DISTRICT HEATING HANDBOOK

FOURTH EDITION
Vol. 1

A Design Guide

Published in the interest of the
District Heating and Cooling Industry by
International District Heating Association
1735 "Eye" St. N.W., Washington, D.C. 20006

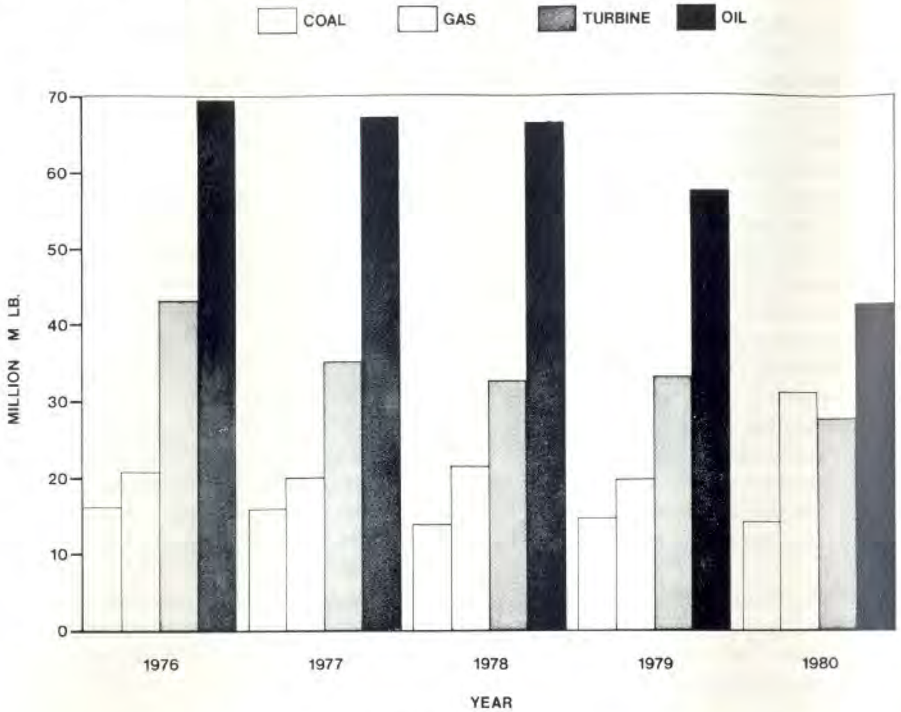

FIGURE 1.2
Pounds of steam produced by fuel type

EXPERIENCE OF OTHER COUNTRIES WITH DISTRICT HEATING

District heating and cooling capacity in several countries are compared in Figure 1.3.

Significant installations of district heating in Europe did not occur until after World War II. Since that time, however, it has developed rapidly and with excellent public acceptance. As the growth of district heating is relatively recent, the European public views it as a "modern" development and approach it with the enthusiasm that greets innovation.

The contemporary success of district heating in Europe has aroused new interest in this country and has led to a movement toward adoption of Europe methods in this nation's cities. While direct application of European methods may not be transferrable to the United States directly because of major differences in power plants, in heating and cooling loads and in patterns of city development, the potential remains great.

The European method uses hot water from back-pressure turbines distributed to customer loads created incrementally as new communities are developed. In this country, new building construction as a percentage of the total existing building volume is low. European systems have sustained winter demand and carry no appreciable air-conditioning loads in summer. In the U.S. where steam is available, it is generally used for heating while electricity powers most cooling machinery resulting in poor load factors for both systems. As a result, electric utilities in the past have heavily promoted electric heating. Existing buildings equipped for steam or electric heat cannot be adapted readily to hot water

