distributed generation technologies such as CHP can be deployed at the point of clean hydrogen production, allowing the use of hydrogen fuel in CHP systems and the realization of corresponding emissions benefits while the development of hydrogen-ready pipelines is still underway.
- Use: While research and development of hydrogen-ready CHP technologies is ongoing, technology manufacturers and end users will need support evaluating what amount of hydrogen current equipment can use, identifying the retrofits and upgrades needed to ensure the adjustment of existing equipment for hydrogen use is easy and affordable, and the development and deployment of new equipment as required.

For Potential Industrial and Commercial Hosts

Potential hosts should consider how CHP helps them achieve their emissions reductions goals without sacrificing a reliable energy supply. CHP can complement renewable energy resources to reduce emissions further while maintaining resiliency. Potential hosts could:

- Learn more about distributed generation resource options such as CHP.
- Learn more about the clean energy options available to them, including how CHP can work with renewable resources and how CHP can operate as part of a microgrid.

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. Potential hosts could:

- Consider how installing CHP can help support resiliency for their own operations.
- Consider how installing CHP at their facility can help support their wider community in the event of severe weather or other event that results in a utility grid outage.

For Electric and Gas Utilities

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. Utilities could:

- Consider CHP during their resource planning for potential application on either side of the meter.
- Consider including CHP in utility resource planning and integrated resource plans (IRPs).
- Consider how CHP can help ease grid constraints.
- Consider how CHP can avoid costs associated with infrastructure buildout
- Consider how CHP can improve the resilience of the utility's system.
- Consider how flexible CHP can benefit the utility grid system.
- Support customers that are interested in installing CHP units on-site 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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