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District Heating/Cogeneration Application Studies for the Minneapolis–St. Paul Area

Market Assessment and Economic Analysis of the St. Paul District Heating System

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Vol. I

ENERGY DIVISION

DISTRICT HEATING/COGENERATION APPLICATION STUDIES FOR THE MINNEAPOLIS–ST. PAUL AREA

MARKET ASSESSMENT AND ECONOMIC ANALYSIS OF THE ST. PAUL DISTRICT HEATING SYSTEM

H. O. Nyman*
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***District Heating Development Company, Inc.**

Prepared by the
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PREFACE

This report is one of a series of application studies of district heating/cogeneration for a U.S. metropolitan area. The technical, economic, environmental, and institutional studies in this series established the general feasibility and desirability of a hot water district heating system using cogenerated thermal energy from utility power plants. St. Paul, Minnesota, is proposing to replace a steam district heating system that serves its central business district with a modern hot water district heating system. The District Heating Development Company, Inc., was established to develop an implementation plan for an economically feasible system.

The District Heating Development Company, Inc., has been funded by the U.S. Department of Energy, the state of Minnesota, the city of St. Paul, and the Northern States Power Company. The Oak Ridge National Laboratory has provided technical management as a part of the overall Twin Cities District Heating Application Studies.

CONVERSION FACTORS

To convert from	To*	Multiply by
lb/h	kg/s	0.0001260
ft^2	m^2	0.09290
in.	cm	2.5400
MBtu or 10^6 Btu	GJ	1.055
Btu/h	kW(t)	0.0002931
MBtu/h or 10^6 Btu/h	MW(t)	0.2931
psi	kPa	6.895
°F	K	$T_K = [(T_{°F} - 32)/1.8] + 273$
$/MBtu	$/GJ	0.9479

*Prefixes are used in the SI system to form decimal multiples of the base units (factors of 10^3): k = 10^3, M = 10^6, and G = 10^9.

ft to meter .3048

ABBREVIATIONS AND ACRONYMS

BOMA	Building Owners and Managers Association
COO	Chief Operating Officer
DH	District heating
DHDC	District Heating Development Company
DOE	Department of Energy
EAW	Environmental Assessment Worksheet
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
HDR	Henningson, Durham and Richardson, Inc.
HW	hot water
HUD	Housing and Urban Development
IDB	Industrial development bond
IRC	Internal Revenue Code
IRS	Internal Revenue Service
MEA	Minnesota Energy Agency
MCHE	Michaud, Dooley, Hallberg, Erickson, & Associates, Inc.
NSP	Northern States Power Company, Inc.
TKDA	Toltz, King, Duvall, Anderson, & Associates, Inc.
UDAG	Urban Development Action Grant

ACKNOWLEDGMENTS

The authors wish to acknowledge the many individuals who have contributed to the various phases of the St. Paul hot water district heating project.

The foremost figure influential in the project's initiation and reality is St. Paul Mayor George Latimer, whose foresight and enthusiasm have carried the project nearly to fruition. A sincere cooperative public-private effort by the following and others has made this project successful: Rudy Brynolfson, Director of Finance, and Herbert Jaehne, Director of Engineering, District Heating Development Company, Inc. (DHDC); DHDC management team and staff; DHDC Board of Directors; Richard Broeker, James O'Leary, and Stephen Wellington, city of St. Paul; Ronald Visness and Ronald Sundberg, Minnesota Energy Agency; William Buth and Cliff Olson, St. Paul Building Owners and Managers Association; Neal Goldenberg, Alan Rubin, William Savage, John Rodousakis, and John Millhone, Department of Energy; Conrad Aas, D. W. Angland, Edward Glass, and Peter Jones, Northern States Power Company; Peter Margen, Studsvik Energiteknik; and Michael Karnitz, Oak Ridge National Laboratory. Also, the significant contributions of the following consultants and subcontractors are recognized: Michael Barnes, Scantec, Inc.; Steve Lynch, E. F. Hutton; Robert Michaud, Michaud, Cooley, Hallberg, Erickson & Associates; James Powers, Metcalf and Eddy, Inc.; Alex Sleiman, HDR; Ken Stocke, Touche-Ross, Inc.; and Kevin Teichman, Ellerbe Associates, Inc. Special appreciation is afforded to C. W. Easton, William Mahlum, and Alice Murphy, whose assistance, guidance, and support have never faltered.

ABSTRACT

The goals of the St. Paul District Heating Demonstration Project are (1) to assess the detailed economic feasibility of a cogeneration, hot water district heating system servicing the commercial core area of St. Paul, Minnesota, and (2) to develop an implementation plan for financing and construction of the first phase of the system over a four- to five-year time span. This report presents the results of the economic feasibility assessment and the implementation plan developed by the District Heating Development Company, Inc., between October 1979 and June 1982. The economic assessment is based on engineering studies of the detailed heat load and market definition, building conversion methods and costs, St. Paul area heat sources, and the conceptual design of the piping distribution system. Extensive use of Swedish hot water district heating technology and experience with cogeneration heat sources is incorporated in the design to minimize capital and operating costs.

The heat load survey determined a 300-MW(t) total heat load in the initial market area. The market is composed of over 300 buildings, including four major hospitals and the State Capitol complex. A significant fraction (50%) of the buildings have internal steam distribution systems, many of which are old and in need of repair. Building conversion studies disclosed a wide range of costs for upgrading and connection of a 250°F hot water supply system.

Costs were estimated for the piping systems, peaking heat sources, and building conversion from project studies. These costs plus costs of 250°F hot water from the NSP High Bridge Station supplied by NSP were key inputs to a preliminary economic feasibility study of the project. The financing of the transmission and distribution system is based on a tax-exempt revenue bonds issue supplemented by a Housing and Urban Development (HUD) Urban Development Action Grant (UDAG). A separate, tax-exempt bond issue is planned for financing of customers' buildings conversions. The preliminary economic feasibility study concluded that 165 MW(t) was the minimum market connected over a four-year construction period to provide the revenues required for the bond issue. The results of the preliminary economic feasibility study established the business plan and key project requirements leading to the construction of a $44 million hot water district heating system in St. Paul.

The first step toward actual implementation of a cogeneration, hot water district heating system was the award in March 1981 of a $7.5 million HUD-UDAG to St. Paul for financing of the system's construction. The final steps toward implementation were achieved in September 1982 when the minimum required customer load was under contract and a final bid for the piping distribution system was accepted. Thus, the final economic feasibility study for the project concluded that the required debt service coverage would be available. Therefore, the revenue bond sale could proceed to complete financing for system construction beginning in early 1983.

