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Potential for District Heating: An Historical Overview

Martin A. Broders

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ABSTRACT

This paper serves as an introduction to district heating. It focuses attention on the potential of district heating to meet our nation's energy conservation, environmental and social objectives. Basic terms are defined and the principle of district heating operation is described. District heating thermal energy sources, transmission and distribution piping and consumer secondary heating systems are discussed in very general terms. To gain a clearer understanding of the current status of district heating in the U.S. today, a brief historical overview is presented. For comparison, the history and status of district heating in Europe is also summarized. The advantages of district heating are outlined, and the primary factors that impeded the implementation of district heating in the United States are discussed.

1. INTRODUCTION

District heating is a technology that originated in the United States in 1877, and more recently has been successfully implemented in many European countries. As originally conceived, thermal energy in the form of steam was produced at a central power plant and distributed through an underground piping network to individual residential, industrial, and commercial buildings. Buildings connected to this district heating network extracted thermal energy from the system rather than produce there own thermal energy from individual building boilers.

One of the major advantages of this type of system is its inherent ability to utilize a variety of different fuels to supply thermal energy. In this regard, a district heating system represents a fuel substitution strategy capable of using more abundant domestic fuels such as coal, refuse, and nuclear energy. Industrial waste heat, geothermal, and solar energy also offer potential as thermal energy sources for district heating. From a national prospective, widespread implementation of district heating offers our nation an opportunity to conserve its scarce natural fuel resources, reduce the importation of foreign oil, and provide a centralized source of thermal energy to meet an increasing urban demand for reliable space and hot water heating.

Modern hot water district heating systems have been developed and successfully implemented in Europe. These hot water systems appear to offer certain advantages over steam district heating systems, especially for larger system applications. Therefore, this document will emphasize the hot water district heating system. Also, district cooling will not be discussed in this document, since it is a subject unto itself.

2. GENERAL DESCRIPTION

Before we proceed into the general description of district heating, it is important that we define two basic terms:

- o Cogeneration is the process of producing both electricity and useful thermal energy from a single energy source.
- o District heating is a system which distributes thermal energy from one or more centralized energy sources to commercial, industrial and residential consumers for space conditioning, potable hot water heating, and auxiliary processes.

Figure 1 illustrates the principle of operation for a hot water district heating system. The three major subsystems; namely, (1) thermal energy sources, (2) transmission and distribution systems, and (3) consumer secondary systems, are described as follows:

2.1 Thermal Energy Sources

The primary thermal energy source for a large district heating system would likely be a steam supplied, turbo-electric power plant. Many existing electric-only power plants can be modified for cogeneration to produce thermal energy for district heating at a relatively low capital cost of \$20 to 30/kW(t).[1] As can can be seen from Fig. 1, there are two basic cogeneration methods, namely back pressure and extraction. The first method uses a steam turbine designed for back pressure operation, and the condenser is replaced with a district water heater which recovers most of the thermal energy normally rejected to the environment. The back pressure turbine is designed so that the steam expansion is terminated at a higher temperature and pressure than in a conventional condensing plant;

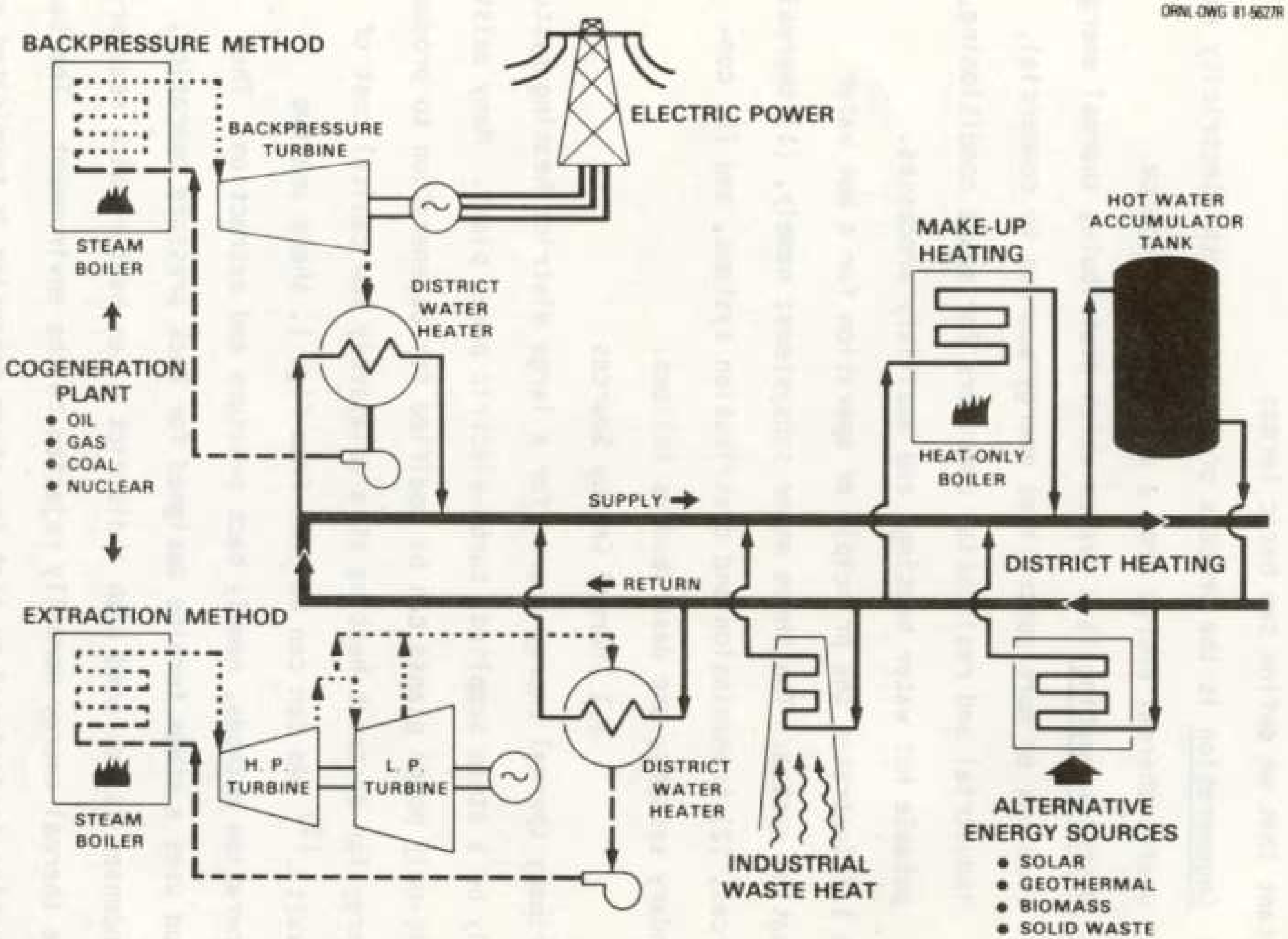

Fig. 1. Hot water district heating system: principle of operation.

e.g., back pressure turbine steam exit conditions of 250°F/30 psia (121°C/207 kPa) compared with conventional turbine steam exit conditions of 100°F/1 psia (38°C/7 kPa). The second method extracts higher heat value steam from the crossover between the high pressure-intermediate pressure-low pressure turbine units and/or at some intermediate point in the units themselves, and supplies this steam directly to a district water heater. In large centralized power plants, it is entirely possible that both cogeneration methods will be used to supply the necessary thermal energy for district heating. It is interesting to note that in Sweden all district heating systems with a heat load greater than 200 MW(t) use cogeneration plants.[2]

Although cogeneration plants are the backbone of large district heating systems, hot water (heat-only) boilers are used in many smaller systems. Either stationary or portable hot water boilers are also an integral part of many larger systems, where they are used during peak-load conditions or as standby units. These hot water boilers have the advantage of low initial capital cost, but are not used for normal base load conditions (see Fig. 2) because of their relatively high operating costs compared with a cogeneration plant. Hot water boiler operating costs can be reduced, however, by the use of lower heat content fuels such as forestry waste chips (biomass) or by the incineration of solid waste. Other comparatively low heat content energy sources such as solar, geothermal and industrial waste heat are also ideally suited for district heating, and can advantageously be used to supplement the thermal energy supplied by cogeneration.

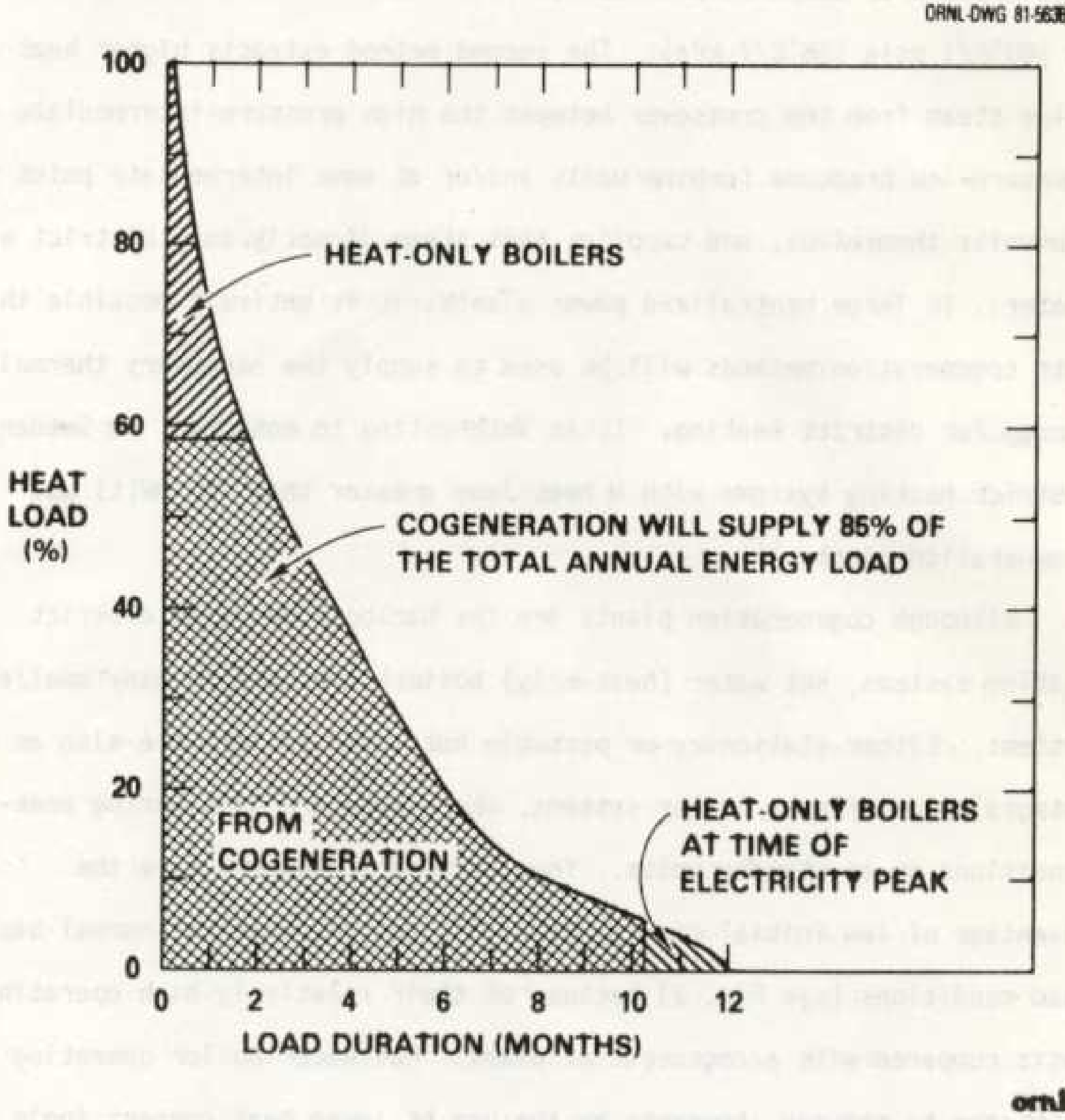

Fig. 2. Heat load duration curve and load split.

