U.S. DEPARTMENT OF
ENERGY
Office of
ENERGY EFFICIENCY & RENEWABLE ENERGY

Combined Heat and Power Technology Fact Sheet Series

District Energy Systems Overview

District energy systems are characterized by one or more central plants producing hot water, steam, and/or chilled water, which then flows through a network of insulated pipes to provide hot water, space heating, and/or air conditioning for nearby buildings. District energy systems serve a variety of end-use markets, including downtowns (central business districts), college and university campuses, hospitals and healthcare facilities, airports, military bases, and industrial complexes. By combining loads for multiple buildings, district energy systems create economies of scale that help reduce energy costs and enable the use of high-efficiency technologies such as combined heat and power (CHP).

Applications

In the United States, district energy[1] systems are typically located on university or college campuses; on hospital or research campuses; on military bases and airports; and in areas of dense building settings, often in the central business districts of larger municipalities (common applications shown in **Figure 2**). Major U.S. cities with downtown district energy systems include New York, Boston, Philadelphia, San Francisco, Denver, Minneapolis, and dozens more. In some cases, the buildings connected to a district energy system are commonly owned, such as in a university campus or hospital setting. In others, the buildings have separate owners, such as in a central business district or segment of a municipality. District energy systems can be designed to serve small or large communities, and the systems can be scaled over time as more buildings are connected. Mature district energy installations can support hundreds of structures.

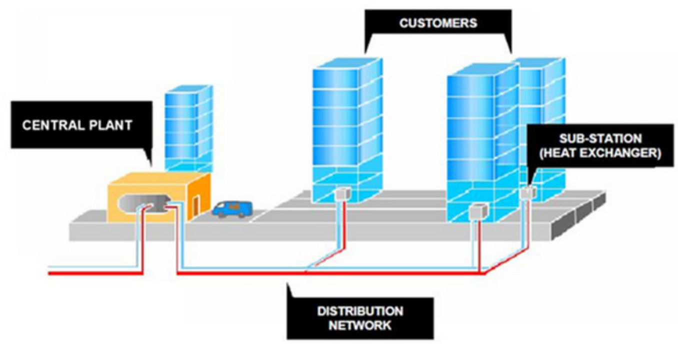

Figure 1. An example of a district energy configuration.
Graphic courtesy of the International District Energy Association (IDEA)

According to a recent U.S. Energy Information Administration report, there are more than 660 district energy systems operating in the United States, with installations in every state, providing heating to an estimated 5.5 billion square feet of floor space and cooling to 1.9 billion square feet of floor space (2012 data).[2] The majority of floor space served by district energy is located in commercial and institutional buildings across the country. CHP plays a significant role in district energy, as it is included in 281 installations (43% of all district energy systems), provides over 6,700 MW of capacity, and generates 30 million MWh of electricity (2012 data).[3]

Figure 2. Common applications for district energy systems.
Graphics credit: ICF

1 Some district energy systems provide only heating services, while others are configured to meet both heating and cooling needs

2 U.S. Energy Information Administration (EIA). U.S. District Energy Market Characterization. Prepared by ICF and IDEA. 2018. Page 1. Available at https://www.eia.gov/analysis/studies/buildings/districtservices/pdf/districtservices.pdf

3 Information provided by International District Energy Association (IDEA).

Technology Description

A district energy system has three major components:

- Thermal energy generating plant
- Distribution piping
- Building interconnections (e.g., meters, valves, pumps)

Most district energy systems in the United States use steam distribution systems to provide thermal energy for space heating and hot water needs of connected buildings. District hot water systems, rather than steam, can also be used to deliver thermal services, which typically increases system efficiency through lower distribution losses. Hot water distribution is well suited to incorporating advanced energy options such as solar thermal and waste heat recovery from industrial processes and data centers.

While most district energy systems supply heating services (space heating and in some cases, water heating), many also provide cooling. For cooling, most district energy systems in the United States use hybrid chiller plants,[4] often coupled with thermal storage. In these systems, water is chilled and distributed through closed-loop networks to provide building air conditioning. Cooling can also be provided with steam supplied through a district heating network and used to drive steam turbine chillers or absorption chillers located at individual buildings.