EXECUTIVE SUMMARY

In July 1979, the District Heating Development Company, Inc. (DHDC), was formed to develop a hot water district heating demonstration system that is economically feasible for the city of St. Paul, Minnesota. A funding proposal was presented to and accepted by the U.S. Department of Energy, Northern States Power Company, the state of Minnesota, and the city of St. Paul to cooperatively fund the project for its study phase. The study phase has now been completed, and the results are presented in this report. In addition, progress of the final design and marketing phase through June of 1982 is also described. Major accomplishments in the study phase include the following:

- Costs were estimated and preliminary conversion techniques established for buildings in the projected market area.
- A permit procedure was established, and a negative declaration of the need for an Environmental Impact Statement for the Environmental Quality Board was made.
- A methodology for estimating the cost of thermal energy from the heat sources was established.
- A conceptual design for the hot water distribution system was completed and a preliminary cost estimate was developed for construction of a 270-MW(t) transmission and distribution system.
- The method of financing the construction of the district heating system was established.
- A preliminary economic feasibility study indicated that 165 MW(t) of customer demand is required for an economically feasible system.

The preliminary economic feasibility study incorporated data from all the other study phases and concluded that proceeding to the final design and market phases was justified. The study established a business plan to follow for the project which will result in a viable hot water district heating project which can be funded and constructed.

In addition to the system costs, the influence of competitive fuels on the district heating rates was also analyzed. In the Minneapolis/St. Paul area, natural gas appeared to be the stiffest competition. The natural gas rates were projected to increase dramatically in the near future, particularly after 1985. Until that time, however, this factor was influential in determining initial hot water district heating rates. Since gas was shown to be the primary competition, hot water district heating rates were set competitively with gas prices. The business plan maintains the debt service coverage while simultaneously minimizing projected construction and financing costs, and the price of thermal energy. At the economically feasible system load of 165 MW(t), a debt service coverage ratio of 1.5 or greater is expected.

The DHDC is, therefore, required to meet certain minimum requirements in its final design and marketing phase so that revenue bonds may be issued. One of the first steps is to establish the necessary 165-MW(t) customer base. This is being accomplished through a phased program which involves marketing 30-year service contracts to individual building owners; local, county, and state governments; and four hospitals. The detailed piping design, which incorporates proven European practices and experience to help minimize costs while attaining a high degree of reliability, is being completed. Since revenue bonds will be used to finance most of the costs of system construction, the detailed design is required to obtain firm construction bids.

Before the bond sale begins, optimum building conversion methods are being established, construction methods finalized, the final economic feasibility study made, and a bond prospectus prepared. Industrial development bonds will be acquired by the St. Paul Housing and Redevelopment Authority for the estimated $44-million system construction. A separate, tax-exempt bond issue will be made by the St. Paul Port Authority to help the DHDC provide building owners with low-cost, long-term financing to pay for conversion of their buildings to a hot water heating supply.

This report details the steps the DHDC has taken to reach this last phase before construction. It collects a wealth of detailed information on hot water district heating based on long-term European experience in the technology. Although the information is specific to the city of St. Paul, Minnesota, much of it can be used for similar projects in other U.S. cities.

The success of the project thus far can be largely attributed to the cooperative support the project has received from a variety of sources, both government and private. Implementation of an energy-efficient, economical, environmentally beneficial, and flexible hot water district heating system in St. Paul can be a major step toward energy conservation in the state and in the nation.

The DHDC is confident that with continued cooperative support, the steps necessary for the project to receive construction funding in 1982 will be completed, and system operation can begin in 1983.*

As the nucleus of a 20-year plan to implement hot water district heating throughout the Twin Cities metropolitan area, the first construction phase of the St. Paul system is planned to be implemented between 1983 and 1987.

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*Project update: On September 30, 1982, all requirements, including the minimum customer contracted load, were met for proceeding with the sale of municipal revenue bonds in December. Thus, all elements of the system's financing are in place, and construction of the piping system will begin in the spring of 1983.

1. INTRODUCTION

In the energy-intensive environment of Minnesota, energy consumers are keenly aware of the need for dependable heating and energy sources. St. Paul has over 8000 degree days in a heating season and is heavily dependent on uncertain and increasingly expensive supplies of oil and natural gas. To provide a secure energy and economic future, a heating system such as hot water district heating is desirable because it relies on more abundant domestic fuels such as coal and is compatible with building energy conservation alternatives.

Having fewer available fossil fuels, most northern European nations have already developed hot water district heating systems serving entire cities and have proved them to be economical, efficient, and environmentally beneficial. The United States has had previous district heating experience with steam distribution, but without such great success in providing community-wide heating service.

First implemented in the United States over 100 years ago, steam district heating experienced rapid growth until the late 1940s when inexpensive oil and gas became available. Now, because of rapidly escalating energy prices and increasing dependence on imported oil, hot water district heating technology is being reassessed. Large, hot water district heating systems have the potential of providing customers over a wide area with space heating at competitive prices while substituting plentiful domestic fuels, such as coal, for premium oil and natural gas fuels.

Hot water district heating is the process by which water, heated by a central heat source, is piped underground to commercial, industrial, and residential consumers for space heating, domestic hot water, and process needs. A district heating system comprises three main elements: a central heat source or sources, a piping system for transmission and distribution, and consumer heat transfer equipment.

The central heat source is usually a heat-only "boiler*" or a turbine in an electrical power plant which has been converted to cogeneration. Cogeneration is the simultaneous production of electricity and useful thermal energy by the same power plant and allows much of the reject heat from the electrical generation process to be used in district heating. Thus, the fuel conversion efficiency of a cogeneration power plant will increase significantly. Normally, electric generating plants convert only one-third of the input fuel energy to electricity; nearly two-thirds of the energy is lost as reject heat into the environment. Cogeneration with hot water district heat production can increase the power plant's fuel conversion efficiency from about 35% to nearly 80%. Therefore, increased fuel conversion efficiency with a cogeneration heat source can result in substantial fuel and cost savings which helps make hot water district heating economical. In addition, the use of more plentiful and

*The term "boiler" is used in a generic but not a literal sense for a source of hot water since "boiling" or vaporization would not actually occur.

lower-cost coal in place of oil and natural gas as the heating fuel contributes to lower and more stable heating costs for the customer of the district heating system and at the same time extends the life and availability of the premium heating fuels.

One of the keys to economically competitive delivery of thermal energy via a district heating system is a piping distribution system that has (1) low capital cost, (2) minimal heat losses, (3) high reliability and low maintenance costs, and (4) compatibility with the heating requirements of the potential market. The choice of a medium temperature—250°F (394 K) maximum—hot water distribution system has been proposed for this demonstration project to capitalize on the extensive experience in European district heating technology to meet the requirements stated above.