2.2 Transmission and Distribution System

The piping network used to transport the primary transmission fluid (water or steam) from the sources of thermal energy and distribute it to the consumer substations (heat exchangers) represents the largest capital cost of a district heating system. As can be seen from Fig. 3, the primary water distributed to the consumer substation is regulated as a function of the outside temperature. In the example[3] shown in Fig. 3, the hot water is controlled between 180°F (82°C) (when the outside temperature is relatively warm) and 300°F (149°C) (when the outside temperature is below zero). Likewise, the return temperature is controlled between 120°F (49°C) and 145°F (63°C). Of course, these supply and return temperatures will vary from system to system.

With cogeneration, district heating supply temperatures are usually reduced during the warm summer months because of reduced consumer energy demand, and to compensate for the increased electric power demand characteristic of this season of the year. It should be pointed out that there is an optimization consideration in the design of district heating piping systems. In general, a high design temperature for the hot water supply reduces the water flow rate and pipe dimensions for a given return water temperature, and may also provide a potential advantage for consumers with existing low pressure steam heating systems. A low design temperature allows more electricity to be generated by the cogeneration plant for a given heat supply, reduces the design pressure required for the system, and allows less expensive piping insulation to be used.[4]

Steel piping is the basic material used to transmit and distribute hot water in district heating systems designed for temperatures up to 300°F (149°C) and pressures up to 250 psig (1724 kPa). Prefabricated

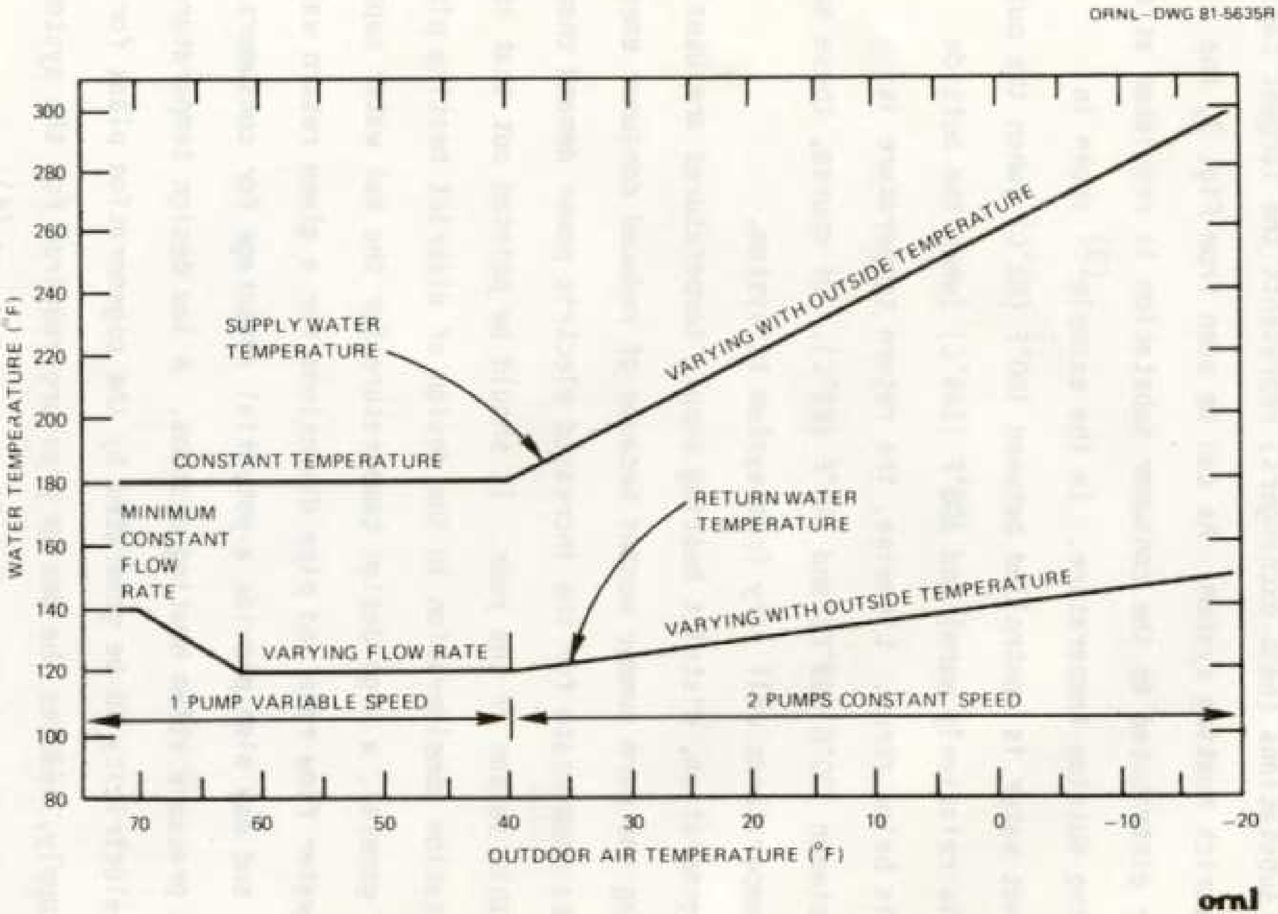

Fig. 3. District heating system: supply and return water temperature profile.

conduits can be used when piping diameters are less than 20 in. (51 cm). These prefabricated conduits use polyurethane foam insulation between the inner steel pipe and the outer protective surface. The transmission piping system uses large-diameter insulated steel pipes to transport hot water from the thermal energy sources (cogeneration plants) to various urban locations. These transmission pipes are usually placed in waterproofed rectangular prefabricated concrete culverts to protect them against ground moisture, or are run in tunnels. The thermal expansion of these pipes is taken up by natural bends, "U" bends, or, in some cases, expansion bellows. The distribution system piping, which transmits thermal energy from the main transmission piping system to the consumer substation (heat exchanger), uses smaller diameter prefabricated pipe which is typically encased in an insulated round conduit and can be laid directly in the ground. Plastic pipe which can be laid directly into grooves of insulation blocks in the ground is a recent development in Sweden(2) and promises to reduce the overall cost of installing a district heating distribution system.

2.3 Consumer Secondary Systems

Thermal energy from the primary district heating distribution system is supplied to the consumer through substation heat exchanger(s) which the consumer usually owns. Typically, this thermal energy is transferred in the heat exchanger to the hot water circulating in the consumer's secondary heating system. This secondary system may actually consist of two subsystems, each with its own heat exchanger, i.e., one for space heating and one for potable hot water heating. Heat supplied to the consumer is metered either by heat-integrating meters or by simple flow meters. The substation heat exchanger(s) and consumer's secondary heating system are designed and operated to achieve a low return water temperature to the primary system. Low water return temperature is important because it allows lower water flow rates, minimizes transmission and distribution system pipe size, and maximizes power yield at the cogeneration plant. Although most consumer secondary systems are used for space and potable hot water heating, certain types of absorption chillers can be operated from a district heating system to meet building air conditioning requirements.

2.4 Feasible Application of District Heating

District heating, like any other energy system, is not applicable for every urban area. As will be discussed in more depth later in this document, the large front-end capital investment required to install a district heating system makes it imperative that the system be justified on its economic merit. The following factors must be carefully considered when determining the economic feasibility of a district heating system:

- Heat load density:[1] The urban area being considered for district heating should have a peak heat load density greater than 20 MW(t)/km^2. As can be seen from Fig. 4, suitable regions for district heating include the downtown areas of major cities, such as Minneapolis and St. Paul, Minnesota; but, seldom include more sparsely populated areas, such as residential areas with single-family houses on one-third acre lots.
- Geographic location:[5] To ensure a high system utilization, district heating should generally be applied in northern communities with large space heating requirements. Figure 5 shows that district heating is best suited for

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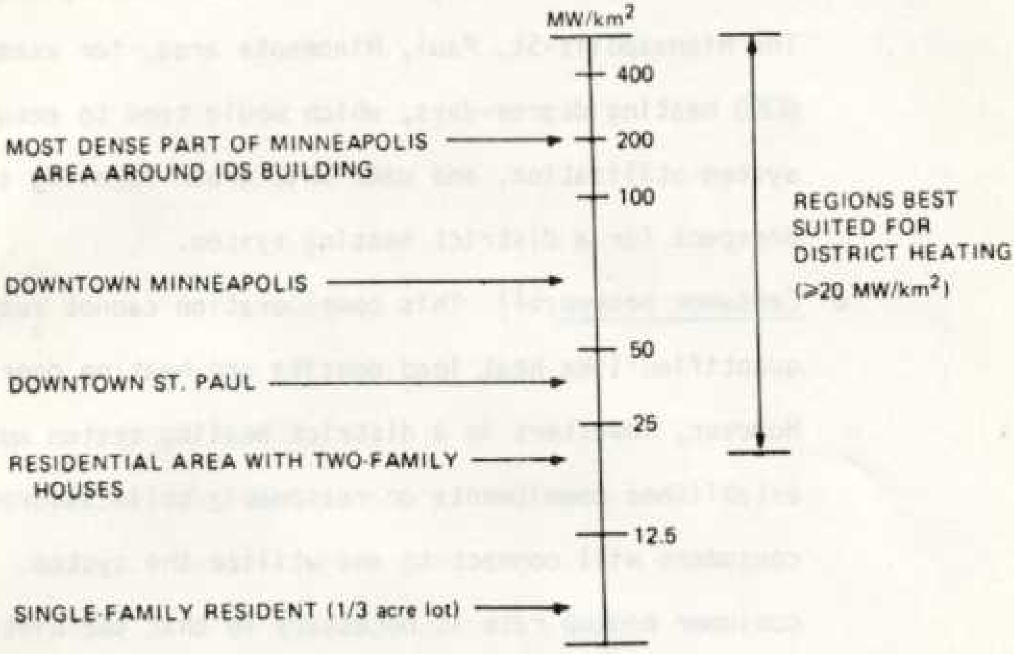

Fig. 4. Comparative urban heat load density values $[MW(t)/km^2]$.

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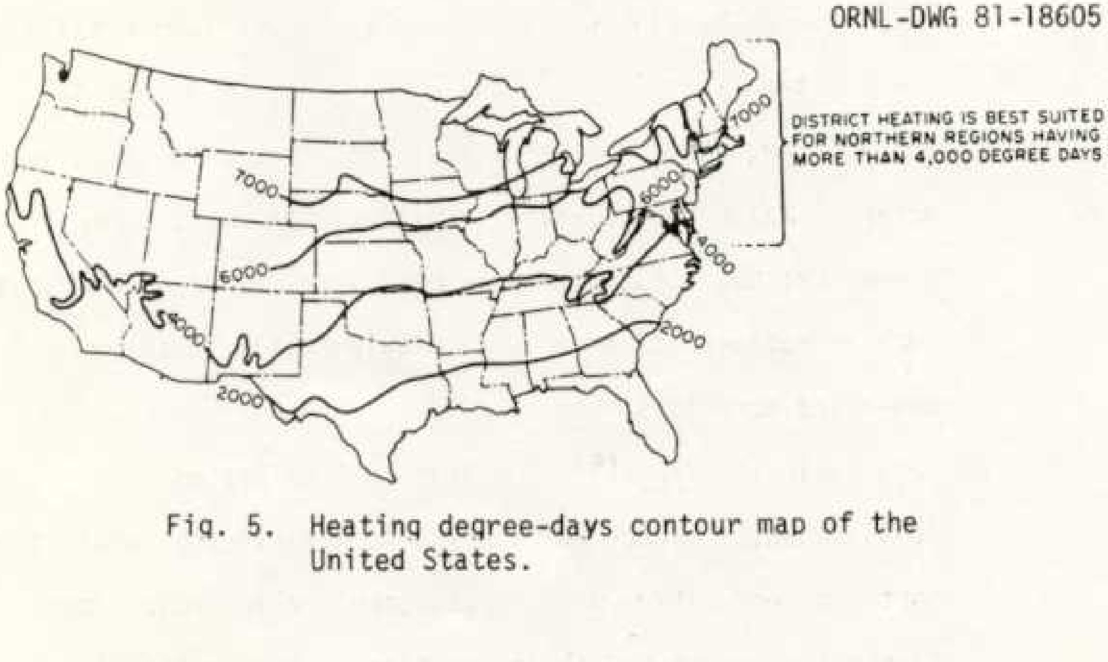

Fig. 5. Heating degree-days contour map of the United States.

northern regions having more than 4000 heating degree-days. The Minneapolis-St. Paul, Minnesota area, for example, has 8000 heating degree-days, which would tend to ensure a high system utilization, and make this urban locality a prime prospect for a district heating system.

