The IEA CHP and DHC Collaborative

CHP/DHC Country Scorecard: United States

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Executive Summary

The United States (U.S.) currently has an installed co-generation[1] capacity of 82.4 gigawatts (GW) of electric capacity at over 4 200 facilities, which represents 8% of current U.S. electricity generating capacity. The majority of current U.S. CHP capacity is located in the industrial sector, accounting for 86% of installed capacity, with the remaining 14 percent located in the services sector. CHP capacity growth has been slow since the late 2000s; however, 2012 had the most new installed capacity since 2005. Industrial facilities still represent the majority of capacity additions; however, new CHP capacity in the services sector is growing at a faster rate, reflecting a changing market atmosphere. [2]

Interest in CHP in the U.S. is rising due to low natural gas prices, the return of manufacturing to the U.S., and growing awareness of the value of energy resiliency. Growing shale gas production in the U.S. has resulted in significant decreases in natural gas prices. Due to these decreased energy costs, industries – such as petrochemical companies – are moving operations back to the U.S. CHP has also become a focus in recent years for its energy security benefits. In 2012, when Hurricane Sandy caused widespread electricity grid outages in the Northeast U.S., the fuel supply system was less affected, and many district energy and CHP systems remained operational. This led to increased interest in ways of enhancing the reliability and resiliency of the electric grid, especially for critical facilities like hospitals, emergency shelters, and police and fire stations. Several states that have been heavily impacted by storm events have enacted laws or financing programs that encourage the development of CHP.

District heating and cooling (DHC) infrastructure in the U.S. has not had the same level of policy support as CHP systems, but nonetheless there has been significant deployment of DHC. The International District Energy Association (IDEA) has identified 601 district energy systems in the US, 289 of which are currently district energy-only systems with 16.6 GW[3] of installed heating capacity. These DHC systems, which do not have CHP integrated, represent a good market opportunity for new CHP installations. CHP installed as part of DHC systems has grown in recent years – there is currently 6.6 GW of CHP generating capacity at DHC systems, spread across 55 downtown systems and 153 university campus district energy systems. This growth is expected to continue as cities, universities, and other DHC installations realise the economic and environmental benefits of CHP.

President Barack Obama expressed the U.S. Federal government's interest in promoting CHP by setting a target of 40 GW of additional CHP by 2020 through an Executive Order signed in August 2012, which would mean an increase of nearly 50% from 2012 levels. State governments also have an important role in new CHP – thirty-four states and the District of Columbia have incentives and/or regulations encouraging the deployment of CHP and DHC.[4] On the other hand, aside from eligibility for tax exempt financing and federal loan guarantees, there are few policy incentives for deployment of district heating and cooling systems in the U.S.

This report provides information on the context for CHP and DHC development in the U.S., summarizes U.S. applications and trends for these technologies, discusses government initiatives for their deployment, and provides policy options that can be used to enhance this effort.

[1] Co-generation is also commonly referred to as combined heat and power (CHP). This report uses the term "co-generation" to refer to the simultaneous generation of heat and electricity.

[2] ICF International and Oak Ridge National Laboratory, 2013.

[3] 1 Btu/h = 3.412 W

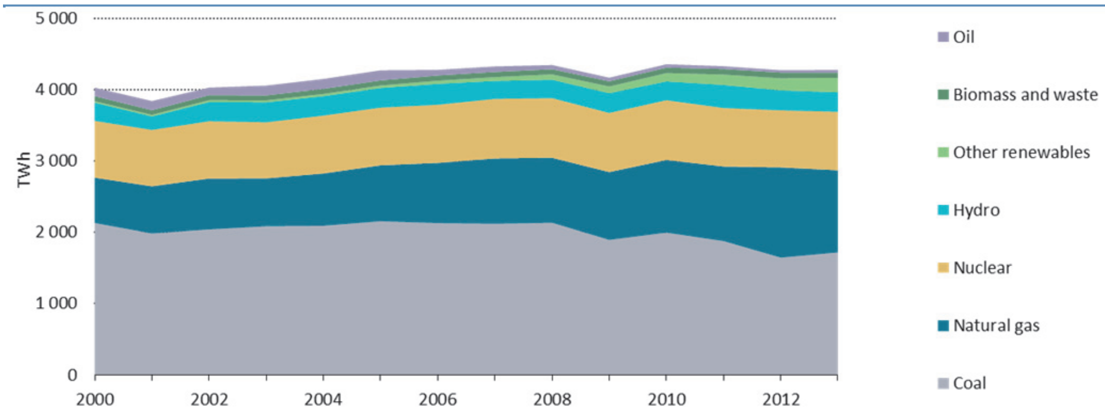
[4] North Carolina State University, 2013.

Energy Overview

The U.S. is the world's second largest energy producer and energy consumer, behind only China. In 2013, most energy consumed in the U.S. came from fossil fuels, which account for around 84% of primary energy supply, whereas nuclear accounts for 10% and renewables and waste, about 6%.[5] While final energy consumption per capita has declined, a growing population and economy have driven absolute energy use up. As the U.S. population expanded by 73% from 1960 to 2012, total primary energy supply (TPES) grew from 42.7 to 89.6 EJ (40.5 to 84.9 quadrillion Btu[6]), an increase of 110%. Energy intensity of GDP (gross domestic product) in the U.S. has declined despite these absolute increases in energy consumption; from 1992 to 2012, energy use per dollar of GDP declined on average by 1.9% per year, due to structural changes in the economy, mainly the shift away from manufacturing to service sectors, which are less energy intensive.[7]

Industry represents 26% of total energy consumption in the U.S. Natural gas, the most commonly used fuel in industry, is expected to increase further in market share due to low prices. In 2012, natural gas energy consumption in the industrial sector was 4.3 EJ (4.1 quadrillion Btu), or 41% of all energy consumed in the industrial sector.

Figure 1 • U.S. electricity generation by fuel, 2000 to 2013



Note: Unless otherwise noted, all tables and figures derive from IEA data and analysis.

Key message • Electricity generation has shifted away from coal, while natural gas has begun to play a larger role in the U.S. power sector.

Electricity generation

The U.S. power sector has shifted increasingly towards the use of natural gas as a fuel for electricity generation, and away from coal, its traditional energy source. This shift, which mirrors similar shifts in other sectors, has largely been driven by recent increases in U.S. production of natural gas and the resulting lower prices. In 2013, coal-fired power accounted for 40% of all electricity generation in the U.S., compared to more than half in 2000. Over this time period,

[5] This paper uses the most recent available statistics from the IEA's Energy Balances reported by member countries to the IEA Secretariat. Differences in conventions and definitions – for example, differences in the sectoral allocation of electricity transmission & distribution losses, fuel refining energy use, and on-site auto-producer CHP fuel use – can create discrepancies between this dataset and US EIA data. For consistency, IEA statistics have been used, except where noted.

[6] 1 quadrillion Btu = 1.055 EJ

[7] US EIA, 2013b.

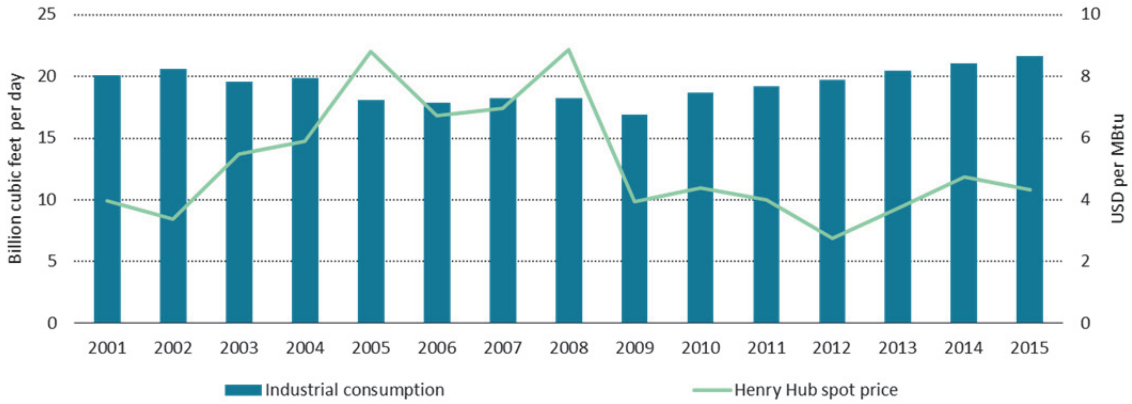
natural gas increased in share from 16% of electricity generation to 27% in 2013, and is expected to surpass coal generation by 2025.[8] Other renewables generation increased more than eightfold, from 21 TWh in 2000 to 204 TWh in 2013.

Natural gas

In addition to having a growing role in industrial energy use and electricity generation, natural gas has become a major driver for CHP development in the U.S., based on the low natural gas prices driven by the boom in shale gas production. From 2000 to 2007, installed natural gas CHP capacity totalled 2 772 MW,[9] which represents 56% of total CHP capacity installed over this 5 year time frame. This increase in natural gas production is a result of large-scale application of horizontal drilling and hydraulic fracturing techniques in shale formations beginning in the early 2000s. The amount of shale gas supplied to the U.S. market has grown by a factor of 14 since 2010, displacing imports and more than offsetting declines in other U.S. production resources.

The uptick in natural gas production has led to much lower domestic gas prices, which are expected to remain at a low level in the mid-term. EIA currently projects that Henry Hub gas prices will remain in the USD 3/MBtu[10] to USD 5/MBtu range through 2030, and expects prices to reach USD 8/MBtu by 2040.[11]

Figure 2 • Industrial natural gas consumption and Henry Hub spot price, 2001 to 2015



Source: US EIA (2013b), *Annual Energy Outlook 2013*, www.eia.gov/forecasts/aeo/index.cfm, Washington DC.

Key message • Low natural gas prices have spurred industrial consumption, and this trend is expected to continue in the short term.

As a result of the natural gas price outlook, a number of energy intensive manufacturers have returned or are considering returning to the U.S. after years of moving their production overseas.[12] Lower natural gas prices have helped reduce overall production costs in the U.S., particularly for energy intensive industries such as the chemical manufacturing sector, which relies on a significant amount of natural gas liquids as a feedstock for production. Many of the proposed new plants in the chemical industry are prime candidates for CHP due to their concurrent need for steam and electricity.

[8] US EIA, 2013b.

[9] ICF International and Oak Ridge National Laboratory, 2013.

[10] 1 MBtu = 1.055 GJ

[11] US EIA, 2013b.

[12] Simchi-Levi, 2012.

Climate Change Context

Federal action

Although the U.S. is a signatory to the United Nations Framework Convention on Climate Change and participated in the development of the Kyoto Protocol, the U.S. Senate has not voted to ratify the treaty. However, the U.S. Federal government has adopted the following measures to help reduce GHG emissions:

- The U.S. Environmental Protection Agency's (EPA) "Tailoring Rule," issued on 13 May 2010, tailors the requirements of the Clean Air Act to focus on Prevention of Significant Deterioration (PSD) and Title V permit requirements on the largest emitting facilities. This rule subjects facilities responsible for nearly 70% of the national GHG emissions from stationary sources to EPA permitting requirements. Tailoring rule PSD requirements currently apply to new facilities with GHG emissions of at least 100 000 tons per year (tpy) of CO_2e and modifications at existing facilities with emissions of at least 75 000 tpy of CO_2e. Title V permitting requirements apply to all facilities that emit at least 100 000 tpy CO_2e. These facilities are the nation's largest emitters, such as power plants, refineries, and cement production facilities.[13]
- Greenhouse gas reporting through the U.S. EPA's mandatory Greenhouse Gas Reporting Program to collect data from large emission sources and publish it online for the public.[14]
- A new Corporate Average Fuel Economy (CAFE) standard that will nearly double fuel economy by 2025 to 54.5 miles per gallon for cars and lights trucks.[15] The CAFE standards were finalized in 2012 and apply to model years 2017 and later.
- Minimum efficiency standards for household appliances – since 2009, 25 new or updated standards have been issued.[16]

President Obama announced a number of plans to reduce GHG emissions in June 2013, as part of the President's Climate Action Plan. A key feature of this plan is to issue EPA regulations limiting CO_2 emissions from new and existing power plants via the Clean Power Plan, placing similar limitations on CO_2 emissions to those for pollutants such as arsenic, lead and mercury. The EPA proposed New Source Performance Standards (NSPS) to regulate CO_2 emissions from new power plants in 2012. In June 2014, the EPA issued a proposed NSPS rule to regulate CO_2 emissions at existing power plants and expects to issue a final rule in June 2015. The current proposal includes state-specific, rate-based targets for power sector CO_2 emissions, and provides guidance on the development of plans to achieve the goals set for each state. The Federal government manages a suite of voluntary, mandatory, and incentive-based programs to address climate change, and has established major government-wide programs to advance climate technologies and improve climate science.[17] The U.S. Federal government is pursuing additional strategies and regulations to reduce greenhouse gas emissions as part of the President's Climate Action Plan by:

- Slowing electric power sector and vehicle emissions;

[13] US EPA, 2014h.
[14] US EPA, 2014e.
[15] US NHTSA, 2014.
[16] US DOE, 2014a.
[17] US EPA, 2014a; US EPA, 2014b; US EPA, 2014c.