Although the consumer can benefit from lowered costs, the environment can also benefit because pollution control devices plus release from tall stacks at the central heat source reduce air pollution. Because fuel is burned at a central source which can be equipped with cost-effective pollution control equipment, combustion emissions from numerous individual boiler stacks on buildings are eliminated so that urban air quality is improved. Cogeneration heat sources also use much of the low-temperature heat normally rejected to a cooling tower, river, or lake so that the thermal effects of power production are reduced.

Hot water district heating also provides for flexibility in the types of fuels and heat sources used for heating in the future. Besides the more common coal and oil, fuel sources may be peat, biomass, municipal solid waste, and nuclear or solar energy; industrial waste heat can also be used as a heat source. Solar-powered district heating is already being developed in several European countries (e.g., Sweden).

Thus, the major benefits which could be realized from implementing a hot water district heating system in an urban center such as St. Paul are (1) energy efficiency, (2) customer economics, (3) environmental benefits, and (4) flexibility in future heat sources. Yet these potential benefits could never be realized in St. Paul until the economic feasibility is examined in detail for the specific market conditions of the central business district of St. Paul. Therefore, the major goals of this report are (1) to present the findings of a detailed study of engineering and economic feasibility of a hot water district heating system in St. Paul and (2) to develop an implementation plant for project financing and construction of the first phase of the system.

2. PROJECT BACKGROUND AND ORGANIZATION

2.1 Background

Investigation of the implementation of an energy-efficient, hot water district heating system in the Twin Cities of St. Paul and Minneapolis began with a study funded by the U.S. Department of Energy (DOE) through Oak Ridge National Laboratory (ORNL) and conducted by Peter Margen of Studsvik Energiteknik ab.[1] Northern States Power Company (NSP), the Minnesota Energy Agency (MEA), DOE, and other local government and private organizations cooperated in this and other area studies. The results indicated that a large regional district heating system would be economically feasible with public financing.

Development of the 2600-MW(t) system resulting from these studies would begin in the high-density areas of the Twin Cities and expand over a 20-year development period using cogenerated heat from several power plants within the Twin Cities area. On an annual basis, over the 20-year development period, the system could save enough energy to heat 200,000 homes. With the overall feasibility of hot water district heating implementation in the Twin Cities shown in the initial studies, St. Paul began to investigate methods to initiate the system. A 75-year-old steam district heating system, previously owned and operated by NSP, is rapidly deteriorating and in need of repair. The steam system could be repaired with a major new investment; it could be abandoned—leaving over 130 customers without a heating source; it could be replaced by a major expansion of the NSP gas distribution system; or it could be replaced by a hot water district heating system.

2.2 Project Organization

Upon recommendation by the MEA[2] to incorporate a nonprofit, hot water district heating development company, the city of St. Paul headed by Mayor George Latimer, St. Paul Building Owners and Managers Association, St. Paul Chamber of Commerce, state of Minnesota, NSP, and local trades and labor organizations established a private, nonprofit company, the District Heating Development Company, Inc. (DHDC). The DHDC proposed to DOE that St. Paul become a pilot project for hot water district heating development in the United States. In July 1979, DOE accepted St. Paul's proposal and agreed to provide consolidated funding for the project with the state of Minnesota, the city of St. Paul, and the NSP.

As a symbol of the cooperative effort found in St. Paul, the DHDC Board of Directors was structured to include representatives from energy users, energy suppliers, and governmental agencies. Hans O. Nyman was selected by the Board as the company's Chief Operating Officer (COO). Nyman had previously been a hot water district heating consultant to the MEA while on leave from his Chief Engineer position at the Uppsala Kraftvarme ab in

Sweden. While at Uppsala, Nyman supervised the initial construction and growth of its 800-MW(t) hot water district heating system which serves 80% of the city's total heating market.

As head of DHDC's management team, the COO is responsible for overall project management and reported project progress to the DHDC Board of Directors, which is the company's policy-making entity.

DHDC's organizational structure is shown in Fig. 2.1. The management team consists of the COO, a director of finance and administration, a director of engineering (on loan from NSP), a legal consultant, and a communications coordinator. The management team and subcontracted consultants were selected according to rigid qualification standards to ensure proper and high-quality results. The mangement team supervised these consultants, whose studies have been used in this report.

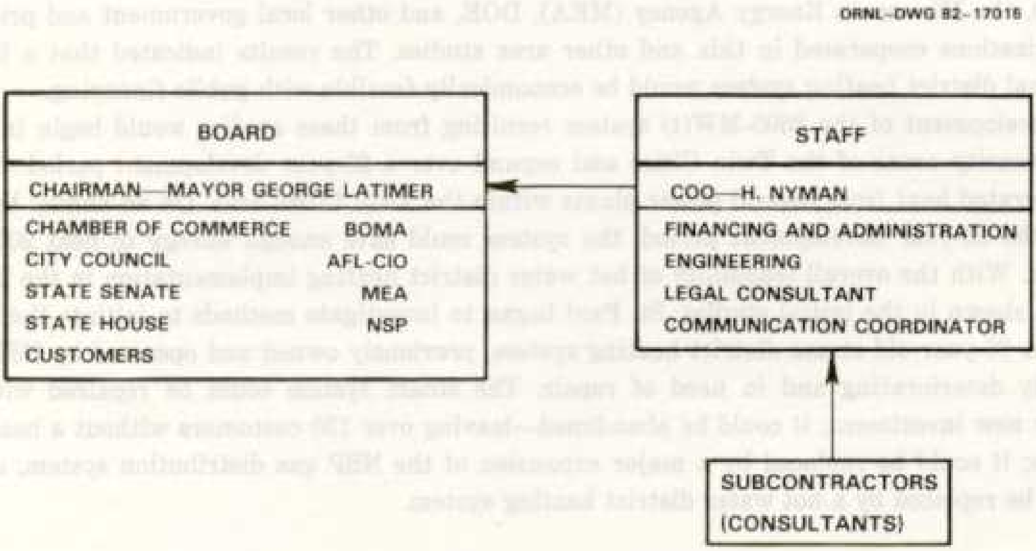

Fig. 2.1. Organization of the District Heating Development Company, Inc.

2.3 Task Organization

Under the COO's direction, the management team undertook its assigned objectives for its first project phase using funding appropriated by the state, federal, and local governments and NSP. These objectives included:

- defining the St. Paul building heat load;
- determining building conversion methods and costs;
- analyzing St. Paul area heat sources;
- defining the piping distribution system and its construction cost;
- determining the cost of thermal energy;

- determining market characteristics and developing a marketing plan;
- determining the economic feasibility of the system; and
- developing an implementation plan for financing the system's construction, developing the operating company structure, and satisfying permit requirements.

