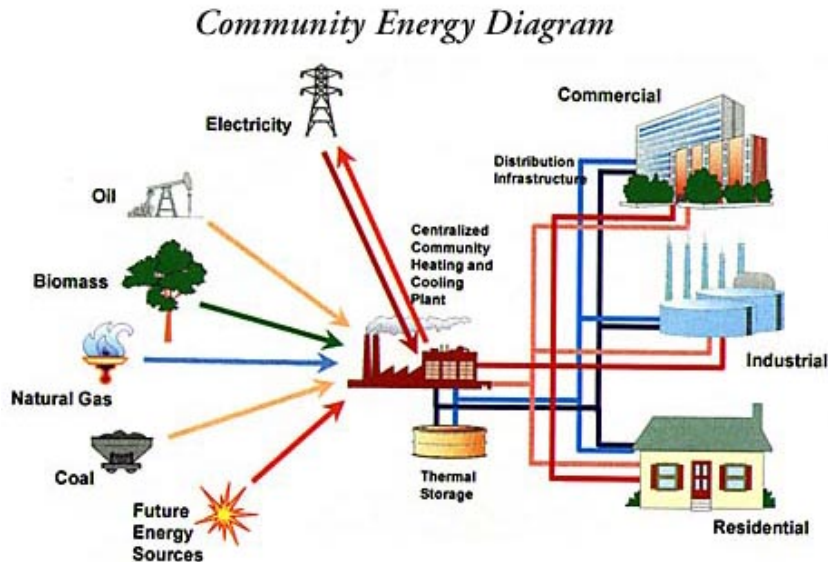


Community - District Energy Systems: Preliminary Planning & Design Standards



Community energy systems refer to the technologies for local generation, distribution and efficient end-use of energy in residential, commercial, industrial, and municipal structures, infrastructure and processes. A comprehensive community energy system also entails the strategic alignment of land uses and urban design features to optimize energy technology performance and to reduce transportation fuel consumption. These include smart-growth features, and in particular mixed-use and transit-oriented development, as they create spatial conditions enabling the economical use of distributed generation and co-generation energy technologies. However, for the purpose of this section, we will focus on centralized community thermal - heating and cooling systems, also known as "district energy systems".¹

District energy systems contribute to community sustainability and security by maximizing the efficient use of a variety of fuels to co-generate and deliver electricity and thermal energy, locally. Because district energy thermal networks aggregate and link the heating and cooling requirements of dozens or hundreds of buildings, they create a greater scale of thermal energy use in a community that facilitates fuel flexible solutions at a central plant or plants and allow for thermal storage applications that would not otherwise be functionally or economically feasible on an individual building basis. In addition to fossil fuels, district energy systems can utilize a combination of locally available renewable resources such as municipal solid waste, community wood waste; landfill gas, wastewater facility methane, biomass, geothermal; lake or ocean

¹ For information on comprehensive community energy system design and development, please visit the National Energy Center for Community Sustainability at www.necsc.us

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water and solar energy. District energy systems also improve local economies by increasing energy reliability, stabilizing energy costs, attracting new businesses to the district served by the system, increasing property values and ultimately, by re-circulating energy dollars in the local economy through capital investment, construction and operation and maintenance jobs.

