Chapter 8

Prospects for District Heating

Chapter 6

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Philadelphia Burner Retrofit

Although a common energy problem in many low-income residences is an inefficient oil burner, the weatherization program has traditionally focused on insulation and storm windows. A pilot program sponsored by DOE in Philadelphia was developed to test a feasible means of upgrading the efficiency of heating equipment on a large scale.[53] Instead of recruiting and training unskilled and semiskilled workers in carpentry and insulation skills, the program enlisted the experience of fuel oil dealers, many of which already perform maintenance on furnaces and boilers.

In the pilot effort, 30 fuel oil dealers in the Philadelphia area retrofitted 145 oil-burning furnaces in Philadelphia during the winter of 1980-81. They installed flame retention burners, corrected unsafe conditions in the heating system, cleaned flue passes, installed clock thermostats, and conducted an instrumented furnace tune-up. The average cost of each job was $500 and payback was expected in 2 years. On average, furnace efficiency increased by 15 percent, consistent with a predicted fuel savings of **20** percent. The program was designed as an alternative or supplement to using low-income energy assistance funds for weatherization or for direct subsidies.

[53] Department of Energy, "Maximizing Energy Assistance to Low-Income Americans: A Pilot Project to Increase Benefits Through Furnance Retrofits," draft paper (undated), and "Increasing Benefits of Energy Assistance Programs Through Oil Furnance Retrofits," July 1981.

In addition to these two prototype programs, there have been other successful approaches to promote weatherization on a wide scale. In Pennsylvania, the State weatherizes homes at a rate of about 1,200 to 1,400 homes a month, more than any other State, and each year about 14,000 homes are weatherized (see ch. 9). California expects to use Vietnam veterans in its California Conservation Corps to promote weatherization in low-income neighborhoods.

These programs are a worthy start, but they still beg two critical questions that must be answered before the energy needs of the poor are truly addressed. One is the linking of energy retrofit to overall housing condition improvement; the other is improving the energy efficiency of rental units, particularly in large multifamily buildings. On the first count, progress is beginning to be made. Philadelphia, Baltimore, and Pittsburgh have all geared local rehab programs in part to encourage energy retrofits (described in ch. 9). Energy conservation requirements and incentives in HUD programs, such as section 312, section 8, and CDBG-sponsored rehab are also helping to encourage retrofit.

Improving the energy efficiency of rental housing, however, is much more elusive. Except for the Fitchburg campaign there have really been no programs that have reached rental housing in a community in any large-scale fashion. And until this happens, a large percentage of the urban poor will continue to live in energy-inefficient buildings and pay more for energy than is necessary or that they can afford.

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Chapter 6
Prospects for District Heating

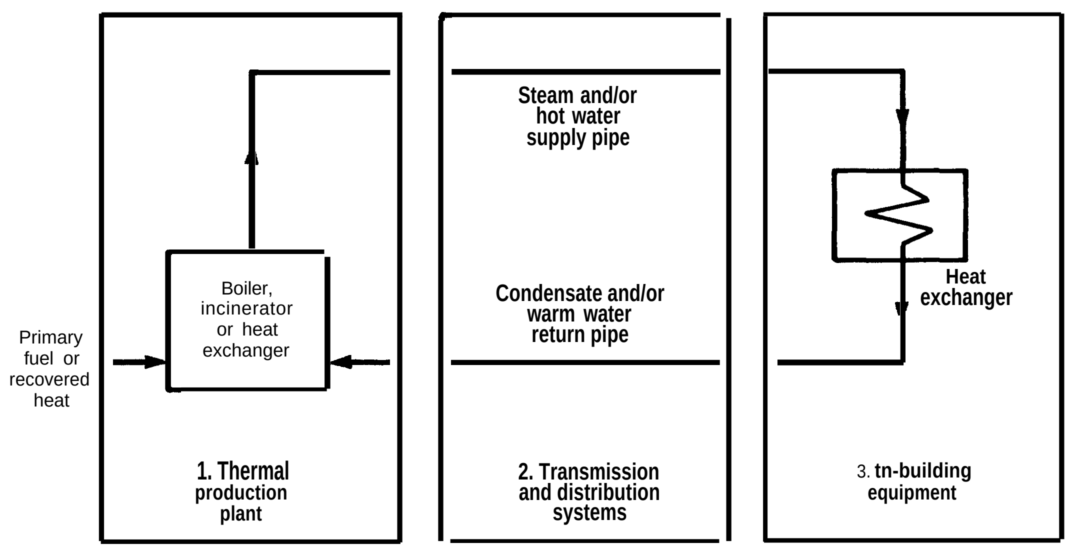
INTRODUCTION

A discussion of the energy efficiency of buildings in cities is not complete without a discussion of district heating, a system that distributes heat in the form of steam or hot water through a piping network to buildings for space and water heating, or industrial process heat (see figs. 42 and 43). The heat may come from any of a wide variety of sources: waste heat from electric generation, centralized burning of coal or oil, solid waste combustion, or solar or geothermal energy. Under the right conditions, a well-managed district heating system is an energy efficient way of supplying heat to city buildings. As will be shown later in the chapter, the high density characteristic of central cities is almost always an essential requirement for an economically viable district heating system although such high density can occasionally be found in suburban office/shopping complexes, or university campuses outside central cities.

From a national energy perspective, district heating offers, under the right conditions, an opportunity for saving fuel oil or natural gas by using them more efficiently, or an opportunity to shift to greater use of coal or renewable resources (including municipal solid waste) for supplying heat to buildings. For district heating customers it offers the prospects for slower increases in energy prices. For local governments, district heating can be a tool in the overall task of economic development since it uses local workers for construction and operation, helps attract new development to central city locations and helps to stabilize energy prices for existing buildings. For a utility, a district heating system may provide a way of making money off waste heat from a downtown powerplant, or adding a new product in a time of slower growth in electricity sales.

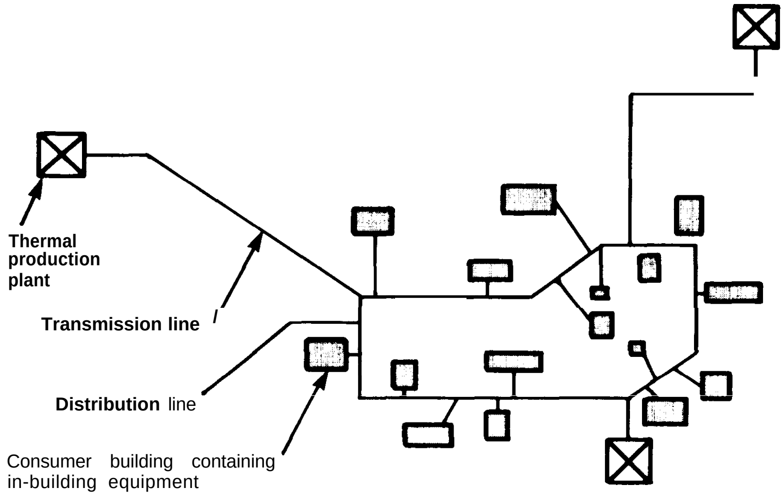
For all the possible advantages of district heating, the design, construction and successful operation of a district heating system is a formidable undertaking whose complexity should not be underestimated. This chapter discusses the

Figure 42.—Three Major Components of a District Heating System



SOURCE W. Pferdehirt and N Kron, Jr , "District Heating From Electric Generating Plants and Municipal Incinerators: Local Planner's Assessment Guide, " Argonne National Laboratory, Argonne, Ill., Energy and Environmental Systems Division for the U.S Department of Energy, prepublication copy, AN L/CNSV-1 2, November 1980.

Figure 43.—Schematic Layout of a Simplified District Heating System



SOURCE: W. Pferdehirt and N. Kron, Jr., "District Heating From Electric Generating Plants and Municipal Incinerators: Local Planner's Assessment Guide," Argonne National Laboratory, Argonne, Ill., Energy and Environmental Systems Division for the U.S. Department of Energy, prepublication copy, AN UC NSV-12, November 1980.

conditions for success of a district heating system both from the perspectives of a city or State government or utility developing and financing a district heating system and from the perspective of future customers who are invited to hookup to such a system.

CONTEXT FOR U.S. DISTRICT HEATING IN THE 1980's

District heating in the United States is not a new idea. The first district heating system using a central heat source connected to a steam pipe was constructed over 100 years ago in Lockport, N.Y. Beginning in the 1890's there was a rapid growth of district heating systems using exhaust steam from noncondensing steam-electric powerplants to heat buildings in nearby business districts. Changes in electric generating technology, however, soon reduced the opportunities for district heating as electric generating plants grew larger, with smaller generating losses, and were moved further from densely settled areas.

As small close-in generating plants were closed down, many district heating systems lost their sources of inexpensive waste heat and had to rely on far more expensive steam-only plants. Prices for steam increased and drove away customers. By the late 1920's, economically failing systems began to close; the decline continued through World War II as inexpensive oil and natural gas became available for heating purposes.

Since then, the number of district heating systems in the United States has remained relatively stable. Fifty-nine of them were recently surveyed in a study for the Electric Power Research Institute (EPRI).[1] (The study excluded the many systems serving military bases, university campuses, and industrial parks.) The four largest U.S. systems (in New York, Philadelphia, Detroit, and Boston) and some other typical systems are shown in table 55.

The statistics in the table tell a sad tale. Only Boston Edison earned a minimally adequate return on fixed assets of 10.3 percent in 1978. Baltimore Gas & Electric earned only 1.8 percent and Detroit Edison lost money on its system.

[1] "Dual Energy Use Systems–District Heating Survey," prepared by EUS, Inc., Pittsburgh, Pa., with Hittman Associates, Inc., Columbia, Md., for the Electric Power Research Institute, EM-1 436, July 1980.

Table 55.—Cities That Already Have Steam Systems

City	Ownership of system	Percent of steam produced by cogeneration	Most recent peak steam sendout (10^3 lb/hr)	Losses in system, percent	Number of customers	Fuels used, percent: Coal	Fuels used, percent: Resid. oil	Fuels used, percent: Natural gas	Return on fixed assets, percent	Current average (1978) price of steam ($/$10^3$ lb)[b]
New York — Consolidated Edison. , ...	Investor	55	11,663 actual (14,983) maximum possible	16	2,285	0	99	1	7.4	6.76
Chicago — Commonwealth Edison.	Investor	(Closed July 5, 1979 – last 4 customers disconnected)								
Philadelphia — Philadelphia Electric	Investor	70	2,431 (3,857)	12	670		100		5.8	5.84
Detroit — Detroit Edison	Investor	38	1,724 (2,931)	18	843	4	9 (#2)	87	– 7.0	5,26
Boston — Boston Edison	Investor	0	1,975 (2,340)	21	465		76	24	10.3	7.05
Baltimore — Baltimore Gas and Electric . . .	Investor	0	819 (990)	14	720		49 (#2)	51	1.8	5.47
Indianapolis — Indianapolis Power & Light.	Investor	46	1,428 (1,722)	15	703	91	8 (#2)	1	4.5	4.21
Lansing — Lansing Board of Water & Light	(Large) municipal	0	260 (400)	12	488	100			— (**loss** of $245,000 in 1978)	3.66
Virginia, Mlnn. — Virglnla Department of Public Utilities	(Small) municipal	79	266 (270)	42	3,301 (70 percent connection)	100			75.0[a]	4,70
Piqua, Ohio — Piqua, Ohio Municipal Power System .	(Small) municipal	100	42 (80)	6.5	8	100			Not available	2.10

[a]They do not include generating plant in net assets of the steam system — they allocate it to the electric system
[b]One thousand lbs of steam has a heat content of about 1 million Btu

NOTES ‘Four largest systems in the United States are New York, Philadelphia, Detroit, and Boston New York is by far largest in the United States and is one of the largest in the world
²Baltimore is a successful system with predominantly commercial customers
‘Indianapolis is a successful system with a large number of industrial customers
‘Chicago s system has been closed, they lacked Interest in D/H and cogeneration and pushed electric heating in new buildings and nuclear power

SOURCE “Dual Energy Use Systems — District Heating Survey,” prepared by EUS, Inc , Pittsburgh, Penn , with Hittman Associates, Inc Columbia, Md for the Electric Power Research Institute, EM 1436, July 1980

The Chicago system closed down in 1979. System losses are high; little advantage is taken of waste heat from cogeneration or coal generation of steam. Many rely heavily on expensive oil or natural gas for steam production. Despite the low rate of return, steam in most systems had a price that made it considerably more expensive than natural gas or heavy fuel oil in 1978 even assuming that the steam was used more efficiently.[2]

There is a more discouraging note, however, that is not revealed by the statistics in table 55 but which can be illustrated by the last decade of operation of the Consolidated Edison (Con Ed) steam system in New York City, “the largest cogenerator of electricity and byproduct steam in the non-Communist world,”[3] Between 1970 and 1978 Con Ed lost 12 percent of its customers and 17 percent of its peak sales volume (in 1972). Over the same period the company raised the price for steam by 345 percent while the price for No. 2 home heating oil increased

[2]Assuming 80 percent efficiency steam at $5 per ton would produce heat at about $6.25 per million Btu. At their 1978 average prices (according to the *DOE Monthly Energy Review*, April 1981) comparable prices for heat assuming 60 percent efficiency would have been: natural gas $4.43 per million Btu; No. 6 heavy fuel oil $3.37 per million Btu; and No. 2 light fuel oil $5.93 per million Btu.