3. PROJECT DESCRIPTION

Through the studies performed in the project's first phase, the DHDC has developed a general description of each of the system's three main components: heat sources, piping distribution system, and building conversion.

3.1 Heat Sources

Various existing types of heat sources are located within or near the project area. These include NSP's coal-fueled High Bridge Generating Plant and the coal- and gas-fueled Third Street District Heating Plant as well as several large oil/gas-fueled boiler installations, such as the State Capitol and the St. Paul Ramsey Medical Center (Fig. 3.1).

The High Bridge Plant will be utilized during the early stages of system growth and will be base-loaded to supply most of the system's energy needs. Existing turbine units and heat-only boilers will be retrofitted for use in the hot water district heating system. Depending on the heating load growth, the turbine units at the High Bridge Plant could be converted to cogeneration as early as 1984 to utilize reject heat from the generation of electric power. A conceptual design and cost estimate for modifying the High Bridge Plant turbines to cogeneration has been developed.[3] The heat-only boilers will be used to supply energy for peak demand periods and also to provide emergency backup capacity.

The Third Street Plant, the State Capitol Complex, and St. Paul Ramsey Medical Center can be connected to the system to provide additional thermal capacity and reliability. Steam to hot water heat exchangers would be used to transfer the heat to the district heating water at the power plants. A conceptual design and cost estimate for modifying these boiler plants to hot water heat sources is presented in ref. 4.

3.2 Piping Distribution System

The district heating water will be pumped through large-diameter (nominal 30-in.) transmission pipelines from the High Bridge Power Plant to major load areas for distribution. A hot water supply and a return line will be routed from the High Bridge Plant to the Third Street Plant through the dense downtown area to the State Capitol Complex. The conceptual piping route is shown in Fig. 3.2. Smaller diameter supply and return distribution pipelines will be routed from the transmission lines to the buildings to be served.

The pressure in the pipes will be a maximum of 250 psig. The 250°F temperature selected for the system has been optimized for use of waste heat through cogeneration and industrial processes. Because the piping technology for these specifications has been proven, the piping is readily available in various designs and configurations. The St. Paul system will most

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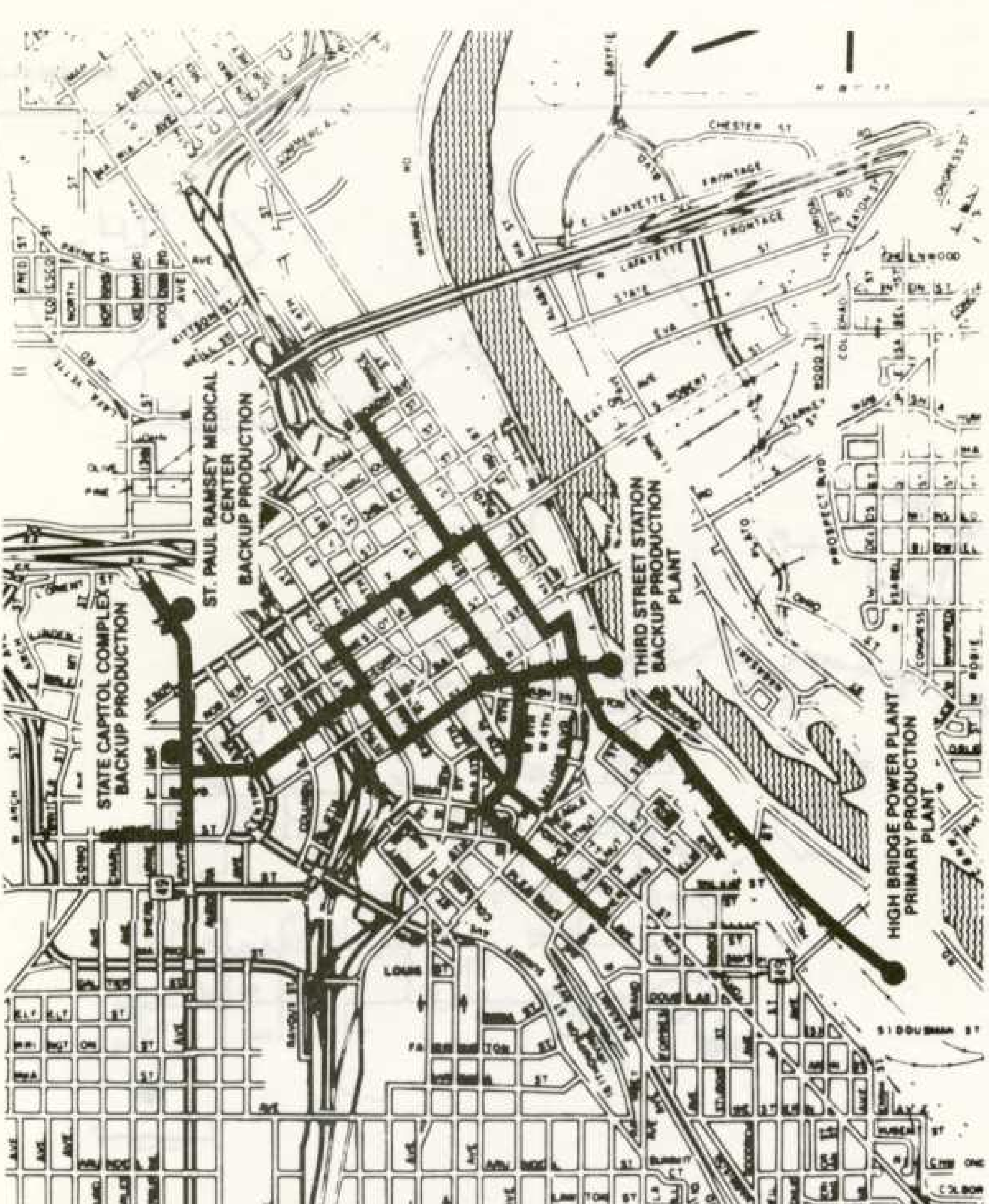

Fig. 3.1. St. Paul 300-MW(t) hot water system serves the downtown core area and capitol complex.