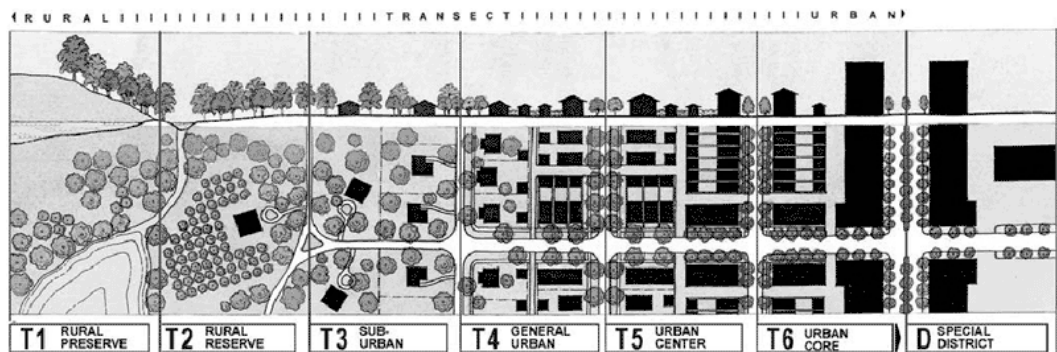
Definition, Explanation & Terms

District energy systems produce electricity, hot water, steam and/or chilled water at a central plant and then distribute the energy through underground wires and pipes to adjacent buildings connected to the system. Electricity is used to energize lights, appliances, equipment and machinery, while hot and chilled water and steam are used for space heating and cooling and a variety of commercial/industrial processing needs.

From a sustainability standpoint, the essential advantage of a district energy system over a conventional central power plant, transmission and distribution system is a far more efficient use of the input fuel relative to end-uses. Typically, only one-third of the fuel energy input to a conventional fossil-fuel power plant is delivered to the end-use consumer as electricity. The vast majority of the energy that is generated is discharged in the form of heat to adjacent rivers, lakes and to the atmosphere, resulting in significant thermal pollution. And while this energy is discharged to the environment, consumers purchase more electricity and natural gas to meet their needs that could have been satisfied by recovering and using the wasted thermal energy.