- Consumer hookup:(1) This consideration cannot readily be quantified like heat load density and heating degree-days. However, investors in a district heating system must have established commitments or reasonably solid assurances that consumers will connect to and utilize the system. A rapid consumer hookup rate is necessary so that the district heating system can begin to generate revenues in order to become profitable in the long run.

3. HISTORY AND STATUS OF DISTRICT HEATING IN THE UNITED STATES

There were some crude attempts in the United States as early as 1798 to heat small groups of buildings, but it was not until 1877 that Birdsill Holly, an inventor and hydraulic engineer, installed the first district heating system in Lockport, New York.(6) Mr. Holly is said to have had three areas of interest in district heating; namely, (1) to heat dwellings and buildings, (2) to furnish steam to fire engines for pumping, and (3) during an actual fire, to smother the flames with steam. The first purpose became the paramount one, and Mr. Holly built a boiler in the cellar of his home in Lockport, New York, and experimented with steam heating by running pipelines throughout his house. The experiment was a success, and he extended an underground steam main down Chestnut Street to a residence some 490 ft (150 m) away. This experiment was also a success, and Mr. Holly organized the Holly Steam Combination Company in Lockport, New York, and thus commercial district heating was born.(7)

Information spread rapidly about the successful district heating developments in Lockport, New York. Within ten years, district heating systems were installed in Bellefonte, Bloomburg, Clearfield, Harrisburg, Hazleton, Lockhaven, Phillipsburg, Reading, Wilkes-Barre, and Williamsport, Pennsylvania. During this time period, systems were also put into operation in Auburn, New York; Burlington, Iowa; Belleville, New York; Dubuque, Iowa; Denver, Colorado; Garden City, Long Island; New Haven, Connecticut; and Springfield, Massachusetts.(6) The story does not stop here. Experts from the larger cities of Cleveland, Philadelphia and New York City visited Lockport, New York, to study this intriguing new idea and went back home to start up similar district heating systems. In 1879, Dr. Charles Edward Emery, a noted engineer, went to Lockport to investigate district heating and evaluate its application for New York City. The results were positive and, around 1880, New York City installed a steam district heating system operated by the New York Steam Company. The new company built an unusual boiler plant. Forty-eight, 250 hp boilers were installed (16 on each of three floors). Three miles of steam mains insulated with mineral wool were laid during the first year.(6) Despite some early system failures, the New York City system proved itself during the "blizzard of 1888" when steam service was one of the few city services that functioned reliably. It is interesting to note that during 1979 Consolidated Edison of New York sold just under 30 billion pounds (13.6 billion kg) of steam, representing approximately 37% of the reported district heating sales in the United States.(8)

A decade after the birth of district heating, the electric industry started its rapid climb to prominence and had a profound effect on the development of district heating. This was around 1887, the year that Philadelphia started its district heating system.(9) The evolution of district heating in Philadelphia is typical of many larger cities, i.e., the 20 or more electric systems (names such as Brush, Maxim and Edison which were common to all large cities of that era) and at least four known steam systems were being consolidated midst considerable controversy and fierce competition. There was also the problem of how best to dispose of the so-called waste or exhaust steam from the reciprocating steam engines used to drive the electric generators. The electric companies, with generating plants ideally located in business and industrial districts, decided to pipe this exhaust steam to their electric customers and sell it for a profit. Thus, around the turn of the century, the electric utilities started to get involved in the steam heating business.

During the early 1900s, some electric companies were tempted to get out of the steam heating business because of marginal or unprofitable operation. However, it became obvious to them that if their electrical business was to grow they must also provide their customers with steam for heating. Many of their potential commercial and industrial customers had their own electrical generators driven by steam engines, the exhaust from which they used to heat their own buildings and facilities. Thus, the electric company had to provide steam service in addition to electric power in order to convince their new customers to shut down their private electric generating plants. As a result, the electric companies became further committed to the steam heating business.

By the late 1920s, three major changes in the electric power generation business were having adverse affects on the district heating business.[6]

- o Condensing type steam turbines were replacing reciprocating steam engines as prime movers for electric generation. There was no longer any exhaust steam available for heating, and the condensing water temperature was too low for space heating.
- o Large electric power plants replaced groups of smaller plants. These larger plants were also moved away from congested areas when electric transmission became possible over greater distances.

- o As the generation of electricity from these larger plants became less expensive, the small in-town plants that were providing steam for district heating became obsolete.

Steam, which had heretofore been regarded as an inexpensive by-product of electric generation, had been sold by the electric companies at a very low price. Now the electric companies were faced with either raising the price of steam services to their valued electric customers, or offsetting their steam heating business losses with electrical business profits. Some electric companies quit the business. Others recognized an obligation to continue providing steam services to their growing list of important electric customers. Those that stayed in the business raised their rates sufficiently to make their steam heating businesses a profitable venture. They also built new steam plants to replace the smaller in-town plants that had become obsolete. For example, in 1927 the Willow Steam Plant was completed in the City of Philadelphia.[9] This plant was devoted to steam for district heating only and provided no electric generation. It contained three boilers, each rated at 125,000 lbs/hr (56,700 kg/hr). It is interesting to note that during 1975, the Philadelphia district heating system provided the Philadelphia Electric Company with 3.4% of its total revenue, while their steam system investment was only 1.3% of the total utility plant.

From an historical perspective, the first application of cogeneration was when the exhaust steam from reciprocating steam engines driving electrical generators was used for district heating. During the early part of the twentieth century, however, the first small cogeneration/district heating systems using steam turbines came into existence.[1] These systems used the exhaust steam from these small dual purpose power plants to heat buildings in the nearby business districts. As a result, district heating combined with cogeneration flourished during the 1920s and 1930s and became widely accepted. It should again be emphasized that the electric utilities were being more and more involved in the district heating business because it was a natural outgrowth of the cogeneration process. Today, the largest district heating systems in the United States are run by the major electric utilities, i.e., Consolidated Edison of New York, Philadelphia Electric, Detroit Edison, Boston Edison, and Indianapolis Power and Light.(8)

During the late 1940s, after several decades of success, district heating declined in the United States. As stated previously, larger more efficient power plants were sited in the less congested suburban areas, and replaced the smaller cogeneration power plants that were located close to the city's business and industrial districts. Technological advances allowing electrical energy to be transmitted efficiently over greater distances also enabled these larger power plants to be located further from the inner city. The net result was that many existing district heating systems went out of business because it was no longer economically feasible to transport steam from the new remotely located power plants to the urban areas served by the district heating system. The further demise of district heating was caused by the rapid expansion in the use of oil and natural gas as fuels to produce the thermal energy necessary to meet our nation's heating demand. With these seemingly inexhaustible and cheap fuels, consumers could once again turn to individual building heating systems supplied with steam or hot water from their own oil- or gas-fired boilers. The energy efficiency and conservation benefits of cogeneration/

district heating were all but ignored until the early 1970s when it was finally recognized that our apparent resources of oil and natural gas were limited.

Despite these setbacks, district heating has survived on a reduced scale in the United States and is today entering a new era of growth potential. Latest statistics from the International District Heating Association for 1979 indicate a total steam sales of just over 80 billion pounds of steam.(8) This number only represents the total steam sales reported by 44 utilities. Therefore, to be more realistic, we must also take into account the additional thermal energy consumed by non-utility district heating systems (government institutions, college campuses, etc.). All things considered, it has been estimated that current district heating systems account for less than 1% of the total annual energy consumed in the United States.(12)(30) Conversely, space and water heating together currently account for about 20% of the total U.S. energy demand,(10) and it is estimated that half of that, or 10% of the total U.S. energy demand, could be supplied by district heating. This confirms other figures which indicate that the district heating industry has realized less than 10% of its potential to date.(11)

4. HISTORY AND STATUS OF DISTRICT HEATING IN EUROPE

The history of district heating in Europe differs from that in the United States. While examples of district heating date back to 1893 when the first system was installed in Hamburg, Germany,[12] significant system developments did not occur until the early 1950s. In western Europe there is a wide variance of capacity, however, it can be generally stated that those countries that developed district heating systems early have a substantial lead in technology, and, with minor exception, now have the largest connected thermal energy capacity. Development of district heating systems in eastern Europe has largely paralleled that of western Europe in that most work has been undertaken since 1950.

Figure 6[12] shows the comparative growth of district heating systems in western Europe between 1960 and 1975. As can be seen, West Germany more than quadrupled (5,000 to over 20,000 MW) its total connected thermal capacity during this 15-year period. Development of district heating systems in Scandinavia has also been remarkable, especially in Sweden. The stimulus for the rapid expansion in Sweden may be due to a number of factors; including a favorable political atmosphere, forward looking planning authorities and energy economics. Figure 7[12] shows the contrast between total connected thermal capacity (MW) and specific connected capacity (MW/million inhabitants). This illustration shows a completely different and more realistic picture of the relative status of district heating in western Europe. Denmark, Finland, and Sweden, for example, show a high level of district heating system development on a per capita basis, while that of West Germany lags behind. Figures 8 and 9[12] show the comparative growth trends and status of district heating in eastern

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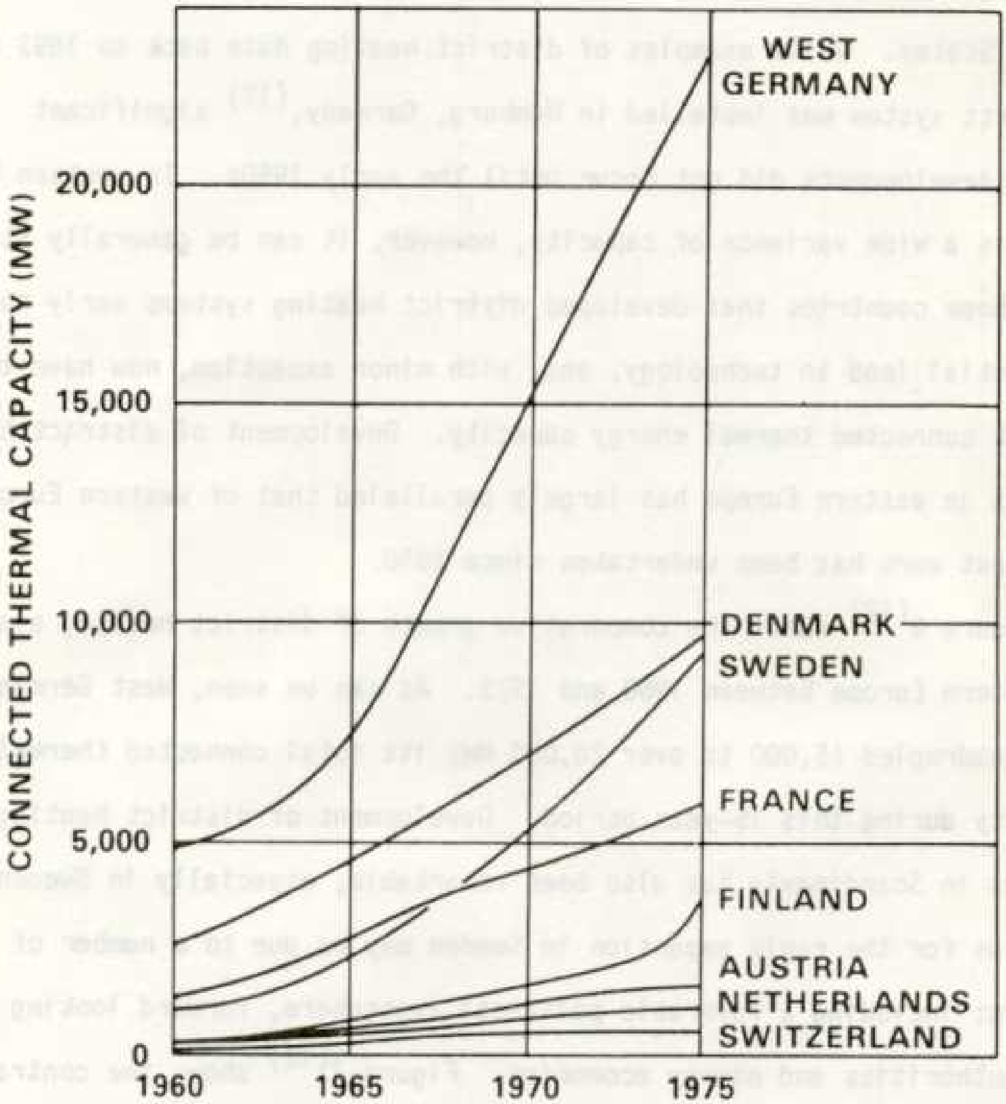

Fig. 6. Development of district heating in western Europe.