- Improving efficiency of homes, buildings, and industry;
- Increasing support for scientific research and technology development;
- Enhancing international cooperation.

State and local action

In the absence of a mandatory Federal GHG target to address climate change, states and regions across the country are implementing their own climate change policies. These include the development of regional greenhouse gas reduction programs, the creation of state and local climate action and adaptation plans, increased focus on energy savings from energy efficiency, and mandates to increase renewable energy generation (often in the form of a Renewable Portfolio Standard (RPS), some of which include support for the increased use of combined heat and power). As of late 2013, twenty states plus the District of Columbia had some form of GHG emission reduction target in place.[18] State and regional initiatives include:

- The Regional Greenhouse Gas Initiative[19] (RGGI) is a cooperative effort by nine Northeast and Mid-Atlantic states to develop a multi-state cap-and-trade program covering GHG emissions. The program is aimed at reducing CO_2 emissions from power plants, but participating states may consider expanding the program to other kinds of sources in the future.
- The state of California has committed to reduce its global warming emissions to 1990 levels by 2020 (25% below business as usual) through the California Global Warming Solutions Act of 2006 (AB 32).[20] This reduction will be accomplished through an enforceable statewide cap on GHG emissions which began in 2013.[21]
- The Western Climate Initiative[22] is a collaborative effort initially led by the Governors of Arizona, California, New Mexico, Oregon, Utah, Montana, Washington, and several Canadian Provinces to develop a regional strategy to address climate change. The WCI partners established a regional goal to reduce greenhouse gas emissions 15% below 2005 levels by 2020. The strategy calls for a regional cap-and-trade program. Only two of the WCI partners, California and Quebec are moving forward with their own cap-and-trade programs.
- The Midwest Climate Change Accord[23] was a regional initiative begun in 2009 by the states of Illinois, Iowa, Kansas, Michigan, Minnesota and Wisconsin, and the Canadian Province of Manitoba to address Climate Change. The Accord recommended that a cap-and-trade program be established and intended to focus on providing incentives for certain strengths within the Midwest such as new "green" technology and sustainable biofuels. Movement on the Midwest Accord stalled in 2011.

[18] Center for Climate and Energy Solutions and C2ES, 2013.

[19] For more information see www.rggi.org.

[20] For more information see www.arb.ca.gov/cc/ab32/ab32.htm.

[21] Union of Concerned Scientists, 2014.

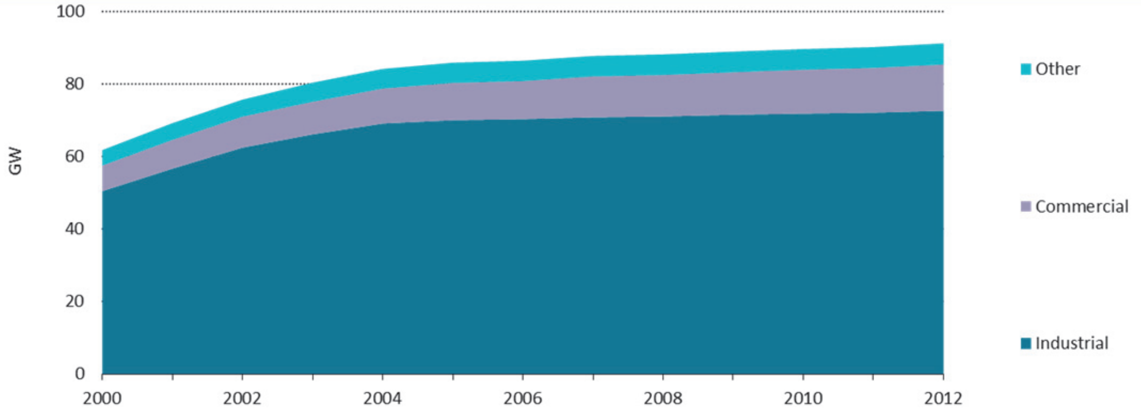
[22] For more information see www.westernclimateinitiative.org.

[23] For more information see www.midwesterngovernors.org.

CHP Status: Technology, Applications and Market Activity

History of combined heat and power in the U.S.

Figure 3 • CHP cumulative capacity by sector in the U.S., 2000 to 2012



Source : ICF International and Oak Ridge National Laboratory (2013), CHP Installation Database, www.eea-inc.com/chpdata/index.html, Washington DC.

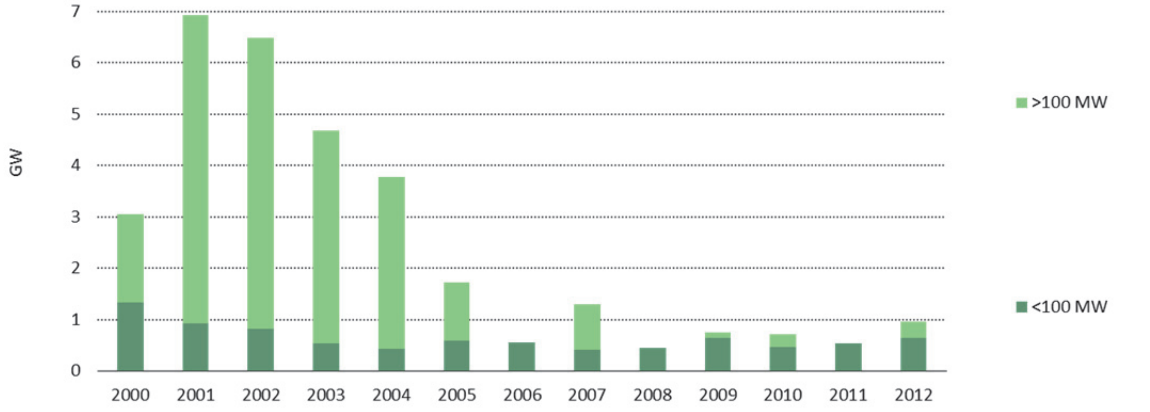
Key message • Most currently installed CHP capacity in the U.S. is in the industrial sector.

Decentralized CHP systems located at industrial and municipal sites were the foundation of the early electric power industry in the United States. However, as power generation technologies advanced, the power industry began to build larger central station facilities in more remote locations and adjacent to large bodies of water to take advantage of increasing economies of scale. CHP became a limited practice utilized by a handful of industries (paper, chemicals, refining and steel). In 1978, Congress passed the Public Utilities Regulatory Policies Act (PURPA) to encourage greater energy efficiency. PURPA provisions encouraged energy efficient CHP and small power production from renewables by establishing a new generating facility classification that "would receive special rate and regulatory treatment" and requiring electric utilities to interconnect with "qualified facilities" (QFs). The implementation of PURPA and the tax incentives were successful in expanding CHP development; installed capacity increased from about 12 GW in 1980 to over 60 GW in 2000. Figure 4 shows the increase in installed CHP capacity since 2000.

The environment for CHP changed in the early 2000s with the advent of restructured wholesale markets for electricity in several regions of the country. Independent power producers (IPP) could sell directly to the market without the need for QF status. However, the movement toward deregulation of power markets in individual states also caused uncertainty, resulting in delayed investments, and as a result, CHP development eventually slowed as shown in Figure 4. These changes also coincided with rising and increasingly volatile natural gas prices in the early 2000s, which further dampened the market for CHP development.

New CHP installed capacity in 2012 was the highest since 2007, but still significantly lower than installations from 2000 to 2004. The CHP market has shifted in the near term to smaller systems (at or below 20 MW) sited at small-to-medium industrial plants and at commercial/institutional facilities located in regions of the country with high retail electricity prices and supportive state policies, such as the Northeast, California and Texas.[24]

Figure 4 • Annual CHP capacity additions, 2000 to 2012

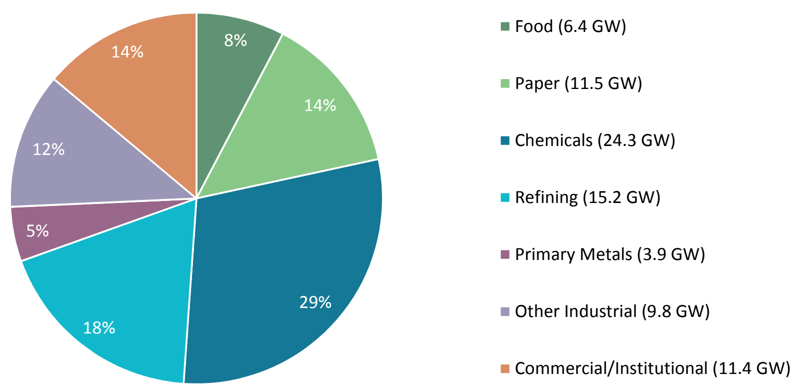


Source : ICF International and Oak Ridge National Laboratory (2013), CHP Installation Database, www.eea-inc.com/chpdata/index.html, Washington DC.

Key message • Addition of CHP capacity has slowed significantly since 2001.

While CHP represents 8% of U.S. electricity generation capacity, it represents over 12% of annual U.S. power generation, reflecting the longer operating hours of CHP plants as compared to conventional forms of generation. CHP is used in a broad range of sectors. Figure 5 shows that 86% of CHP capacity in the United States is found in industry, primarily providing power and steam to large industries such as chemicals, paper, refining, food processing and metals. CHP in the services sector is currently limited (14% of existing CHP capacity), but growing in use to provide power, heating, and, in many cases, cooling, to hospitals, schools, university campuses, nursing homes, hotels, and office and apartment complexes. In the services sector, CHP is also used for district heating and cooling, which currently makes up 23% of the installed CHP capacity in the sector.

Figure 5 • Existing CHP capacity in the United States by sector, 2012



Source: ICF International and Oak Ridge National Laboratory (2013), CHP Installation Database, www.eea-inc.com/chpdata/index.html, Washington DC.

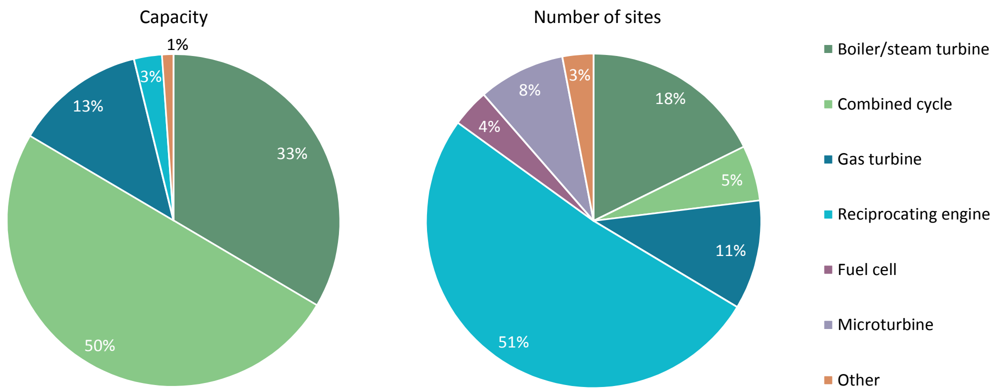
Key message • The chemicals and refining sectors make up a significant portion of installed CHP capacity.

[24] Hedman, 2007.

Existing CHP installations in the U.S. use a diverse mix of fuels, with natural gas being the most common fuel at 70% of CHP capacity. Coal and process wastes[25] make up the remainder (15% and 8% respectively), followed by biomass, wood, oil, and other waste fuels.[26] Interest in biomass and waste fuels has increased in recent years as policymakers and consumers seek to use more renewable and locally-available fuel sources.

In addition to economic factors, which drive the prominent use of natural gas as a fuel for CHP in the United States, the prevalence of gas turbine and combined cycle (gas turbine/steam turbine) systems among existing CHP systems also plays a role. Additionally, air quality and emissions compliance regulations tend to favour natural gas over other fossil fuels, especially in dense urban locations. Figure 6 shows that combined cycle systems and gas turbines represent of the majority of existing CHP capacity, though reciprocating engines are more common by number of sites. Boiler/steam turbine systems, which represent 33% of total CHP capacity, are typically fuelled by solid fuels such as coal and wood waste. Reciprocating engines are the most commonly installed technology, at 51% of existing CHP systems in the United States.

Figure 6 • U.S. CHP capacity and CHP sites by technology, 2013



Source : ICF International and Oak Ridge National Laboratory (2013), CHP Installation Database, www.eea-inc.com/chpdata/index.html, Washington DC.