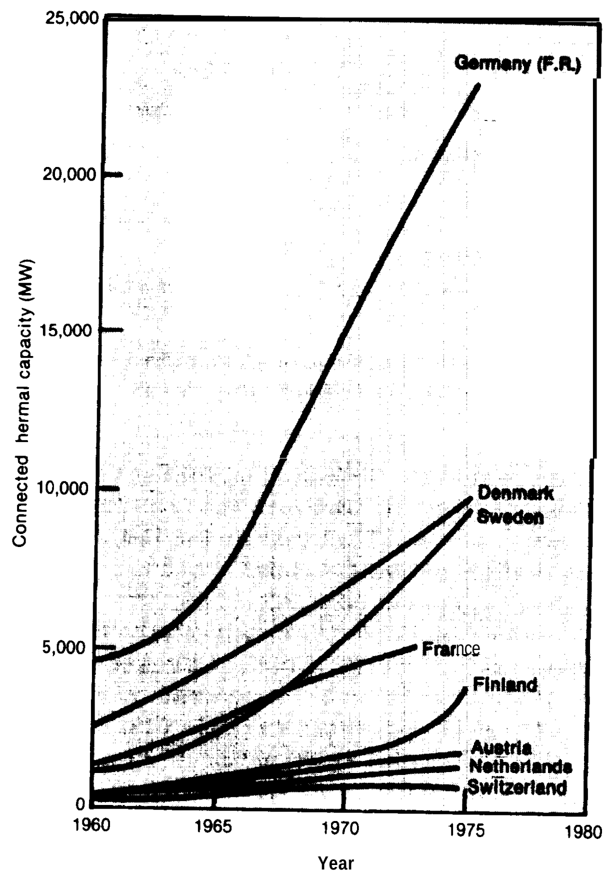
[3]Edward F. Renshaw, “Public Utilities and the Promotion of District Heating,” Public *Utilities Fortnightly*, July 17, 1980.

by 173 percent, Relative to fuel oil the Con Ed system lost substantial competitive ground.

The experience in Europe with district heating has been completely different, Countries in both Western and Eastern Europe have greatly increased their district heating capacity since 1960, as can be seen in figures 44 and 45.[4] Virtually all of the European systems use hot water rather than steam to send thermal energy to buildings. Constructed more recently, they have taken advantage of improvements in technology that allow the more effective hot water systems. Sweden, with its population of 8 million people

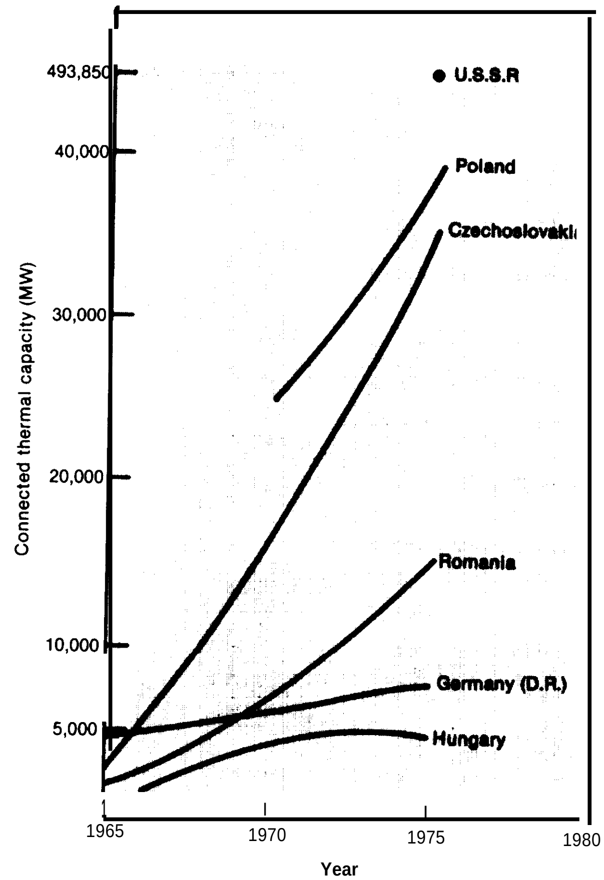
[4] *Cogeneration of Electricity and Useful Heat,* B. W. Wilkinson, and R. W. Barnes (eds.) (Boca Raton, Fla.: CRC Press, Inc., 1980).

Figure 44.—Development of Connected Thermal Capacity (Western Europe)



SOURCE: *Cogeneration of Electricity and Useful I-leaf,* B. W. Wilkinson and R. W. Barnes (eds.) (Boca Raton, Fla.: CRC Press, Inc., 1980).

Figure 45.—Development of Connected Thermal Capacity (Eastern Europe)



SOURCE: *Cogeneration of Electricity and Useful Heat,* B. W. Wilkinson and R. W. Barnes (eds.) (Boca Raton, Fla.: CRC Press, Inc., 1980).

has an installed capacity of **12,000** MW of district heating compared to the U.S. capacity of 7,400 MW. Sweden plans to almost triple this capacity by 2000, to 30,000 MW. In Sweden, as well as other Scandinavian countries, the majority of new electric generating plants are cogenerators, and urban-waste incinerators are constructed routinely to supply waste heat to district heating systems.

The greater success of district heating systems in Scandinavia and Germany than in the United States cannot be explained by differences in climate, density, or heating demand per capita. European cities where district heating has thrived are comparable to American cities where district heating either does not exist or has floundered, Stockholm is quite comparable to Buffalo; Chicago is much denser and demands more heat than Hamburg; and Detroit is quite comparable to West Berlin (see table 56).

The theoretical advantages of European-style hot water systems over American-style steam are increasingly well understood in the United States and all new systems known to be under consideration would use hot water. The advantages and disadvantages of steam and hot water systems are summarized for convenience in table 57. One of the most important advantages is that plastic transmission and distribution pipes can be used for hot water while steel pipe must be used for the higher temperature steam. Plastic pipe is itself less expensive than steel pipe, and is far easier to maintain because it does not corrode. The lower temperature of hot water and the lack of pipe corrosion also reduces the likely thermal losses of the system from the very high (15 to 45 percent) losses from steam systems to much more modest losses of 5 to 15 percent from hot water systems.[5] For this reason heat sources for hot water systems may be practical up to 70 miles from the city or industry where the hot water is to be used.

At present, no major district heating system is under construction in the United States. One downtown system, for St. Paul, Minn., is in an advanced stage of planning and is described in more detail in box K. Construction of much smaller system, in Trenton, owned by a group of private investors, is about to begin (see box L). The rest of the discussion in this chapter is based on preliminary feasibility studies for district heating systems in other major cities. Most of the analysis has been done by Argonne National Laboratory.

[5] Private communication with Tom Casten, president, Cogeneration Development Corp.; EPRI, "Dual Energy Use Systems," op. cit.; and H. S. Geller, "Thermal Distribution Systems and Residential District Heating," Princeton University Center for Energy and Environmental Studies, No. 97, August 1980.

Table 56.—Heating Degree Days (above 65° F) and Population Densities

City	Heating degree days	Total population (lo')	Population density, people/acre	Annual per capita residential space heat consumption (10^6 Btu)
1. Helsinki[a]	8,400	750	2.4	17.1
2. Minneapolis	8,400	434	12.3	42.7
3. Stockholm	8,100	750	16.2	21.8
4. Buffalo	7,100	463	17.5	36.1
5. Malmo	6,700	254	9.5	18.0
6. Hamburg	6,300	1,800	9.7	19.9
7. Denver	6,300	515	8.4	32.3
8. Chicago	6,200	3,367	23.6	31.3
9. Detroit	6,200	1,511	17.1	31.3
10. West Berlin	6,100	2,000	16.9	19.0
11. New York	5,000	7,895	41.3	25.6

[a] Metropolitan Area.

NOTE. European cities listed are known to have extensive district heating systems.

SOURCE J. Karkheck, J. Powell, and E Beardsworth, "Prospects for District Heating in the United States," *Science,* vol *195,* Mar 11, 1977, pp. 948-955

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Table 57.—Summary Chart-Comparison of Steam District Heating to Hot Water District Heating

System	Advantages	Disadvantages
Steam district heating	1. Pumps not required 2. Can be a one pipe system with no return 3. Retrofit of old urban steam buildings may be easier	1. Piping range of 1 to 2 miles, 3 miles maximum 2. If steam is extracted from a cogenerator, a great deal of electricity is sacrificed 3. Steel pipes are required — they are expensive and they corrode 4. Water must be conditioned to prevent mineralization 5. If condensate is not returned (it usually is not), water, water conditioning, and low grade energy are wasted 6. Use of high temperature steam for space heat/service water heating is a poor energy end use match 7. High heat loss during distribution (15-45 percent) 8. Piping, boiler, personnel codes are stringent; steam is not as safe as hot water 9. Installation is difficult — pitched piping, steam traps, pipe expansion, manholes 10. Maintenance costs are higher than hot water systems 11. Metering energy use is difficult 12. Very susceptible to miss-sizing or loss of large customer 13. Difficult to operate under conditions of varying load
Hot water district heating	1. Piping range of 15 miles, possibly up to 70 miles 2. Less cogenerator electricity sacrifice than for steam 3. Plastic pipes can be used — less expensive, no corrosion 4. Water need not be conditioned; if it is, closed loop anyway 5. Closed loop, so water is not wasted nor is low grade energy 6. Good energy end use match 7. Low heat loss during transmission/distribution (5-15 percent) 8. Construction/operation codes easier to meet; relatively safe 9. installation, retrofit to buildings generally easier than steam 10. Lower maintenance costs than steam systems 11. Metering energy use is relatively easy 12. Not as susceptible to miss-sizing **as** steam systems are 13. Easy to operate under conditions of varying thermal load 14. Hot water can be stored	1. Pumps are required — system balancing is important 2. System needs two pipes 3. Cannot provide high pressure steam if a customer on the circuit requires it — only can act as preheat

SOURCE: Off Ice of Technology Assessment

Box K.-A Citywide System To Be Built In Phases-The District Heating System of St. Paul, Minn.*

In July 1981, the District Heating Development Corp. of St. Paul, Minn., signed its first 30-year contract to provide 3 MW of thermal energy to a major district heating customer. If all goes well and enough customers also sign 30-year contracts, about $35 million of revenue bonds will be marketed in the winter of 1982 and the country's largest hot water district heating system will be launched.

The first phase of the project will provide 165 MW of thermal energy to large customers –State government buildings, hospitals, and private office buildings in downtown St. Paul-and is planned to cost a total of $77 million. The project is a model of public-private corporation. Of the total, $9 million will be contributed by the Northern States Power Co. to convert a powerplant to provide hot water as well as electricity. Another estimated $23 million will be spent by building owners to convert their buildings to use district hot water. Financing assistance for building owners with poor access internal funds is being arranged by the St. Paul Port Authority. The rest of the funds for the district heating system will come from the city. To supplement the revenue bonds and permit lower cost debt service there is a $7.5 million HUD/UDAG grant and a $2.5 million loan from the city. In all, the effetive debt service cost of the city portion of the financing will average about 10.9-percent annual interest.

The District Heating Development Co. is a nonprofit corporation whose board is chaired by the mayor of St. Paul and includes representatives of the Northern States Power Co., business and labor groups, customers, and State government. The chief executive officer, Hans Nyman, has experience in European district heating. Oak Ridge National Laboratory managed the initial feasibility study for the project and continues to provide technical management.

The district heating system-the design of which drew heavily on techniques developed in Europe-will use relatively low-temperature pressurized hot water (250° F) compatible with inexpensive prefabricated polyurethane pipe.

Transmission pipes for the system are large enough for a second phase construction of an additional 145 MW of thermal energy bringing the total to 300 MW. The total cost of the second phase of the system is estimated to be an additional $2 million to $3 million. There are also preliminary plans to expand the system to nearby residential areas and across the Mississippi River to Minneapolis.

*James O. Kolb, St. Paul *District Heating Demonstration Project: Economic Feasibility* and Implementation Strategy, presentation to Integrated Energy Systems Task Force Aug. 11, 1981, and conversation with Monica Westerlund of the St. Paul District Heating Development Corp., October 1981.

Box L.-A Small Cogeneration and District Heating System for Downtown Trenton*

Ground will be broken in the fall of 1981 for a privately owned cogeneration and district heating system which is expected to provide heat to 25 large buildings including the State of New Jersey office buildings and the Mercer Medical Center, a large hospital complex. The feasibility of the project was originally determined under a district heating study grant to the city from the Department of Energy. A private partnership called Trenton District Energy Co. will own the system and will be managed by another private company, Cogeneration Development Corp. Financing includes $10 million of tax-free New Jersey industrial revenue bonds, a $1 million grant from the Department of Energy, a $4 million Urban Development Action Grant (UDAG) loan at 20 years initially at 6-percent interest then adjusted to the market interest rate and the remaining $3 million to $4 million to be raised from limited partners in a syndication. The project will produce pressurized hot water at 320° to 400° F and electricity from medium-speed diesel engines designed to use both fuel oil and natural gas. The pressurized hot water will be dispatched first to customers needing low-pressure steam and then on to customers needing lower temperature hot water. The company will sell electricity to Public Service Electric & Gas at an agreed-upon price formula of electricity.