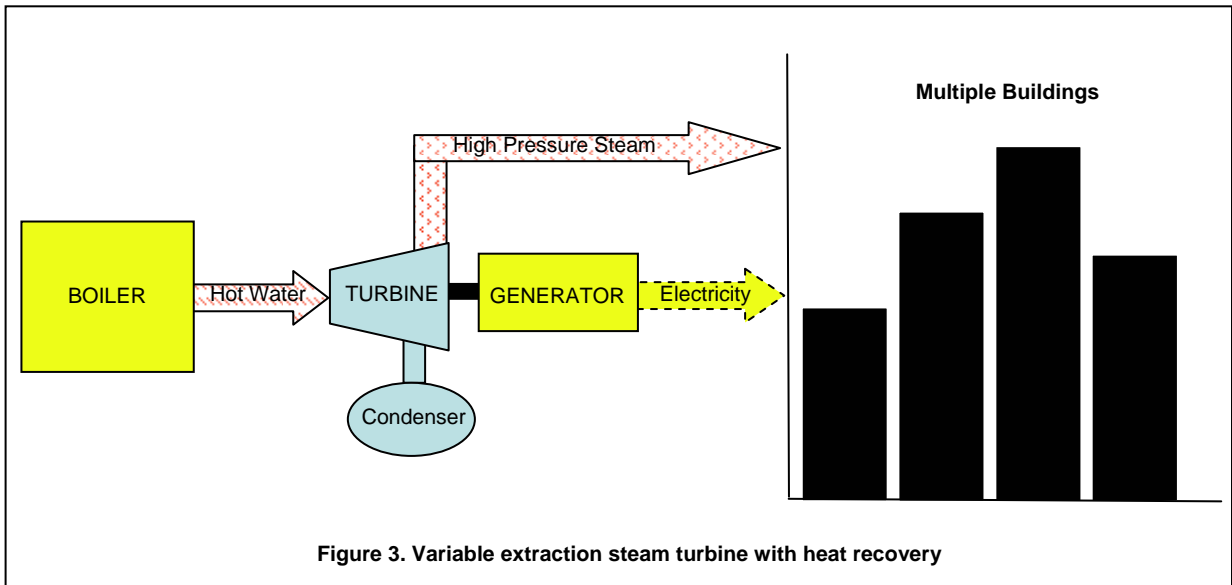
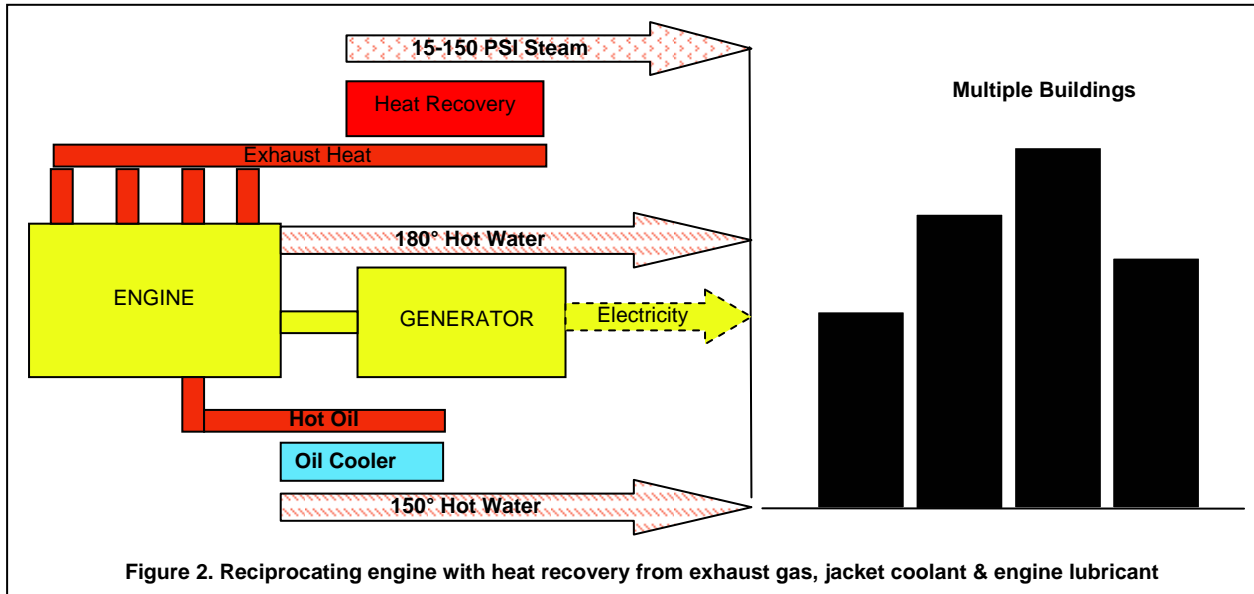
By contrast, local district energy systems capture most of the heat energy generated in electricity production and use it to produce steam and hot and chilled water. This process is known as co-generation and is made possible by combined heat and power or "CHP" technologies such as gas fired reciprocating engines, gas turbines, heat exchangers and absorption chillers (See figures 2, 3 & 4).

Community Transect (Figure 1)