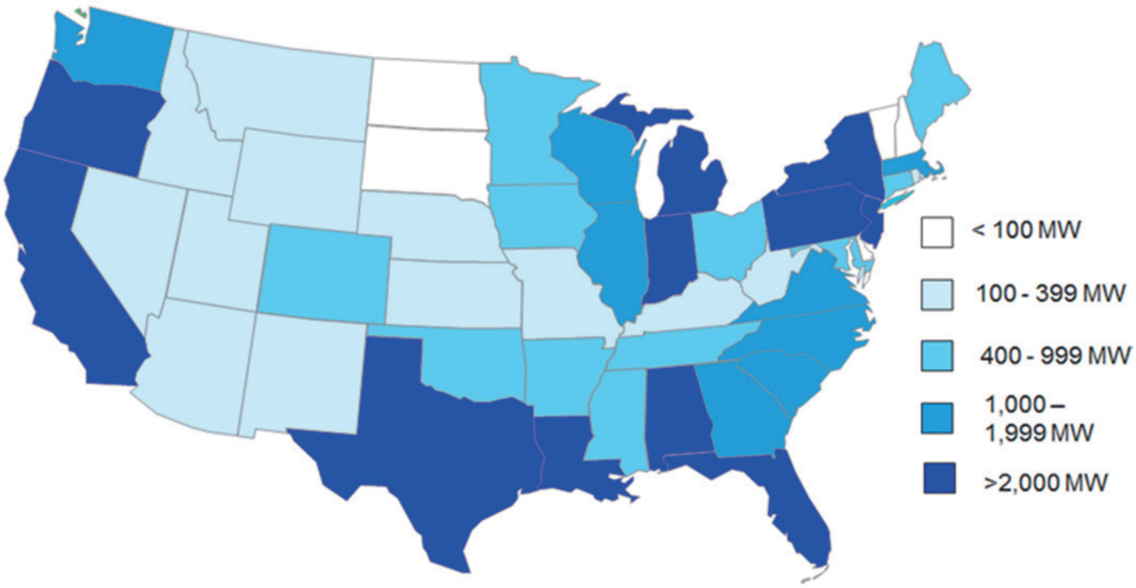
Key message • Though combined cycle systems account for a larger share of CHP capacity, reciprocating engines, which are typically small-scale, are the most commonly used system by number of sites.

There are significant regional differences in the distribution of CHP sites and capacity. Some states are far ahead of others in terms of adopting policies that encourage CHP growth, most notably California, New York and Connecticut, which offer financial and other incentives to CHP projects. Other regional variations can be traced to electricity price variations, energy market structures, and industrial development. For example, chemicals and refining facilities are common in the Gulf Coast states and paper production in the Southeast. States with higher overall energy demand, more energy-intensive industry, and dense population centres with concentrated electricity and thermal energy demand naturally have the highest absolute amounts of CHP capacity.

[25] Process wastes include blast furnace gas, coke oven gas, black liquor, and other industrial waste products.

[26] ICF International and Oak Ridge National Laboratory, 2013.

Figure 7 • Installed CHP capacity by state, 2013



Note : This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area.
Source : ICF International and Oak Ridge National Laboratory (2013), CHP Installation Database, www.eea-inc.com/chpdata/index.html, Washington DC.

Key message • The level of installed CHP capacity varies greatly across states and regions.

Industrial applications

Industrial CHP installations in the U.S. are typically large (greater than 20 MW); however, CHP installations in this sector have been limited in recent years due to volatile natural gas prices and excess power capacity in many regions. Market activity is increasing as electricity rates are rising in many regions and the supply and price outlook for natural gas has stabilised. Pressures from environmental regulations have made natural gas-fired CHP a beneficial alternative to installing costly emissions control equipment on existing power plants.[27] Additionally, this sector is particularly interested in resiliency due to essential nature of many facilities that are susceptible to man-made and natural disasters. CHP systems can provide industrial and other applications with the benefits of reliability under extreme conditions; for example, during Hurricane Sandy, some industrial facilities in the northeastern U.S. were able to remain up and running due to their CHP systems.[28]

Small and commercial applications

CHP installations in commercial facilities make up 56% of CHP sites in the U.S. but account for only 14% of capacity (Figure 6). This is due to the relatively small size of these facilities, which are typically much smaller than industrial facilities. Applications in the services sector are seen as

[27] The EPA's Boiler MACT (Maximum Achievable Control Technology) regulations allow natural gas-fired systems to follow work practice standards such as periodic tune-ups, instead of having to meet actual emissions limits.
US EPA, 2013a; US DOE, 2014b.

[28] ICF International, 2013.

potential growth markets for CHP in the U.S. The U.S. Department of Energy and CHP equipment manufacturers have both invested in technology improvements for small plants, focusing on increasing efficiency, incorporating new thermally activated technologies to provide both heating and cooling services, and integrating components and controls into cost effective packages. [29] However, unique barriers for these markets persist.

District heating and cooling applications

About 1.3% of commercial buildings in the U.S. are heated using district heating networks[30], and its share of overall space heating demand is small. District cooling also covers a small share of space cooling demand, though less data is available on these systems.

Modern district energy systems can employ economies of scale and operational diversity when connecting to a large, diverse portfolio of customers. By aggregating the thermal requirements of dozens or even hundreds of different buildings, these systems can deploy industrial grade equipment to utilize multiple fuels and technologies that would otherwise not be economically or technically feasible for individual buildings, such as natural cooling from lakes or rivers; direct geothermal or waste wood combustion. Additionally, the availability of district energy service can reduce the capital cost of developing an office building by cutting the boiler and chiller plant capital cost from the project, reducing the size and scale of mechanical rooms and electrical vaults, and allowing for valuable roof space to be re-purposed for other revenue generating uses. The energy benefits of district heating and cooling require modern, integrated systems that employ highly insulated, low temperature networks for efficient distribution, and should be coupled with energy-efficient buildings in order to ensure energy efficiency from a systems perspective.

In North America, district energy systems are typically located in dense urban settings in the central business districts of cities; on university or college campuses; on hospital or research campuses; military bases and airports. District energy systems in North America typically serve "clusters" of buildings, which are sometimes commonly owned, as in the case of a private or public university campus or hospital. In US cities and urban areas, district energy systems primarily serve commercial office space; hotels; sports arenas and convention centers; government buildings and urban residential towers (apartment buildings and condominiums). Unlike Scandinavian or northern European cities and towns, where residential buildings may represent a majority of the customer base, in the US, residential space is very often a small portion of the overall customer mix for DHC.

Frequently, however, in downtown systems, the customer buildings (and prospective new customer buildings) have distinct and separate owners; are generally located near each other in a dense central business district or segment of the city, and are interconnected individually to the distribution piping network. The number of customer buildings served by a typical district energy system may range from as few as three or four in the early stages of new system development to as many as 1 800+ customer buildings in the case of the Con Edison Steam Operations in Manhattan, the largest district steam system in the world.

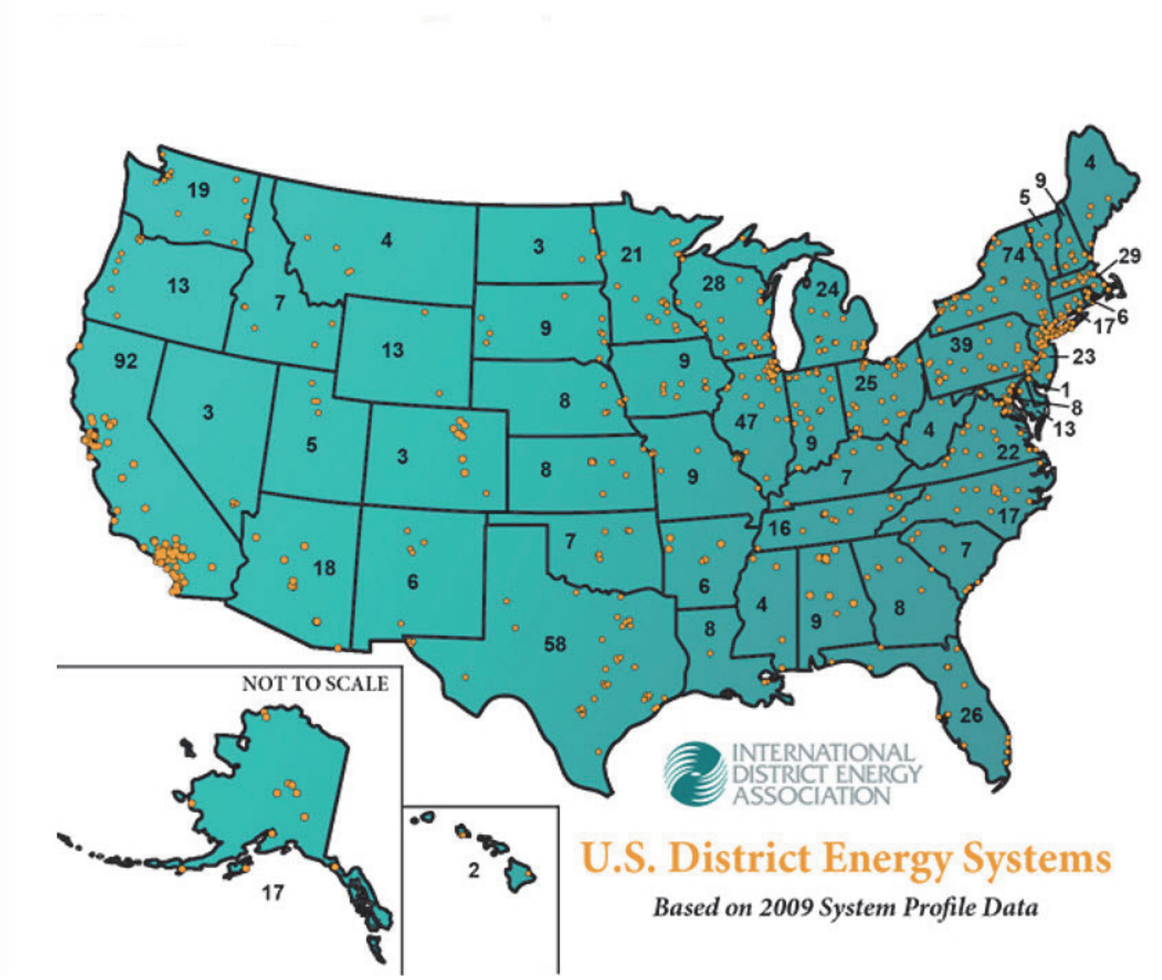
There are currently 106 U.S. downtown district energy systems, 55 of which incorporate CHP into their systems. The systems represent over 15.8 GW_{th} (54 000 MBtu/h) of heating capacity, over

[29] US DOE and EPA, 2012.

[30] US EIA, 2003.

4.9 GW (1 387 000 U.S. refrigeration tons)[31] of cooling capacity and close to 3.8 GW of CHP electricity generation capacity.[32] There are 375 university campus district energy systems in the U.S., nearly one-half of these campuses incorporate CHP into their systems.[33] These systems represent over 26.4 GW_{th} (90 000 MBtu/h) of heating capacity, over 7.6 GW (2 166 000 USRt) of cooling capacity and over 2.9 GW of CHP electricity generating capacity.[34] Since 1990, 34 new downtown district cooling systems have been developed in U.S. cities. District cooling growth has been spurred by increased demand for air conditioning in office, residential and event space as well as for process comfort and humidity control in laboratories, data centres, and research and production facilities.

Figure 8 • U.S. district energy systems map



Note: Numbers shown refer to total number of district energy systems in the state.

This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area.

Source: IDEA (2009), "U.S. District Energy Systems Map", www.districtenergy.org/u-s-district-energy-systems-map, accessed 2014.

Key message • 837 district energy systems exist throughout the U.S.