*Private communication with Tom Casten, President, Cogeneration Development Corp.

CONDITIONS FOR VIABILITY OF A DISTRICT HEATING SYSTEM IN THE UNITED STATES

Before beginning a detailed discussion of the technical and economic feasibility of district heating, it is useful to understand the framework within which a district heating system may be said to be successful. The formula for viable district heating will vary based on whether it is privately owned or publicly owned, subsidized or unsubsidized. All the subsequent economics will follow accordingly.

If a district heating system is unsubsidized and privately owned, by a utility or group of investors, it must raise all its capital in the unsubsidized financial markets, pay all operating costs without subsidy, pay all Federal, State, and local taxes on income, sales, and property and still charge a low enough price for hot water that a large enough number of customers are willing not only to buy hot water (rather than oil, gas, coal, or electricity) but also (in many cases) to retrofit their buildings so that they can use hot water (or occasionally low-pressure steam).

As in any business, planning to make this happen is a risky and tricky problem. District heating shares with some other major investments, such as new towns and mass transit systems, the characteristic that a major fraction of the **total cost is the initial capital cost before there are any revenues. Unless contracts with prospective customers are secured in advance there is no guarantee that enough customers will actually hookup to the system to cover the fixed capital costs. [n dealing with prospective customers,** not only must the hot water price be right but a hookup must be perceived as convenient and beneficial given the extra trouble of converting from one system to another system.

Nonprofit and/or subsidized district heating systems, on the other hand, can offer hot water at prices below full for-profit unsubsidized systems. Nonprofit systems can break even; they do not have to provide a return on investment. They may be exempt from Federal, State, or local taxes. The capital costs of district heating can be subsidized by using tax-free bonds such as *general obligation bonds* (backed by the taxing authority of a local government) or *revenue* bonds (to be repaid from project revenues) or by guaranteeing taxable bonds such as *industrial revenue bonds.* The subsidy will take the form of lost tax revenue to the Federal Government or increased risk to the local government. The subsidy may also take the form of an outright grant from Federal or State government to pay part of the capital costs of the district heating project,

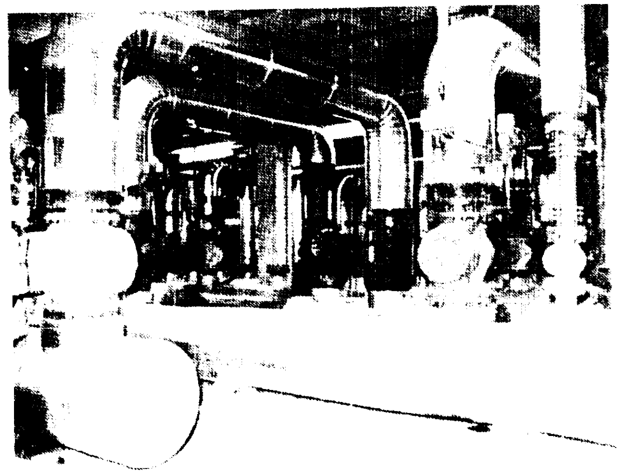
Once the district heating system has been built, however, it is the interaction among its own prices, the prices of competing fuels and its customers' preferences that determines if the system can charge high enough prices to enough customers to cover its full annualized capital cost and operating cost. A vicious cycle may set i n if the system has too few customers to cover its full costs. Raising prices to the remaining customers to makeup for the shortfall may only succeed in reducing the number of customers still further. It is this kind of vicious cycle that has befallen the Con Ed steam system and most of the mass transit systems in the major U.S. cities. Once a district heating system falls into such a vicious cycle then its operating costs might have to be subsidized at least until the prices of competing sources of fuel rise high enough to encourage new district heating system customers or bring back the defecting ones. Without a requirement for customers to hookup, the potential of just such a vicious cycle must be considered in the planning for every district heating project.

It is in this context that the capital costs, operating costs, and finance of district heating systems must be considered. If district heating systems, conventionally financed, cannot price their heat output to be competitive with oil, gas, or electricity used efficiently to run heat pumps, then they must be subsidized. The subsidy may be justified for purposes of stabilizing local energy prices, influencing local development patterns, clean air, local jobs, or saving oil imports. The size of the subsidy can be estimated and compared to the value of these potential goals.

CAPITAL COSTS OF DISTRICT HEATING

District heating is a very capital-intensive energy source which, in effect, substitutes the cost of capital for the cost of fuel. The overall capital cost and how it is financed are the major, and virtually the only, influences on the competitive viability of district heating. This is particularly true in periods such as 1980 and 1981 when high real interest rates and expected high inflation rates combine to make the costs of financing any capital investments *very* high.

As public works projects, citywide district heating systems rank among the most expensive, far more expensive than major projects to repair bridges, replace storm sewers, or replace fleets of buses. In size and scope, they are comparable mainly to mass transit projects. To place district heating in perspective, table 58 shows some estimated costs of typical urban public



b) Distributor arrangement for high-temperature water

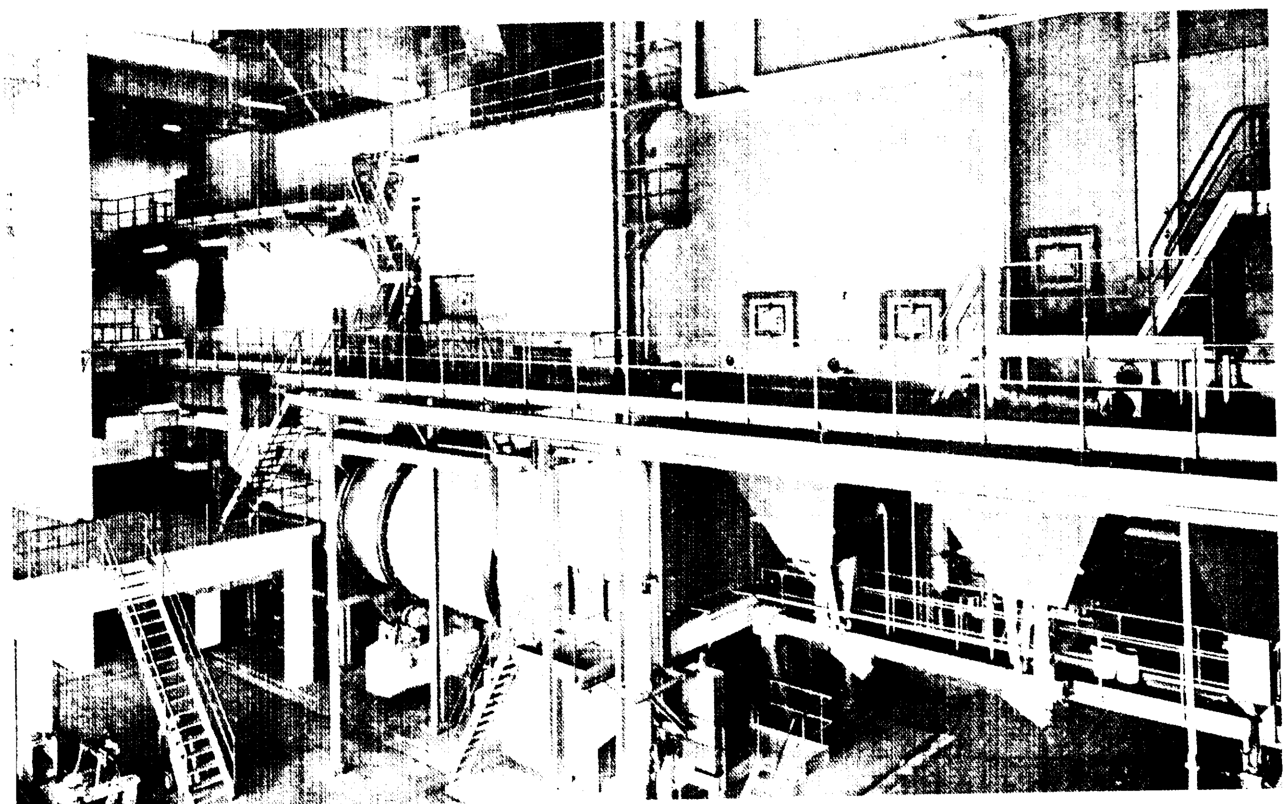
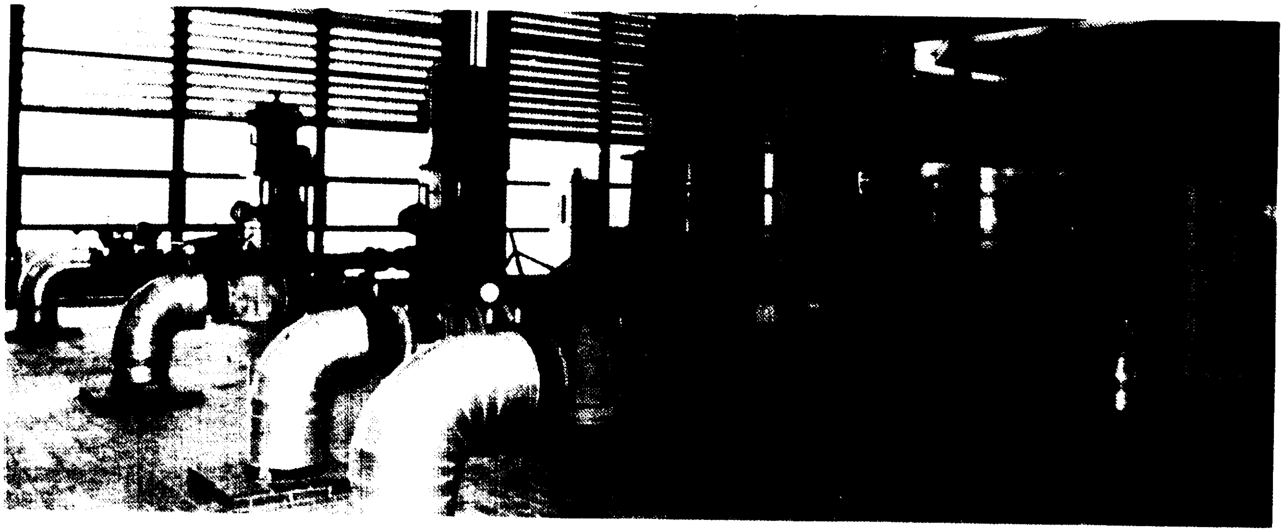
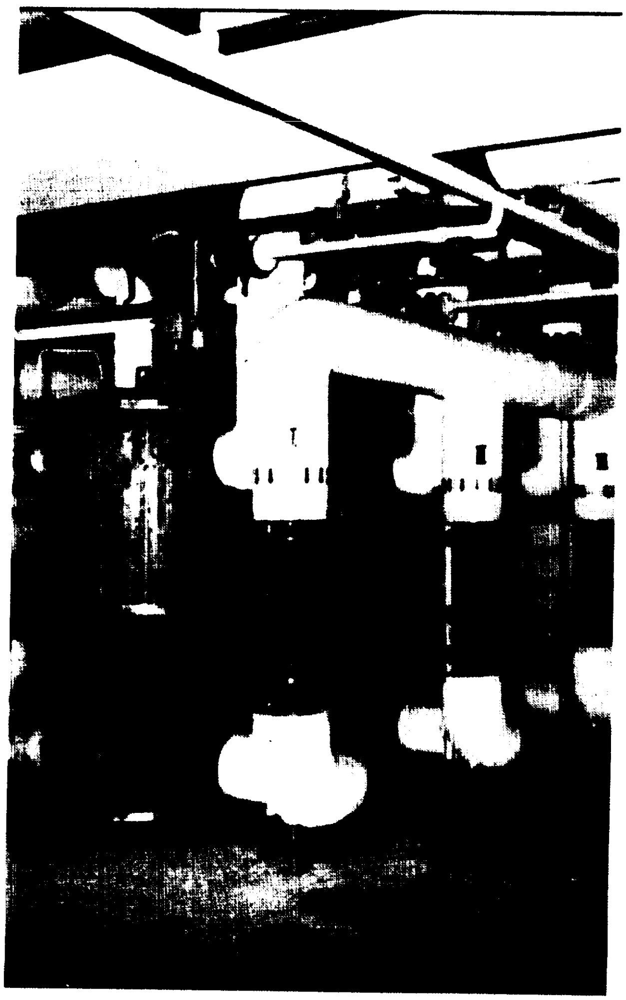