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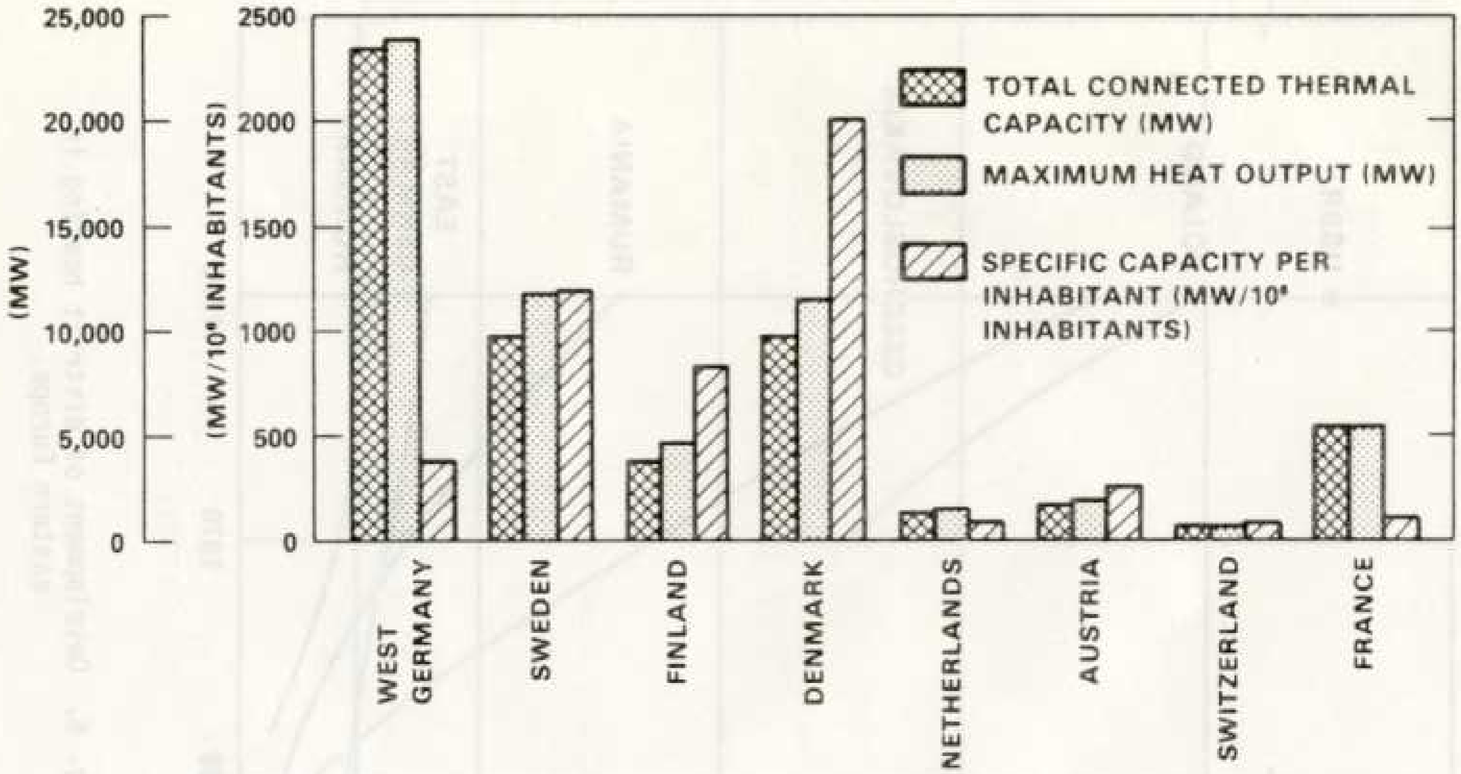

Fig. 7. Comparison between connected and specific capacities: western Europe.

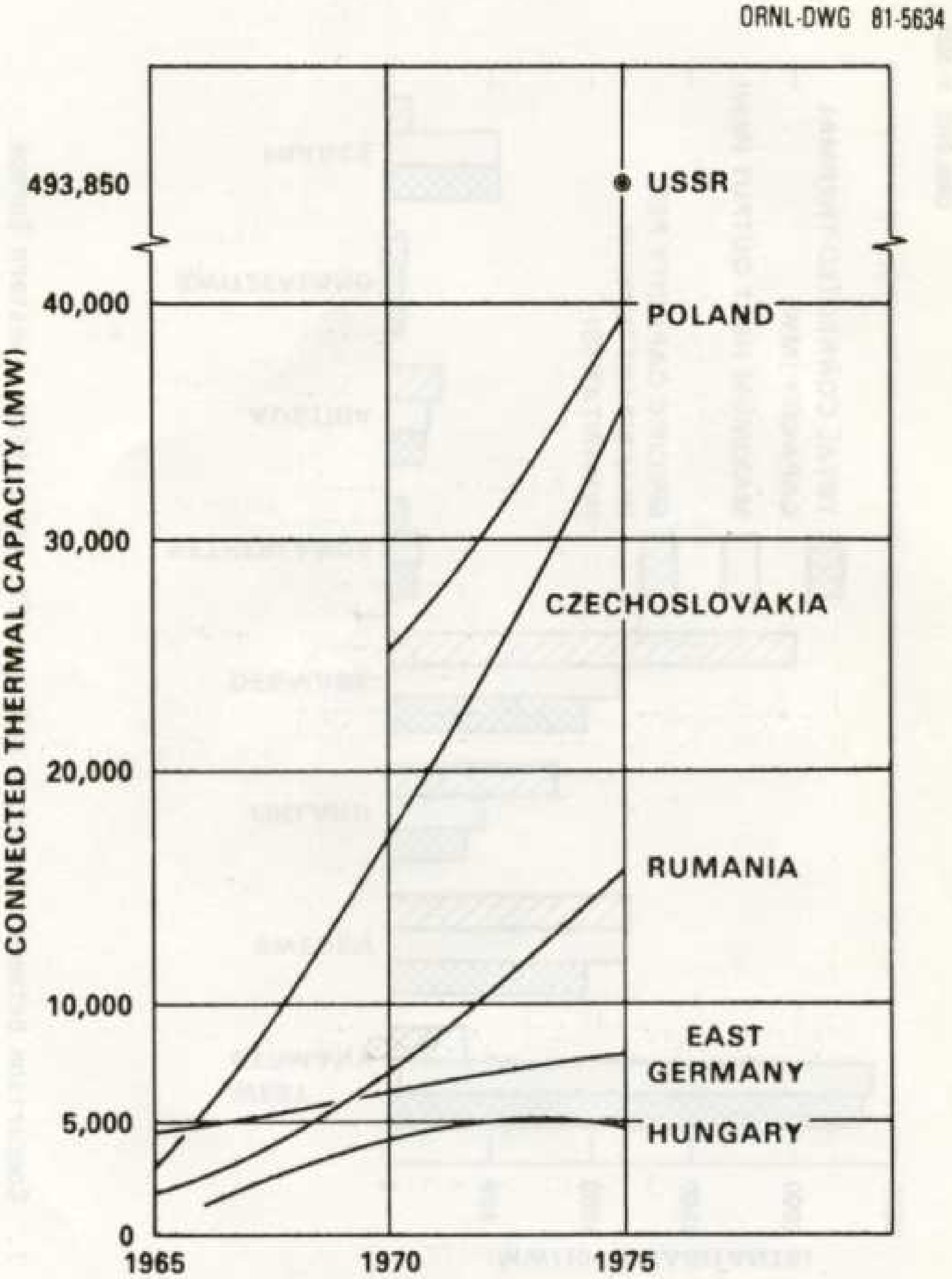

Fig. 8. Development of district heating in eastern Europe.

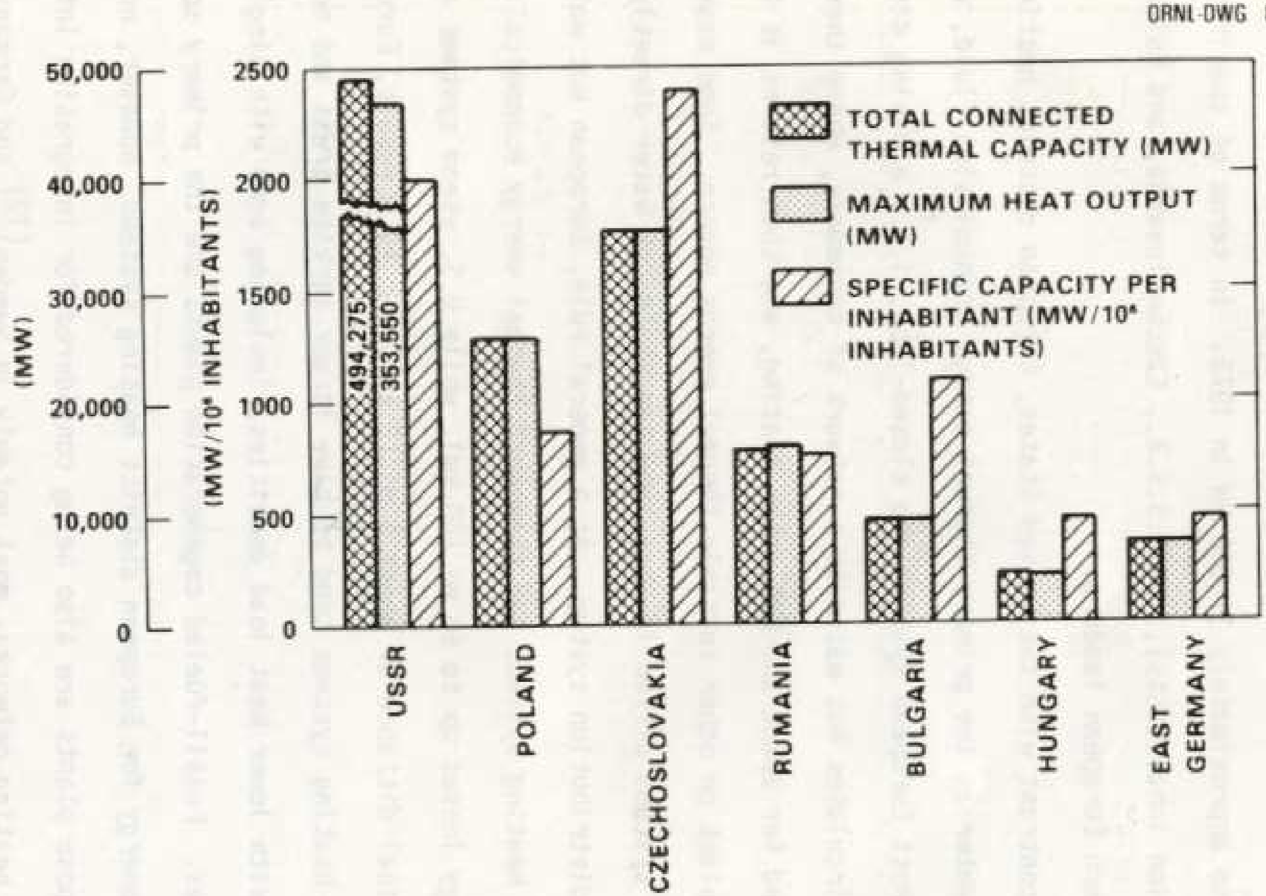

Fig. 9. Comparisons between connected and specific capacities: eastern Europe.