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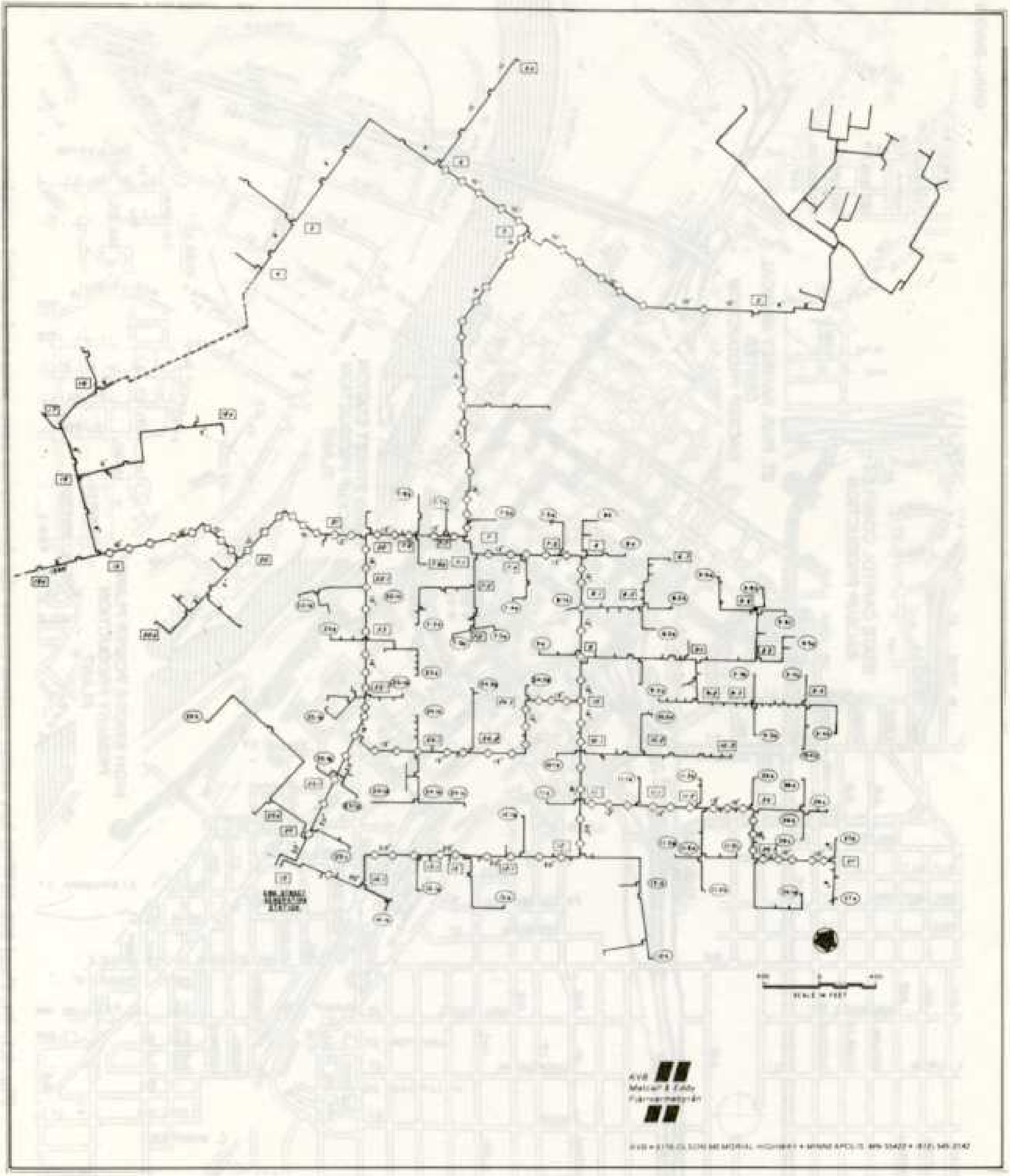

Fig. 3.2. Conceptual piping route.

likely use the direct buried, prefabricated piping conduits with steel pipe, insulated with polyurethane and encased by a polyethylene jacket similar to those used in Europe.

Although a hot water district heating project of this size has not been previously implemented to serve a U.S. urban center, hot water district heating has been technically proven and used extensively in northern European countries for nearly 30 years. Due to their extensive experience, the Europeans have been able to refine the technology for increased reliability and cost effectiveness. The St. Paul project has benefited from the European experiences. European district heating consultants, working in conjunction with U.S. engineering consultants, have been retained for the preliminary system design.

The piping system will be constructed in sections. As each section is completed it will become operational and produce revenue for the system. The distribution piping will initially be constructed to the greatest heat load demand areas, the State Capitol Complex and the four major hospitals. As many connections as possible will be made to other buildings along these routes.

The system will continue to grow and operate in this manner over the multiyear construction period. Piping loops will be constructed in the later growth stages to increase system reliability.

3.3 Building Conversion

3.3.1 Primary Considerations

The buildings that are connected to the district heating system will be converted to use the hot water thermal energy in an efficient manner. The existing building heating systems will be modified to use the hot water thermal energy for heating, domestic hot water, and process loads. When necessary, conversion of the heating systems from steam distribution to hot water distribution will permit more precise control and regulation. Such conversions will increase the comfort of the occupants while simultaneously providing energy conservation. Hot water building distribution systems will also permit new energy savings concepts to be implemented as new energy codes are developed in the future.

Because the central distribution system will be hot water with a maximum supply temperature of 250°F, existing buildings using steam perimeter heating will have their heating systems converted to hydronic operation when they connect to the district heating system. New buildings in the service area will be encouraged to incorporate hydronic heating systems. The majority of the buildings connected to the system during the initial five-year development period will be existing buildings. Therefore, the investigation of cost-effective conversion methods and techniques for a wide variety of building heating types became an important element in the economic feasibility of this project.

The work involved in converting any building to a hydronic system and connecting it to the district heating system depends primarily on the existing system in the building. Buildings that already have hydronic heating systems are generally quite easy to connect. Buildings that have an existing steam heating system are generally harder to connect. The heating demand for 214 downtown St. Paul buildings totals approximately 140-MW(t). The majority of the existing buildings—132 out of 214—have steam heating systems.

Typical building heating systems comprise three parts (Fig. 3.3)—perimeter radiation, air-handling ventilation, and domestic water heating. Most downtown area buildings have all three parts. Those buildings which do not have both perimeter radiation and ventilation heating generally have only perimeter radiation heating.