Photo credits: Ramboll and Hannemann consulting engineers, Denmark

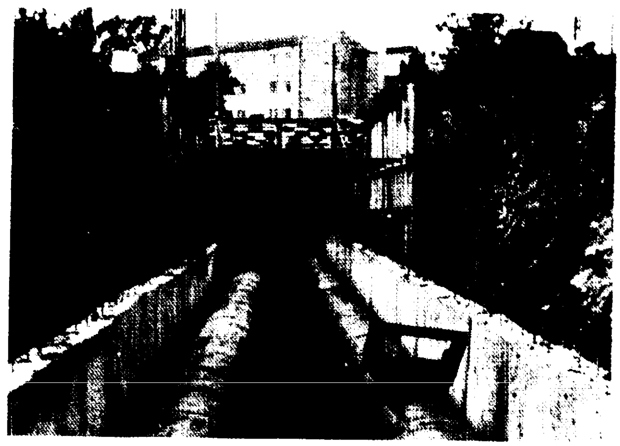
Capital equipment for a district heating system in Denmark using heat from municipal solid waste include:
a) Furnace and boiler for incineration of rubbish



c) Main pumps in heating station



d) Heat exchanger arrangement at tapping point



e) High-temperature district heating pipe during construction

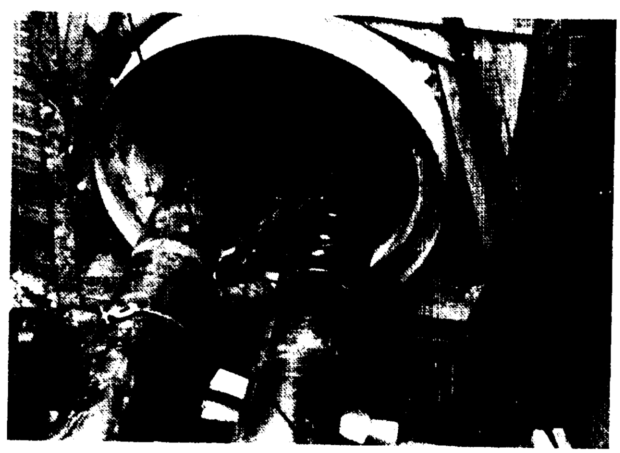


Photo credits: Ramboll and Hannemann consulting engineers, Denmark

f) Concrete duct under mainroad

Table 58.—Comparison of the Estimated Capital Cost of District Heating Systems With Other Major Urban Public Works Projects

	Capital cost millions of dollars
1. Purchasing 100 new buses for transit system	15"
2. Storm sewer budget for 5 years for the city of Tampa	18.5[b]
3. First phase of district heating system for downtown St, Paul	77'
4. Repair of the Queensboro Bridge in New York City.	120[d]
5. Waterpipe system replacement in Lynn, Mass. (170 miles)	500'
6. Buffalo, N.Y. subway system	450'
7. City-wide district heating system serving central business district plus 1 to 4 family residential area of Minneapolis-St. Paul	1,2009
8. Washington, D.C. district heating system.	895-1,985[h]
9. Cleveland, Ohio district heating system.	1,248-2,882[h]
10. Milwaukee, Wis. district heating system.	1,247-2,856[h]
11. Washington, D.C. subway system (101 miles)	8,200'

SOURCES "Telephone conversation with General Motors, Public Affairs Off Ice, Washington, D C , Mar 17, 1981
[b]City of Tampa Capital Improvements Budget for Oct 1, 19813 through Sept 30, 1986
[c]J O Kolb "St Paul District Heating Demonstration Project Economic Feasibility and Implementation Strategy, " presentation to Integrated Energy Systems Task Group Aug 11, 1981
[d]Engineering News Review, "Aging Landmark Stands to be Fixed " ENR Feature, Jan 31, 1986
'Presentation by Jack Casey, Director, Public Works, city of Lynn, to the World Bank, "On Repairing Aging Water Mains, " Jan 10, 1979
[f]Telephone conversation with Tom Murphy, Mayor's office, Buffalo
[g]Peter Margen, Kyele Larsson, Lars-Ake Cronholm, Jan-Erik Marklimo, Studsvik Energiteknik AB *District Heating/Cogeneration Application Studies for the Minneapolis/St Paul Area,* Oak Ridge National Laboratory, Oct 1979
[h]D J Santini, A A Davis and S M Marder "Economic and Technical Analysis of Retrofit to Cogenerating District System. North Central Cities, Argonne National Laboratory, Argonne, Ill ANUCNSV-TM-11, June 1979
'Telephone conversation with Metro Public Affairs Off Ice, Washington, D C , Mar 11, 1981

works projects compared with the estimated cost of the proposed St. Paul district heating system and several systems for other cities for which preliminary cost estimates have been done.

The most likely prospect for a viable district heating system is one that uses waste heat from an electric generating plant for its heat source. This section first analyzes the theoretical capital costs of a hot water district heating system that uses waste heat, partly because the most analytical work has been done on these kinds of systems. Many other sources of heat can be used, however, such as nonelectricity generating coal combustion, heat from municipal solid waste, solar ponds or collectors, and geothermal energy. Less is known about the actual and potential costs of such systems, but what is known is discussed in the next section. There is also a brief discussion of district cooling and of converting existing steam systems to hot water.

The choice of an assumption about capital recovery rate is also critical to assessing the viability of a district heating system. In the first part of this section, the capital costs of different proposed systems are analyzed assuming a *capital recovery rate*[6] of O. 1s which corresponds to the midrange of rates of return allowed for regulated utilities. This is probably the lowest capital recovery rate possible if the district heating system is to be unsubsidized and owned by private investors. In 1980-81 regulated utilities requested rates of return ranging from 16 to 18 percent.[7] Unregulated private investors typically demand higher rates of return, equivalent to a capital recovery rate of 0.20 or 0.25. Since the financing assumption is critical to the viability of district heating, there is a full discussion later in this section of the impact of assumed capital recovery factors on the annualized costs of district heating.

Components of capital cost. There are five chief components of the capital cost of a district heating system using waste heat from a powerplant:

1. The cost of retrofitting the powerplant to produce heat.
2. The cost of replacing the lost generating capacity when the powerplant is retrofitted to produce electricity and hot water. (This is not a cost for all systems.)

[6]The capital recovery rate is defined at the annual rate in which the initial Investment is amortized. It includes interest and repayment of principal and is the same each year over a fixed term. A capital recovery rate of 0.15 would amortize an investment over 20 years at an Interest rate of something over 14 percent.

[7]Edison Electric Institute "Comments," presented at the Federal Energy Regulatory Commission's *Public Conference on the Financial Condition of the Electric Utility Industry in the United States,* Mar. 6, 1981, p. 5.

3. The cost of the system of large pipes to transmit the hot water from the heat source to the general area(s) where it **will be used.**
4. The cost of the system of smaller pipes to distribute the hot water to individual customers.
5. The cost of retrofitting some buildings to use district hot water.

By far the largest of these five cost components are the transmission and distribution system costs. Together they average 55 to 60 percent of the total capital cost of possible district heating systems for nine cities as estimated by Argonne Labs (see fig. 46). For the five Midwestern cities with somewhat lower density, distribution costs were nearly double transmission costs. For the four Northeastern cities, the higher share of transmission costs reflected the generally longer distances that waste heat had to be transmitted from the powerplant sources.[8]

Not all district heating systems must include one of the five costs—the cost of replacing the lost electric generating capacity. The proposed system for St. Paul, for example, does not because waste heat from the electric: generating plant will only be used on an interruptible basis when the full generating capacity is not required. At times of peak demand for electricity, when the full generating capacity is needed, heat for the district system will be supplied from a standby boiler from the existing steam district heat system in downtown St. Paul which has been purchased by the new hot water district heating company.

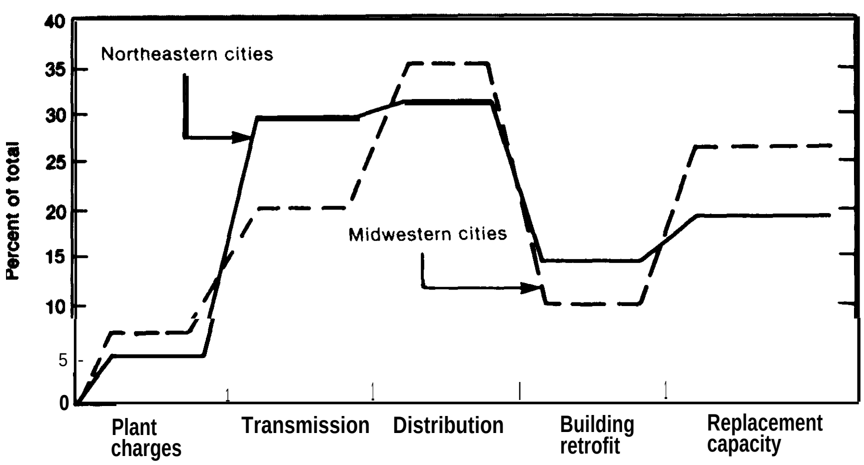
[8]The four Northeastern cities are Baltimore, Boston, Philadelphia, and Washington. The five Midwestern cities are Chicago, Cleveland, Detroit, Milwaukee, and St. Louis.

Some district heating systems may not cover all or any of the costs of retrofitting buildings to accept district hot water (or district steam). Since (as is discussed below) this is a significant barrier to building hookups, it is likely that most district heating systems will at least arrange favorable financing for building owners in order to ensure the maximum number of customers to cover the fixed cost of the system.

The rest of this section describes each of the major components of capital cost of a district heating system.

Capital Costs of Waste Heat Recovery—Plant Retrofit and Replacing Lost Generating Capacity. Waste heat recovery can be a small or a fairly large share of total district heating system cost, depending on whether much electric generating capacity is lost, and whether it has to be

Figure 46.—Components of a System Cost as a Percentage of Total Costs

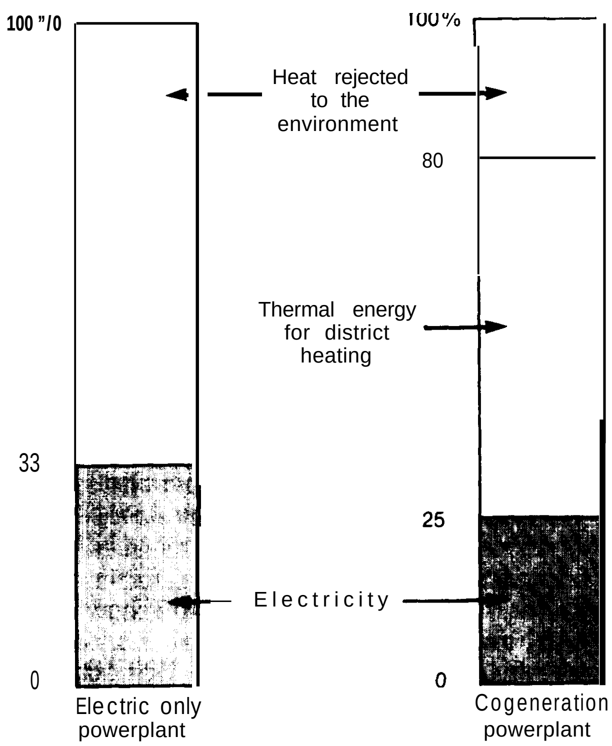


SOURCE: D. J. Santini, and S. S. Bemon, "Feasibility of District Heating and Cooling of Core Areas of Major Northern Cities by Cogeneration from Central Station Powerplants", paper presented at Northeastern Regional Science Association Meetings, Amherst, Mass., May 1979.

replaced. In the diagram in figure 47, the electricity-only powerplant uses 33 percent of the heat in the fuel for electricity and wastes the rest. The cogeneration plant, on the other hand, **used** only 25 percent of the fuel for electricity, but makes available another **55 percent of the** fuel for heat for district heating.

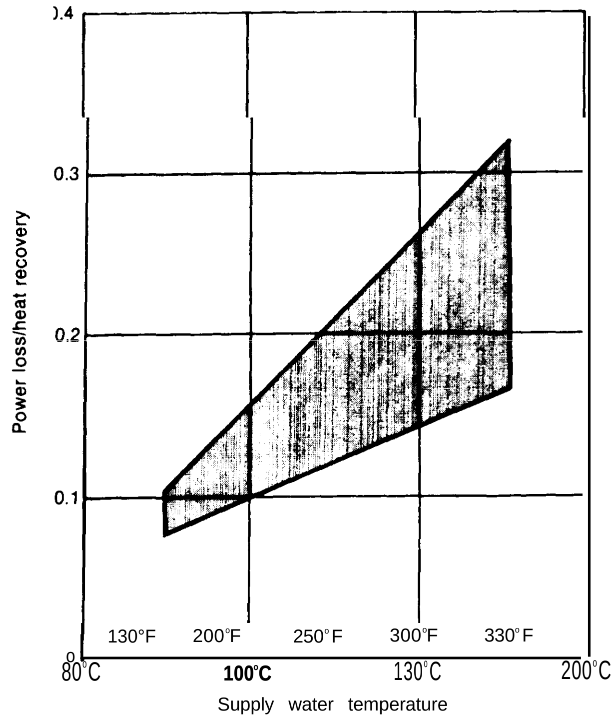
How much electric generating capacity must be sacrificed to make waste heat available for district heating depends both on the type of cogenerating equipment and on the temperature of the waste heat that is being removed. The higher the temperature of the waste heat, the greater the loss in electric-generating capacity. Figure 48 shows that for steam at 330° F the loss in generating capacity is **close to 20 percent of the heat recovery. As the temperature drops to 150°** F, the loss in generating capacity shrinks dramatically.

Figure 47.—Comparison of Fuel Utilization of Electric-Only and Cogeneration Powerplants



SOURCE: R. E. Sundberg and H. O. Nyman, "District Heating/Cogeneration Application Studies for the Minneapolis-St. Paul Area: Methods and Cost Estimates for Converting Existing Buildings to Hot Water District Heating," Oak Ridge National Laboratory, Oak Ridge, Term., ORNL/TM-6830/P4, October 1979.