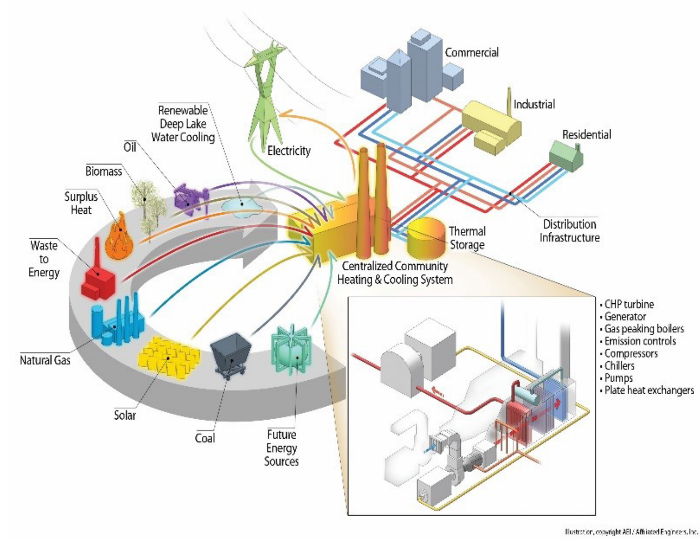

Figure 3. Many different fuels are used by district energy systems. Graphics credit: IDEA

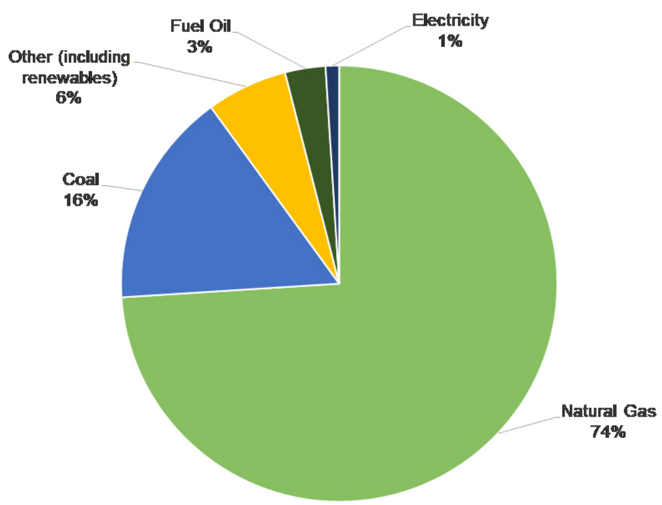

Figure 4. Fuel use in district energy systems (2012 data).

District energy systems can be configured to provide electricity through the use of CHP or other technologies. **Figure 3** shows district energy system integrated with CHP, along with various fuel alternatives that can be utilized in district systems.[5] District energy systems that generate electricity are often configured as microgrids. In a microgrid environment, the district energy system can continue to deliver thermal energy and electricity in the event of a grid outage.

Most district energy systems are currently fossil-fuel-based, with nearly three-fourths of fuel consumption coming from natural gas, as shown in **Figure 4**.[6] Other fuels used in district energy systems include coal, fuel oil, biomass, biogas, landfill gas, municipal solid waste, geothermal, solar thermal, and electricity. Electricity is used when cooling is provided by electric and/or hybrid chiller plants, often coupled with thermal storage. The amount of electricity consumption is low relative to other fuels because electric chiller plants tend to have high coefficients of performance, meaning they can deliver large amounts of cooling energy with relatively small amounts of electricity.

Benefits

Energy efficiency, security, and resilience are key benefits provided by district energy systems.

Energy Efficiency

A district energy system benefits its connected buildings by delivering high-efficiency heating and cooling services,

4 Hybrid chiller plants use a combination of electric chillers and absorption chillers to produce chilled water for end users.

5 EIA. 2018. Page 20.

6 Ibid.

providing fuel and technology flexibility brought on by economies of scale, and opening up additional productive space in the buildings themselves by eliminating individual boilers, chillers, and cooling towers. Many of the energy efficiency advantages result from aggregating diverse heating and cooling loads from multiple buildings into a steadier and more predictable combined load. A central energy plant that serves the aggregated heating and/or cooling demand of many buildings is generally more efficient than a collection of diverse on-site heating and cooling systems that ramp steeply up and down to meet daily and hourly needs of individual buildings.[7]

A district energy distribution system serves as a type of energy storage, with steam, hot water, or chilled water circulating in the system, effectively smoothing the load for the central plant. Combining a number of diverse load profiles allows the central energy plant equipment to operate at high load factors, with resulting higher levels of efficiency. Serving a more stable, predictable combined load not only promotes higher load factors but also reduces the need for excess peak heating or cooling capacity. Aggregating the energy requirements of dozens or even hundreds of buildings provides economies of scale that allow district energy systems to employ high-efficiency technologies and industrial-grade equipment, such as condensing economizers, that would typically not be economically or technically feasible for individual buildings.