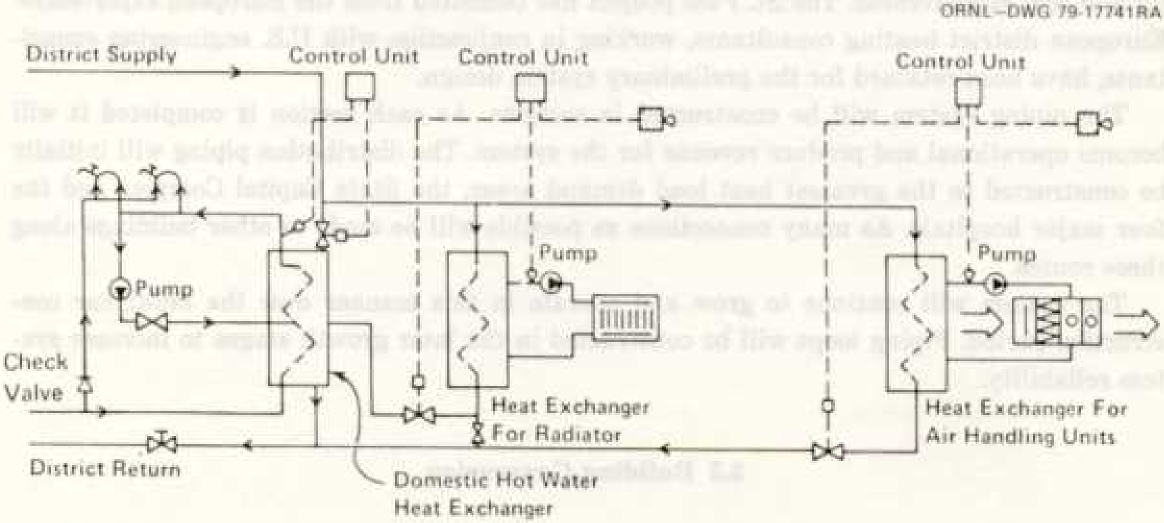

Fig. 3.3. Building heating system connected to district heating emphasizes low return temperature.

3.3.2 General Conversion Guidelines

There are many specific configurations for both connecting a hot water district heating system to a building heating system and converting the building system to a configuration that is compatible with thermal energy supplied by hot water. This is because of the large number of individual building heating systems and types of buildings (commercial and office space, hotels, restaurants, schools, museums and sports facilities, and multifamily residential units) that exist in a mature urban center such as St. Paul, Minnesota. The discussion that follows is intended only to give general guidelines as to the conversion approaches that can be used in the connection of existing builldings to a hot water district heating system. For a more detailed discussion of building conversion techniques and costs, see Sect. 4.3.

The most extensive heating system modifications are required for buildings with steam perimeter heating that must be converted to hot water (or hydronic) operation. Conversion of an existing steam perimeter system is difficult because both distribution piping and terminal units may need to be changed. Steam supply piping, if in good condition, can often be reused for hot water, but condensate return piping is often too small or not routed for return to a central location.

Steam perimeter heating circuits can be converted to hot water service if they are in good condition and have radiation units that are compatible with hot water. However, often the radiation equipment in older buildings is not in good condition. In these buildings, there are so many changes involved in piping and controls that to reuse the existing radiation equipment may save little in installation cost and leaves a very weak link in an otherwise like-new system.

Steam heating coils in ventilation units can be an expensive conversion element. Because of coil designs, existing steam coils may provide insufficient heating when converted to hot water, and field revision costs are comparable to replacement costs. Fortunately, new energy standards have reduced outdoor air requirements to the point where many steam heating coils have been shut off. These coils therefore do not have to be converted. Using the same philosophy of design, many addtional steam coils can be shut off rather than converted at the time of building conversion. Where a small need for ventilation heat remains, piping hot water to existing steam coils and/or cooling coils or the addition of auxiliary electric heating coils may keep conversion costs down.

The connection of an existing hydronic perimeter heating system to hot water district heating is relatively easy because the distribution systems and terminal units within the building are already compatible with a hot water supply. Only the interface with the district system and some control elements need to be changed.

Buildings with a furnace for their heat source can generally have hot water coils added to the furnace or the duct work. Where this is not possible, new hydronic baseboard radiation can be installed, but this is a more difficult and expensive conversion method. Buildings with furnaces usually have a gas-fired domestic water heater. A heat exchanger using district heating water can be installed before the water heater to change the heat source from gas to district-heated water and to retain the storage capacity in the existing water heater. This conversion method, of course, applies to any building with a gas-fired water heater.

Steam domestic water heaters are generally converted to hot water by replacement of the steam tube bundle with a hot water tube bundle.

4. ENGINEERING STUDIES

Detailed engineering studies were initiated early in the project to provide a realistic basis for performing an economic feasibility analysis and to prepare for ultimate implementation of a new hot water district heating system. The scope and results of these studies are presented in this chapter.

4.1 Define St. Paul Building Heat Load

The first task undertaken by the DHDC was to define the St. Paul building heat load. The objective was to gather, through telephone and in-person surveys, technical information and data on the heating systems and energy consumption of over 300 buildings in the hot water district heating market area. Comprehensive survey sheets were compiled for each building and are important reference materials for this project. Sample survey forms are in Appendix A, Part 1.

The information gathered from these surveys was compiled and analyzed in a projected heat load report. From the report, a heat load and market definition was developed. For 307 buildings and potential customers, a detailed survey determined

1. location;
2. owner and building use;
3. energy uses, demands, and annual consumption;
4. energy sources—oil, gas, electric, steam district heat;
5. building characteristics; and
6. heating, ventilating, and air-conditioning system characteristics.

One of the most important parts of the definition is shown in Table 4.1, which details the building heat load by fuel type. As indicated, the heat load market within the project area is diverse, representing a mix of fuel types.

Interruptible gas customers currently make up 49% of the market area heat load; steam district heating customers are the next largest group at 31%. Firm gas customers are the next largest portion of the downtown area heat load, at 12%. Oil and electric customers make up a comparatively low percentage of the load.

Firm gas and electricity are the two fuel types which may not be as economically feasible to convert and connect to the hot water system. Present firm gas prices are competitive with estimated initial prices for hot water district heating; however, gas prices are expected to rise higher and faster than hot water district heating prices. "All electric" buildings are generally designed and constructed in a manner that makes conversion to a hot water system impractical.

Table 4.1. Heat load analysis

In each fuel category there are two rows of numbers: the first is for buildings under 500 kW(t), the second is for buildings of 500 kW(t) or more.

Fuel type	No. of buildings	Percentage of total	Heat load [kW(t)]	Percentage of total	Average [kW(t)]
Firm gas	88	33	9,973	12	113
	14		21,060		1504
Interruptible gas	26	21	5,426	49	208
	39		116,014		2974
Oil	9	3	603	0.5	67
	1		581		581
Steam—high pressure	10		2,255		225
	29	13	57,535	23	1983
Steam—low pressure	47	18	6,619	8	140
	8		13,062		1632
Electric convertible	1	0.5	172	1	172
	1		1,706		1706
Electric nonconvertible	4	1.0	0		0
	0		0		0
Fuel unknown	17	7	3,700	6	217
	6		11,000		1833
Unheated	7	3	0		0
	0		0		0
Total	307		249,706		

The types of building heating systems in the area show the market's diversity. A representative survey of 221 buildings, shown in Table 4.2, was conducted in the initial stages of the project. Since the building heating types were to play an ever-increasing role in the building conversion studies, a definitive breakdown of these systems was made (Sect. 4.3).

