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Oddgeir Gudmundsson, Jan Eric Thorsen

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Oddgeir Gudmundsson, Director Projects
Jan Eric Thorsen, Director, Danfoss Heating Segment Application Centre, Danfoss A/S

Reaching energy efficiency goals with district energy networks

Improving energy efficiency, reducing carbon emissions and cutting energy bills are ever-growing concerns for almost everyone – industry and manufacturing, commercial facilities, government entities and personal homeowners alike. There is a demand for efficient and clean energy technologies that will help achieve these goals.

According to the U.S. Department of Energy, the average efficiency of power generation in the United States has remained at 34 percent since the 1960s. Every year, more energy is lost as wasted heat in power generation in the United States than the total energy use of Japan.

However, there are long-established technologies that can reduce this wasted energy by nearly half. District energy networks are a solution for more-efficient building heating and cooling that has long been popular and has proven successful around the world. But for various reasons, they are underutilized in North America.

There is a wealth of research and real-world examples that support the validity of utilizing district energy networks in many applications and locations. District energy networks take heat from all available sources and use it to fulfill space heating or cooling and hot water demands, making them an extremely flexible solution. And because the systems can be fed with heat that would otherwise be wasted, the model results in a more efficient and cost-effective energy system.

A logical way – though not the only option – to implement a district energy network is in relation with a combined heat and power (CHP) plant. A mix of district energy and CHP can lead to fuel efficiency of more than 90 percent, compared to the 45 to 50 percent fuel efficiency typically seen in new power-only plants.

What is a district energy network?

The term district energy network describes a system where a single or more thermal-generating energy source serves multiple buildings in an area, through a piping distribution system. District energy systems can be split into a district heating system and a district cooling system. A system where water is heated in one or more large units and then delivered to consumers via pipe network is district heating. Consumers' systems extract the heat from the water before it is sent back to the heating units. A district cooling system works the same way, except the water is cooled in one or more large chillers and then sent to the consumers via pipe network. Consumers' systems then use the cooled water to extract heat from their buildings. Water is an efficient medium to transport heating and cooling over long distances, because of the high heat capacity of water.

District energy networks provide significant flexibility because they can utilize the excess heat already being generated from many sources, such as power plants, wind farms, steel mills, geothermal, solar thermal or landfill operations. This wasted energy, often in the form of steam or radiant heat, currently produced at various types of facilities can be fed directly into a heat distribution system to heat many buildings and homes in the area, or it can be used in absorption heat pumps to cool the water in district cooling systems.

Basically any thermal-generating entity can be a source for a district energy network, possibly saving the need to have dedicated heating and cooling equipment in the buildings that are connected via the network.

While district energy networks pair especially well with CHP plants and this is a common model for implementation, a CHP plant is not a requirement to establish a district energy network. There are other structures and options that make district energy feasible, for example geothermal heat or surplus heat from industry and waste incinerations.

Pairing CHP and district energy networks

Just like district energy networks, combined heat and power systems have been around for decades. CHP, sometimes also called cogeneration, is an integrated energy system that provides both electric power and heat from a single fuel source. It can be used to either replace or supplement conventional separate heat and power.

Consider the example of most power plants in the United States, which create steam as a byproduct that is then expelled as wasted heat. In a CHP system, the energy in this otherwise lost byproduct is captured and used to provide heating and cooling to buildings. Process or space heating can be produced by the steam or hot water waste, though the capability for cooling may be less obvious. Cooling can be produced by utilizing the heat from the power production to drive a chiller with an absorption heat pump, as mentioned above.

CHP systems can use a diverse set of fuels to operate, including natural gas, biomass, coal and process waste, which adds to their flexibility. They can also provide significant energy efficiency benefits – reaching more than 90 percent efficiency in using fuels, compared to power-only plants, which typically achieve efficiency less than half of that.

These systems are becoming more prominent in the United States in smaller scale applications. Currently, installed capacity is more than 82 gigawatts of CHP at more than 4,400 industrial and commercial facilities, according to the U.S. Department of Energy. This is 8 percent of the country's generating capacity – compared to more than 30 percent in countries such as Denmark, Finland and the Netherlands.