European countries. As shown in Fig. 8, the Soviet Union had by far the largest total connected thermal capacity in 1975; not only in eastern Europe, but also in the entire world. Also of note is the fact that Czechoslovakian district heating system capacity rose from under 5,000 MW in 1965 to approximately 35,000 MW in 1975. In terms of specific capacity (MW/million inhabitants), the U.S.S.R., Czechoslovakia, and Bulgaria are the eastern European leaders.

In contrast with the United States, European district heating systems use hot water as the primary thermal energy transmission fluid, rather than steam. Most European systems are closed-loop, i.e., a piping distribution system circulates hot water to a network of consumers, where thermal energy is removed for space and hot water heating, and then returns it to a cogeneration plant or other suitable thermal energy source. Some eastern European systems differ in that they tap their hot water directly from the primary distribution system. As a general rule, European hot water district heating systems can transport thermal energy economically and with low energy losses up to 50 mi (80 km), while U.S. steam systems are limited to a nominal distance of about 5 mi (8 km).[1] As a result, European district heating systems tend to have larger service areas and serve regions with lower heat load densities, including some with single-family residences. Fossil-fueled cogeneration plants are the primary source of thermal energy for European district heating systems, however, nuclear dual-purpose plants are also being considered for integration into European district heating networks, most notably in Sweden[13] and Germany.[14] In general, it may be said that the development of district heating in Europe prior to the 1973/1974 oil crisis was economically and environmentally motivated. After that time, however, energy conservation and energy independence (decreased dependence on foreign oil) became high priority stimuli for European district heating growth.[12] The remainder of this section will discuss district heating programs in several European countries that have made significant progress.

4.1 The Soviet Union

The Soviet Union is the world leader in cogeneration/district heating systems application, with an estimated total connected thermal capacity of 493,850 MW(t) in 1975.[12] It is estimated that 70% of the Soviet Union's urban heat demand, and 54% of its entire space and hot water heat load is met through district heating.[10] Moscow, Leningrad, Kharkov, Kiev, Minsk, Rostov, and many other Russian cities have extensive district heating networks. Approximately 60% of the district heat in the Soviet Union is supplied by cogeneration plants.[10] For example, in 1974 it was reported that the Soviet Union was operating over 1000 cogeneration plants that supplied thermal energy for heating to over 800 cities.[15] Most of these cogeneration plants were of relatively high capacity. It is also interesting to note that, in 1977, 35% of all Soviet electric power plants were operating in a cogeneration mode.[16] Nuclear cogeneration is also gaining prominence in the Soviet Union. A small nuclear cogeneration plant is located at Bilibino located in eastern Siberia 100 km north of the Arctic Circle. This 48 MW(e) plus 116 MW(t) cogeneration system supports a community of 15,000 people.[17] The Soviet Union is also planning to build nuclear cogeneration plants in the vicinity of Moscow with an overall capacity of 2000 MW(e) plus 2092 MW(t) (7.14 billion Btu/hr).[16] The centrally planned economy of the U.S.S.R. has enabled them to construct large-scale electric power/thermal energy plants. This is possible because location, size and composition of a new community, including the integral planning of industrial complexes, is basically done by government institutes located in Moscow.

4.2 Finland

The first five district heating systems, and the first cogeneration plants were built in Finland in the 1950s. By the end of 1975, 17% of Finland's inhabitants were connected to a district heating system.[18] By the end of 1976 there were 40 Finnish communities being served by district heating systems. These systems had a total installed pipeline length of 1276 km and delivered 9850 GWh of heat to Finnish consumers. Of that total thermal energy supplied to consumers, approximately 60% was produced by cogeneration. Today, every Finnish locality with at least 30,000 inhabitants has a district heating system. Also, new buildings constructed in localities served by district heating are, almost without exception, equipped with central space heating and common hot water heating equipment suitable for connection to the district heating system.

The Helsinki hot water district heating system started operation in 1957, and cogeneration providing thermal energy for that system began in 1960.[19] When the system began, there were approximately 220 district heating consumers. By the end of 1979, this number increased to just under 5000 consumers, which represents approximately 70% of the potential district heating consumers in the city of Helsinki. The system is still growing and this figure is expected to exceed 85% by 1990. Total heat sales in Helsinki at the end of 1979 were 4863 GWh (16,593 billion Btu). Also, at the end of 1979 the total heat and electric power generating capacities of the Helsinki system were 2093 MW(t) (7.14 billion Btu/hr), and 585 MW(e), respectively, and the total length of district heating pipelines was 505 km. It is reported that the Helsinki hot water district heating system is the largest one in western Europe today.[19]

4.3 Sweden

Up to the end of the 1940s, electric power generation in Sweden was primarily based on hydro-electric power. As electrical energy demand increased, the point was reached where no further exploitable sources of hydro-electric power were available, and the alternatives were either to purchase electric power or to build steam power plants. Although there was some initial resistance by the government State Power Board, the most economical approach proved to be the combined generation of electric power and thermal energy by cogeneration. So district heating systems were established in Sweden in order to utilize that country's heat demand as a basis for economical electric power generation in cogeneration plants. During the 1960s many Swedish towns installed district heating systems, and by 1970 it had proven itself as a sound economic alternative to individual building heating. As a result of Sweden's growing environmental consciousness, environmental protection also became a further stimulus for district heating development. The 1973/1974 oil crisis provided a final argument in favor of cogeneration/district heating based on its high fuel conversion efficiency.[20]

Today, over 40% of Sweden's total energy consumption goes for space and hot water heating, and almost 25% of that heat demand is met by district heating. In 1978 there were more than 50 district heating systems in operation in Sweden.[2] Today Sweden has a total connected thermal power demand of approximately 12,000 MW(t), and by the year 2000 this figure is expected to go as high as 30,000 MW(t).[20] Sweden has no domestic fossil fuels, and at the present time, about 70% of its total energy demand is supplied by imported oil. Sweden's cogeneration plants are almost entirely dependent on oil. Nevertheless, because of their high fuel conversion efficiency, cogeneration plants provide most of the thermal energy for Sweden's larger district heating systems. For example, the Malmo cogeneration plant is one of the most efficient having achieved an operating efficiency of 88%.[21] Nuclear energy is also going to play an important role in Sweden's overall energy plans, especially for the new large central power plant applications. It should be noted that Sweden was early in demonstrating nuclear district heating by the Agesta Heavy Water Reactor commissioned in 1964. For ten years this pilot plant delivered 10 MW(e) and 80 MW(t) of heat to the suburb "Farsta" of Stockholm with a very good reliability record.[22] Sweden is also fully committed to the optimum use of its own domestic fuel resources such as wood, peat and refuse. In 1978, for example, there were 14 refuse incineration plants in Sweden burning over 600,000 tons of refuse annually and providing the heat equivalent of 1800 GW(t).[2] The projected district heating system growth for Stockholm, a city with some 700,000 inhabitants serves as a final demonstration of Sweden's commitment to district heating. In 1978, Stockholm met 27% of its space and hot water heating demand with district heating. They estimate this figure will increase to 90% by the year 2000, also, that thermal energy delivered to Stockholm for district heating will increase from its level of 2700 GW(t) per year in 1978 to 9000 GW(t) by the year 2000.[23]

4.4 Denmark

District heating in Denmark dates back some 50 years, however, it has been just during the last 20 years that it has made its greatest progress.[24] Denmark has the distinction of having the highest specific connected thermal energy capacity in western Europe; i.e., 2000 MW/million inhabitants.[12] Fifty percent of Denmark's energy consumption is for heating, and at the present time about 40% of its households are supplied with heat from a district heating network.[25]

Denmark also has the unfortunate distinction of having the highest proportion of oil usage in western Europe. In 1978, for example, approximately 88% of its total energy demand was supplied by oil.[12] For this reason, Denmark is increasing its use of comparatively low-heat content energy sources for district heating. Refuse incineration is a Danish specialty. Currently about 60% of Denmark's solid waste is used to provide thermal energy for district heating, which is equivalent to supplying about 5% of this country's total heat demand.[25] A future goal is to incinerate 75% of its domestic and industrial waste materials for district heating applications. Denmark also considers the use of nuclear power as an economically feasible means of ensuring that its future electrical and thermal energy demands are met.

4.5 West Germany

Germany can trace its district heating roots back to 1893 when the first European district heating system was installed in Hamburg. Today the West German district heating network is the largest in western Europe in terms of total connected thermal capacity, which in 1975 was approximately

24,000 MW(t). At that time there were 112 utilities operating 104 cogeneration plants and 3653 heat-only boilers, and supplying thermal energy to a total of 526 district heating grids.[26] This picture changes, however, when Germany's specific connected thermal capacity is compared with that of the Scandinavian countries. For example, in 1975 Germany provided less than 400 MW(t) for heating per million inhabitants while Denmark supplied five times that amount of heat (2000 MW(t)/million inhabitants).[12] This comparatively low per capita figure, coupled with the fact that Germany only supplies heat to about 6% of its population,[10] emphasizes that Germany has great potential for future district heating development. The results of a recent German study[26] support this fact; i.e., that district heating in Germany can be quadrupled by 1990, and that district heating can meet 25% of that country's total heat demand. Another interesting conclusion of this study was that implementation of this ambitious district heating program could result in energy savings of about 425×10^{12} Btu/yr (450×10^{15} joules/yr). This, of course, is an extremely important consideration for a country that is highly dependent on imported oil.

4.6 Great Britain

Although district heating was introduced in Great Britain over 75 years ago, overall progress has been slow and the concept of a centralized home heating supply has only been a recent occurence.[27] Early system failures gave district heating a reputation of being unreliable, however, another factor that may have contributed to the slow growth of district heating systems in Great Britain is the restrictive governmental policies that have been imposed on the state-owned utilities.[12]

Regardless of this slow growth pattern, two London area district heating systems deserve mention.

The Pimlico hot water district heating system was completed in 1961 and serves about 11,000 people. Exhaust steam from two backpressure turbines supplies the thermal energy for this system, and a hot water accumulator tank is used to balance the heat load in the distribution system. The Nottingham district heating system will be the largest in Great Britain, with a total connected heating load reaching 129 MW(t) (440M Btu/hr) in 1980.(27) In 1978, it was reported that 4700 local dwellings two major commercial developments, Trent Polytechnic Institute, and many other administrative buildings, health centers, libraries, etc. were connected to the Nottingham system.(28) It is anticipated that by 1980 about 6000 buildings will be connected to the Nottingham district heating system.(27) Incinerated municipal waste is the primary thermal energy source supplying this district heating system. The flue gases from these incinerators generate high pressure steam in water tube boilers which in turn passes through backpressure turbines and provides the thermal energy necessary for the hot water district heating system.

5. ADVANTAGES AND DISADVANTAGES OF DISTRICT HEATING

5.1 Reducing the Consumption of Oil and Natural Gas: A Matter of National Concern

Our dependence on foreign oil is evidenced by the fact that during 1980 approximately 41% of the oil consumed in the U.S. was imported.[29] Any significant curtailment of this foreign oil supply not only threatens our national security, but also our economic stability. Foreign oil import has been a major contributor to our nation's double-digit inflation, and the U.S. international trade deficit. Few American citizens have escaped the wrath of this national dilemma.

Compounding the problem is the fact that our own national resources of oil and natural gas are presumably limited, thereby escalating them to a "premium" fuel category. In an effort to stimulate further U.S. exploration of these "premium" fuels, domestic prices are being deregulated. The consumer will bear the brunt of this costly endeavor by paying increasingly higher fuel prices. No doubt additional sources of oil and natural gas will be discovered in the U.S., but probably not in sufficient quantity to resolve our basic national concern. Several options are available to reduce our dependence on foreign oil and to control the use of our own oil and natural gas resources. [NOTE: Oil and natural gas are the fuels currently being used to supply approximately 75% of the total U.S. energy demand.][29] We can reduce the demand for these "premium" fuels through comprehensive national conservation efforts, and the use of more plentiful domestic energy sources. This includes such options as the adoption of "total energy systems" and improving the efficiency of many thermal energy end-use devices.[10]

One way to aid in resolving this national problem is to adopt an aggressive district heating program in the United States. As will be discussed in more detail later in this document, district heating offers the opportunity to use alternative and renewable energy sources (thereby reducing the consumption of oil and natural gas), as well as improving overall power plant performance by more efficient fuel utilization and conservation of thermal energy normally rejected to the environment. These conservation opportunities can be amplified tenfold when we recognize that district heating has realized less than 10% of its potential to date.