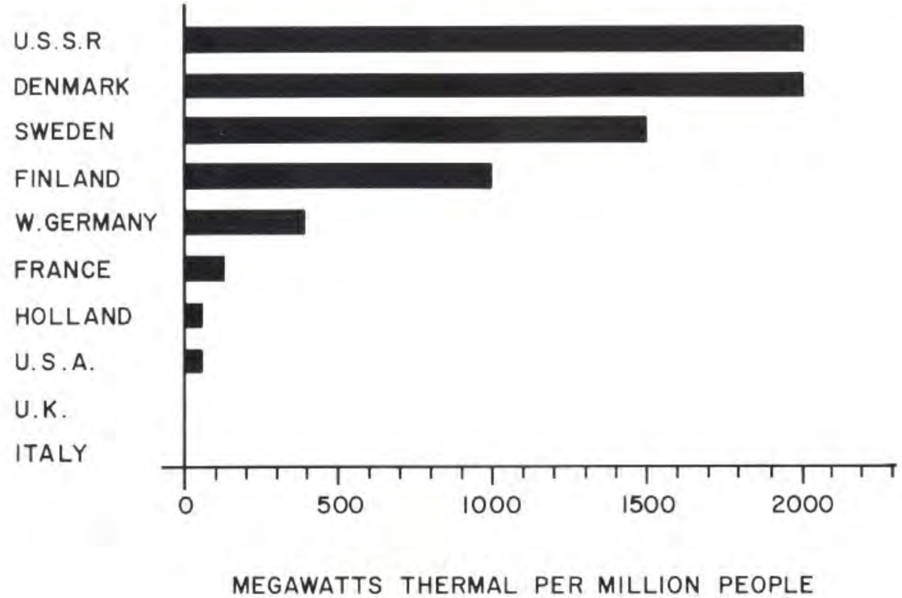

FIGURE 1.3
Installed district heating and cooling capacity

systems and hot water cooling devices are not efficient in comparison with electrically-driven units.

Electrical generating practice in the U.S. differs greatly from the European customs. In Europe, turbines generally utilize back-pressure design in sizes ranging from 50 to 300 MW with throttle pressures below 2,400 psi, whereas in this country, units generally use a condensing design with capacities ranging from 600 to 1300 MW at pressures from 2,400 to 3,500 psi.

In addition to these engineering and load differences today, electric utility plants take eight to ten years to site, design, and build. Developers cannot project the utility needs for their buildings on such a long-range basis. In Europe, the considerably smaller plants are built more nearly in the same time frame as housing and commercial developments.

Over the past 25 years, most northern European countries have centralized heat production and combined the generation of heat and electricity. More than 30% of all homes in Denmark are supplied by district heating and 90% of all towns with populations exceeding 2,000 people have some sort of centralized heat supply. The Danish national energy plan includes a heating program that would allow 40% of the country's total heat consumption in 1990 to be met by residual heat from electric power station generation. In Sweden 35 cities and towns have district heating systems using hot water as the heat distribution medium supplied from plants having only hot water boilers.

When heat loads exceed 100 MW, combined heat and power plants are the usual source. The U.S.S.R. has 970 combined heat and power stations with a capacity of 45,000 MW out of a total capacity of 207,000 MW for all electric power stations. West Germany has 472 district heating networks. The government is studying the feasibility of a national grid of district heating systems supplied by large power stations. It has been estimated that 40% of the heat for space and water heating could be supplied in this way.

The district heating programs of several countries are detailed in the following sections.

Finland

In Finland 14% of all homes are served by district heating systems. The majority of these, because of the efficiencies of high density, are in Helsinki. In that city, 65% of the homes are kept warm through district heating, with a goal for 1990 of 85%. Feed and return pipelines for the Helsinki system total 250 miles.

The energy for much of Finnish district heating is supplied by waste heat from nuclear plants. The waste heat is not only utilized in the system, but also reduces by half the effluent heat discharged into the ocean in nuclear cooling processes. In Helsinki, district heating not only has aided in the elimination of environmental pollution, but also has turned a profit for the city.

In 1976, Helsinki had four cogeneration heat and power stations—four heating plants for peak loads and 36 transportable heating plants. Two additional heating stations are planned by 1984 and another pair by 1993.