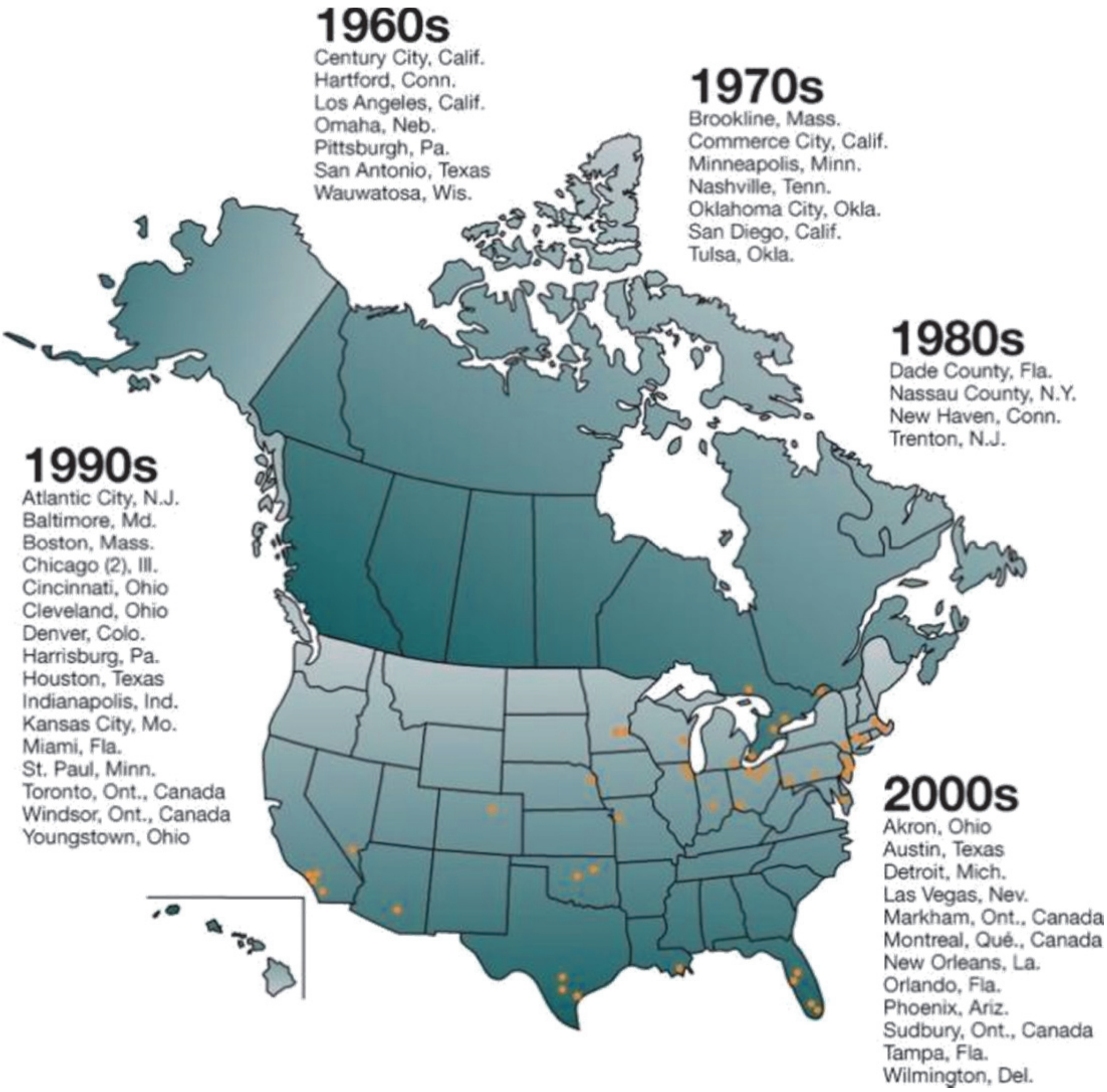
[31] 1 USRt = 3.52 kW

[32] US DOE and IDEA, 2011.

[33] ICF International and Oak Ridge National Laboratory, 2013.

[34] US DOE and IDEA, 2011.

Figure 9 • New downtown district cooling systems built in the U.S. and Canada



Note : This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area.
Source: IDEA (2009), "U.S. District Energy Systems Map", www.districtenergy.org/u-s-district-energy-systems-map, accessed 2014.

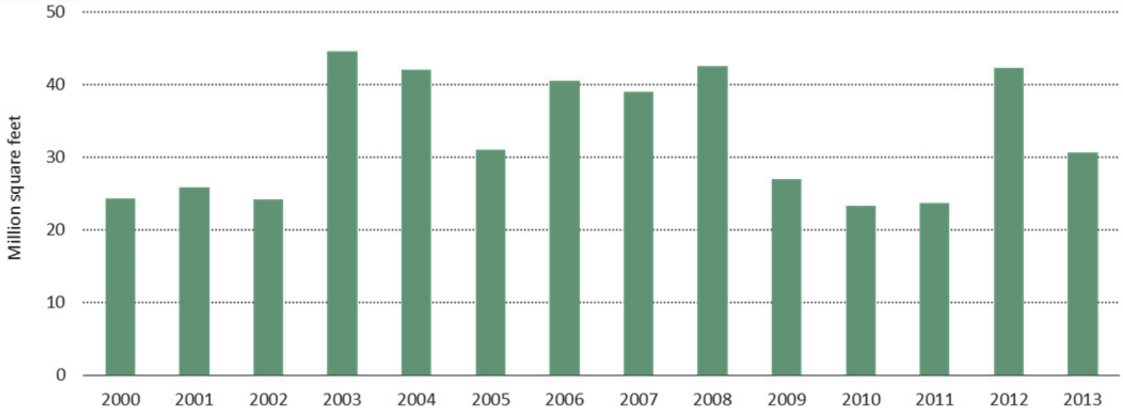
Key message • Downtown district cooling systems have seen strong growth since the 1960s.

Across the US, there has been growing interest among cities, towns, local governments and mixed-use private developers in the design and deployment of new district heating and cooling systems, particularly in the Northeast where natural gas availability and distribution is limited and biomass and wood waste are locally available. For example, the State of Vermont recently commissioned a new biomass district heating facility for the State Capitol buildings in Montpelier, VT along with district hot water service to multiple city-owned and private buildings in the downtown business district. Feasibility assessments have taken place in Washington, California, Texas, Colorado, New Mexico, Massachusetts, Connecticut, New York and Maine.

Mature downtown steam systems exist in some U.S. cities as well. In U.S. cities like Philadelphia, San Francisco, Boston or Denver, these systems serve between 200 and 500 buildings. Larger and established combination district heating and district cooling systems such as those in Hartford, Minneapolis, and Indianapolis, generally serve between 65 and 150 buildings for cooling and between 50 and 200 buildings for heating. In most cases, the urban district energy system typically serves over 50% of the Class A commercial office space in the central business district and in some cases, market share exceeds 85%.[35]

The district energy industry across the U.S. has been growing steadily and organically year over year. Shown in Figure 10, member systems of the IDEA have reported over 53 million square metres (m^2) (572 million square feet)[36] of new customer space connected or re-committed to district energy service since 1990, equating to an average customer growth of 2.2 million m^2 (23.8 million square feet) of customer space added each year.

Figure 10 • Annual DHC customer space additions, 2000 to 2013



Source: IDEA internal estimates.

Key message • District energy systems have grown significantly since 2000.

[35] See District Energy St. Paul, www.districtenergy.com, Hartford Steam Company; www.hartfordsteam.com.

[36] 1 square metre = 10.764 square feet

Box 1 • Case Study 1 – Boston & Cambridge, Massachusetts district energy network with CHP

Figure 11 • Boston & Cambridge, Massachusetts, district energy network

The cities of Boston and Cambridge, Massachusetts are both divided and linked together by the Charles River. The thriving, knowledge-based economy of Boston and Cambridge is anchored by world-class educational institutions, notably Harvard University and Massachusetts Institute of Technology in Cambridge, and equally prestigious healthcare campuses including Massachusetts General Hospital, as well as the Dana Farber Cancer Institute, Brigham & Women's Hospital and Harvard Medical School in the Longwood Medical Area of Boston. All of these institutions are served by district heating and cooling services from a variety of networks.

Veolia owns and operates the district energy networks that serve approximately 250 buildings, including 70% of the largest downtown office towers in the central business district and the Back Bay sections of Boston, the biotech corridor of Cambridge, and the Longwood Medical Area of Boston. Highly reliable district heating and cooling service has been integral energy infrastructure in the regional economy for many decades, with approximately 381 megatonnes (Mt)[37] (or 840 billion lbs) of steam produced annually from CHP, reducing CO_2 emissions by about 281 kt[38] (310 000 short tons) on average per year.[39]

Since 2008, Veolia has invested nearly USD 168 million in renewal and expansion of the central plants and distribution systems in both cities. Two notable recent investments are the acquisition of the 256 MW Kendall CHP Station located in Cambridge, near MIT, and a major pipeline extension installing new connecting the Kendall CHP Station to the downtown Boston district heating network, via 46 centimetre (cm)[40] (18 inch) diameter steam piping essentially doubling the annual volume of CHP steam supply to about 771 Mt (1.7 million lbs) per year.

[37] 1 tonne = 2 204.6 lb

[38] 1 short ton = 0.907 tonnes

[39] Emissions reductions based on comparison to meeting steam and electricity demand using on-site natural gas boilers and importing electricity from the grid.

[40] 1 inch = 2.54 centimetres

Figure 12 • Route of Green Steam pipeline extension from Cambridge to Boston district steam network

Source: Veolia, 2014.

This pipeline project represents a “triple win” for the region, yielding lower cost energy at higher efficiency while simultaneously reducing the environmental impact to benefit the citizens, district energy consumers and the ecosystem of the Charles River. The Kendall plant’s once-through cooling system used to withdraw an average of 265 million litres[41] (70 million gallons per day) from the river, which was discharged back into the river at temperatures around 41°C (105°F). The new steam pipe and planned plant reconfiguration recover heat previously lost to the environment and will eliminate thermal pollution, while improving the natural habitat for sensitive fish populations as well as citizens using the river for sailing and other recreation. Recovering this surplus heat for use by buildings served by DH, avoids another 150 kilotonnes (kt) (165 000 short tons) of CO_2 emissions.

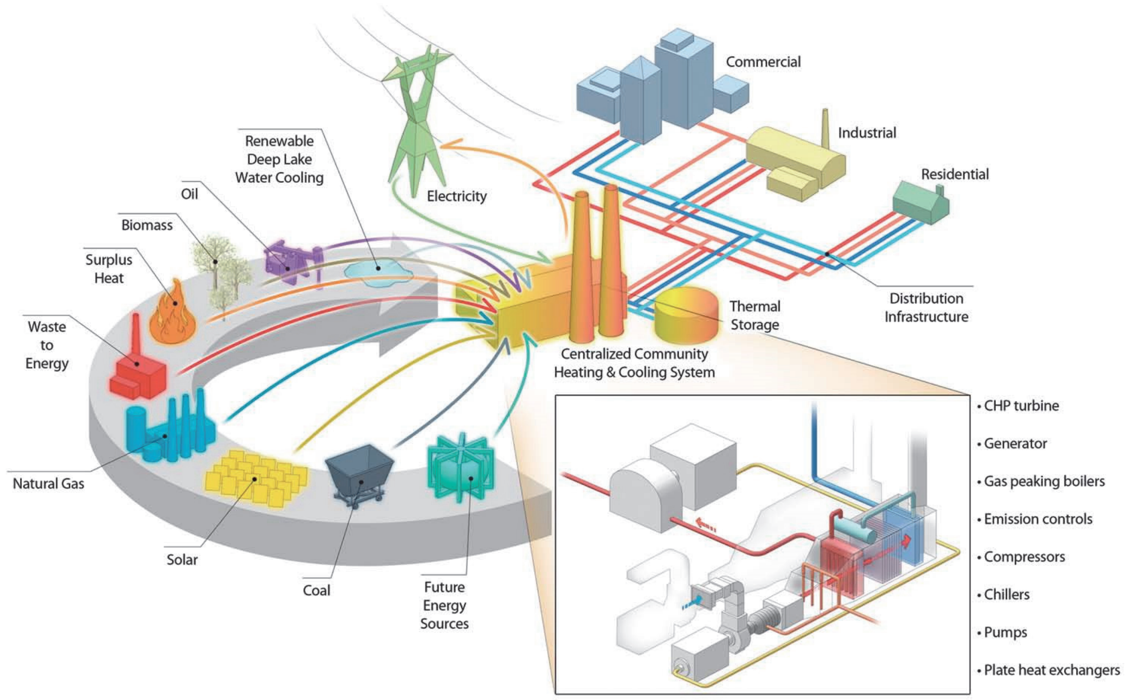
Emergence of microgrids

Microgrids are systems that integrate small-scale distributed energy resources within clearly defined boundaries and act as a single controllable entity with respect to the grid, and can connect and disconnect from the grid as needed, in contrast to DHC systems, which typically distribute thermal energy from a central plant to a number of facilities connected through a

[41] 1 gallon = 3.785 litres

piped distribution system.[42] With the recognition of greater frequency and severity of extreme weather patterns causing grid interruptions and increasing risk of business interruptions, end-users and planners in the U.S. are turning to microgrids, which are typically small-scale, as a means to invest in more resilient local energy operations. As depicted in Figure 13, the diversity of energy options and fuel flexibility creates a market advantage for microgrids/district energy systems and sets up the district energy system as an asset for community energy planning.