A further indication of the potential for district heating is the broad acceptance and successful implementation of district heating in Europe, the Soviet Union and recently, Japan. District heating is now used by about a third of the Swedish and Danish populations, serves 70% of Soviet urban heat demand, and is supplied in West Germany through some 474 central heating networks.[30] Much of this growth, especially in western Europe, occurred after the oil crisis of 1973/1974, when energy conservation and energy independence (decreased dependence on foreign oil) became high priority stimuli for district heating systems. If we follow the example set by our European counterparts, it is forecast that by the year 2000 the United States could be saving about 1 million barrels of oil or natural gas equivalent a day by the implementation of a national district heating program.[31][1]

5.2 Protecting our Environment and Preserving our Natural Resources

A significant amount of the sulphur dioxide and particulate matter in the urban environment originates from small predominantly oil-fired boilers supplying the heating needs of commercial buildings, industrial facilities and urban housing. These small boilers with low level stacks are usually uncontrolled sources of air pollution. A major effect of installing a district heating system is to replace a large number of these small boilers with large centralized cogeneration power plants. In general, these large power plants operate more efficiently and are better maintained than small boilers. This increased overall efficiency can be attributed to cogeneration, which is inherently much more efficient than electric-only power generation (to be discussed in more depth later in this section), and the more complete and uniform combustion of fuel which is characteristic of larger boilers.[20] This results in a significant reduction in the amount of fuel burned to meet a given thermal energy and electric energy demand, and may result in a net reduction in the amount of pollutants being discharged into the atmosphere, depending on the local fuel mix. Also, these large centralized cogeneration power plants are fitted with pollution control equipment, which not only reduces the concentration of sulphur dioxide in the urban atmosphere, but also reduces particulate emissions by collecting them at their source. Finally, with a district heating system the flue gases from these large power plants are discharged through very high stacks and dispersed far above the city. The result is cleaner street-level air;[20] however, these pollutants may be exported to some distant location where they can again have an adverse environmental effect such as "acid rain".

Experience in Sweden has proven that substantial reductions in sulphur dioxide concentrations can occur in cities employing district heating.[32] For example, Stockholm, when it started its district heating system in the 1950s, had an average annual sulphur dioxide concentration of 200 micrograms per cubic meter (200 $\mu g/m^3$). In 1980, these concentrations were reduced to about 120 $\mu g/m^3$. By the year 2000, when the system will be completed, it is anticipated that the sulphur dioxide emissions will be reduced to about 40 $\mu g/m^3$. This represents a fivefold reduction in air pollution in Stockholm, and is half of the current U.S. health standard of 80 $\mu g/m^3$.

Conventional electric-only power generation plants discharge large amounts of thermal energy either into the air or the water. If the power plant condenser uses ambient cooling water from a local river, lake or other water source, then the heated discharge is dispersed into these nearby waters. Power plant environmental impact statements have literally devoted hundreds of pages to the discussion of fish protection. There is genuine concern in our society today over the protection of aquatic life from power plant thermal pollution. Some of the concerns being addressed are: What are the impacts on aquatic organisms passing through power plant cooling systems or exposed to heated water discharged by the power plant facility? What impacts can result from discharge of cooling system treatment chemicals such as chlorine to a receiving body of water?[33]

More recent emphasis is being given to "cooling tower drift". Because drift from power plant cooling towers deposits undesirable salts and treatment chemicals on land, there is increased concern over the adverse environmental impact to the terrestrial area. For example, recent Oak Ridge National Laboratory (ORNL) studies have been conducted to determine the extent to which hexavalent chromium, a constituent of a corrosion inhibitor widely used in cooling towers, entered and persisted in the environment. It was found that almost 75% of this treatment chemical fell within 1 km downwind of the cooling tower from which it was discharged.[33]

These environmental concerns are significantly reduced in those communities that introduce district heating/cogeneration systems. A large quantity of the thermal energy normally discharged into the air and water is instead used to supply the thermal energy needed for a district heating system. As will be discussed in more detail in a later section, the substitution of a cogeneration power plant for a conventional power plant can reduce total system energy losses by about 43%. The net result of this large thermal energy saving is to reduce the condenser ambient cooling water requirements. It then follows that less heated water will be discharged into nearby waters, thereby lessening the environmental impact of thermal pollution on aquatic life. Also, less overall cooling tower operation will be required for heat removal, which in turn lessens any adverse environmental impact to the local terrestrial area that could result from "cooling tower drift."

In recent years the United States has become increasingly concerned about the depletion of its water resources. Installation of a hot water district heating/cogeneration system offers inherent water conservation characteristics. First, since hot water district heating systems are closed—loop, very little water loss is experienced. More significant, however, is the point that we have already made; namely, that a district heating/cogeneration plant operates more efficiently than a comparable electric-only power plant (i.e., total system energy loss to the environment is reduced by about 43%). Since less heat is rejected, the condenser cooling water requirements can be reduced, which in turn demands less cooling tower operation for heat removal. It then follows that the scaled down cooling tower operation reduces the water losses inherent in this heat transfer process. When hot water district heating systems are being considered as replacements for steam district heating systems, considerable water savings can be realized. For example, the University of Minnesota estimated that it could conserve 280 x 10^6 gallons of groundwater each year if it replaced its existing steam heating system (with a 10% condensate loss) with a hot water community heating system.[34]

Thus far we have described how a district heating/cogeneration system offers the potential to clean our air, conserve our water resources, reduce thermal pollution of our waters and reduce the adverse environmental impact of "cooling tower drift". As a final note, the introduction of a district heating system can reduce the volume of landfill requirements for the disposal of solid waste. This advantage is realized when solid waste is incinerated and the heat recovered to provide thermal energy for district heating. It is estimated that the incineration of solid waste can reduce the volume of landfill requirements by as much as 97%.[34] Furthermore, if metals and glass are recovered, and clinkers and fly ash are used for road building, the volume of solid waste requiring disposal can be further reduced.[35]

5.3 Improved Energy Production Efficiency and Flexibility

The second largest cost component of district heating is the cost of producing thermal energy at a centralized power plant. Cogeneration, the production of both electricity and useful thermal energy from a single plant, is a process that can produce relatively inexpensive thermal energy. Conventional electric-only power plants can be modified or built to incorporate the cogeneration process. The advantage of cogeneration is the greatly improved fuel conversion efficiency. The introduction of cogeneration increases the fuel conversion efficiency of a conventional electric-only power plant from about 35% to as high as 78% (see Fig. 10). This means

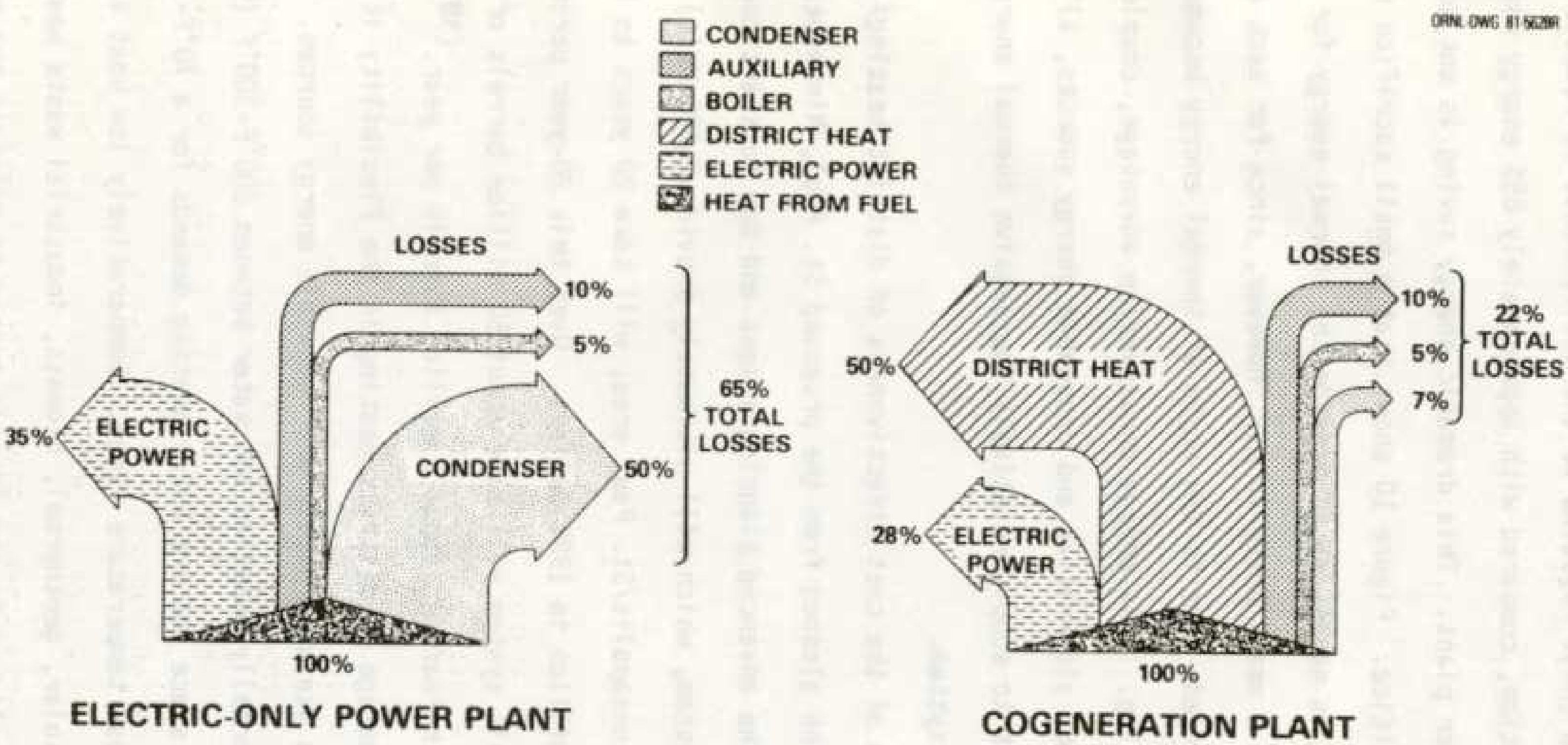

Fig. 10. Fuel conversion efficiency: conventional vs. cogeneration.

that energy wasted (heat rejected to the environment) is reduced to about 22% with cogeneration, compared with approximately 65% energy wasted in an electric-only power plant. This dramatic energy saving is not achievable without some sacrifice. Figure 10 shows that a small sacrifice of electrical energy is necessary to provide the thermal energy for district heating. This is a small price to pay, however, since for each unit of electricity sacrified, five to ten units of thermal energy become available for district heating. This energy conservation advantage, coupled with the supplemental use of alternative and renewable energy sources, allows the cogeneration plant to supply relatively inexpensive thermal energy to a district heating system.

A rough idea of the cost effectiveness of district heating/ cogeneration can be gleaned from the proposed St. Paul, Minnesota, system which is now in the advanced planning stages and due to start construction in 1982. This system, which will ultimately provide 2,600 MW(t) to a large portion of the Minneapolis/St. Paul area, will take 20 years to build and cost about $750 million in 1980 dollars. Over this 20-year period, it is estimated that this system will save about 50 million barrels of oil or equivalent, and thereafter, about 5 million barrels per year.(36)

Another advantage of district heating is the flexibility it provides to urban areas to use alternative and renewable energy sources. A district heating system normally supplies hot water between 200°F-300°F (93°C-149°C) to meet building space and hot water heating demands for a 70°F-140°F (21°C-60°C) end use temperature range. Comparatively low heat value energy sources such as solar, geothermal, biomass, industrial waste heat, and incineration of solid waste are ideally suited to maintain the moderate supply temperature range for a hot water district heating system. Thermal energy from these alternative and renewable energy sources can advantageously be used to supplement the thermal energy supplied by cogeneration.