Modern high-efficiency district energy systems combine district heating and cooling with elements such as CHP, thermal storage, geothermal heat pumps, deep lake cooling, and local microgrids. CHP can deliver electricity and thermal energy services at overall efficiencies of 65% to 80%, an improvement over the national average of 51% for these services when provided separately by central station power generation and on-site boilers.[8] Aggregating the thermal and electricity loads of multiple buildings and users leads to an economy of scale that enables larger, more efficient combustion turbine and engine generators in CHP systems, thereby bringing CHP efficiency benefits to energy users that may not have had sufficient heating or cooling loads to implement this technology on their own.

Energy Security and Resilience

The energy security and resilience benefits of district energy infrastructure are widely recognized, and district energy systems are often used to support mission-critical operations in hospitals, university research centers, military bases, and specialty industries such as food processing and pharmaceuticals. With integration of CHP and microgrid technologies, district energy systems can provide exceptionally high reliability, providing electricity and thermal energy (both heating and cooling), even during unexpected grid outages.[9] A 48 MW district energy CHP system in provides resilient electricity, chilled water, and steam to 18 healthcare facilities on the Texas Medical Center campus in Houston, Texas. This system was able to continue operating during Hurricane Harvey and its aftermath in 2017, allowing the campus to meet patients' needs during the storm.

Figure 5. Texas Medical Center district energy CHP system in Houston, TX. Source: International District Energy Association

District energy provides high reliability because industrial-grade equipment and controls, with redundancy, are inherent in the design and operation of district energy installations. Systems are professionally operated and maintained and subject to continuous testing and monitoring, as well as frequent retro-commissioning. Industry best practices include continuous operational monitoring, advanced load forecasting, and advanced controls to optimize operations for both internal needs and the needs of the regional electricity grid.

7 U.S. Department of Energy (DOE), Publication pending. Energy Efficiency and Energy Security Benefits of District Energy. Report to Congress. Pages 10–11.

8 U.S. Environmental Protection Agency, Combined Heat and Power Partnership. CHP Benefits. https://www.epa.gov/chp/chp-benefits. Accessed February 2020.

9 DOE. Report to Congress. Pages 17–18.

District energy systems can be adapted to multiple fuel types, which contributes to the energy security of communities served by district energy. Such flexibility ensures systems are not solely dependent on a single resource stream or imported fuel supply, which not only enhances fuel security but also creates purchasing options. Systems can be configured to use local fuels such as wood waste from tree trimmings, tire-derived fuel, landfill gas, and manufacturing waste streams. Local operational control ensures that investment decisions are made close to the point of impact. Investing in local energy infrastructure also keeps energy dollars recirculating in the local economy, often producing a "multiplier effect" on local jobs and tax revenues.

Table 1 provides a summary of key district energy benefits grouped by stakeholder: customers, cities and communities, the electric grid, and the environment.[10] Major crosscutting benefits include reduced building capital costs; diverse fuel choices and improved fuel security; integration of renewables at large scale; and greater comfort and convenience in individual buildings, thanks to lower noise, reduced vibration levels, and better space utilization.

Table 1. District Energy Benefits by Stakeholder

Benefits to Customers	• Higher energy efficiency • Lower building costs (no separate boilers, chillers, or other related hardware) • Easier building operation and maintenance • Enhanced building aesthetics and comfort (reduced noise and vibration) • Improved reliability (industrial-grade district energy equipment is more robust than commercial equipment installed at building level)
Benefits to Cities and Communities	• Reduced first cost for new development • Flexibility in use of fuel sources, including local or regional fuel sources (wood waste, biomass, waste heat, etc.) that keep energy dollars recirculating in local economy • Architectural and aesthetic advantages, with roofs free of mechanical equipment • Grey water/treated sewage effluent usable for condenser water (owing to central plant scale), conserving potable water for consumption • Capacity to provide baseload power and heat for microgrids, enhancing resilience and reducing regional greenhouse gas emissions
Benefits to Grid Infrastructure	• Reduced peak demand (enabled by aggregating loads and shifting peak demand with thermal energy storage) • Fewer natural gas peaking stations • Lower transmission and distribution costs
Benefits to the Environment	• Reduced air emissions, including greenhouse gases, as a result of greater fuel efficiency of district energy systems that include CHP • Increased adoption of renewable energy sources at scale, replacing higher-emitting central station generation with low- and zero-emitting technologies • Improved stormwater management owing to free roof space, which can be used for low-impact storm water management strategies and mitigation of excessive runoff

District energy networks—particularly those incorporating CHP—provide an opportunity to deliver energy more efficiently, with environmental benefits as well as improved energy security, reliability, and resilience for facility operations. ■

U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

For more information, visit: energy.gov/CHP/
or email us at: CHP@ee.energy.gov

DOE/EE-2125 · September 2020

10 Adapted from EIA. 2018. Pages 28–31.