Figure 13 • Integration of various fuel sources into a central district energy facility



Source: IDEA, 2014

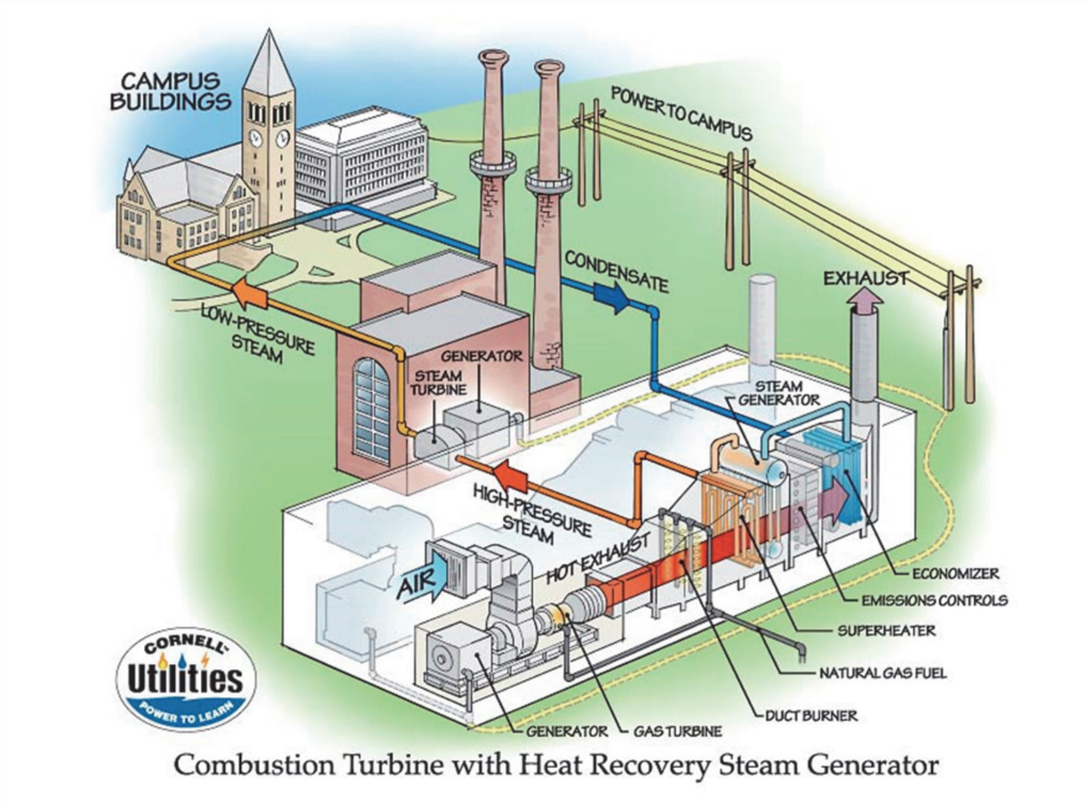
Key message • Microgrids can integrate a number of different fuel sources within a district energy system.

While many regulatory and market conditions need to be resolved for widespread deployment, operating examples of microgrids have been in use at college and university campuses for decades. In practice, a microgrid would have the capability to operate in isolation from the regional power grid during an outage and provide power and heat and/or cooling to a defined cluster of end users. Many college university campuses that house valuable research have implemented district energy/CHP as a means to enhance operational reliability. These more robust operating systems have been further designed to operate in "island mode" during severe weather or other events. The microgrid has the capability to "black start" when the grid is down and once the larger grid service is restored it can also re-connect and smoothly re-integrate operations. As core infrastructure, robust microgrids have a district energy/CHP facility to optimize efficiency and utilize thermal energy, renewable energy, thermal energy storage and a variety of controls topologies to enhance regional energy resiliency.

[42] US DOE, EPA, and HUD, 2013.

Box 2 • Case Study 2 – Cornell University DHC and CHP

Figure 14 • Cornell University district heating network with CHP



Source: IDEA, 2014.

Cornell University in Ithaca, New York, has developed a Climate Action Plan which identifies implementation of natural gas-fired CHP as the most effective means to cut indirect emissions of CO_2. By shifting from coal to natural gas, Cornell was able to cut coal use by over 50% and reduce campus CO_2 emissions by 45 kt (50 000 short tons) per year. Commissioned in 2009, the CHP facility is rated at 30 MW electric capacity and 105.7 MW_{th} (300 000 lb/h[43]) of heating capacity. It produces 180 Gigawatt hour (GWh) of electricity and 340 kt[44] (750 000 klbs) of steam per year. The Cornell CHP unit is designed to enhance electricity reliability, provide cost effective and cleaner steam capacity and offers future fuel flexibility. If in the future liquid biofuels become economically attractive, Cornell can switch over the entire 200 building campus to greener fuels via a valve in the central plant, rather than implementing a fuel switch at each individual building.

Cornell's CHP system has been integrated into the University's 37 MW microgrid, which also consists of a 1 MW hydropower generator and a small solar installation. Cornell's CHP system has been designed to be able to island from the main grid in order to provide continuous service to the University, and has been designed with black-start capability. Cornell's CHP and microgrid integration project cost USD 60 million and returns on this investment are expected to be in the range of 8 to 10% annually.

[43] 1 lb steam/hr (300 psi, saturated) = 1 202 Btu/h.

[44] 1 Mt = 2 204 622 klb.

Government CHP and DHC Promotion Policies

The U.S. Department of Energy and the U.S. Environmental Protection Agency lead a variety of research and market transformation programs for CHP development many of which include DHC with CHP, though they have no specific programs focused exclusively on DHC. In terms of policy, the following key legislation and Executive Actions regarding CHP have been enacted over the past decade:

- The Energy Policy Act of 2005 established limited-term tax incentives[45] for two emerging CHP technologies (fuel cells and microturbines) and for renewable generation.[46]
- The Energy Independence and Security Act of 2007 authorized a number of grant programs and regulatory incentives for CHP and waste energy recovery.
- The American Recovery and Reinvestment Act of 2009 re-authorized a number of grant and loan programs for which CHP is eligible.
- In 2012, President Obama issued Executive Order 13624 – Accelerating Investment in Industrial Energy Efficiency. This Executive Order sets a national goal of 40 GW of new, cost-effective CHP in the U.S. by the end of 2020. The Order also directed the DOE to conduct regional meetings to promote CHP and discuss best practices for dealing with current barriers. If the target is met it would save one Quad[47] of energy, about 1% of U.S. annual energy consumption.

Many state governments are also developing policies and programs that address their specific energy challenges, including recognizing how CHP and DHC can provide additional benefits.

- **Removing unintended utility tariff barriers to CHP**. Electric utilities typically charge special rates for electricity and for services associated with distributed generation systems like CHP, including supplemental rates, standby rates, and buyback rates for excess power. If not properly designed, these rates can create barriers to the use of CHP. Appropriate rate design is critical to allowing utility cost recovery while also providing appropriate price signals for clean energy supply. States such as California, New York, Illinois, Massachusetts, and Oregon are exploring different types of rate structures that allow utilities to maintain profitability and also encourage the deployment of customer-sited CHP.[48]
- **Establishing interconnection standards**. Economic use of CHP for most customers requires integration with the utility grid for back-up and supplemental power needs, and in some cases, sale of excess power. In order to be successful, CHP systems must be able to safely, reliably and economically interconnect with the existing utility grid system. Understanding the various fees associated with interconnecting to the grid can be challenging and costly if not planned for accurately. Therefore, states are encouraging CHP by establishing uniform processes and technical requirements for grid interconnection. Twenty-five states have established standard interconnection rules that can be applied to CHP systems.[49] These rules may include CHP best practices, such as covering all distributed generation technologies, use

[45] These incentives are currently active until December 31, 2016.

[46] This act also presumes that qualified facilities (QFs) have nondiscriminatory access to the market but the QF can rebut this presumption in a filing to FERC.

[47] 1 Quad (1 quadrillion Btu) = 1.055 EJ

[48] State and Local Energy Efficiency Action Network, 2013.

[49] North Carolina State University, 2013.

of standard technical requirements and appropriate system capacity limits.[50]

- **Energy Resource Standards**. As of April 2014, some form of portfolio standard (renewable portfolio standards [RPS], energy efficiency resource standards [EERS], alternative portfolio standards [APS] or a combination of these) has been established in 41 states and the District of Columbia. Twenty-five states explicitly define CHP and/or waste heat recovery as an eligible resource, however from state to state the specifics of how CHP qualifies vary.[51] Some states do not explicitly identify CHP as an eligible resource, but CHP systems can qualify as long as they are powered with a qualifying renewable fuel/technology. Many states have size limits on the electrical capacity of CHP systems that can qualify, and every state varies on the financial value of portfolio standard credit.

- **Enacting output-based air pollution regulations**. Output-based regulations relate air emissions to the productive output of a process and encourage the use of fuel conversion efficiency as an air pollution control or prevention measure. Output-based regulations that include both the thermal and electric output of a CHP process can recognize the higher efficiency and environmental benefits of CHP. Output-based regulation can be applied in conventional emission rate regulations. Eighteen states have implemented output-based regulations with recognition of thermal output for CHP systems, particularly for smaller systems. Some states have adopted output-based allocation methodologies that include both electricity and thermal output of CHP systems. These can create a significant incentive for CHP facilities. At the Federal level, EPA has established a number of output-based New Source Performance Standards (NSPS). The Federal NSPS for NO_x from electric utility boilers and the NSPS for combustion turbines are structured as output-based. Each rule also contains compliance provisions for CHP. In addition, the EPA's Boiler MACT regulations and proposed NSPS for regulating CO_2 emissions from new power plants are both output-based.[52]

[50] For more information see ACEEE's Policies and Resources for CHP Deployment, see: State Interconnection Rules. www.aceee.org/sector/state-policy/toolkit/chp/interconnection.

[51] North Carolina State University, 2013.

[52] US EPA, 2004; US EPA, 2011; US EPA, 2013; US EPA, 2014a.

Stakeholders

Federal agencies

U.S. Department of Energy (DOE) –The mission of the DOE is to ensure America's security and prosperity by addressing its energy, environmental and nuclear challenges through transformative science and technology solutions. In addition to supporting research, in 2001 the DOE established the first of what are now seven regional CHP centres focused on advancing CHP and DHC. These regional expert groups, now known as CHP Technical Assistance Partnerships (CHP TAPs), provide market assessment, technical assistance and educational support for CHP development, including DHC with CHP.[53] More recently, DOE has collaborated with the State and Local Energy Efficiency Action Network (SEE Action) and funded research for the Federal Energy Management Program and the Loan Programs Office. DOE stresses CHP as a key component of distributed energy that provides a cost-effective, near-term opportunity to improve the nation's energy, environmental, and economic future. DOE has also promoted CHP's vital role to critical infrastructure in response to Hurricane Sandy by providing information to consider when configuring CHP to operate independently of the grid.[54]

DOE supports a variety of market studies related to CHP, the CHP Installation Database, and the seven regional CHP TAPs while also partnering with the SEE Action to develop resources on CHP implementation at a state level, including best practice policies. DOE has led CHP technology development, demonstration, and deployment, partnering with consortia in the commercial building marketplace and with owners and operators of merchant stores, light industry, supermarkets, restaurants, hotels, hospital and health care, multi-family dwellings, and high-tech industries. Through technical and financial support, best practices information, education and training, and improvements in energy efficiency, cost-effectiveness, and integration, DOE's efforts have resulted in enhanced market penetration.

U.S. Environmental Protection Agency's Combined Heat and Power Partnership (CHPP) – The mission of EPA is to protect human health and the environment.[55] The EPA established the CHP Partnership in 2001 as a voluntary program that promotes high-efficiency CHP technologies across the United States. The Partnership works closely with energy users, the CHP industry, state and local governments, and other clean energy stakeholders to facilitate the development of new projects and to promote their environmental and economic benefits.

Congress

Senate Committee on Energy and Natural Resources –This Committee has oversight in the following major areas related to energy: energy resources and development, nuclear energy, public lands and their renewable resources, surface mining, Federal coal, oil, and gas, other mineral leasing, territories and insular possessions, and water resources.[56]

[53] US DOE, 2014b; US DOE, 2014a.

[54] US DOE, EPA, and HUD, 2013.

[55] US EPA, 2014g.

[56] US Senate Committee on Energy & Natural Resources, 2014.

Senate Committee on Environment and Public Works – This Committee has jurisdiction over environmental policy areas including air pollution, climate change policies, water pollution and water resources, and solid waste disposal and recycling.[57]

House Committee on Energy and Commerce – This Committee maintains principal responsibility for legislative oversight relating interstate and foreign commerce, including public health, air quality and environmental health, and the supply and delivery of energy.[58]

State and local government associations

State and local regulatory agencies also play a major role in setting policies relevant to CHP and DHC in the U.S. The air pollution control agencies in 45 states and territories and 116 metropolitan areas in the U.S. are represented by the **National Association of Clean Air Agencies (NACAA).** The NACAA aims to improve the effectiveness of state and local level air pollution agencies while enhancing the cooperation of Federal, state, and local regulatory agencies, in order to promote good management of air resources.[59] Similarly, the **National Association of State Energy Officials (NASEO)** is a national level non-profit organization for governor-designated energy officials from each state and territory across the United States, to promote peer learning and to advocate on behalf of state energy offices to Congress and Federal agencies.[60] **National Association of Regulatory Utility Commissioners (NARUC)** is a non-profit organization of state public service commissions who regulate energy, telecommunications, water, and transportation utilities. The mission is to serve the public interest by improving the quality and effectiveness of public utility regulation.[61]

Industry and non-governmental organizations

There are many local, state, regional and national industrial and non-governmental organizations active in CHP and DHC efforts. The organisations cited below are not an exhaustive list, but rather a selection of several key groups. Other non-governmental and industry organisations are also active in the CHP and DHC arena in the U.S.