5.4 Addressing the Needs of Urban Communities

The advantages of installing a district heating system that have been discussed thus far also provide direct benefits to urban communities. Reducing the consumption of oil and natural gas through the use of alternative and renewable energy sources makes our cities less vulnerable to the consequences of curtailment of these "premium" fuels, such as was experienced during the 1973/1974 oil crisis. Improved power plant performance through cogeneration enables more efficient fuel utilization and conservation of thermal energy commonly rejected. The dollar savings resulting from this more efficient operation can be passed on to the cities and the consumers that they serve. Finally, an improvement in urban air quality can also be the direct result of installing a district heating system. There are also several other distinct advantages of installing a district heating/cogeneration system that address specific urban community needs.

- District heating can make cities more competitive with suburban areas. Officials in St. Paul, Minnesota, estimate that by 1988 their proposed district heating system will provide thermal energy for space and hot water heating at about 50% of the cost of using oil as a fuel, and about 75% of the cost of using natural gas.(36) Cost savings such as these can be passed on to the urban consumer, making it more attractive for him to stay in the city rather than migrate to the suburbs. The resulting benefit to the city is to retain and expand both their tax and employment base.

- District heating will help stabilize heating costs for urban consumers. Without district heating, urban consumers with individual building heating systems are directly affected by rapidly escalating fuel prices and the uncertainties of fuel supply. On the other hand, district heating system customers are less affected by fuel price escalation and supply uncertainties, because only 30% of the annual cost of supplying thermal energy to them is fuel cost (see Fig. 11).

  Low-income, multi-family buildings, including public housing and the Department of Housing and Urban Development (HUD)-assisted housing, tend to be located within close proximity to the high heat demand areas which would form the core of a district heating system. Large fuel subsidies are being paid by the Federal government to tenants in many of these structures. Moreover, the rate of building abandonment due to fuel costs has increased steadily in this segment of the housing stock. District heat could relieve what will be an increasingly difficult and expensive problem for government in future years.

- District heating will provide the urban community with an opportunity to help the cities with their energy planning and management. Today many cities are not totally equipped to analyze their energy use, to make effective energy

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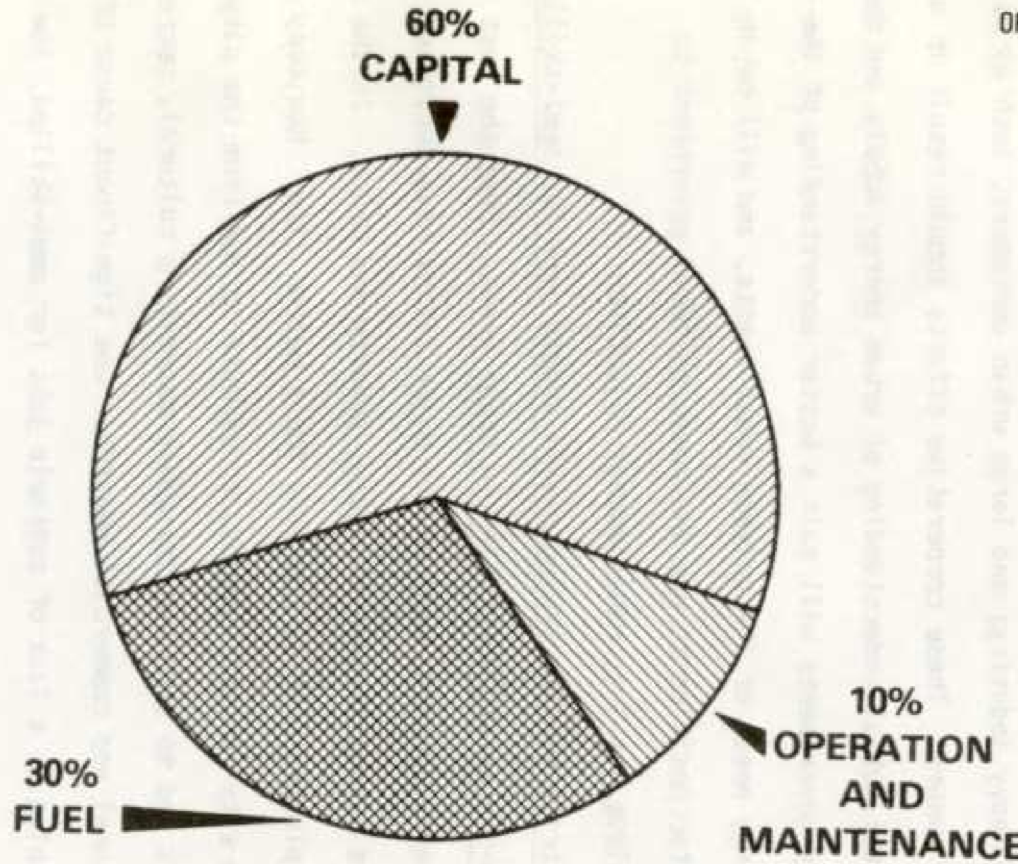

Fig. 11. Capital investment is the largest cost component of district heating.

conservation decisions, and to decide how best to develop new energy sources. Planning, building and operating a district heating system will require close cooperation among city governments; professional energy managers, such as utilities and heavy industry; and large urban consumers, such as building owners. These cooperative efforts should result in a much better mutual understanding of urban energy supply and demand. City governments will gain a better understanding of the energy needs of its private constituents, and will be in a better position to use the power of local government to achieve its long range energy objectives.

- <u>District heating projects will create jobs for semi-skilled, low-income and minorities in urban areas</u>. Over the past several decades, many of our major cities have declined, and have become centers of decay, poverty and crime. In the past, people migrated to the city for a better life. Now they leave the city for the suburbs, or commute to and from the city to work and to seek out its other short-term cultural, recreational and commercial rewards. One significant cause of this problem is a lack of suitable jobs for semi-skilled, low income and minorities who maintain their residence in the inner city. Implementation of a district heating system for a large city could easily be a billion dollar project, last for 20 years, and generate many low-skill and minority employment opportunities.

A recent economic assessment of the St. Paul District Heating Project[37] demonstrates the potential benefits of district heating in terms of providing low-skilled and minority employment opportunities in the inner city area. The initial demonstration phase of this hot water district heating project will last 5-6 years, will cost approximately $82 million, and will provide 220 MW of thermal energy for space and water heating in downtown St. Paul, Minnesota. This project also has the potential of expanding over a 20-year period to a 2600 MW(t) district heating system in concert with the sister city of Minneapolis. It is estimated by the St. Paul District Heating Project that approximately 40 persons will be employed to operate the 220 MW(t) district heating system. An additional 120 persons would be employed directly in project construction activities. If this district heating system were to stimulate an additional 1800 MW of thermal energy capacity to be completed during the 15-year period following the project demonstration phase, then one could extrapolate that roughly three times the number of construction workers (360 per year) would be employed for 15 years. There would also be a substantial increase in system operating personnel as the hot water district heating system progressively grew. This project is particularly attractive to the City of St. Paul since it will take place in the inner city, and will provide many low as well as semi-skilled job opportunities for its low income and minority residents.

A recent study by Argonne National Laboratory,[38] which compares the employment effects of a cogeneration/district heating project with equivalent coal-fired power plant and synfuel projects, concludes that the cogeneration/district heating project will be almost twice as labor intensive in the center city area. Furthermore, the cogeneration/district heating project would require greater use of low-skill labor, and aid in reducing minority unemployment in economically depressed neighborhoods by hiring resident unemployed construction workers.

5.5 Providing the Consumer with a Cost Effective Alternative

Being able to tie into a district heating system offers the individual urban consumer distinct advantages over operating their own boilers or other means of generating thermal energy for space and hot water heating. The main advantage to the consumer is clearly economic. This advantage stems primarily from the fuel flexibility aspect of district heating and the conservation of thermal energy offered by cogeneration. Both of these economic aspects have already been discussed in detail. Suffice it to say that if you can install a system such as district heating which enables you to burn less expensive and more abundant domestic fuels, and also improve your fuel conversion efficiency to greatly reduce the amount of thermal energy rejected to the environment; then the resultant cost savings can, in part, be passed on to the consumer. Summarized below are some additional advantages (which also have cost saving implications) to the consumer that connects to a district heating system.

- For new construction, there is a smaller capital investment required for the heating system, and less floor space is required for central heating equipment.
- Consumer central heating equipment is generally simpler, more reliable and requires less maintenance (heat exchanger vs. boiler).
- Consumer central heating equipment is relatively safer than using equipment fired with combustible fuels.
- For larger buildings, the staff needed to operate the central heating equipment (individual boilers) can be reduced.
- Consumer fuel-handling and storage problems, characteristic of conventional central heating equipment, can be eliminated.
- Sooting problems associated with burning oil can be eliminated.

5.6 Technical Barriers to the Development of District Heating

Although district heating was introduced in the United States over a 100 years ago and has developed slowly during this time period, it is essentially a new and basically unfamiliar concept to most Americans. Those systems that have been installed in the U.S. primarily use steam as the heat transport medium, while in Europe hot water district heating systems are primarily used. These steam systems can transport thermal energy over short distances, but become increasingly difficult and costly to operate over distances exceeding five miles. As a result, steam district heating systems are only effective in meeting the high density heat load demands encountered in the central core of cities, industrial complexes or other centralized facilities such as college campuses. Here.

lies the major technical reason why existing U.S. district heating systems have not expanded beyond these high density heat load service areas. This also explains, in part, why steam utilities have little possibility to grow with their city and run the risk of doing business in only a relatively small area.

Unfortunately some of these steam systems have been branded with a reputation for inefficient operation which has in some areas created a negative public feeling toward district heating. Some of this negativism is well deserved. Statistics reveal a wide range of system losses (send-out minus metered sales) attributable to such causes as metering inaccuracies, no condensate return, deteriorated insulation and leaks of one sort or another.[11] Also steam measurement is in general of marginal accuracy and reliability, and probably needs the emphasis of a major research program. On the other hand, steam district heating has some inherent technical disadvantages which should <u>not</u> be charged to the steam utility as operating inefficiency. These include: limited maximum distribution range, large temperature losses, large water losses (especially when no condensate is returned), and higher costs due to steam trap maintenance and corrosion of condensate pipe.[2]

In addition to the barriers discussed above, there are several other technical disadvantages which impede the current district heating implementation efforts in the United States:

- A relatively small application of steam district heating in the U.S. has impeded the emergence of a mature state-of-the-art technology. In Europe, district heating system materials, system components and construction technology has developed to keep pace with the rapid growth of district heating.

- o Specific district heating system components such as thermal energy metering devices are still relatively expensive when compared to comparable equipment used in other energy systems.
- o A hot water district heating system has limited application to cooling systems. While a steam system will allow both steam-turbine-driven chillers and absorption chillers to be operated, hot water systems allow only certain types of absorption chillers to be used.[4]
- o During the early phases of operation, cogeneration may present the utility operator with load management problems when trying to meet competing demands for both electrical and thermal energy.
- o District heating piping system installation may cause limited disruption in urban areas, but no more so than with any other public utilities project.

5.7 Institutional Factors that Impede the Implementation of District Heating

One of the major disadvantages of installing a district heating/ cogeneration system is the large front end capital investment necessary to install the piping distribution network, convert building heating systems, and modify existing power plants with new or retrofit equipment.[39] A recent Argonne National Laboratory study[40] estimates the total cost of delivering thermal energy to consumers in six northern U.S. cities.

These cost estimates, which are summarized below, assume that thermal energy for district heating is obtained from an existing power plant retrofitted for cogeneration.