Basic evaluations were made from the initial survey. Although only 32% of the buildings surveyed are considered large buildings [>500 kW(t) of heat load], these buildings comprise over 85% of the heat load in the market area. Buildings with peak loads below 500 kW(t) are considered more difficult to connect to the system because of high unit conversion costs. This assumption should be qualified, however, since some of the smaller steam-heated buildings will most likely be connected to the system because of the eventual phaseout of the steam district heating system. Buildings with unknown fuel types were also assumed to be potential customers.

Table 4.2. Survey of building heating systems

Building type	Peak demand [kW(t)]	Steam boiler or steam district heat[a] — Steam: No.	Steam: Avg. kW(t)	Steam and hot water: No.	Steam and hot water: Avg. kW(t)	Hot water: No.	Hot water: Avg. kW(t)	Boiler[a]—hot water: No.	Boiler[a]—hot water: Avg. kW(t)	Furnace[a]—air heating: No.	Furnace[a]—air heating: Avg. kW(t)
Industrial	Over 4000	1	9,200								
	3000 to 4000										
	2000 to 3000										
	1500 to 2000	1	1,805								
	1000 to 1500										
	500 to 1000	2	858								
	Under 500	7	153								
Office	Over 4000			1	9,291	1	4,311				
	3000 to 4000										
	2000 to 3000	6	2,585	1	2,410						
	1500 to 2000	1	1,773			1	1,858				
	1000 to 1500	1	1,284					1	1,307		
	500 to 1000	5	626			2	693	2	807		
	Under 500	18	225	2	436			5	624	7	96
Hotel	Over 4000										
	3000 to 4000			1	3,661						
	2000 to 3000										
	1500 to 2000										
	1000 to 1500										
	500 to 1000	1	510	1	664			1	824		
	Under 500										
Apartment	Over 4000					1	5,223				
	3000 to 4000										
	2000 to 3000	1	2,449								
	1500 to 2000	1	1,900								
	1000 to 1500			1	1,176						
	500 to 1000	3	898								
	Under 500	5	220					2	279	2	52
Other	Over 4000			7	9,014						
	3000 to 4000	2	3,443	1	3,576						
	2000 to 3000	2	4,724	1	2,776						
	1500 to 2000							1	1,500		
	1000 to 1500	6	1,257								
	500 to 1000	9	680			1	600	1	967	1	765
	Under 500	60	165	2	155	4	232	11	74	27	81
	Total	132	88,088[b]	18	87,907[b]	10	14,306[b]	24	10,704[b]	37	3,728[b]

[a]Source of building heating supply.
[b]Total peak demand for building heating supply.

Within the core downtown market area, the DHDC plans to connect one hospital, St. Joseph's, representing 8 MW(t), and a large manufacturing company, the Gillette Company. Three other major hospitals, United, St. Paul Ramsey, and Bethesda, all on the outskirts of the initial construction phase, are also potential customers for the system, representing 11-, 13-, and 8-MW(t) loads, respectively. Also on the outskirts are two other major heat loads: the State Capitol Complex at 15 MW(t) and a major housing complex at 6 MW(t).

Heating load growth through new development in the downtown area is expected to be 5 to 6 MW(t) annually. The city of St. Paul is planning to aid the growth of district heating by placing a compatibility statement in its building permits; new buildings will be required to be compatible for connection to the hot water district heating system.

The total 30 to 40 MW(t) growth in downtown St. Paul is expected to be largely in commercial, office, and housing space. A substantial effort is being made to draw residents into the core city area. Several major condominium developments are already under construction.

The market heat load data, a sample of which has been described and projected above, were compiled and analyzed through a data-based computer system for incorporation into the market penetration analysis (Sect. 5.3). This information provided a base for the intensive marketing effort which was made in the later stages of the project.

4.2 Analyze Potential for Supplying Cooling Loads

The potential for supplying future heating loads and current cooling loads supplied by absorption chillers were studied. The absorption chillers in the DHDC market area are tabulated in Table 4.3. This table lists the twenty absorption units in the market area, totalling 9902 tons—9326 tons if the two standby units at the state capitol are not included. The average size of these units is 495 tons.

Based upon European practice, the normal summertime district-heated supply water temperature is 180 to 200°F. This temperature range is adequate for the normal domestic hot water requirements of each building, thereby reducing the distribution losses and

Table 4.3. Absorption refrigeration units in the DHDC market area

Building	No. of units	Total tons	Manufacturer	Age (years)[a]
Arts and Science Center	1	500	Trane	17
Metro Square	1	500	Trane	10
	1	500	Carrier	33
St. Joseph's Hospital—boiler plant	1	365	York[b]	22
Condolett II	1	222	Trane	3
Public Health Center	1	94	Carrier	23
West Publishing Co.	2	600	Carrier	3
N.W. Bell Telephone Co.	2	600	Trane	14
	1	205	Trane	8
Wabasha Court	1	150	Trane	11
St. Luke's Hospital	1	750	Carrier	1
St. Paul Ramsey Medical Center	2	1760	Carrier	15
State Capitol Complex	2	1500	Carrier	7
Boiler	1	1490	Trane	1
Standby—DOT[c]	1	560	Carrier	22
	1	106	Carrier	22
Total	20	9902		

[a]In 1980.
[b]Steam turbine.
[c]Department of Transportation.

increasing the efficiency of the system. Since most existing absorption chillers are designed to operate on steam or high-temperature water (250°F), the temperature requirements of absorption chillers are not compatible with a reduced-temperature-range summer operation of the district heating system.

Information obtained from the Trane Company, a heating and cooling company contacted for the study, shows that the Trane absorption chillers will operate at 100% of their rated capacity using 250°F water. Trane personnel believe that their units could be relatively easily converted from steam to hot water; however, the absorption chiller capacity is directly dependent upon the supply water temperature to the unit. A 200°F supply water temperature will produce the following maximum capacities (for Trane units), depending upon the number of passes through the concentrator section of the unit: one pass, 53% of rated load; two passes, 50%; three passes, 47%; four passes, 44%.

Although the capacity is increased at any given supply water temperature by limiting the number of passes through the concentrator, the return water temperature to the district heating system is also increased. The following table shows the relationship between passes and return water temperatures at 200 and 250°F supply water temperatures.

No. of concentrator passes	250°F*	200°F*
1	232	191
2	230	188
3	229	185
4	224	182

*Supply water temperature.

The temperature drop across the absorption unit is an important economic parameter for the district heating system; a large drop ensures reduced flow rates and minimized pumping needs. Piping heat losses are also reduced because of the lower temperature needed in the district heating supply line.