International District Energy Association (IDEA) – IDEA is a non-profit industry association, formed in 1909, which today represents about 2 000 members in 26 countries who own, operate, design and optimize district energy systems serving cities, communities and campuses. Over 57% of IDEA members are owner/operators of district energy systems. Through conferences, training, workshops and advocacy, IDEA provides peer-to-peer exchange in industry best practices to enhance educational experiences for district energy professionals, assist members in marketing the benefits of district energy, and provides advocacy to secure more favorable policies, legislation, and regulations for district energy.[62] Since releasing the guidebook, *Community Energy: Planning, Development & Deployment*, in 2012, IDEA has supported dozens of early stage feasibility assessments in a range of applications and settings.

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[57] US Senate Committee on Environment & Public Works, 2014.

[58] US House of Representatives Energy & Commerce Committee, 2014.

[59] NACAA, 2014.

[60] NASEO, 2014.

[61] NARUC, 2014.

[62] IDEA, 2014.

Combined Heat and Power Association (CHPA) - CHP Association (CHPA) brings together diverse market interests to promote the growth of clean, efficient local energy generation in the United States. CHP Association's mission is to increase deployment of combined heat and power and waste energy recovery systems to benefit the environment and the economy. The CHP Association documents the benefits of clean heat and power to the public and decision-makers. The association sponsors conferences, workshops, and advocacy events for the benefit of its members and prepares reports and releases to educate the public about clean heat and power.[63]

American Council for an Energy Efficiency Economy (ACEEE) - The American Council for an Energy-Efficient Economy is a nonprofit organization dedicated to advancing energy efficiency as a means of promoting economic prosperity, energy security, and environmental protection. ACEEE conducts technical and policy assessments on energy efficiency topics including CHP.[64]

[63] CHPA, 2014.

[64] ACEEE, 2014.

CHP/DHC Challenges

The relative price of fuel and electricity and the costs of CHP/DHC alternatives have an important impact on the commercial viability of CHP/DHC. Elimination of regulatory and institutional barriers to CHP has been primarily focused at the state and local levels of government. However, a "patchwork" of state and local policies and regulations still exist (see the summary of U.S. state policies table in the Appendix).[65] Related to the site-specific economics of CHP/DHC, regulatory and market barriers in the U.S. include:

Grid interconnection – The current lack of uniformity in interconnection standards makes it difficult for equipment manufacturers to design and produce modular packages that can easily connect to the grid many contexts, and can create hurdles for timely project development. Complexities in interconnection requirements lessen the economic viability of some CHP facilities and increased complexities for DHC. Also, many of the states with standardized interconnection procedures have size limits that are too small to be applicable to most CHP systems.[66]

Utility tariff structures – Most investor-owned utilities in the U.S. use a combination of demand, energy, and customer charges. Rate structures that focus more heavily on non-bypassable customer charges and high demand charges with ratchets, which are very common particularly in the Midwest and Southern regions of the country, reduce the economic savings potential of CHP. These rate structures, combined with the fact that every utility tariff structure is different, create hurdles for CHP developers who have to learn how to optimize CHP operation under a variety of different structures. Moreover, "departing load charges" have been assessed on CHP projects as a surcharge or payment to the local utilities for future lost revenue or to reflect the lost revenue or coverage of "wires charges" to compensate for continued access to the distribution networks. These charges, when not reasonably calculated, can add costs to CHP deployment that impair the project economics and may stall new CHP system construction.

Standby/back-up charges – Standby and back-up charges are applicable to other forms of distributed generation, not just CHP. However, facilities with CHP systems usually require standby/back-up service from the utility to provide power during periods when the system is down due to routine maintenance or unplanned outages, which make the structure of these charges particularly important for CHP systems. Electric utilities often assess specific standby charges to cover the additional costs the utilities incur as they continue to provide generating, transmission, and/or distribution capacity (depending on the structure of the utility) to supply backup power when requested (sometimes on short notice). The level of these charges is often a point of contention between the utility and the consumer, and can create barriers to CHP.[67] A variety of studies have been conducted on the impact of standby rates on CHP economics and many states allow for standby rates to be high enough that they can significantly deter the economics of CHP projects. Project economics can also sometimes be burdened by departing load charges, which act as exit fees in certain utility service areas.[68]

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[65] State and Local Energy Efficiency Action Network, 2013.

[66] A key element to the market success of CHP is the ability to safely, reliably, and economically interconnect with the existing utility grid system. In the U.S., a number of states have adopted state-wide interconnection standards that may include measures such as implementing streamlined procedures, clear timelines, simplified contracts, and appropriate application fees that may the process easier for DG systems. In states without a standard in place, or for CHP systems that are larger than size thresholds for participation in the state-wide standard, the CHP project owner must contact the local electric distribution utility to interconnect, and utility interconnection requirements can vary widely in complexity and cost.

[67] US EPA, 2014d.

[68] Departing load charges are only applicable in certain states (primarily California) and only apply to distributed generation technologies.

Future energy price uncertainty – For the economics of a CHP project to be favourable, the project needs a high "spark spread", defined as the difference between the price received by a generator for final energy produced and the cost of the natural gas or other fuel source needed to produce that electricity and heating or cooling service.[69] CHP is most economical in areas where the electric prices are high and fuel prices are low (typically in California and the Northeastern states). In recent years, fuel prices have been volatile, which has created an environment where potential CHP sites see the investment in CHP as risky. However, recent stabilisation of natural gas prices could counteract this perception. Viability of individual projects is highly dependent on local market conditions, particularly fuel and electricity prices which can be subject to significant regional variation.

Lack of recognition of CHP in environmental regulations – Most U.S. environmental regulations have historically established emission limits based on heat input (lbs/MBtu) or exhaust concentration (parts per million [ppm]). These input-based limits do not recognize or encourage the higher efficiency offered by CHP. Nor do they account for the pollution prevention benefits of efficiency in ways that encourage the application of more efficient generation approaches. Since CHP generates both electricity and thermal energy on-site, it can potentially increase on-site emissions from an input based regulation perspective even while it reduces the total overall emissions of the larger geographic area served by the traditional, aggregated generation source. A lack of output-based emissions limits fails to recognize CHP's contribution to emissions reductions in a larger geographic region. Thus environmental permitting can be a barrier to CHP development, rather than incentivizing and recognizing its benefits.[70]

Tax policies – CHP systems do not fall into a specific tax depreciation category. As a result, the depreciation period can range from five to 39 years. These disparate depreciation policies may discourage CHP project ownership arrangements, increasing the difficulty of raising capital and discouraging development. For DHC systems, distribution piping investments are eligible for tax exempt financing, but due to high soft costs (e.g. non-labour and equipment costs) and issuance requirements for tax exempt bonds, this source of funding is often not utilized unless the capital investment exceeds USD 40 to 50 million.

Local market conditions –

- **Ability to sell excess electricity** – In some jurisdictions to sell excess electricity is also a significant uncertainty for investment decisions. Choosing the size that maximizes efficiency (i.e., sizing to the thermal load) often can produce power in excess of the host site's requirements when the host has a large thermal demand.[71] In many jurisdictions power purchase agreements (PPAs) are hard to establish at prices that are reasonable to justify this sizing method.
- **Identifying and securing anchor customers** – Large, stable and long term users are often key to successful development of district energy systems. Private sector investment targets often inhibit projects with longer term economic returns or less investor certainty.

Customer perceptions – CHP/DHC is typically not part of an energy user's core business and is often subject to higher economic returns for a project to move forward. Since smaller industrial and commercial customers do not typically have the in-house expertise in energy procurement and management, this creates a lack of awareness of CHP/DHC opportunities. At a municipal level, community leaders are seeking development guidance on district energy through the IDEA

[69] US EIA, 2013a.

[70] US EPA, 2011.

[71] State and Local Energy Efficiency Action Network, 2013.

guidebook *"Community Energy: Planning, Development and Delivery"* which outlines the steps to assessing, evaluating and deploying energy mapping and project development of economically viable district energy systems.

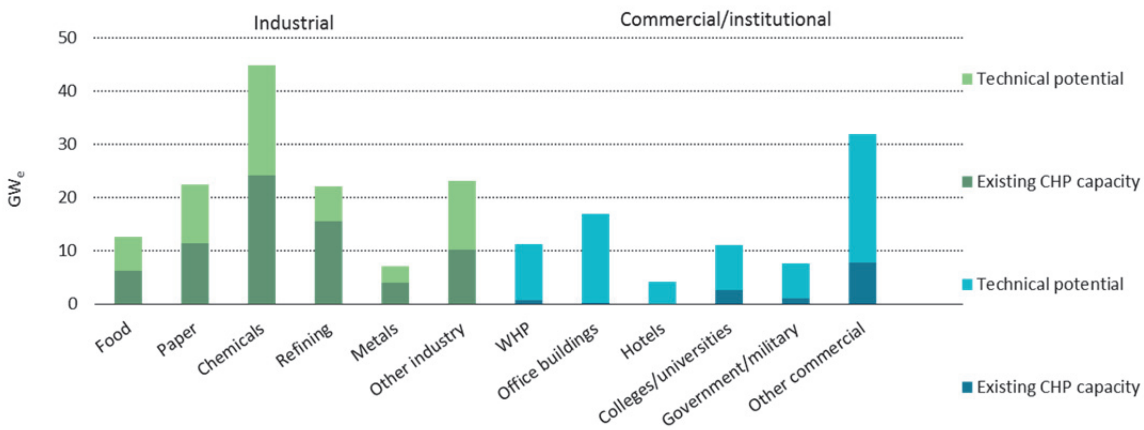
Policy uncertainty for long term capital investment – CHP and DHC require significant capital investments and the equipment has a long lifetime. It can be challenging to make investment decisions in a constantly changing policy environment or an environment with only near-term certainty. For example, pending treatment of carbon costs and other GHG costs is a significant unknown in the decision to invest in CHP.

CHP/DHC Potential and Benefits

Continuing moderate gas prices will be a strong incentive for CHP market development, as most existing CHP systems use natural gas (72% of capacity). This, coupled with a Federal target to increase CHP, state incentives, and Federal regulations to reduce air emissions, including GHG emissions, the outlook for U.S. CHP development is bright.

Like other forms of energy efficiency, CHP represents a largely untapped resource that exists in a variety of energy-intensive industries, institutions, and commercial businesses. Recent estimates indicate the technical potential[72] for additional CHP at existing industrial facilities is around 60 GW of electric capacity, with the technical potential for CHP in the services sector at just over 65 GW of electric capacity, for a total of over 125 GW.[73]

Figure 15 • Remaining U.S. technical potential for industrial and services sector co-generation



Sources : ICF International and Oak Ridge National Laboratory (2013), CHP Installation Database, www.eea-inc.com/chpdata/index.html, Washington DC ; ICF International internal estimates.

Key message • Technical potential for CHP remains in a number of industrial and services sectors.

The 60 GW of industrial technical potential outlined above represents efficient CHP systems sized to the baseload thermal demand of the site and does not include the potential for producing electricity for export to the grid beyond the facility's on-site demand. This export capacity in industry represents another significant resource base of clean, efficient CHP. The technical potential in industrial applications more than doubles to 130 GW of electric capacity if systems are sized to the thermal demand without a cap in power output, and excess electricity generated but not used on site could be easily exported to the grid or sold to adjacent users.[74]

[72] The technical market potential is an estimation of market size constrained only by technological limits—the ability of CHP technologies to fit existing customer energy needs. The technical potential includes sites that have the energy consumption characteristics that could apply CHP, and potential for these sites is sized to meet baseload thermal demand. The technical market potential does not consider screening for other factors such as ability to retrofit, owner interest in applying CHP, capital availability, fuel availability, and variation of energy consumption within customer application/size classes. All of these factors affect the feasibility, cost and ultimate acceptance of CHP at a site and are critical in the actual economic implementation of CHP.

[73] US DOE and US EPA, 2012.

[74] Based on ICF International internal estimates.

Box 3 • Case Study 3 – Frito-Lay CHP system

Figure 16 • Frito-Lay snack plant, Killingly, Connecticut

Source: PepsiCo, 2014.

The 4.6 MW gas turbine CHP system at Frito-Lay's Killingly, Connecticut snack plant provides 90% of the facility's electric needs and 80% of its steam needs.[75]

System benefits:

- Achieves high efficiency – fuel efficiency exceeds 70% on average annually.
- Reduces emissions – the system at Frito-Lay has cut the facility's GHG emissions by more than 5%.
- Mitigates the strain on the local electricity grid.
- Enables continued facility operations during power outages, including during Hurricane Irene in 2011 and Hurricane Sandy in 2012.