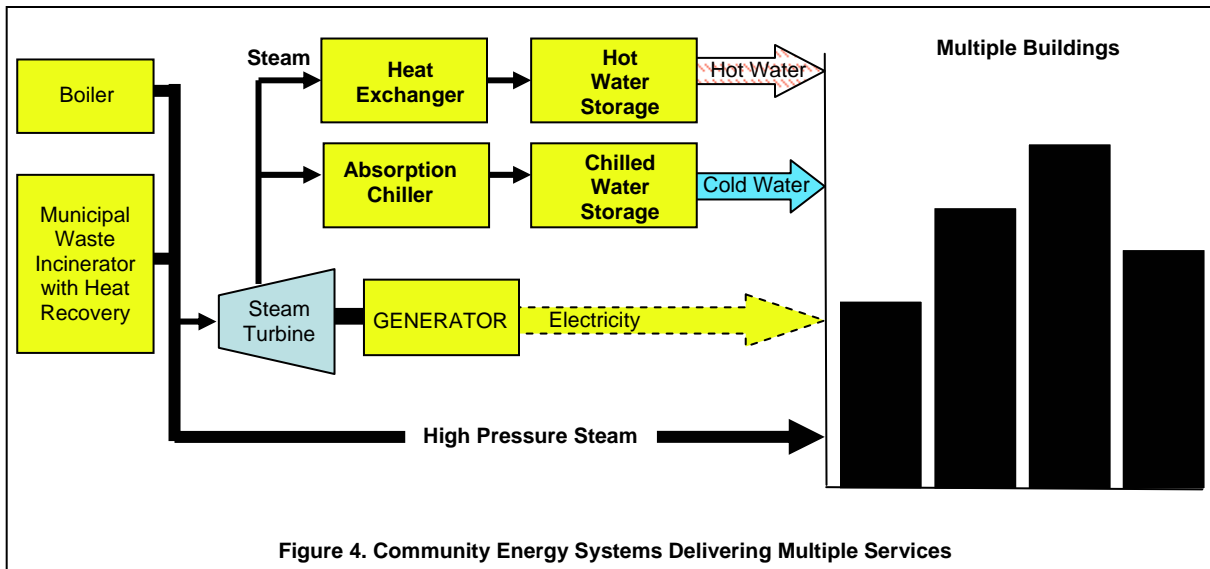


CHP							
DHC							

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Rules & Conditions

There are four classifications of district heating and cooling (DHC) systems differentiated by characteristics of the areas they serve. These include:

- Densely populated urban areas
- High-density building clusters
- Industrial or research campuses
- Low-density residential areas

As a rule of thumb, there are three requirements that must be met for a DHC system to operate economically:

- First, there must be a high load density - determined by the thermal load per unit of building floor space, number of stories and total number of buildings in the area to be served. The capital investment in a DHC system designed for a greenfield development site must be at least partially recovered through a contribution margin of energy sales to end-users that are located within close proximity to one another. In an existing urban site, there must be a significant vertical density of customer buildings to be served to warrant the considerable cost per trench foot of constructing the underground network of piping for a DHC system.
- Second, there must be a large annual load factor - the ratio between the actual amounts of energy consumed annually to the amount of energy that would be consumed if the peak thermal load were to be imposed continuously for a full year. In other words, thermal energy requirements must be significant enough throughout the year that the capital cost recovery of a DHC plant and piping network is not allocated to a limited period of off-peak demand.

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- Third, there must be a rapid rate of consumer connections to the system. This last requirement is particularly important since 50%-75% of the total district energy system investment is the cost of installing the transmission and distribution network piping. The sequence and location of “anchor users” relative to the main central plant and distribution trunk are also important factors to consider.

DHC systems have proven to be very cost-effective in densely populated urban areas where there are a variety of building types, end-uses and nearby sources of thermal energy such as power plants, industrial sites and municipal solid waste disposal facilities. DHC systems serving areas of this size typically entail a phased construction period of 20-30 years, miles of distribution piping and several thousand megawatts of electrical capacity to meet consumer demand. These systems can ultimately cost in the hundreds of millions of dollars and typically involve extensive and complex institutional arrangements to plan, finance, build and operate. Moreover, in an urban setting, district energy systems compete openly with on-site alternatives like boilers, chillers and electric heat. The energy market can also be complex and the risks of constructing a DHC system can be significant as there are no assurances that customers will connect to and use the systems' services.

DHC systems serving high-density clusters such as suburban shopping malls, healthcare and hospitals complexes, university campuses and mixed-use complexes can be designed and installed in only 3-10 years. These systems have much smaller distribution networks and need only several hundred megawatts of generating capacity. Typical costs for these smaller systems can range from a few million to tens of millions of dollars and typically involve institutional arrangements involving only a few decision makers in the development process. In institutional settings where the central plant is owned by the same entity as the end-user buildings, market risk for return on capital is reduced.

The economics of DHC systems designed to serve industrial complexes are driven principally by their demands for process steam and hot water. These systems are often similar in size and complexity to systems serving high-density clusters. Low-density residential areas have not proven to be a cost effective application for district heating and cooling in the United States given the high capital costs and low rates of utilization per trench foot of distribution piping investment. Residential application of district heating has however proven to be cost effective in Europe and Scandinavia where residential densities are typically higher. These systems are designed for residential blocks with a generating capacity of 1-3 megawatts and deliver low-temperature hot water to their consumers. In fact, in many northern European cities, district heating is the predominant source of comfort and may exceed 85% market share of residential space. Given the success of these European models, residential district energy systems are now being considered for several new, large-scale residential development projects in California and across the nation.