Recognizing the benefits of CHP, the Obama administration has set a goal of achieving 40 gigawatts of new, cost-effective CHP by 2020. According to the Department of Energy, meeting this goal would:

- Increase total CHP capacity in the United States by 50 percent in less than a decade.
- Save energy users $10 billion a year compared to current energy use.
- Save one quadrillion BTUs (Quad) of energy – the equivalent of 1 percent of all energy use in the United States.
- Reduce emissions by 150 million metric tons of CO_2 annually, equivalent to the emissions from over 25 million cars.

It's notable that the U.S. Capitol building and congressional buildings will soon by powered by a CHP plant – joining entities such as the General Services Administration and the National Institutes of Health on the list of government organizations that operate CHP facilities.

Utilizing the technologies of CHP and district energy together can enhance the benefits of both. A CHP plant can be an ideal heat source for a district energy network, making it feasible to use existing power plants and facilities that are generating power to establish a district energy network.

Consider an example of an individual building with high-efficiency gas boilers with a fuel consumption of 1.0 units, where heat generation is 0.9 units and 0.1 units is wasted heat. That building is connected to a power-only plant where fuel consumption is 1.7 units and power generation is 0.5 units, for 1.2 units of wasted heat. In this case, total fuel consumption is 2.7 units.

Compare this to using a CHP and district heating network. In this scenario, individual buildings have the same heat demand of 0.9 units, which is supplied by the district heating system. The connected CHP plant has fuel consumption of 1.7 units, power generation of 0.5 units, heat of 1 unit that is supplied to district heating, and wasted heat of 0.2 units. Total fuel consumption is only 1.7 units in this model, and the energy savings is 1 unit, or 100 percent of the individual building's fuel use in the first example.

Where can these solutions be used?

District energy networks fit especially well with CHP plants in urban areas that require large amounts of electricity and heat during cold periods and cooling during warm periods.

These systems are influenced by the area's heat density. When they are established in an epicenter with a high heat demand, they typically provide a good return on investment. As a result, a dense population area located in a colder climate region with longer heating seasons is an especially good candidate for district heating systems.

Smaller district heating systems are also feasible, as long as there is a heat/power-generation source available with sufficient volumes of heat that can be utilized. District cooling systems are especially well-suited to warm climates and provide good ROI. District cooling systems have also proven to be very attractive for commercial buildings in cold regions, for example in Sweden and Finland.

The necessary infrastructure requirements are already in place in many cases, which contributes to the efficiency of the district energy and CHP options.

In addition, the resilience of district energy systems is another significant benefit. Because these systems are independent of the heat source, if something occurs at the heat source to interrupt service, it's possible to feed in heat from other sources. This resiliency also helps resist fuel cost fluctuations, which has been shown in Denmark, where the systems are widely used.

The Danish model

Denmark is a top performing European country in CHP development. Combining heat and power generation has been a key component in the development of the energy sector and in creating a cost-effective heat and power supply, according to a 2014 report from the Danish Energy Agency.

District heating supplies more than 60 percent of all Denmark households with heat for space heating and hot tap water in 2013, and more than 70 percent of the heat distributed through district heating is generated in CHP plants, according to the report. CHPs accounted for almost 60 percent of the thermal power generation in Denmark in 2013, with efficiency rates of up to 92 percent.

Gross energy consumption in the country has been reduced by 11 percent due to the development of CHP, the report states.

The use of CHP in city-wide district heating networks began on a major scale in Denmark during the 1980s after the oil crisis. The implementation of district heating and CHP has over the years been supported by various funding sources, including tax exemptions and investment grants.

Since then, Denmark has also expanded on the idea of using district heating networks as a flexible energy infrastructure in relation to the increased number of renewable power sources, such as wind and solar farms.

Danfoss has contributed to this leadership position by taking a holistic approach to help further develop these types of systems and the components and technologies involved.

What lies ahead for district energy?

A main challenge in more widespread implementation of CHP and district heating is the high up-front investment cost and guaranteeing a sufficiently high connection rate at the start of the operation. This can be avoided by using municipal heat zoning, which would require all buildings in an area to be connected.

These technologies have the potential to provide substantial energy efficiency and cost-saving benefits in the long run. District energy networks have a proven track record in decarbonizing the energy mix through the invariance of the heat source, and such systems are the simplest and most cost-efficient way to fulfill climate goals.

In addition, district energy networks can be utilized beyond their combination with CHP plants – to provide real opportunities to save energy and costs.

More information

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Danfoss A/S
Heating Segment • heating.danfoss.com • +45 7488 2222 • E-Mail: heating@danfoss.com