A 2009 study by McKinsey and Company estimated that 50 GW of CHP in industrial and large services sector applications could be deployable at reasonable returns with the current equipment and energy prices.[76] Estimates of both technical and economic potential would likely be greater today given the improving outlook in natural gas supply and prices.[77]

IDEA has identified 289 known district thermal only systems (not equipped with CHP) with 16.6 GW (56 736 MBtu/h) of installed heating capacity. Assuming a 50% heating system load factor, this segment represents a technical potential of between 5.6 GW_e and 14.2 GW_e of CHP capacity across the U.S., depending on technology selection, without accounting for regional and more specific market barriers.[78]

The areas of the country with the highest technical potential for CHP correspond to areas with high population or industrial activity. Some of these same regions overlap with areas having beneficial spark spreads for CHP and policy atmosphere's conducive to CHP growth. Figure 15 shows the comparison of existing CHP capacity to the remaining technical potential for additional installations.

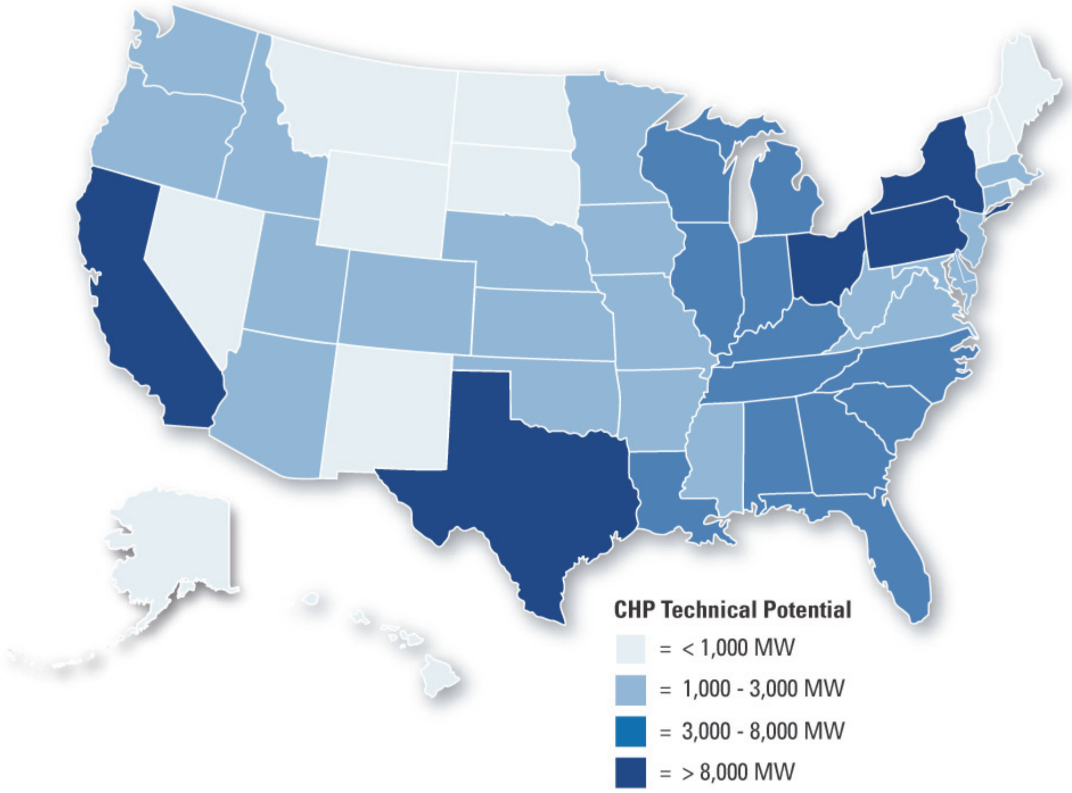
[75] US DOE, 2011.

[76] McKinsey and Company, 2009.

[77] State and Local Energy Efficiency Action Network, 2013.

[78] IDEA has assumed that new CHP units will use either gas turbines (requiring 5000 lbs of steam per hour per MW of electrical capacity) or reciprocating engines (requiring 2000 lbs of steam per hour per MW of electrical capacity).

Figure 17 • U.S. CHP potential by state



Note: The technical market potential does not consider screening for economic rate of return, or other factors such as ability to retrofit, owner interest in applying CHP, capital availability, natural gas availability, and variation of energy consumption within customer application/size class. However, the technical potential as outlined is useful in understanding the potential size and distribution of the target CHP markets among the states.

This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area.

Source: ICF internal estimates, 2013.

Key message • Technical potential for CHP installations varies across regions, with the greatest potential in Texas, California, Ohio, Pennsylvania and New York.

Summary Policy Recommendations

In recent years, there has been moderate progress in implementing measures to promote efficient CHP and DHC in the U.S., following a slowdown in deployment in the early 2000s. However, a clearer visibility of the environmental benefits of these technologies will help create cost-effective growth opportunities, and realise sizeable additional benefits.

Federal and state government support

- **Recognize the complete value of efficient generation** and use of energy as an offset to other sources of local or regional sources of emissions.
    - Quantify these benefits using emissions databases, such as EPA's Emissions and Generation Resource Integrated Database (eGRID), to identify displaced emissions from the regional grid mix due to CHP and DHC.
    - Include CHP and efficient DHC in pending GHG legislation and programs, including EPA's NSPS Section 111(d) rulemaking and Congressional bills providing incentives such as tax breaks or grants for CHP and efficient DHC.
    - Include CHP and efficient DHC in a national level clean energy portfolio standard.
    - Recognize the benefits that distributed generation or microgrid resources provide to the local and regional electricity grid including capacity, ancillary benefits such as reactive power support, balancing capacity for intermittent resources, relief of distribution congestion and enhanced resiliency for hosts.
- **Help level the playing field for CHP and DHC** through regulatory and policy standardisation measures at the state level, including:
    - Implement standardised interconnection rules in states where they do not already exist and expand current standardised interconnection rules to cover all CHP system sizes to facilitate CHP access to electricity grids.
    - Develop transparent standby rate policies that suitably recognize the benefits of CHP and DHC while appropriately compensating utilities for their services, and eliminate exit fees for new CHP and DHC installations.
    - Standardise siting and environmental permitting policies.
    - Establish uniform tax policies with respect to CHP and DHC projects.
    - Promote the use of output-based emissions standards, such as through the New Source Performance Standards (NSPS) for new generating units.[79]
- **Consider alternatives to overcome market barriers**, including:
    - Expanding current Federal investment tax credits for high efficiency CHP and providing an investment tax credit for DHC systems, as well as providing Federal production tax credits for high efficiency CHP and DHC installations.
    - Facilitating grid access and sale of excess electricity to make efficiently-sized CHP projects more economically feasible.

[79] US EPA, 2014i.

- **Promote a stable policy environment** that encourages long term capital investment in efficient CHP and DHC systems.
- **Support expanded related technology research, development, demonstration and deployment**, particularly in biomass and small-to-medium sized applications.

Private sector initiatives

- **Develop and promote an integrated approach** that combines low energy buildings with modern, low temperature distribution networks to bring low-carbon heat and cooling to urban areas.
- **Develop innovative business models** which can accommodate the needs of investors and service providers, integrate CHP and DHC into energy systems and allow further deployment of efficient technologies and systems.
- Independent System Operators (ISOs), which operate and manage many regional electricity grids, should **properly value the combined electricity and thermal outputs** of CHP, considering plant heat rate as an efficiency measure when ranking plant dispatch in regional or state operating systems.
- **Further raise the profile of CHP and DHC** as effective energy efficiency measures through outreach and wider communication of success stories.
- **Continue supporting platforms for knowledge sharing** and promotion of best practices.

CHP/DHC Scorecard

To aid in comparing amongst countries, the IEA has developed a Scorecard of a country's CHP and DHC policy efforts that takes into account the effectiveness of the policy framework to create an **energy efficiency rewarding environment which enables realising cost-effective CHP/DHC potentials** from the perspective of past and existing policies, as well as statements and commitments of intent respect to future related policies.

Each country is given a scorecard rating as follows:

No material policy effort or intent to promote CHP/DHC. The market is not expected to grow for the foreseeable future. Rating: 1

Some minor recognition of the benefits of efficient CHP/DHC, but policies are not fully effective or are otherwise insufficient to promote CHP/DHC deployment. Rating: 2

There is recognition of the benefits of efficient CHP/DHC, accompanied by the introduction of some measures to accelerate the development of CHP/DHC, but these technologies are not effectively prioritized compared to other energy solutions. In addition, the country lacks an integrated CHP/DHC strategy. As a result, realized CHP/DHC potentials are likely to be modest. Rating: 3

Efficient CHP/DHC and cost-reflective heat and electricity tariffs are an energy policy priority and a series of effective policies are implemented as part of a coherent energy strategy which rewards energy efficiency. Significant growth is expected in the deployment of CHP/DHC. Rating: 4

A world reference in realising CHP/DHC potentials, with a clear and proven strategy for rewarding energy efficiency. CHP/DHC role is expected to remain important with a CHP/DHC integrated policy strategy aiming to continuously seek for further deployment opportunities. Rating: 5

US's CHP Policy Rating Benchmarked against Global Best Practice: 3

The IEA CHP and DHC Collaborative and IEA Supported Related Initiatives

The IEA CHP and DHC Collaborative was initiated in 2007 with the goal of accelerating deployment of cost-effective, clean CHP and efficient DHC technologies leading to reduced CO_2 emissions and increased overall efficiency of the energy system by an increased use of waste heat and low-carbon renewable energy resources; and of providing a platform for stakeholders to share best practices policies, experiences and applied solutions on these technologies. Collaborators of this initiative include governments, international organizations, regional industrial associations and the private sector, including equipment suppliers and utility companies.

This initiative has completed so far several publications which provide a vision of CHP and district energy potential, along with an overview of policy best practices and recommendations of options to consider when implementing these policies. The Collaborative results also highlighted the benefits of an integrated energy system approach with CHP technologies assisting in balancing electricity production from variable renewables. For more information about the Collaborative, please visit www.iea.org/chp/.

The Implementing Agreement for a Program of RD&D on District Heating and Cooling, including the Integration of Combined Heat and Power (DHC IA), is a multilateral technology initiative supported by the IEA. The nine member countries of the DHC IA deal with the design, performance and operation of distribution systems and consumer installations. In operation since 1983, the DHC IA is dedicated to helping make DHC and CHP powerful tools for energy conservation and the reduction of environmental impacts of supplying heat. For more information, please visit www.iea-dhc.org.

The CHP and DHC Working Group under the Global Superior Energy Performance Partnership (GSEP)

As part of the Global Superior Energy Performance Partnership (GSEP)[80], the Clean Energy Ministerial CHP and DHC Working Group was created in 2010 and it is currently led by Finland. The CHP and DHC Working Group's goal is to increase awareness and adoption of CHP and district energy as a means to reduce fuel consumption, GHG emissions, and other air pollutants harmful to the environment and human health, and to increase the use of renewable sources for heat and power production.[81] Activities that the Working Group will pursue include evaluating the national potential for CHP to reduce fuel consumption and GHG emissions, identifying market and regulatory barriers to CHP, leading targeted education and outreach, and developing best practices and sharing information on new technologies and processes. Since the re-launch of the IEA CHP/DHC Collaborative in 2013, both groups have worked closely together towards a common goal.

[80] Clean Energy Ministerial. Global Superior Energy Performance Partnership (GSEP). www.cleanenergyministerial.org/Our-Work/Initiatives/Buildings-and-Industry.

[81] Clean Energy Ministerial. GSEP Combined Heat and Power and Efficient District Heating and Cooling Working Group. www.cleanenergyministerial.org/Our-Work/Initiatives/Buildings-and-Industry/CHP.

Annex: U.S. CHP and DHC Background Data

Table 1 • Annual additional CHP installed capacity, by sector, size and application, 2000 to 2012

		2000	2006	2008	2009	2010	2011	2012
Total CHP capacity (GW_e)		**58.97**	**82.04**	**83.71**	**83.90**	**81.73**	**81.83**	**82.37**
Additional installed capacity (GW_e)		**2.99**	**0.52**	**0.43**	**0.72**	**0.69**	**0.62**	**0.87**
Additional CHP installed capacity by sector (GW_e)	*Utility*	0.06	0.00	0.08	0.07	0.01	0.00	0.01
	Industrial	2.82	0.30	0.26	0.49	0.34	0.42	0.60
	Residential & Commercial	0.08	0.20	0.09	0.16	0.34	0.20	0.22
	DHC	0.03	0.00	0.00	0.00	0.00	0.00	0.05
Additional CHP installed capacity by size (GW_e)	*1 kW_e – 10 MW_e*	0.23	0.21	0.17	0.18	0.14	0.11	0.25
	10 MW_e – 100 MW_e	1.06	0.31	0.26	0.43	0.29	0.35	0.31
	100 MW_e and larger	1.70	0.00	0.00	0.11	0.25	0.16	0.31
Additional CHP installed capacity by application (GW_e)	*Backpressure steam turbines*	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Extraction steam turbines	0.37	0.24	0.11	0.43	0.06	0.33	0.38
	Gas turbines with heat recovery	0.53	0.10	0.00	0.03	0.34	0.07	0.02
	Combined cycle gas turbines	2.00	0.06	0.15	0.14	0.20	0.09	0.20
	Internal combustion engines	0.08	0.10	0.09	0.08	0.07	0.05	0.22
	Other	0.01	0.02	0.08	0.05	0.02	0.08	0.05

Note: Data shown is annual additional installed capacity. The annual additional capacity considers new capacity only, rather than net additional capacity.