Figure 48.—Power Loss per Heat Recovery for District Heating From Cogeneration as the Supply Water Temperature Increases

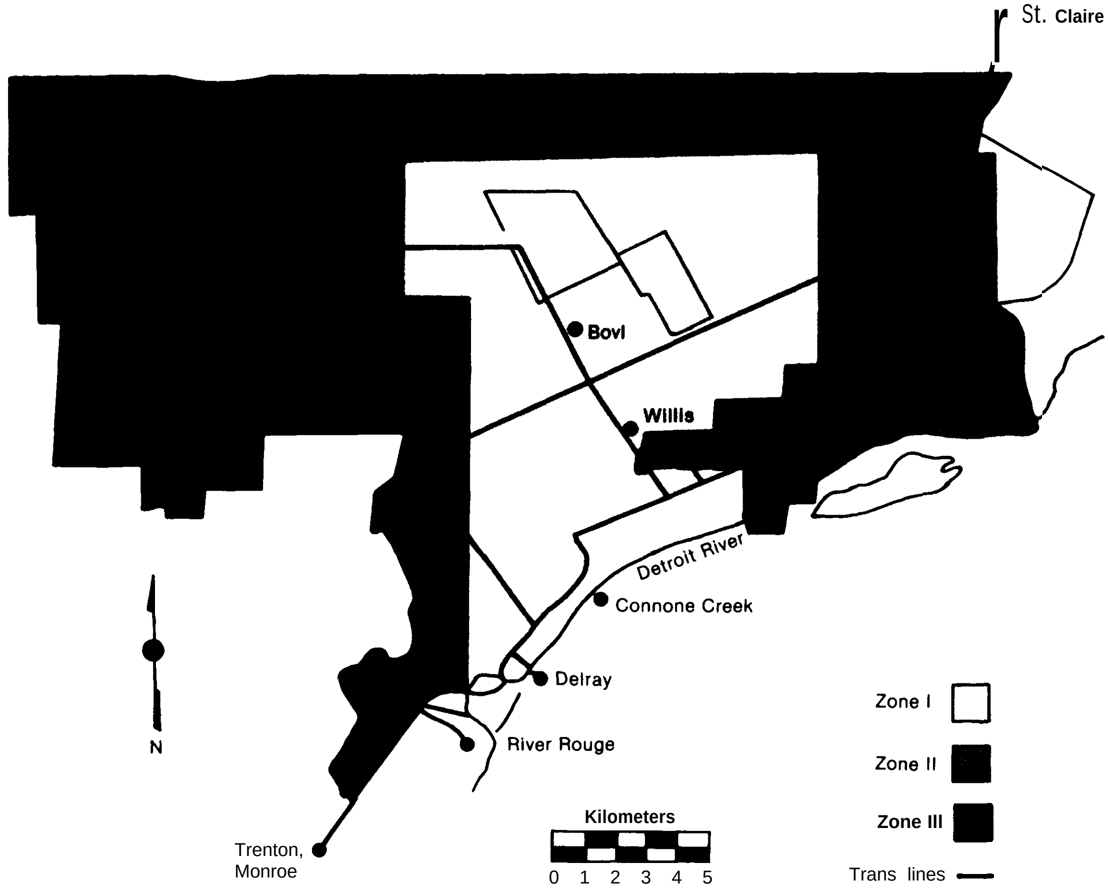


SOURCE. O Seppanen, and W Aho, "Building Systems and District Heating," Ekono, Inc., Bellevue, Wash , presented at the Integrated Energy Systems Task Group Technical Review Meeting, Mar 10, 1981, organized by the National Bureau of Standards, Washington, D C

Thus for cities and regions in which replacement of lost generating capacity would be a significant cost, designing a district heat system for relatively low-temperature hot water will help reduce that cost to a minimum. Low-temperature hot water may be somewhat more expensive to transmit and distribute than high-temperature hot water, so these costs must be weighed against the savings in electricity capacity.

Transmission and Distribution Cost. Since transmission and distribution costs are always the major part of the costs of district heating, the careful design of district heating to minimize the costs of transmission and distribution will have a major impact on reducing the overall costs of the district heating. Figure 49 shows a typical proposed layout of transmission lines for a hot water district heating system for the city of Detroit. It includes several long feeder lines from outside the proposed heat demand zones and

Figure 49.—Thermal Demand Zones and Transmission Supply Lines for the Study City of Detroit, Mich.



SOURCE: D J. Santini, A. A Davis, and S. M Marder, "Economic and Technical Analysis of Retrofit to Cogenerating District Energy Systems. North Central Cities," Argonne National Laboratory, Argonne, Ill , ANL/CNSV-TM-ll, June 1979.

several loops within the demand zone—in all over 100 km of transmission pipes. Prices for transmission pipes (as estimated in the feasibility study for St. Paul) range from several hundred dollars per foot for a 10-inch pipe to several thousand for a 60-inch pipe.[9] Transmission lines alone are estimated to cost between $456 million and $859 million for the Detroit system (or between $1,300 and $2,600 per foot).

Because of the high costs of transmission lines it is much easier to have a viable district heating system if the heat source is located close to the heat users. At $2,000 per foot, running a 60-inch pipe an extra 15 miles to a powerplant heat source will cost an extra $158 million. For hot water systems there is also some loss of heat from long transmission lines although far less than for long-distance transmission of steam.

The costs of a district heating distribution system are minimized if the number and length of distribution pipes can be minimized. Minimum costs occur for a small number of customers located close together, each using large amounts of heat. None of the existing steam systems shown in table 55 has more than **3,500** customers. Most have less than 1,000 customers. Con Ed's customers average 5.1 million Btu per hour, a peak demand for steam (equivalent to **5** million to 10,000 million Btu heat demand for a heat season, characteristic of a building of **100,000 to 200,000 ft^2).**

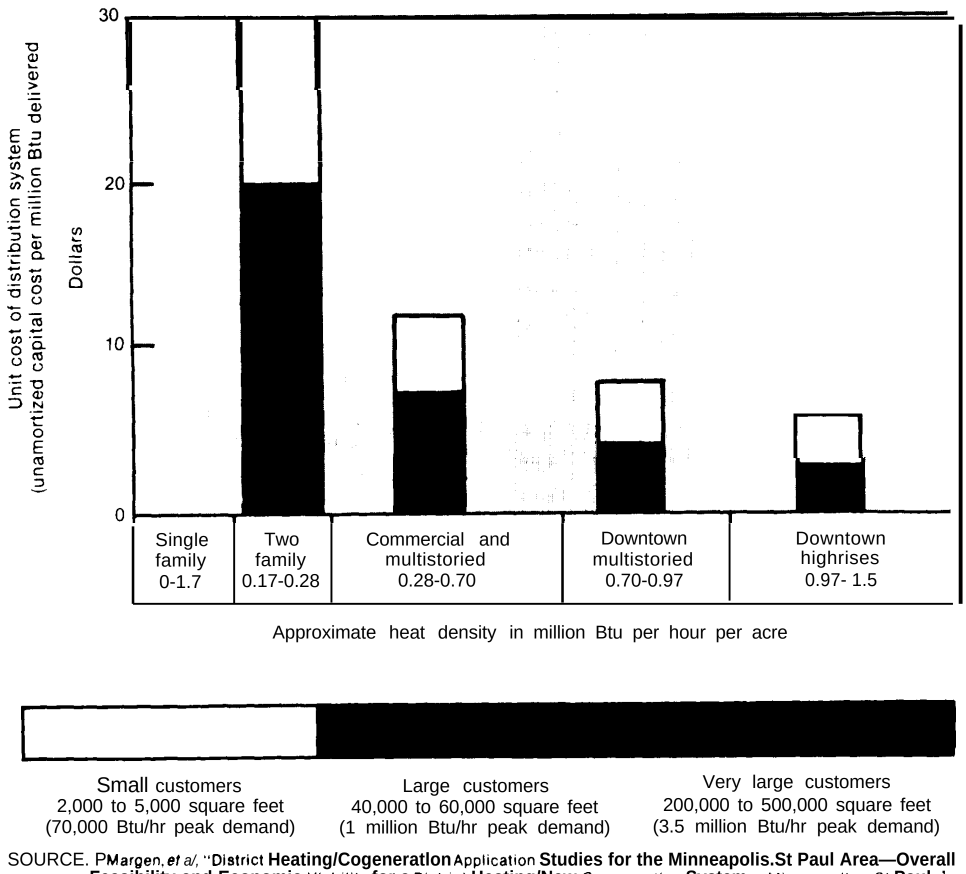
[9] Margen, et al., op. cit. in source for fig. 50.

As customers get smaller and more spread out, the "heat density" of the area to be served by district heating is said to diminish, and this sharply increases the cost of the distribution system. In heat densities typical of high-rise central business districts the total unamortized capital cost of a distribution system may vary from less than a $1 per annual million Btu delivered for big customers to about $7 for small customers. In areas whose heat density is more characteristic of duplex or row housing, the unamortized capital cost of distribution to small customers may go as high as **$30 per annual delivered million** Btu. (See fig. 50 which shows an analysis of distribution system costs typical of Stockholm, Sweden, which was used as part of the feasibility study for the St. Paul district heating system.)

The temperature of the hot water being distributed also affects the cost of distribution. At temperatures below 250° F, the steel pipes carrying the hot water can be insulated with polyurethane foam insulation inside an outer plastic polyethylene casing. These are far cheaper than the steel pipes encased in an outer steel casing that must be used for higher temperature hot water or steam distribution.

Building Retrofit Costs. The cost of retrofitting buildings to use district heat is a substantial cost for district heating systems being installed in older cities, such as St. Paul, where buildings already have heating systems, either distribution systems for steam district heat or self-contained boilers or furnaces using natural gas, fuel oil, or

Figure 50.—Relationship of Average Heat Density and Customer Size to Costs of District Heat Distribution (as estimated for Stockholm, Sweden)



SOURCE. P Margen, *et al*, "District Heating/Cogeneratlon Application Studies for the Minneapolis.St Paul Area—Overall Feasibility and Economic Viability for a District Heating/New Cogeneration System in Minneapolis—St Paul,' Oak Ridge National Laboratory, Oak Ridge, Term , ORNL/TM-6830/P3, October 1979, p 61, and Off Ice of Technology Assessment, electricity. The cost of retrofit is usually borne by the building owners, but may be borne in part by the district heating system as a marketing device. District heating systems may also have to assist with financing retrofit. The easiest buildings systems to convert to district hot water are obviously those which already use hot water. The hot water boiler is then replaced by a heat exchanger that uses the district hot water for a heat source. Buildings that use steam are probably next most easy to convert because the steam radiators can often be converted to hot water. The steam distribution system, however, must usually be replaced with a larger two-pipe piping system to accommodate hot water rather than steam. Alternatively, high-pressure district hot water can be converted to steam inside a building for use in the building's steam radiators. Cities with existing steam district heating systems have large numbers of buildings equipped to use district steam heat.

Buildings with oil or gas furnaces and air distribution systems can sometimes provide heat to the air by wrapping hot water pipes around the ducts or furnace. If this does not prove possible then a more expensive step is necessary—installing hot water baseboard radiation. Those buildings whose systems adapt only at great expense to district heating are those buildings with "complex" systems (described in ch. 3) where air systems have individual electric coils to reheat the air in zones where heat is needed.

All other things being equal, the costs of building retrofit (as for distribution systems) are least per delivered million Btu for large heat users and most for small heat users. The St. Paul feasibility study also examined these costs. The costs to convert a steam system to district heating for a moderate size building averaging 1.7 million Btu per hour of heat demand (or about 4,500 million Btu a season) would be about $9 unamortized capital cost per annual million Btu. Once a building demands 10 times that amount of heat, the costs of retrofit fall sharply–to less than $3 unamortized cost per annual million Btu (see fig. 51).

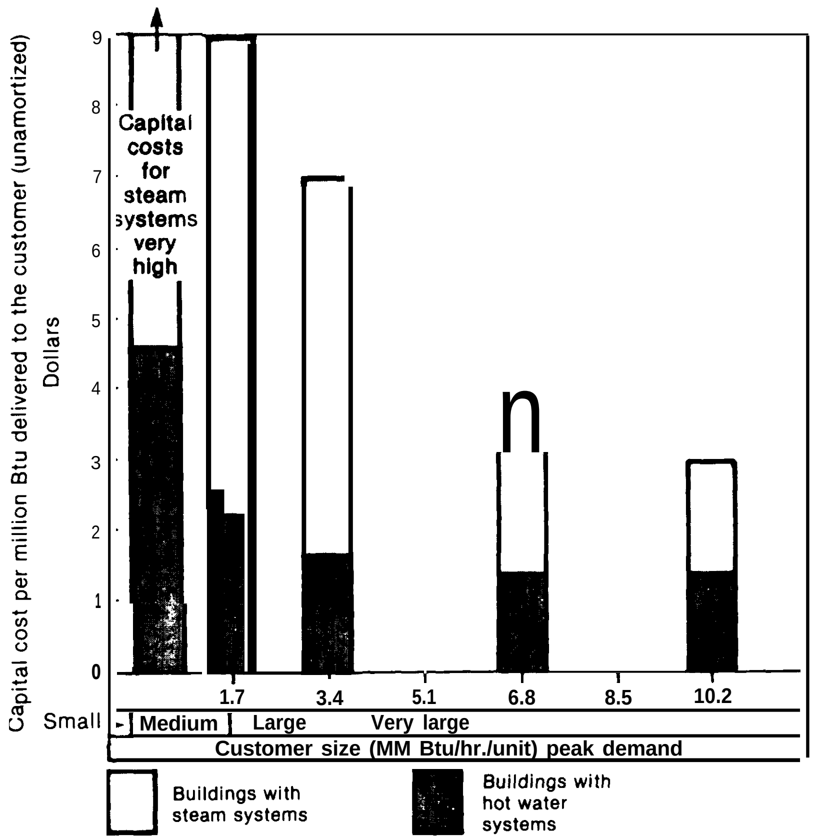
At $9 per annual million Btu a retrofit that allowed a building owner to save $1 per million Btu on his heating costs by using district heat instead of fuel, would take 9 years to pay back cost. For many building owners these retrofits would cost $0.50 to $1 per ft^2, well above the accepted threshold below which capital expenditures can be easily financed (see the discussion of building owner decisions in ch. 4).