Table 1. Total* Delivered Cost of Energy (\$/10^6 Btu)
(Based on an 8% finance rate and 1978 \$ values)

City	Low Cost	High Cost
St. Louis	5.61	12.95
Milwaukee	4.66	10.95
Washington, DC	5.15	11.52
Cleveland	4.82	11.59
Detroit	5.47	12.57
Chicago	4.66	10.14
*Average total cost -	5.06/10^6 Btu	11.62/10^6 Btu

*(Includes capital, O&M and fuel costs)

Assuming that capital costs are about 60% of the total delivered thermal energy cost (see Fig. 11); then based on the above study, the average capital cost for implementing a district heating system would be in the range of \$3 to \$7/million Btu. These cost figures compare favorably with the \$9.70/10^6 Btu total delivered energy cost estimate for the St. Paul, Minnesota District Heating Project.[41] Of this \$9.70/10^6 Btu cost figure, \$5.80 goes for capital expenditures alone (based on a \$67.3 million investment, 10% finance rate, and 1981 dollars). Although the allocation of cost varies from system to system, it is further estimated that about 55% of the capital investment goes into the transmission and distribution piping system alone (see Fig. 12).

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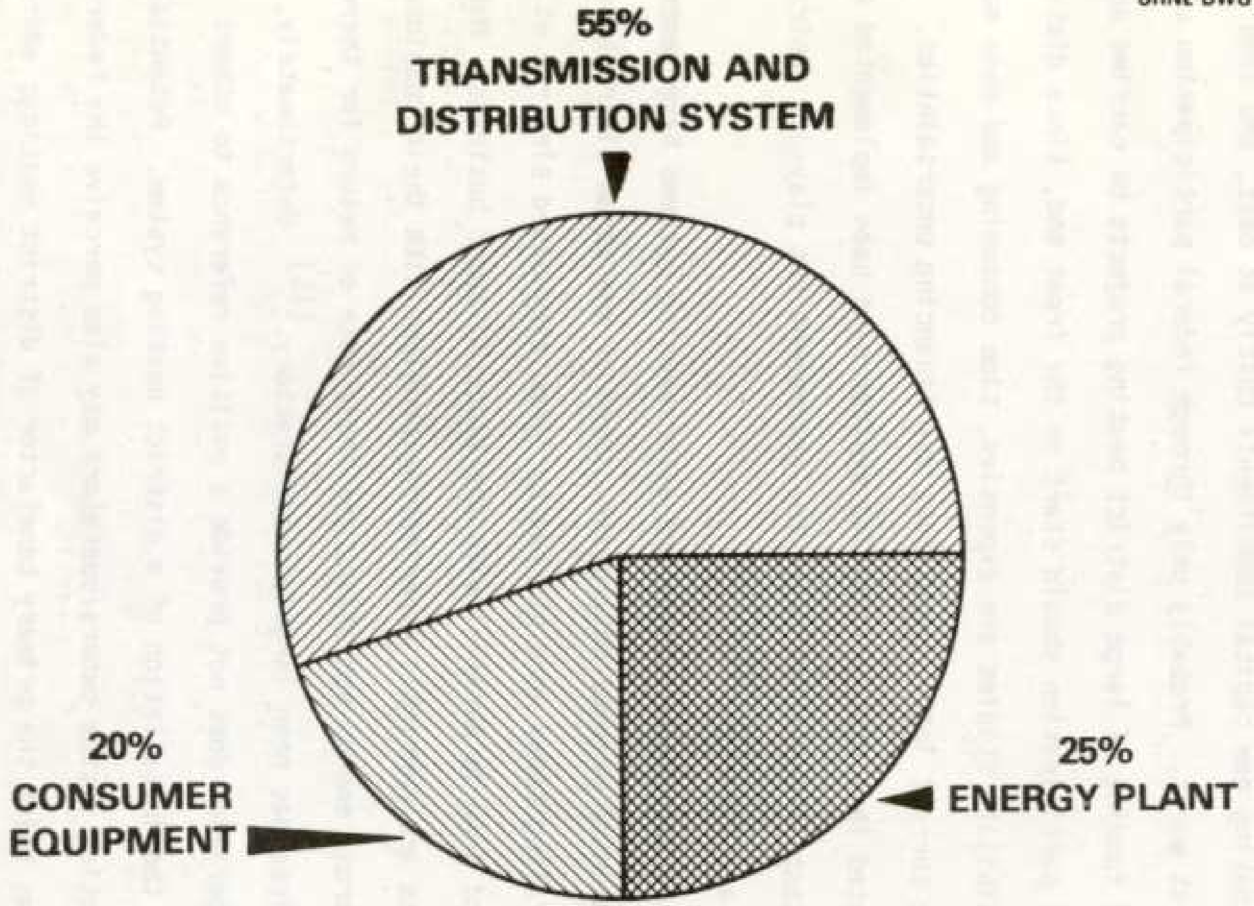

Fig. 12. Distribution piping is the largest district heating capital cost.

To finance these systems, it becomes necessary to mobilize large amounts of capital which require the involvement of many diverse groups, perhaps with conflicting interests. To compound the problem, tight money markets are making new capital commitments costly at best, and even unavailable at worst. Probably only through federal participation can the planning and funding of large district heating projects be carried out. This federal participation should start on the front end, since district heating feasibility studies are expensive, time consuming and made more difficult by current legal, regulatory and financing uncertainties. It should be noted that district heating systems have been implemented to the greatest extent in countries where the government has played a central role in planning and finance.[10]

In the United States, space and water heating systems have generally been the domain of private enterprise. Most of the steam district heating systems operating today were started by large city-based electric utility companies and grew in parallel with the electric power business. Many of these systems are currently experiencing problems with their combined electric/thermal energy operation, and their rate of return for thermal energy services has been largely unsatisfactory.[11] Unfortunately, our U.S. experience does not provide a positive reference to others considering the installation of a district heating system. Potential district heating system owners/operators may also perceive the Federal government as being the primary benefactor of district heating; addressing national issues such as reducing our dependency on foreign oil, cleaning up our environment and reducing our balance of payments. The question then arises: How much financial risk is private enterprise willing to take to be a "patriot" and contribute to the resolution of national issues? In reality, the potential district heating system owner/operator must visualize a clear profit which offsets any financial risk involved.

A recent survey(42) was conducted to review the current state of utility owned district heating systems in the U.S. The conclusions reached by this survey indicate a generally negative electric utility management attitude toward district heating:

"U.S. district heating systems use steam system technology which has higher costs than the European type of hot water systems.

- o From a utility standpoint, the manpower and cost required for management of these systems are large relative to the return on investment or as compared with a similar effort on the electric operation.
- o The cost of installation of the district heating distribution system is viewed as the largest economic impediment to revitalizing or building new district heating systems.
- o Although hot water systems appear technologically superior to steam for district heating, the European district heating experience is not directly applicable to the U.S. because of differences in environmental regulations, subsidies, requirements (in eastern Europe) for customer hookup, and greater oil dependence in Europe for heating."

This survey[42] further elaborates some of the specific reasons why these utility managers are generally unenthusiastic about their current steam-supplied systems which are either unprofitable or marginally profitable ventures:

- o "Competition from electric and natural gas heating and on-site boilers;
- o High cost of distribution piping (up to $1500 per foot) and man-holes (up to $25,000);
- o Unfavorable tax structures and delays in obtaining rate relief from regulatory agencies;
- o Fuel-use restrictions due to environmental regulations;
- o High distribution losses, typically averaging 15% of sendout;
- o Low system load factors, typically averaging only 33%;
- o High cost of converting distribution from steam to more efficient hot water;
- o Excessive amount of executive management time required for district heating systems relative to net income generated."

This picture is not really as bleak as it may seem. There are a number of utilities actively exploring or implementing district heating projects:[36] Northern States Power in two Minnesota cities; Detroit Edison in Detroit, Michigan; United Illuminating in Bridgeport, Connecticut; Potomac Electric Power Company (PEPCO) in Washington, D.C.; Public Service Electric and Gas in northern New Jersey; and many municipal utilities in smaller communities.

The fact that current Federal policy does not support district heating is evident from the following examples:[36]

- Neither tax-exempt revenue bond financing above the small issue Industrial Development Bond (IDB) limit nor investment tax credits are available for district heating piping distribution networks under current law. A high percentage of the capital cost (approximately 55%) lies in the transmission and distribution piping, which at present does not qualify for either tax-exempt revenue bond financing above the $10 million dollar small issue limit or investment tax credits. An amendment to the windfall profits tax, which would have provided unrestricted tax-exempt financing for district heating piping, was eliminated in the conference committee. This is a serious impediment because many cities, particularly distressed cities, often cannot and probably should not use general obligation tax-exempt bonding for these systems. Although projects can be built using utility financing, they will necessarily be more restricted in scope, concentrating on areas of high demand and utilization, and the community will not receive the maximum benefit.

- The applicability of the Environmental Protection Agency (EPA) "bubble policy" to district heating/cogeneration is not clear. Utilities would have considerably greater incentive to get involved if credit for reduced building emissions could be applied against increased power plant emissions. For example, PEPCO, in a letter to EPA dated March 18, 1980, proposed to retrofit its coal-fired Potomac River Generating Station with thermal extraction equipment and supply steam to the Government Service Administration (GSA) district heating system, thereby minimizing use of oil-fired heat only boilers and reducing particulate emissions. PEPCO asks that the "bubble policy be applied to permit it to switch the Benning plant from #4 and #6 fuel oil, which would save the utility about $3 million a year and still leave a net reduction in particulate matter. EPA has not, to our knowledge, ruled on this matter. An important issue here is whether EPA will permit an offset for reductions in uncontrolled, and thus uncounted, building emission sources.

- o <u>DOE-Economic Regulatory Administration (ERA) policy does not encourage district heating/cogeneration</u>. There are a number of incentives which could be included in the final Fuel Use Act regulations. For example, in the cogeneration exemptions, applicants that are supporting district heating projects could be given priority. In the fuel allocation area, incentives could be given to community cogeneration systems by providing priorities in the allocation of natural gas.
- o <u>DOE-Federal Energy Regulatory Commission (FERC) policy does not encourage district heating/cogeneration</u>. The Federal Energy Regulatory Commission could influence utility participation by working with state public service commissions to allow fuel adjustment clause pass throughs only to utilities which are making efforts to conserve scarce fuel by implementing district heating systems, where feasible and cost effective. It could permit cost of work in progress to be included in a utility's rate base for cogeneration equipment and district heating facilities.

Several other institutional issues may create an unacceptable risk and serve as a deterrent to the development and implementation of district heating/cogeneration systems:[43]

- o Although procedures exist in some states, there is generally no legally defined methodology and procedure for allocating costs to electrical and thermal energy obtained from privately owned cogeneration power plants.
- o There is no long range permitting processing that will provide reasonable assurances of completing long range system development objectives.
- o There is concern that initial regulation of new systems by a Public Service Commission could possibly result in excessive administrative costs and a loss of operating flexibility.
- o There are no clearly defined controls to ensure that a district heating system thermal energy supplier (such as a local industry) will meet their supply commitments on a continuing basis to ensure efficient overall system operation.
- o A significant time period may exist between the construction of the system and the establishment of a sufficient customer base to achieve economic system operations.
- o Potential consumers are reluctant to make the front-end capital investment to convert existing building heating systems to connect to a hot water district heating system.

6. SUMMARY AND CONCLUSIONS

The proper application of district heating can contribute to achievement of national conservation, environmental, and social objectives. District heating offers important advantages that not only address national concerns, but also result in benefits to the urban community and its constituency; i.e., improved air quality, reduced consumption of oil and natural gas, and inner city employment opportunities, to mention only a few. District heating is basically a well developed and technically sound concept. Minor technical barriers can readily be overcome with the adoption of a national district heating program. Conversely, it appears that financial, regulatory, and other institutional issues are the major factors that currently impede the wide spread or national implementation of district heating. In balance, however, the advantages of district heating appear to outweigh the disadvantages.

The history of district heating in the United States dates back to 1877, and emphasizes the role of electric utilities in the development of steam district heating systems. Unfortunately, this history also records the fact that many of the older U.S. steam district heating systems have been branded with a reputation for inefficient and only marginally profitable operations. European district heating, on the other hand, did not develop to any significant degree until the 1950s. However, during the past 30 years, the development of hot water district heating in both eastern and western Europe has been rapid and is distinguished by its many operational successes. Future U.S. district heating development and implementation should capitalize on this successful European operating experience with hot water district heating systems.

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