Frequently Asked Question

"Who are the leaders globally, in community energy systems and in particular district heating systems?"

The Scandinavian nations of Denmark, Finland, and Sweden have been using district energy systems and improving upon cogeneration technologies for more than 85 years now. Since the energy crises of the 1970's, Denmark has been a world leader in combining district heating technology and investments with government policies to build and strengthen the district heating industry. Denmark has dramatically reduced dependence on foreign sources of oil and simultaneously reduced emissions from fuel combustion. Over 60% of the homes in Denmark are now served by district heating. The largest users of district heating systems in the world are also the nations that had previously comprised the Union of Soviet Socialist Republics. During the early 1980s Russia had over 1,000 district power and heating systems in operation serving more than 800 Soviet cities.

In Japan, since the 1970's, and in Korea, since the 1980's, urban planners have carefully integrated efficient cogeneration systems with district heating and cooling systems. For example, the Korea District Heating Corporation (KDHC - www.kdhc.co.kr) began operations in 1985 and today provides district energy service to 788,000 households. These households represent over 60% of that country's population. KDHC plans to double in size over the next decade to serve over 1.4 million households in and around the city of Seoul.

"What type of project delivery method should be utilized to implement a district cooling business?"

The International District Energy Association website (www.districtenergy.org) provides many information resources on the subject in general and one paper in particular explores the two most common methods: design-bid & build; and design & build. The paper also describes the impact of each method on a business and the most effective way to manage the associated risks. The paper enables the reader to put the capital cost of a project within the context of other issues that affect the success of a business.

Standards

It is important to note that there is not a universal standard for the configuration of a district energy system that will be applicable in all settings. This is due to the fact that the availability of alternative energy sources, potential for cogeneration, peak hourly loads, energy pricing, annual energy consumption patterns and market potential will vary by region and by the specific site. Additionally, underground soil and congestion conditions, soil types, urban density and building HVAC systems can effect technical design considerations. Ambient weather trends and the ratio of customer space uses, such as commercial office, residential, retail and mixed use; event and arena space and

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high-volume users like hospitals, research and data centers all impact system design parameters.

There are however, a set of standard factors, minimum requirements and ranges to consider when investigating the economic and technical feasibility of a district energy system utilizing cogeneration or municipal waste incineration. These include the following:

- Ambient Air Temperatures - There must be a minimum of 4,000 heating degree days in a year to make DHC system economically feasible for space heating. A degree day unit (referred to as a degree day) is a measurement of indoor heating requirements affected by outside temperatures. The number of degree day units for any given day is calculated by subtracting the mean outside temperature from 65°F, and the total degree-days for any longer period is the sum of the degree days of the individual days in that period. Degree day tables & maps are available from the National Climatic Data Center at the U.S. Department of Commerce. For district cooling systems, customers typically should consume more than 1000 equivalent full load hours. In other words, a 200 ton peak demand building, should consume 200,000 ton hours over the course of a year.
- Area Energy Demand - Each unit of land area to be served by a district heating system must have a high hourly and annual thermal energy demand.
- Location of Thermal Plant - The energy production plant must be located close to the area to be served to reduce capital costs and thermal losses in transmission.
- Transmission Distances - Three to five miles is the maximum distance between a production plant and the end of the distribution network for an economical steam line. 15 miles is the maximum distance for a hot water line when thermal energy is derived from an electrical power plant. 3 miles is the maximum distance for a hot water line when thermal energy is derived from a municipal solid waste incinerator.
- Land Use Zoning Threshold - All zones in which 50% or more of the land is designated for single-family detached housing, single-family attached housing, town houses, open space or other low energy intensity uses are generally not considered viable for district energy systems.
- Cooling Load Concentration - For central cooling plants to be practical, cooling load concentrations must be 150 to 250 tons per 100 lineal feet of distribution piping runs.
- Piping System Cost - If the cost of the piping system is less than one third of the cost of the total chilled water system cost, than consideration should be given to the central chilled water system.