The capital costs of building retrofit are, for these reasons, a component of district heating that is difficult to handle since they are a potential obstacle to customer hookup. There are arguments for at least sharing them between customers and system and perhaps for the system assuming the whole cost, The more small buildings or difficult-to-retrofit buildings there are in a potential district heating zone the more difficult it may be to share or absorb these costs and this may pose a major obstacle to the success of district heating,

District Heat for New Buildings. In contrast to existing buildings, hookup to a district heating system offers substantial economic benefits to owners of new buildings who may save up to **$250,000** on the cost of a self-contained heating system. Eliminating a self-contained heating system **also frees** up significant rentable space in the building and saves on labor and maintenance costs. Thus, district heating systems may have the best chance of obtaining long-term contracts with significant numbers of customers if they are able to start with new buildings in a downtown redevelopment area or rapidly growing area around a new subway system or suburban transportation crossroads.

The Impact of Different Financing Assumptions. The annual capital costs of some of the district heating systems listed in table 58 will vary greatly according to what assumption is made about the capital recovery factor. Table 59 shows the estimated costs for two of the cities with capital recovery factors of 0.10, 0.15 and 0.20. A capital recovery factor of 0.10 is approximately equivalent to paying 8-percent interest on a 20-year loan while a capital recovery factor of 0.20 is equivalent to an interest rate of almost 20 percent for a loan of the same term.

Figure 51 .—Building Retrofit Costs as Building Size Increases



SOURCES, P Margen, et al , "District Heating/Cogeneration Application Studies for the Minneapolis-St. Paul Area—Overall Feasibility and Economic Viability for a District Heating/New Cogeneration System in Minneapolis-St Paul," Oak Ridge National Laboratory, Oak Ridge, Term., ORNL/TM-6830/P3, October 1979, p 65; and the Off Ice of Technology Assessment.

Table 59.—Annualized Capital Costs for Proposed District Heating Systems Under Alternative Capital Recovery Factors (in dollars)

Proposed systems (one zone with highest thermal load)	Annual capital cost per million Btu	
	Cleveland	Milwaukee
High estimate of costs (unamortized)	($69.28)	($76.60)
Capital recovery factor of:		
0.10	6.93	7.67
0.15	10.40	11.51
0.20	13.86	15.34
Low estimate of costs (unamortized)	(29.70)	(36.33)
Annual capital recovery factor of:		
0.10	2.97	3.63
0.15	4.46	5.45
0.20	$ 5.94	$ 7.26

SOURCE: Office of Technology Assessment using data from Santini, et al , "Economic and Technical Analysis of Retrofit to Cogenerating District Energy Systems. North Central Cities," Argonne National Lab. June 1979.

The annual capital costs of a district heating system with a capital recovery factor of 0.20 will be double those of a system with a recovery factor of 0.10. Since capital costs are such a large fraction of total costs the interest rate will make the major difference in whether the district heating prices are competitive with alternative sources of heat.

VARIATIONS IN DISTRICT HEATING SYSTEMS

All district heating systems have in common the major capital expense of transmission and distribution systems. Some variation in capital costs is possible, however, by varying the sources of heat. District piping systems can also be varied by using them to carry cool or lukewarm water for heat pumps.

Sources of heat other than waste heat that can be used for district heating systems include: direct coal combustion without cogeneration, cogeneration using oil or natural gas, municipal solid waste, and solar and geothermal energy. Less is known about the costs of some of these and most of these methods would only be possible in certain cities in the United States. Each is described briefly below.

Direct coal combustion, without cogeneration, takes advantage of the lower fuel cost of coal and the economies of scale in handling coal and processing it centrally. The capital cost is comparable to the capital cost of retrofitting an existing powerplant for district heating plus replacing lost generating capacity, but far more than the cost of retrofitting the powerplant alone (see table 60).

Direct coal combustion without cogeneration may make sense in cases where sources of waste heat could be made available only if the lost electric capacity were replaced, In many cities there are environmental restrictions prohibiting on new sources of coal combustion; these would have to be waived for a new coal boiler for district heating.

Table 60.—Comparison of Capital Costs for a Heat-Only Coal Boiler and Recovery of Waste Heat From Electricity Generation

	Total capital cost per delivered million Btu	Capital cost per million Btu at a capital recovery factor of 0.15
Fluidized bed coal burning low pressure boiler ?	$15.85	$2.38
Detroit system:[b]		
Powerplant retrofit	**2.25- 4.48**	**.33- .61**
Replace lost generating capacity	**8.89-11.19**	**1.33-1.67**
Total	11.14-15.61	1.66-2.28

SOURCES: Pferdehirt and Kron, op. cit., Davy McKee Corp., "Cost Comparison Study, Industrial Size Boilers; 10,000 to 400,000 Pounds per Hour," October 1979.

The operating and maintenance costs will be substantially higher for a heat-only coal boiler than they will be for a retrofit powerplant. This is because all the operating cost and fuel cost of the heat-only boiler must be charged to the district heating system while the fuel costs and operating cost of a cogenerating powerplant are *shared* between district heating and electricity generation.

Cogeneration Using Fuel Oil or Natural Gas. For small-scale district heating systems such as the Trenton system (described in box L) or the Harvard Medical Area System (described in box M) it may make sense to provide district heat using oil or natural gas fired diesel cogenerators, or other small-scale cogenerators. The many varieties of these cogenerators and the economic and regulatory problems affecting their use will be the subject of an entire forthcoming OTA report "industrial and Commercial Cogeneration." The cost of the more expensive fuel can be recovered in part from sales of electricity to one or more utilities, Such a small-scale system can serve as the core of a larger district heating system that can expand over time to the point where it makes economic sense to use coal directly, or after converted to a gas.

Municipal Solid Waste. Municipal solid waste may be an excellent source of heat for district heating especially in densely populated urban areas where landfill costs for disposal of solid waste are high. It is not easy to retrofit existing incinerators for heat recovery, however. Efficient production of heat from solid waste almost always requires new construction or extensive rebuilding.[10]

Furthermore, few cities have enough solid waste to produce heat in any large quantities. Only 23 cities and 72 standard metropolitan sta-

[10] For more information on energy from solid waste see Office of Technology Assessment, U.S. Congress, *Materials and Energy From Municipal Waste,* OTA-M-93 (Washington, D. C.: U.S. Government Printing Office, July 1 979).

tistical areas produce more than 1,000 tons per day of municipal solid waste (see tables 61 and 62). Given some standard assumptions about the heat content of solid waste and the efficiency of heat recovery, 1,000 tons per day would produce about 700,000 million Btu over a heating season of 100 days. This is equivalent to less than 5 percent of the heat production of the first proposed citywide St. Paul district heating system. [11]

The costs of heat from solid waste are sufficiently high that they must be offset by charging tipping fees to those unloading the solid waste if the heat is to be competitively priced. The annualized cost of steam per million Btu from waterwall incineration, for example (including operating and maintenance costs), has been estimated at about $3.80 per million Btu.[12] A tipping fee of $10 per ton would reduce the cost of heat by about $1.50 per million Btu, to a total of **$2.30 per million** Btu for the cost of heat alone without transmission or distribution costs.

A tipping fee of $10 per ton would be equivalent to the high end of the estimated current range of tipping fees of $2 to $10 per ton at urban landfills throughout the country .13 In the future, however, in congested areas, landfill costs are expected to increase. Thus, heat from solid waste for district heating should be an economically viable but modest contributor to district heating systems.

Solar Energy. In principle, solar energy would be used to supply heat for district heating. In practice, the capital cost of such heat is far above the cost of alternative sources of heat.

The cheapest and simplest source of solar heat to a district heating system is a solar pond. This is a shallow body of water with a dense salt-water solution on the bottom and increasingly less salty, and lighter layers above it. The bottom of the pond is blackened and heat is absorbed in the heavy salty layers up to temperatures of 150° to 200° F and is prevented from being dissipated by the lighter layers of water. The hot salty water at the bottom of the pond can then be used to heat water for district heating by passing through a heat exchanger.

A detailed analysis of the costs of a 400-acre solar pond for district heat was done for Northampton, Mass.[14] (see table 63). Without including the land cost for the pond, the cost of constructing it was estimated at $88 million for an

Table 61 .—U.S. City Size, Population and Waste Production in 1975

City size range (thousands)	Number of cities	Population (million)	Average population per city (thousands)	Average municipal solid waste per city (tons/day)
5-10	1,463	10.3	7.1	12
10-20	977	13.8	14.1	25
20-25	238	5.3	22.0	39
25-50	514	17.9	34.9	61
50-100 ...., . . .	230	16.1	70.0	122
100-250. , ...	105	14.9	142.0	248
250-500	34	11.8	348.0	609
500-1,000	17	11.3	664.0	1,160
Over 1,000	6	17.8	2,970.0	5,200

SOURCE. Off Ice of Technology Assessment, U.S. Congress, *Materials and Energy From Municipal Waste*, OTA-M-93 (Washington, D C U.S. Government Printing Office, July 1979)

Table 62.—U.S. Standard Metropolitan Statistical Areas (SMSAs) Size, Population, and Waste Production in 1975

SMSA size (thousands)	Number of SMSAs	Population[a] (million)	Average population per SMSA (thousands)	Average municipal solid waste per SMSA (tons/day)
Under 100	27	2.5	92	160
100-250 . . .	97	16.6	171	300
250-500 . .	63	22,7	361	630
500-1,000	37	27.1	733	1,280
1,000 -2,000	20	28.3	1,417	2,480
2,000 -3,000	8	19,0	2,373	4,150
Over 3,000	7	40.0	5,693	9,960

SOURCE. Office of Technology Assessment, U S. Congress, *Materials and Energy From Municipal Waste*, OTA-M-93 @Washington, D. C." U.S. Government Printing Office, July 1979)

[11] The heat output (in mi l lions of Btu) from 1,000 tons Per day of waste was calculated by assuming a heat production of 5,000 Btu per pound of solid waste combusted at 68 percent efficiency for a total of 6.8 million Btu per ton. Multiplied by 100 days at 1,000 tons per day gives 680,000 million Btu over a heating season. Sources for the calculation: Off Ice of Technology Assessment, op. cit.; and Pferdehirt, op. cit. (source for figs. 1 and 2).

[12] Office of Technology Assessment, op. cit., p. 124. Assumes a cost of $25.60 per ton and 6.8 mi llion Btu per ton.

[13] "Resource Recovery Activities, " reprinted from *NCRR Bulletin*, National Center for Resource Recovery, Inc., vol. 10, No. 3, September 1980; and "Small Power Production and Cogeneration Facilities–Qualifying Status/Rates and Exemptlons–Appendixes to draft Environmental Impact Statement, " SRI International, Menlo Park, California for the Federal Energy Regulatory Commission, Washington, D. C., FE RC/EIS 001 9/D, June 1980.

[14] A. s. Kras and R. La Viale, I I 1, "Commu nity Solar Ponds, ' *Environment*, vol. 22, No. 6, pp. 25-33, July/August 1980.

Table 63.—Costs of Solar Heat Compared to Heat-Only Coal Boiler for District Heating

	Capital cost/delivered million Btu (in dollars)	
	Unamortized	Amortized at 0.15/year
Heat source only:		
Heat only coal boiler (estimate)	**$ 15.85**	**$ 2.38**
Northampton solar pond (estimate)	**103.30**	**15.50**
Total system:		
Northampton solar pond	**148.52**	**22.30**
Lyckebo Sweden system	$623.00	$93.45

SOURCES: Coal boiler cost estimates from table 60 above; solar pond estimates from A. S. Krass and R. La Viape III, "Community Solar Ponds," *Environment* volume 22, no. 6, pp. 25-33, July/August 1980; costs for Lyckebo system from J. Gleason, "Efficient Fossil and Solar District Heating Systems: Preliminary Report" to the Solar Energy Research Institute and the New England Sustainable Energy Project, 1980.

unamortized cost of about $103.30 per delivered million Btu for the source of heat alone. This is a cost far greater, for example, than the cost of heat-only coal-burning described above. At a capital recovery rate of 0.15, heat from the solar pond would cost about $15 per delivered million Btu while heat from the coal boiler would cost about $2.40 per delivered million Btu.