Source: U.S. Department of Energy internal estimates, 2014.

Table 2 • Annual additional CHP electricity production, heat production, and fuel inputs, 2000 to 2012

		2000	2006	2008	2009	2010	2011	2012
Electricity production from additional CHP capacity (GWh)		**22 148**	**3 613**	**2 810**	**5 032**	**4 964**	**4 459**	**6 124**
CHP electricity production by sector (GWh)	*Utility*	307.7	52.4	382.9	356.2	67.7	17.9	35.5
	Industrial	21 066.3	2 005.5	1 872.1	3 649.5	2 463.0	3 072.7	4 386.3
	Residential & Commercial	541.0	1 554.7	548.4	989.5	2 433.0	1 367.0	1 319.7
	DHC	232.5	0.0	6.8	36.8	0.0	1.5	382.5
Total national electricity production (TWh)		428 376	584 320	596 055	600 737	603 558	607 943	614 056
Heat production from additional CHP capacity (GWh)		**27 448**	**7 528**	**6 779**	**12 322**	**7 168**	**10 544**	**14 055**
CHP heat production by sector (GWh)	*Utility*	596.5	117.0	783.6	777.0	212.9	57.9	79.9
	Industrial	25 339.7	4 319.0	4 813.7	9 507.9	2 866.6	8 009.2	10 804.3
	Residential & Commercial	1 060.0	3 092.1	1 106.8	1 966.3	4 088.6	2 474.5	2 475.2
	DHC	452.0	0.0	75.0	70.5	0.0	2.1	696.0
Total national heat production (GWh)		727 336	894 918	923 520	935 008	941 933	952 477	966 525
Fuel input for additional CHP capacity (GWh)		**75 797**	**15 950**	**13 095**	**24 300**	**17 728**	**21 132**	**27 784**
CHP fuel input by fuel type (GWh)	*Natural gas*	55 622.2	7 957.9	5 249.4	5 271.0	14 497.7	5 215.6	8 544.0
	Coal	8 003.3	876.0	0.0	3 551.7	1 513.1	995.4	12 343.4
	Oil	4 050.7	456.6	18.5	568.2	115.9	23.0	199.7
	Biogas/Biomass	1 090.2	2 533.9	859.4	10 628.4	1 133.5	4 829.4	4 055.7
	Other	7 030.9	4 116.6	6 967.4	4 280.5	468.1	10 068.3	2 641.4
CHP overall efficiency (ratio)		**0.65**	**0.70**	**0.73**	**0.71**	**0.68**	**0.71**	**0.73**

Note: Data represents annual generation and fuel input from additional capacity. Generation data is reported on net basis. CHP overall efficiency ratio based on reported CHP electricity and heat production and CHP fuel input statistics. CHP heat production from industrial CHP includes industrial heat/steam generation which is used on-site or sold to neighbouring industrial sites, however heat sold to DH networks is not included. Original reported data given in MBtu (1 GWh = 3 412.14 MBtu).

Source: U.S. Department of Energy internal estimates, 2014.

Table 3 • Nameplate heat generation capacity associated with district heating networks, 2011

Region	Installed nameplate heat generation capacity [TJ steam/hour]
Midwest	22.6
Mid-Atlantic	14.4
Southeast	12.0
Northeast	6.3
Gulf Coast	6.2
Pacific	4.0
Northwest	3.8
Intermountain	2.4
U.S. Total	**71.6**

Note: Assuming 150 psig saturated steam. Steam enthalpy for saturated steam at 150 psig = 2 781.82 kJ/kg.
Source: IDEA internal estimates, 2014.

Table 4 • Summary of U.S. state policies

State	Interconnection[82]	Portfolio standards[83]	Output-based regulations[84]	Standby rate policy[85]
Alabama				
Alaska				Fair to Average
Arizona		Mandatory, renewably-fueled CHP qualifies		Poor to Fair
Arkansas		Mandatory, CHP may qualify	Allowance trading	Poor to Fair
California	CHP, no limit specified	Mandatory, CHP may qualify	Conventional emissions limit, Small DG rule and Emissions Portfolio Standard (EPS)	Average
Colorado	CHP up to 10 MW	Mandatory, CHP may qualify, Waste Heat to Power (WHP) qualifies		Fair to Average
Connecticut	CHP up to 20 MW	Mandatory, CHP qualifies[86]	Small DG rule, Allowance trading, Allowance set-asides, and Emissions Performance Standard (EPS)	Average
Delaware		Mandatory, renewably-fueled CHP and WHP qualifies, other types of CHP may qualify	Conventional emissions limit	Fair to Average

[82] North Carolina State University, 2013.

[83] US EPA, 2013b.

[84] US EPA, 2011.

[85] ACEEE, 2011.

ACEEE gives states a score of 1 to 5 based on their standby rate policies in effect, with five being the highest score. A score of five is deemed “excellent” in the table, a score of 4 = “good”, 3 = “average”, 2 = “fair”, and 1 = “poor.” More recent ACEEE Scorecards do not give states a rating for their standby rates.

[86] “CHP qualifies” means that most forms of CHP such as renewable-fueled and natural gas-fired CHP qualify under the standard.

State	Interconnection[82]	Portfolio standards[83]	Output-based regulations[84]	Standby rate policy[85]
Florida	CHP up to 2 MW	Voluntary, CHP may qualify		Poor to Fair
Georgia				
Hawaii	CHP, no limit specified	Mandatory, CHP qualifies		Average to Good
Idaho				Fair to Average
Illinois	CHP, no limit specified	Mandatory, renewably-fueled CHP qualifies, other types of CHP may qualify	Allowance trading, and Allowance set-asides	Fair to Average
Indiana	CHP, no limit specified	Voluntary, includes CHP	Allowance trading, and Allowance set-asides	Fair to Average
Iowa	CHP, up to 10 MW	Mandatory, renewably-fueled CHP qualifies, other types of CHP may qualify		
Kansas		Mandatory, renewably-fueled CHP qualifies		
Kentucky				Poor to Fair
Louisiana		Voluntary, renewably-fueled CHP and WHP qualifies		
Maine		Mandatory, CHP qualifies	Conventional emissions limit	Excellent
Maryland	CHP, up to 10 MW	Mandatory, renewably-fueled CHP qualifies, other types of CHP may qualify		Fair to Average
Massachusetts	CHP, no limit specified	Mandatory, CHP qualifies	Conventional emissions limit, Small DG rule, Allowance trading, Allowance set-asides, and Emissions Performance Standard (EPS)	Poor to Fair
Michigan	CHP, no limit specified	Mandatory, renewably-fueled CHP and WHP qualifies, other types of CHP may qualify		
Minnesota	CHP, up to 10 MW	Mandatory, renewably-fueled CHP and WHP qualifies		Fair to Average
Mississippi				Poor to Fair
Missouri		Mandatory, renewably-fueled CHP qualifies, and other types of CHP may qualify	Allowance trading, and Allowance set-asides	Fair to Average
Montana		Mandatory, renewably-fueled CHP qualifies		Fair to Average
Nebraska		Voluntary, renewably-fueled CHP qualifies		Poor to Fair
Nevada		Mandatory, CHP and WHP qualifies		Average
New Hampshire	CHP, up to 1 MW	Mandatory, renewably-fueled CHP qualifies	Conventional emissions limit	Fair to Average

State	Interconnection[82]	Portfolio standards[83]	Output-based regulations[84]	Standby rate policy[85]
New Jersey		Mandatory, renewably-fueled CHP qualifies	Allowance trading, and Allowance set-asides	Average
New Mexico	CHP, up to 80 MW	Mandatory, renewably-fueled CHP qualifies, other types of CHP may qualify		
New York	CHP, up to 2 MW	Mandatory, CHP qualifies		Poor to Fair
North Carolina	CHP, no limit specified	Mandatory, CHP qualifies		Poor to Fair
North Dakota		Voluntary, renewably-fueled CHP and WHP qualifies		Poor to Fair
Ohio	CHP, up to 20 MW	Mandatory, CHP and WHP qualifies	Allowance trading	Poor to Fair
Oklahoma		Voluntary, renewably-fueled CHP and WHP qualifies		
Oregon	CHP, greater than 20 MW	Mandatory, renewably-fueled CHP qualifies	Emissions Performance Standard (EPS)	Average
Pennsylvania	CHP, up to 5 MW	Mandatory, CHP qualifies	Allowance trading	Fair to Average
Rhode Island		Mandatory, CHP qualifies	Conventional emissions limit	Fair to Average
South Carolina				
South Dakota	CHP, up to 10 MW	Voluntary, renewably-fueled CHP and WHP qualifies		Poor to Fair
Tennessee				Poor to Fair
Texas	CHP, up to 10 MW	Mandatory, renewably-fueled CHP qualifies and other types of CHP may qualify	Small DG rule	Fair to Average
Utah		Voluntary, renewably-fueled CHP and WHP qualifies		
Vermont	CHP, no limit specified	Voluntary, CHP qualifies		Poor to Fair
Virginia		Voluntary, renewably-fueled CHP qualifies		
Washington	CHP, up to 20 MW	Mandatory, CHP qualifies	Emissions Performance Standard (EPS)	Poor to Fair
West Virginia	CHP up to 2 MW	Mandatory, CHP qualifies		Fair to Average
Wisconsin	CHP up to 15 MW	Mandatory, includes renewably-fueled CHP, other types of CHP may qualify	Allowance trading	Fair to Average
Wyoming				

Acronyms, Abbreviations and Units of Measure

Acronyms and abbreviations

6DS	6 Degrees Scenario
ACEEE	American Council for an Energy-Efficient Economy
APS	Alternative Portfolio Standard
CAFE	Corporate Average Fuel Economy
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
CHP	Combined heat and power
CHPA	Combined Heat and Power Association
CHPP	U.S. EPA Combined Heat and Power Partnership
CHP TAP	U.S. DOE CHP Technical Assistance Partnership
DG	Distributed generation
DHC	District heating and cooling
DOE	U.S. Department of Energy
EERS	Energy Efficiency Resource Standard
eGRID	U.S. EPA Emissions and Generation Resource Integrated Database
EIA	U.S. Energy Information Administration
EPA	U.S. Environmental Protection Agency
EPS	Emissions performance standard
GDP	Gross domestic product
GHG	Greenhouse gas
GSEP	Global Superior Energy Performance Partnership
IDEA	International District Energy Association
IEA	International Energy Agency
IPP	Independent Power Producer
ISO	Independent System Operator
MACT	Maximum Achievable Control Technology
NACAA	National Association of Clean Air Agencies
NASEO	National Association of State Energy Officials
NARUC	National Association of Regulatory Utility Commissioners
NO_x	Nitrogen oxides
NSPS	New Source Performance Standards
PPA	Power purchase agreement
PSD	Prevention of Significant Deterioration
PURPA	Public Utilities Regulatory Policies Act
QF	Qualified Facility
RGGI	Regional Greenhouse Gas Initiative
RPS	Renewable Portfolio Standard
SEE Action	State and Local Energy Efficiency Action Network
TPES	Total primary energy supply
U.S.	United States
WCI	Western Climate Initiative
WHP	Waste Heat to Power

Units of measure

°C	degree Celsius
°F	degree Fahrenheit
cm	centimetre
Btu	British thermal unit
EJ	exajoule
Gt	gigatonne
GW	gigawatt
GW_e	gigawatt electric
GWh	gigawatt hour
GW_{th}	gigawatt thermal
J	joule
lb	pound
lb/h	pounds per hour
lb/MBtu	pounds per MBtu
klb	kilopound
kt	kilotonne
m^2	square metre
MBtu	million Btu
MBtu/h	million Btu per hour
Mt	megatonne
MW	megawatt
MWh	megawatt hour
MW_{th}	megawatt thermal
PJ	petajoule
ppm	parts per million
psig	pounds per square inch gauge
Quad	quadrillion Btu
short ton	unit of weight equal to 2 000 lbs
t	tonne
TJ	terajoule
tpy	short tons per year
tcf	trillion cubic feet
TWh	terawatt hour
USD	United States dollar
USRt	United States refrigeration ton
W	watt

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