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- Substantial Anchor Load – In the phased construction of a new district energy system, it is advisable that an anchor tenant or initial user sign up for at least 20% of the initial plant capacity investment. The capital risk is further mitigated with a higher percentage pre-subscribed to the service. An important spatial consideration - the location of the anchor load should be proximate to the future market density and not an isolated node on a network.
- Plant Footprint - In urban settings, the high cost of real estate significantly impacts the economic feasibility of a DHC system as central plant space requirements can be considerable. Consequently, many cities have integrated district heating and cooling plants into the frame of urban parking garages to increase the yield of the real estate parcel and to provide incremental income for a reasonable companion use.
- Condenser Water Sources – Many DHC systems utilize contiguous rivers, lakes and bays for condenser water and/or winter cooling cycles. This minimizes air rights for locating cooling towers and provides a low cost source of winter cooling to data centers and high-rise building cores.
- Age of Buildings and Life Cycle – The opportunity to avoid the capital costs of replacement heating and cooling equipment is the most important factor in a building owner’s decision to connect to a DHC system. In planning a DHC system for an existing urban site, consideration must be given to the age, type and life cycle stage for the individual buildings within the proposed service area. Sites predominantly occupied by newer buildings with existing “in-building” boiler and chiller equipment will not prove to be economical for a DHC system, as owners of these buildings will not be inclined to connect to the system.
- Utility Rates – A full understanding of the natural gas and electric utility rates in effect at a proposed development site is absolutely essential in determining the economic feasibility of a DHC system. In many urban areas where time-of-day rates, load factor ratchet penalties and high-peak electric demands exist, district cooling systems with thermal or ice storage prove to be very economically attractive. A thorough analysis of existing rate structures must be one of the first tasks engaged by planners examining the potential feasibility of a DHC system.

Historical Timeline

- Ancient Rome Heated water piped through bath, greenhouse & palace complexes
- 1300s Hot water systems gain prominence in France & throughout Europe
- 1853 1st U.S. district steam system built at US Naval Academy in Annapolis, Maryland

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- 1877 First municipal district steam heating system built in Lockport, New York
- 1882 New York City Steam Company begins serving lower Manhattan
- 1906 Thomas Edison builds electric generation station in Philadelphia & co-generates steam, creating the district heating system that still serves the city today
- 1962 Hartford, CT commissions the first downtown combined steam & chilled water district heating & cooling system
- 1970's The first eleven downtown district heating and cooling systems are built in US cities by the local natural gas distribution company
- 1980s Hundreds of colleges and universities build district heating and cooling systems. District energy networks are built in South Korea; Japan and Malaysia
- 1990s Investor-owned electric utilities form non-regulated subsidiaries to build downtown district-cooling systems
- 2000's From 1990 through 2006, over 375,000,000 square feet of customer space is connected to district energy systems. Huge district cooling systems are built in the Middle East to support vast real estate development in Abu Dhabi, Dubai and across the Gulf Region.
- Future Decentralized combined cooling, heat & power systems supplying & receiving energy from self-generating buildings through interconnected micro-grids

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Links

International District Energy Association (IDEA) - www.districtenergy.org

Danish Board of District Heating (DBDH) - www.dbdh.dk/index.html

Korea District Heating Corporation (KDHC) - www.kdhc.co.kr/eng

Japan Heat Services Utility Association (JHSUA) - www.jdhc.or.jp/en

Euroheat and Power Association (Euroheat) - www.euroheat.org

National Energy Center for Sustainable Communities - www.necsc.us

Global Energy Network for Sustainable Communities - www.globalenergynetwork.org

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