Solar heat from two completed projects in Sweden, Lyckebo and Inglestad, is even more expensive. The total cost of the district heat is about $625 per delivered million Btu in unamortized capital costs and about $94 per million Btu if amortized at 0.15 per year.[15]

Geothermal. Heat from the Earth or geothermal energy is a fine source of heat for district heating for the few potential district heating systems located near a geothermal field. Boise, Idaho, established a district heating system from geothermal hot water in 1890. **A recent estimate of the cost of expanding the system calculates that the annualized cost of the hot water from the enlarged system would be only $2.30** per million Btu.[16] Two recent systems have been built from scratch, in Midland, S. Dak. and Mammouth Lakes, Calif., with unamortized capital costs of $39 to $44 per annual delivered million Btu. These systems thus have capital costs quite comparable **to** the first phase of the proposed St. Paul district heating system.[17]

Few large cities are located near geothermal fields. In addition, there are several other problems with geothermal systems. The most obvious is that it may be difficult to locate a geothermal field and estimate its size. In Iceland and New Zealand where geothermal heat is used frequently, the average lifetime of geothermal well is no more than 20 to 30 years.[18] Hot geothermal brine is corrosive and difficult to transport. Improvements are needed in many aspects of a geothermal technology, such as well drilling and pipeline construction, in order to bring costs down.

Other Variations on District Heating: District Cooling and Water for Heat Pumps. There are three other, more comprehensive, variations on the basic district heating system that may have considerable promise for the future, although little effort has been made to date to estimate their costs. District cooling may prove an attractive supplement to district heating in the South and *district water for heat pumps* may also be economically viable in the North as well as the South.

District Cooling. High-temperature pressurized hot water or steam can be used for cooling by building owners with absorption air-conditioners. Many buildings in such cities as Baltimore and New York use steam from the existing steam system to run absorptive air-conditioners. The new hot water district heating systems under consideration, however, could only provide heat for absorption air-conditioners if the temperature is greater than 250° F.

Central chillers, using electricity or heat (if they are absorption air-conditioners), can also provide chilled water to a district heating system. In this case the transmission and distribution systems cost would be greater than for the

[15] P. Margen, "Economics of Solar District Heating," *Sunworld,* vol. 4, No. 4, pp. 128-134, 1980.

[16] T. M. Guldman and B. D. Rosenthal, "Modeling the Interactions Between Geothermal Energy Use and Urban Structure," Energy, vol. 6, pp. 351-368, April 1981.

[17] N. L. Book, et al., "Economics of Low Temperature, Direct Use Applications of Geothermal Energy," *Energy, vol.* 6, pp. 317-322, April 1981.

[18] C. H. Bloomster, B. A. Garrett-Price, and L. L. Fassbender, "Residential Heating Costs–A Comparison of Geothermal, Solar, and Conventional Resources," Pacific Northwest Laboratory, PNL-3200, August 1980.

hot water only system described above since four pipes would have to be laid, two for chilled water and two for hot water. Maintenance and materials cost, however, is lower for pipes carrying chilled water and Btu losses could also be lower. In new communities, where piping system costs can be minimized and the district heating and cooling can substitute for conventional heating systems and air-conditioners, district heating and cooling may make economic sense.[19]

District Water Systems With Heat Pumps. Heat pumps can make effective use of lukewarm or cool water that is being returned to a heat source such as a cogenerating powerplant. When a system is well designed the temperature of return water can be as low as 50° to 80° F, too low to heat a building but high enough to allow a heat pump to function at high efficiency (coefficients of performance of 2.5 or better) even when air temperatures are very low. Such a system, combining district heat with water suitable for increasing the efficiency of heat pumps is under development in Easton, Md., sponsored by the municipal utility there. In principle a district piping system could also be used to make low-temperature geothermal sources or ground water available for use during the winter months to enhance the efficiency of heat pumps.

For all such systems, the high capital cost of piping must be compared to the extra efficiency of a central chiller or higher efficiency operations of heat pumps. Under some conditions the value of the latter may outweigh the piping system cost.

[19] A wide variety of district heating and Cooling systems are analyzed in *Application of Solar Energy to Today's* Energy Needs, vol. II, Office of Technology Assessment, OTA-E-77 (Washington, D. C.: U.S. Government Printing Office, June 1978).

Retrofit of Existing Steam Systems To Use Hot Water. The prime locations for hot water district heating in many major American cities—Boston, New York, Baltimore, St. Paul, Minneapolis, Chicago, and Detroit among others—are already occupied by existing or recently closed down steam systems. In principle, some of the maintenance costs and thermal losses associated with steam systems might be avoided if the steam systems were converted to pressurized hot water.

In practice such conversion of existing systems from steam to hot water would be costly and difficult, Hot water pipes must be larger than steam pipes for the same Btu volume. Furthermore, an extra set of pipes would have to be laid to carry the return flow of cool water. (Steam **systems either** dump the condensed steam or have it return along the bottom of the outgoing pipe.)

The buildings hooked up to the steam district heating system would have to be retrofitted to use hot water. Absorption air-conditioners using district steam (very common in cities such as Baltimore) would only continue to function if the new district heating system used high-temperature pressurized hot water.

Because of the difficulty of retrofitting them, the large number of existing and recently defunct steam district heating systems is a major obstacle to the rapid penetration of hot water systems in U.S. cities. New hot water district heating systems in these cities may have to incorporate plans to purchase these old systems (as the St. Paul system did in the summer of 1981) and try to convert their customers to hot water. Heat sources for the old systems, as in the St, Paul case, can be used as backup for the new systems.

NONCAPITAL COSTS OF DISTRICT HEATING

Most of the cost of district heating is the annualized cost of capital. There are, however, two other kinds of costs:

- operating and maintenance cost of the distribution system, and
- operations and maintenance cost and fuel cost of whatever heat source is used.

Distribution System Operations and Maintenance (O&M). T-he cost of operating and maintaining a steam system can be very high espe-

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cially as it gets old because the pipes corrode over time and the steam traps (V-shaped depressions where the steam condensate drips out) get clogged and must be cleared by access through a manhole. In principle hot water systems are easier to maintain. There are no steam traps and plastic pipes used in the distribution systems do not corrode. In a district heating planning guide, Argonne Laboratory estimates the cost of operating a hot water transmission and distribution system at 1 percent of the initial capital cost of those systems, based on experience in Denmark and Sweden. Depending on the capital cost of the transmission and distribution systems, the O&M cost would vary from $0.18 to $0.46 per million Btu delivered for the Washington system.

The O&M and fuel cost of the heat source will vary with the extent to which the cost of heat is shared with electricity generation, All of the cost of a heat-only coal boiler will be borne by the district heating system while only a share of the cost of the cogenerating electricity plant will be charged to district heating. For one plant analyzed in the Argonne Planning Guide the plant O&M and fuel costs were estimated to be eight times the O&M for the distribution lines.[20] Thus fuel and O&M for the waste heat from the powerplant are likely to run between $1.50 and $4 per million Btu and total fuel and O&M costs would then range from $1.70 to $4.50 per delivered million Btu of heat.

[20] Pferdehirt, op. cit., p. 40

COMPETITIVE PRICING OF DISTRICT HEATING SYSTEMS AND THE BUILDING OWNER'S POINT OF VIEW

The best district heating system in the world will not be a success if buildings do not hook up to it. Whether they do or do not will depend, first of all, on whether the price of the district heat is competitive with the existing sources of heat to the building. Beyond price there are further considerations which may hinder building hookups even if the price is competitive. The building owner may have to pay for his own retrofits. If so, the cost of district heat will be lower but the building owner will have to finance or come up with the cash for a retrofit which is estimated to cost from under $0.70 to over $2.70 per square foot.[21] Even if the building owner does not have to pay for his own retrofit, he may be reluctant to risk a change to a new heating and/or cooling system without clear guarantee that he will be saved expense.

How competitive district heating prices will be to a particular building owner depends on three factors:

- The price of the district heat.
- The current price of the fuel or electricity used to heat (or cool) the building and the expected increases in those prices.
- The efficiency with which that fuel is used compared to the efficiency of the potential district heat.

The latter two factors combined will give the owner a theoretical break-even price, below which district heat will cost less than his current source of heat.

As seen above, the cost of district heat itself is primarily determined by the annual cost of capital used to construct the system. In a situation in which the price of district heat must be low to compete with the building owner's current source of heat, it may be possible to obtain less expensive financing to keep the district heat prices low enough.

Using the capital costs estimated by Argonne for a possible district heating system in Milwaukee, OTA analyzed what the financing rate (expressed as an annual capital recovery factor) would have to be for the district heat to be competitive with different kinds of fuel used at different levels of efficiency, The results are shown

[21] D. T. Santini and S. S. Bernow, *Feasibility of District Heating and Cooling in Core Areas of Major Northern U.S. Cities by Cogeneration From Central Station Powerplants,* presented at the Northeast Regional Science Association Meetings, Amherst, Mass., May 18-20, 1979.

in table 64. In the best situation, if the district heat is competing with No. 2 distillate heating oil and the district heating system is constructed with the low estimate of costs, the system could be privately financed at an annual capital recovery factor of 0.15 to 0.19 and still be priced lower than the competition.

In the worst situation, on the other hand, if the system costs as much as the high cost estimate and if it is competing with No. 6 residual heating oil or natural gas used at the same efficiency (80 percent) as the district heat, then the district heat would only be competitive if it were financed at the miniscule capital recovery rate of 3 percent per year.

The Impact of Price Escalation in Competing Fuels. It is widely believed that natural gas and heating oil will increase in price faster than inflation and that this increase will make district heating competitive in several years against fuels with which it is not now competitive. The critical question, however, is not whether fuels will increase faster than inflation in general but whether they will increase faster than the construction cost for building a district heating system. Over the decade from 1970 to 1980, for example, construction costs increased somewhat faster than inflation.

OTA estimated (in table 65) how many years it would take before a proposed district heating system (for the city of Milwaukee) would be competitive with distillate and with residual

Table 65.—impact of Fuel Escalation Assumptions on the Break-Even Point in a Proposed District Heating System for Milwaukee

	If fuel cost escalates (at an annual rate) faster than the capital costs of district heating		
	2%	50/0	10%
	In how many years would there be a breakeven point		
Building uses No. 2 **at** *0.65* efficiency			
Low cost @ 0.15 CRF[a]	— Immediate breakeven —		
High cost @ 0.15 CRF	20 years	8 years	4 years
High cost @ 0.10 CRF	4 years	2 years	1 year
Building uses No. 6 at *0.65* efficiency			
Low cost system @ 0.15 CRF	15 years	6 years	3 years
High cost system @ 0.15CRF	45 years	18 years	9 years
High cost @ 0.10 CRF	28 years	11 years	6 years

[a]CRF = Capital recovery factor equals fixed annual rate In which capital investment Is amortized.

SOURCE: Office of Technology Assessment using data from Santini, et al , op cit., table 5.

Table 64.—Subsidized Financing Would Be Required in Some Cases for District Heating To Be Competitive With Fuel Oil

	Energy price[a]	Breakeven district heating price[b]	Capital recovery factor required for breakeven price Milwaukee system[c]	
	Dollars/million Btu		High cost	Low cost
Building 1: Burns No. 2 (distillate) heating oil at 0.65 efficiency	**$7.50**	**$8.95**	**0.09**	**0.19**
Building 2: Burns No. 2 (distillate) heating oil at 0.80 efficiency	**7.50**	**7.50**	**0.07**	**0.15**
Building 3: Burns No. 6 (residual) heating oil at 0.65 efficiency	**4.50**	**5.54**	**0.05**	**0.10**
Building 4: Burns No. 6 (residual) heating oil at 0.80 efficiency	**$4.50**	**$4.50**	**0.03**	**0.07**

[a]This corresponds t. late 1980 prices of $1,04 per gallon for distillate (No 2) fuel oil and $2800 per barrel residual (No 6) fuel oi l as reported in the Department of Energy *Monthly Energy Review*.
[b]Assumes that district heat is used with 80 percent efficiency in the building.
[c]Capital recovery factor equals fixed annual rate in which capital investment is amortized (principal plus interest)

SOURCE: Off Ice of Technology Assessment using data from Santini, et al., op. cit., "North Central Cities."

heating oil (assuming lower efficiency use of fuel than district heat). The low cost district heating system would break even immediately against distillate if conventionally financed. The high cost system on the other hand would not break even for 4 years (at conventional financing) even if distillate were to escalate in price each year 10 percent faster than the construction costs of district heat, When competing against residual fuel oil even the low cost system would not break even under conventional finance for 3 years at the high fuel escalation rates.

District Heating as a Hedge for Building Owners Against Future Rapid Energy Price increases. In principle, district heating could be a good hedge against future price hikes. The debt service for a single phase of a district heating system, constructed all at once and not expanded, will not increase at all from year to year and over time will decrease in constant dollars. The only part of the price of the district heating price to escalate will be the fuel and O&M cost.

Most district heating systems, analyzed by Argonne, however, would be constructed in phases. The St. Paul-Minneapolis system is expected to take 20 years to construct. As each new phase is added to the system the debt service to cover the higher construction cost of that phase will be averaged in with the less expensive debt service of earlier phases and the average price of district heat for all customers is likely to rise. Thus, for each individual building owner the price relationships expressed in table 65 are likely to govern his expectations about break-even points. If his current fuel costs less than the price of district heating it is not likely to escalate much faster than 10 percent faster than district heating, and all the rest of table 65 applies in calculating the number of years before break even.