Sweden

Sweden relies on approximately 50 district heating systems, owned by the communities they serve to provide space heating and domestic hot water. In Stockholm, about 50% of the inhabitants are served by district heating with the goal for the year 2000 set at 90%. District heating is strongly emphasized as part of the nation's national fuels policy.

Sweden is heavily dependent upon imported fossil fuels. It is estimated that, in Stockholm alone, district heating saves an estimated $11 million or more annually in reduced fuel oil consumption. District heating systems are required to connect any eligible applicant to the system. Loans and grants are made available so the new subscriber can afford to make the connection. In small or new communities, mobile boilers may provide the heat but, as the community grows, a more permanent installation is made.

Denmark

One of the earliest European nations to use district heating, Denmark has used cogeneration technology for nearly 60 years. Fifty percent of all energy consumption in Denmark is for space heating, with district systems supplying 40% of all Danish households.

A deliberate emphasis has been put on use of energy sources such as coal, uranium, and residual fuel oil as well as domestic and industrial wastes in district heating applications.

Denmark is a pioneer in the use of refuse, where about 60% of all waste is used for district heating. This supplies 5% of the total heat consumed in the nation. The national goal is to increase this percentage to 75% of all waste.

Hook-up to district heating is not mandatory; however, costs of district heating are kept low enough to generate demand strictly on the basis of competition. A subscriber agrees to purchase heat for a minimum of 20 years—usually the repayment period of the loan covering connection charges.

England

England is beginning to explore expansion of a district heating concept. A policy of regenerating electricity at the absolute lowest cost has led away from experiments in cogeneration. A new philosophy has recently been propounded which would have the government look at cogeneration in terms of electricity as a by-product of heat rather than the alternative.

West Germany

West Germany is heavily dependent upon imported fuels. As a result, the government is studying a variety of alternative space heating technologies. Many cities and towns currently have district heating systems. Although dual-purpose power plants are not widely favored, industrial cogeneration does have public support.

A government study is assessing the possibilities of a nationwide district heating "super-grid" to interconnect all cities with populations of 40,000 or more. Such a grid would utilize heat from all available sources.

Switzerland

With a relatively high standard of living, it is not the economics of fossil fuels which have prompted Switzerland to begin expansion of its district heating systems, but a concern for the environment. With a relatively low urban density and abundant water power, district heating is still in its infancy in this nation, however, its implementation has begun on a small scale.

Italy

The climate of this sourthern European nation is milder than most other nations on that continent. Brescia, on Lake Garda in North Central Italy, has a municipally-owned urban district heating system employing a back-pressure turbine with 30 MW electrical generating capacity. A second unit is just coming on line. Supplemental boilers provide superheated water during peak periods and during warm weather when heat is needed only for domestic hot water.

Union of Soviet Socialist Republics

Russia is the largest user of district heating in the world, with a cogeneration capacity far more than the rest of the world combined. Over 1,000 stations provide heat and electricity to 800 Soviet cities. The centrally planned economy, which can dictate the size, location and composition of new communities, makes installation of district heating systems easy and efficient. As a result, over half of domestic heat in the U.S.S.R. is provided by district heating through cogeneration.

In planning new communities, loads are forecast on a five-to-ten year basis. Before a new thermal power station is built, an 8 to 12 billion Btu/hr heat load and a 200 MW electrical load are required. Until that point is reached, local heat-only boiler plants supply the hot water, while electric needs are provided through a link with the national grid.

Czechoslovakia, Rumania, Poland, Hungary, and Bulgaria

Czechoslovakia leads Eastern European nations in developed district heating capacity. Altogether, 157 cities have district heating systems in that nation. Poland and Rumania have concentrated on large district heating systems. In

Poland and Czechoslovakia, where coal is abundant, district heating is still in its early stages, with small sized systems predominant.