To sum up, district heating systems under current cost estimates can only compete, if they are to be conventionally financed, with building owners using the highest cost fuel. Competing against building owners using natural gas or residual oil requires substantial financing subsidy, especially if the actual costs of the system are at the high end of the estimate.

CONTINGENCIES IN PLANNING A DISTRICT HEATING SYSTEM

planning and carrying out a project of the scale of district heating is inevitably risky since fairly narrow conditions must be met for theoretical economic success. There is a long list of things which may go wrong:

- The costs may be much greater than anticipated. A Rand study of cost overruns in major public and private projects calculated that the average cost overrun in eight rapid transit projects and 58 major building projects was over 50 percent. For one-of-a-kind projects, cost overruns were higher–l 10 percent .22
- Fewer customers may sign up than anticipated.
- Customers may demand less heat than anticipated.
- Financing costs may go up in the middle of the project.
- There may be delays in getting environmental and other approvals which prolong debt service and add considerably to financing costs.

All these problems are illustrated by the experience of a private district heating and cooling cogeneration project which was scheduled to become fully operational in 1981. Constructed by Harvard University for five hospitals in Boston and its own medical, dental, and public health schools, it is the largest cogeneration/district heating project–private or public–to be built in the decade of the 1970's. The project described in box M, ran into almost all the problems listed above. Costs, in current dollars,

[22] Edward W. Merrow, Stephen W. Chapel, and Christopher Worthing, "A Review of Cost Estimation in New Technologies: Implications for Energy Process Plants," Rand Corp., July 1979.

Box M.-Setbacks . . . The Harvard Medical Area Cogenerating and District Heating Plant*

When the first estimate was made in 1972, it looked expensive ($50 million) to build a cogenerating plant to supply steam and electricity to five Boston hospitals and the Harvard Schools of Medicine, Dental Medicine and Public Health but it appeared to save substantial energy ($2 million worth of electricity per year) compared to simply rebuilding the existing steam plant. Now the original estimate looks like a bargain.

Eleven years later, the plant is producing steam and chilled water but all the diesels to cogenerate steam and electricity will not be installed until the summer of 1982. The project has been plagued by construction cost overruns and sharply increased interest rates. Moreover, the installation of the six diesels (which were purchased in 1974 for $1 million each) has been delayed for more than 3 years because of protracted hearings on environmental impacts. The first round of State review included 186 hours of oral testimony and produced 7,300 pages of transcript and documents. The State review finally approved the diesels in May 1981, but the approval contains 32 specific constraints on the diesel operation.

As of the fall of 1981, the best estimate of the total cost of the project—including construction cost overruns, higher interest rates and extra interest due to delays—is a total of $230 million, almost five times the original estimate. Reestimates now in progress could bring the total even higher. Several hoped-for financing schemes have been thwarted. The Boston hospitals have been willing to sign 40-year contracts as customers but have not been willing to become partners in the venture. Plans for leverage-lease financing with several different private financing organizations also fell through. Harvard University remains the sole owner of the plant. Negotiations are now underway for tax-exempt revenue bond financing through the Massachusetts Health and Educational Facilities Administration.

There are probably no real morals to this story except that projects should be designed to be resilient to at least some forms of bad luck, if not to all the forms that plagued this project. Furthermore, large projects and first-of-a-kind projects may be even more vulnerable to setbacks than others. Meanwhile the project will begin to provide electricity by the summer of 1982 and within a decade electricity costs may have escalated enough that it will look in retrospect like a central station prudent investment.

*David Rosen "Background on the Medical Area Total Energy Plant," a paper distributed at the Integrated Energy Systems Task Group technical review meeting Aug. 11, 1981; "How Does It Feel To Have a 73-Megawatt Headache?" *Harvard Magazine*, July-August 1980, pp. 19-20.

were four times the 1972 estimate. Financing costs doubled in the middle of the project and delays for environmental approvals added more than 3 years of debt servicing cost.

There are tricky problems associated with the initial sizing of the system. If the actual demand for heat is overestimated, the transmission and distribution pipes may be larger and cost more than necessary, and this can add significantly to the capital cost of the system. OTA analyzed (for a proposed Washington, D.C. system) how several different contingencies might affect the total annualized capital cost (and therefore price) of district heat. The results are shown in table 66. Compared to the base case, for example, district heating would cost $0.50 per million Btu more if there were 40 percent conservation after district heating customers signed up. To avoid these shortfalls in customers and demand, financing in many district heating systems is contingent on the signing of 20- or 30-year "take-or-pay" contracts with major customers. In these contracts, the customer agrees to pay for a certain amount of district heat, whether or not it is used.

Conservation and District Heating. Many of the conservation measures described in chapter 3 as suitable for office buildings and multifamily buildings would not be applicable to a building heated with district heat. Some would, however, be equally cost effective. In multifamily buildings domestic hot water improvements such as storage tank insulation and flow restrictors could reduce the hot water demand, and night insulation or storm windows could reduce the space heat demand. Office buildings can achieve significant savings by installing zoned thermostats to turn off the heating systems when people are not using the space. They can also use fans and heat pumps to move heat from computer rooms, laundries, and restaurants into other areas of the buildings. Such measures, if they cost $15 to $20 per million Btu saved (unamortized capital cost) will cost the owners of the buildings less than continued high volume use of district heat.

Table 66.—How Different Contingencies Can Affect the Total Cost of a Proposed District Heating System for Washington, D.C.

Assume a hot water D/H **system for Washington, D. C., from table 6 using midpoint cost values (1978 dollars) — all 4 zones**

Subsystem / Case	Transmission line cost 10^6 dollars	Local distribution cost 10^6 dollars	Building retrofit cost 10^6 dollars	Powerplant retrofit[a] 10^6 dollars	Replacement Of lost electricity capacity[b] 10^6 dollars	Total capital cost 10^6 dollars	Thermal load provided by D/H 10° Btu/yr	Total capital cost per delivered Btu dollars/ 10^6 Btu/yr
1. Under current conditions with 100 percent of buildings connected . . .	$346.5	$481.5	$184.5	$96.5	$331.0	$1,440.0	25,879	$55.64
2. Only 60 percent of the buildings are connected.	346.5	288.9	110.7	96.5	304.5	1,147.1	15,527	73.88
3. Assume 40 percent conservation with 100 percent connected	346.5	481,5	184.5	96.5	304.5	1,413.5	15,527	91.03
4. Assume 40 percent conservation with 60 percent of the buildings connected	346.5	288.9	110.7	96.5	288.6	1,131.2	9,316	121.43
5. Assume loss of a major customer (10 percent of load) after installation with current conservation levels and 100 percent connection	$346.5	$481.5	$184.5	$96.5	$324.4	$1,433.4	23,291	$61.54

[a]Powerplant retrofit is assumed relatively fixed cost, even with decrease in thermal load.
[b]Replacement of lost electric capacity here assumes that one unit of electricity is gained for every five units of thermal load decrease. Stated more conventionally, five units of thermal energy are produced for every one unit of electricity sacrificed,

SOURCE: Office of Technology Assessment using data on district heating costs for Washington, D.C. system in Santini, et al., op. cit., for tables 9 and 10.

Given the relatively high energy use of American buildings compared to European buildings it is likely that building owners will continue to make investments that save energy at least over the next decade. Since a serious overestimate of district heat demand can lead to substantial increases in fixed costs per delivered Btu, it is important that the potential conservation steps by building owners be allowed for in the initial sizing of the district heating system and even encouraged before a final heat load is estimated.

Competition With Other Utilities and Fuel providers. If it is large enough, a district heating system can cut deeply into the most lucrative market of natural gas utilities and fuel oil dealers. The large users which are the best customers for district heating are also the best customers for other energy suppliers since transaction costs are low for the volume sold. To the extent that such competitors are strong in a community, it may be more difficult to get community-wide support for district heating.

CONDITIONS FOR A SUCCESSFUL DISTRICT HEATING SYSTEM

Under high financing costs, the economic competitiveness of a capital-intensive technology such as district heating is fragile. Under such conditions a series of unlucky breaks can prevent a system from being economically viable except when heavily subsidized. Communities that are more likely to have successful district heating systems would have some distinct characteristics, although successful systems are certainly possible in communities without these characteristics:

1. Cold climate. This is not a required characteristic but it helps. A cold climate can have two impacts that reduce the costs of a district heating system. By increasing the peak heating demands of any given set of customers—multifamily or high-rise office build i rigs-the relative cost per million Btu of distributing heat to that customer on the peak day is reduced. Furthermore, cities in cold climates generally have longer heating seasons and better load factors (ratios of average demand to peak demand). Table 67 shows the total heating degree days, peak degree days, and load factor for several cities in the United States. The low load factor of a city such as Memphis (0.19) compared to Milwaukee's (0.30) will directly increase the costs of district heating since revenues from a 35 percent smaller heat demand must pay for the same transmission and distribution system, All other things being equal, district heat costing $9.67 per million Btu in Milwaukee will cost $14.11 in Memphis.

Table 67.—Climactic Influences on Heating Loads for Selected Cities

Region and city	Annual heating degree days	Temperature on heating design day (“F)	Degrees below 65° on heating design day	“Load factor”[a]
Northeast and North Central				
Boston	5,621	9°	56	0.28
Milwaukee	7,444	–40	69	0.30
Minneapolis-St. Paul	8,159	– 12°	77	0.29
South and West				
Los Angeles	1,819	40°	25	0.20
Baltimore	4,729	13°	52	0.25
Dallas	2,382	22°	43	0.15
Memphis	3,227	18°	47	0.19
Seattle	5,185	26°	39	0.36

[a] The load factor is calculated by dividing the total heating degree days by the Product Of degrees below 65°F on the heating design day (the systems designed peak load) times 365 days (annual HDD - design day HDD x 365 days)

SOURCE Santini and Bernow, source for fig. 4.

2. *A core of large, closely packed customers with strong commitments to district heating.* Such a group of customers can form a dependable nucleus of demand and revenues for district heating. The costs of a distribution system to such customers–if properly sized–should be at a minimum. Planning guides recommend that district heating systems sign "take or pay" or similar long-term contracts with such customers in the planning stage. Such contracts eliminate some of the uncertainty about future hookups and the size of future heat demands. The core of the St. Paul system will be a set of municipal buildings and several large commercial and industrial customers. Thirty year contracts will be signed with these customers before bonds can be sold to pay for the construction of the systems.[23] Other systems could use a new urban renewal area, a set of hospitals, or university buildings as the core customers.

Given the favorable economies of a district heating system for a core group of customers, there is a strong case to be made for starting with small viable district heating systems such as the Trenton System (box L) and adding sections only as a larger market **for district heat** proves feasible.

3. *A source of heat close to customers.* This characteristic minimizes transmission costs which can also be considerable. Technically, hot water can be transported up to 70 miles from a heat source to a city, but the transmission cost is proportional.

4. *Excellent project management to hold down construction costs.* District heating is an enormous construction job and it must be managed accordingly. Naive management can lead to major cost overruns with devastating consequences for prices.

5. Lowest *possible financing costs.* Utility participation is probably essential to get relatively low-cost financing if the district heating system is to be privately built. As we have seen, however, it is likely to be necessary to subsidize debt service in order to have district heating prices competitive with other fuels at least in the early years. State or local industrial revenue bonds, with government guarantees will bring interest costs down somewhat. Regular revenue bonds that are tax exempt will bring interest costs down still further.

Justification for Sponsoring and Subsidizing District Heating. There are many hard-to-quantify reasons why a local or State government may wish to sponsor (and usually subsidize), a district heating project. District heating employs local workers, spends money locally and this is likely to have a local multiplier effect that stimulates local economic activity. District heating is also almost certain to stabilize energy prices for local building owners although it may take several, or many, years for the price of district heat to be substantially below competing fuels. A district heating system is a visible form of investment in a community and may add, both practically and symbolically, to the attractiveness of a community to future business and investors.

Nonetheless, it should be realized that district heating may prove to be expensive for the community or State. District heating systems may have to be subsidized both initially and over time if they get into a situation where revenues are insufficient to cover fixed **costs. These costs should** be fully appreciated and weighed against the expected benefits.

[23] James O. Kolb, op. cit. (source for box K).

OPTIONS FOR FEDERAL POLICY TOWARD DISTRICT HEATING

The Federal Government may be wise to leave to the States the option of whether or not to subsidize district heating, since it is likely to be successful only in areas with very specific characteristics. However, there are several useful things the Federal Government can do short of actual subsidy.

- Improve the state of knowledge of district cooling. Can it be a viable combination with district heating for Southern cities?
- Improve the state of knowledge about the prospects for existing steam systems? Can they be retrofit for hot water? Improved in other ways?
- Consider the development of a plan to keep more steam systems from closing down. Tax forgiveness measures might be considered.
- Assist States and localities with the technical and other aspects of the marketing of district heating to potential customers including techniques for retrofitting buildi rigs.

The greatest impact that the Federal Government is likely to have on district heating is indirect—through its interest rate policy. A drop of several percentage points in financing costs would make many nonviable proposed systems economically attractive.