In Rumania, 50% of all space heating is provided through district heating systems; however, only one-third of that comes from cogeneration, the bulk being from single-purpose equipment. Bulgaria has abundant coal and, therefore, has led in the highest use of cogeneration facilities of any of the Eastern European block nations.

DISTRICT HEATING TECHNOLOGY, MARKETS AND COSTS

District heating systems can be classified according to the type of area they serve, with different system technology and design necessary for optimum performance in each area type. Typical classifications by service area or market are:

1. Densely populated urban areas.
2. High density building clusters.
3. Industrial complexes.
4. Low density residential areas.

Studies of existing systems have shown that district heating can be economically productive in the first three markets listed above. The experience of European communities show that, when correctly applied, single family residential areas could be served economically also.

Three main factors determine whether or not district heating will be economically productive in a given environment.

- Heat-load density.
- Annual load factor.
- Rate of consumer connections.

A majority of the capital investment required for a district heating system goes into the costly facilities needed for transmission and distribution. This will run from 50% to 75% of the total. To be cost effective, District Heating and Cooling (DHC) requires a high heat-load density. Economics alone may rule out single-family residential areas under current conditions. Changes in economics or technology such as development of low-cost, non-metallic piping, improved installation techniques, and low-cost metering could change the outlook, however.

For economical operation, a district heating system must connect the maximum number of users in a service area to the system as soon as practical. This rate of consumer connections sets the pace for revenue which, in turn, determines the economic success or failure of the system. Once the system is in operation and the initial consumer connection rate satisfactory, the cost of connecting new buildings into the system is often less than the cost of furnace or boiler installations. Cost of conversion for existing buildings depends on multiple factors, such as age, type and condition of existing equipment, since conversion to district heating becomes most attractive when existing systems are in need of replacement.

Densely Populated Urban Areas

In the central core of densely populated metropolitan areas, district heating systems should be multi-purpose in order to serve as large a number of consumers as possible. A twenty- to thirty-year phased construction period would not be unlikely for such a system. Massive amounts of financing would be required for the miles of distribution pipes and the several thousand

megawatts of capacity needed. Often, only a small portion of the total system cost is needed initially, with the bulk of the costs being provided through sales revenues.

In contrast, a system for a smaller city core area would require only a few hundred megawatt capacity and but a few miles of distribution piping. Construction could range from only a few years up to about ten years, with capital requirements running in the tens of millions of dollars. Some characteristics would be common to systems in both areas:

1. A variety of building types and energy uses will be included. Several simultaneous services will be required.
2. Thermal energy sources probably will be surplus heat from electric and industrial plants, urban waste disposal facilities, geothermal wells, or solar collectors.
3. Distribution network costs will comprise a majority of the system costs.
4. Institutional arrangements for achieving a successful system will be extensive and complex, involving both public and private sectors.

High Density Clusters

High density developments include such potential system users as suburban shopping centers, a university campus, a high density highrise residential complex, or a high density mixed suburban development. Characteristics of the system include:

1. Both plants and distribution network will probably be new and designed specifically for the application.
2. The distribution network may be relatively small, comprising a small part of total system cost.
3. Coal fired systems may be used for larger systems, with oil and gas used in smaller applications.
4. Central source may be a new cogeneration plant or a facility making use of surplus heat from an existing industrial or electric plant.
5. Institutional arrangements are usually simple, involving only a few decision-makers.
6. Financing would be from a few million to a few tens of million dollars. Construction would run from a few years to ten years in one or two phases.

Industrial Complexes

Special demands of systems for industrial complexes rule the type of system and its economics. Steam, hot water, or both may be necessary, and industrial process loads will dominate system use. Central plant technology and fuels will be similar to those for high density clusters.

Institutional arrangements should be simple, but varied thermal requirements may make distribution systems complex. A high utilization factor makes for favorable economics.

Low Density Residential Areas

A district heating system for low-density residential developments typically would serve an area dominated by single or duplex residential units. Such systems would probably have the following in common:

1. Cost of the distribution system, most likely low temperature hot water, would dominate construction costs.