The cost for connecting existing steam absorption machines to hot water is approximately $10,000 to $15,000 per unit. This conversion cost does not include increased pipe sizes and piping from service entrances to the units; a rough estimate would be about $50,000 per service entrance.

If the temperature in the hot water district heating system is maintained at 250°F or above to allow the absorption chillers to operate at full capacity, the district heating system itself will be adversely affected. First of all, a number of technical factors are affected by operation of the district heating system at elevated temperatures over the greater portion of the year.

1. There will be increased thermal losses from the entire system, estimated at about $30,000 per year at initial rates.
2. Because of the high return temperature, the system would be unable to utilize back pressure turbines in future expansions.

3. The system will require a closed condensate circuit at all thermal sources because of the high return water temperature.

Second, if the supply water temperature is to be over 250°F for appreciable periods (i.e., 400 to 500 h per year), the entire design will have to be reviewed for compliance with the Minnesota high-pressure piping code. Also, longer periods at temperatures up to 270°F may degrade the polyurethane insulation around the piping and would therefore require expensive substitute materials. Finally, operation of the system at over 220°F generally makes it more difficult to service the system during outages and repairs.

Perhaps the most important evaluation criteria for whether hot water district heating should supply cooling loads is the significantly higher efficiency of electric compression chillers. The primary energy required for a 1-ton steam absorption chiller is 20,000 Btu compared with 12,000 Btu for an electric chiller. For example, the State Capitol Complex currently has 300 tons of steam absorption chilling; this represents one-third of the steam absorption cooling needs in the market area. By changing to electrical chillers, the state estimates it could save $0.10 per ton per hour in operational and energy costs. With an estimated 1000 full-load hours per average cooling season, a simple payback would be achieved in less than five years.

The average cost for replacing an absorption machine with an electrical compression chiller is approximately $300 to $500 per ton, depending upon the size of the machine, the difficulty of moving the equipment in and out of the building, and the cost of electrical service to the new unit. This unit cost represents a total of $2.8 million to $4 million for the DHDC target market area. The costs given are averages and do not include the salvage or resale value of the existing equipment.

Because of rapidly increasing steam prices and the significantly higher efficiency for the electrical centrifugal chiller, the DHDC projects that existing steam absorption chillers will soon be replaced. The decision was thus made not to make any investment in the hot water district system in order to serve absorption cooling units in the initial market area.

4.3 Determine Building Conversion Methods and Costs

Several studies were made on the feasibility of making the St. Paul market area building heating systems compatible with the hot water district heating system. There are many specific configurations for both connecting a hot water district heating system to a building heating system and for converting the building system to a configuration that is compatible with thermal energy supplied by hot water. This is because of the large number of individual building heating systems and types of buildings—commercial and office space, hotels, restaurants, schools, museums and sports facilities, and multifamily residential units—that exist in a mature urban center such as St. Paul.

One of the main concerns in studies of market area buildings was the use of an optimum system temperature. Through studies (described in more detail in Sect. 4.5), it was decided that the highest system supply temperature would be 250°F. The two main reasons for this decision were (1) the Minnesota Building Code temperature limitation and (2) the most cost-effective pipe conduit design with polyurethane foam insulation would not withstand temperatures much beyond the 250°F temperature limit.

With these basic factors in mind, the following studies were performed.

4.3.1 Levi Johannesson, Consultant

One of the first studies was compiled by a Swedish district heating building conversion expert, Levi Johannesson, from Orebro, Sweden. The following is an overview of his work.

The St. Paul market area buildings use heat for domestic hot water heaters, air heaters, humidifiers, kitchens, radiators, air coolers, and swimming pools; heat is also used to melt snow and for process heating.

The goals should be to adapt the building's heating system to hot water with a relatively low supply temperature, to control the heat usage in relation to outside temperatures, and to maintain the lowest possible return temperatures. This technique, presented in Fig. 4.1, allows the district heating system's supply temperature to be run in relation to

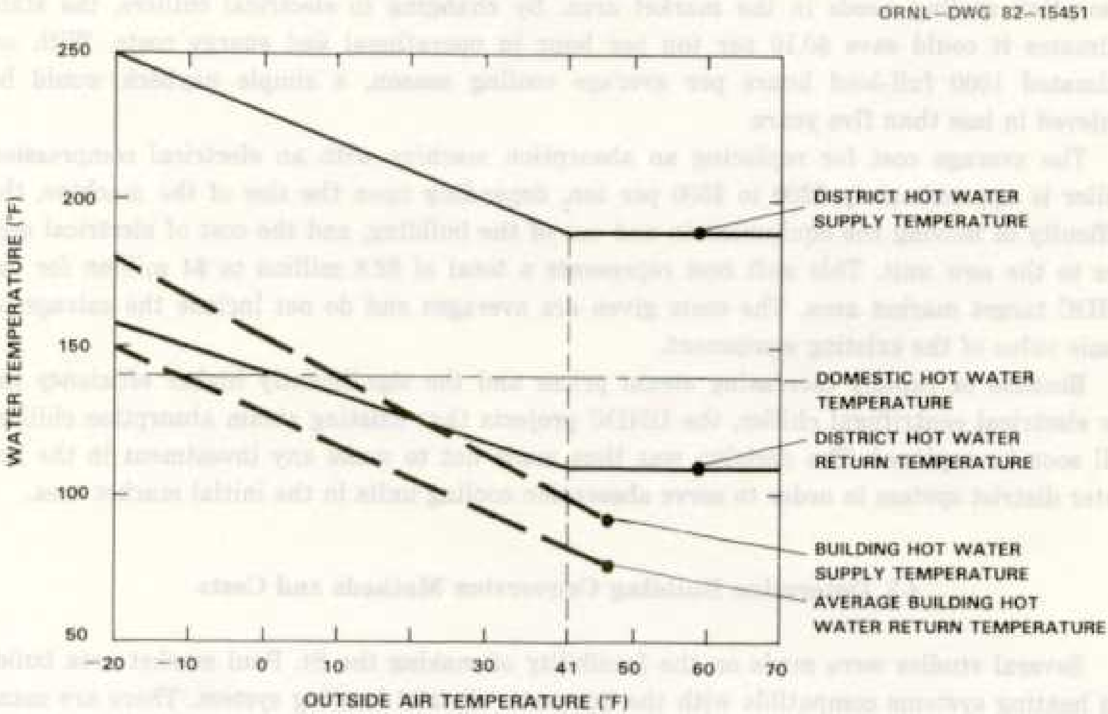

Fig. 4.1. Hot water temperatures for district heating system and hydronic building heating system as a function of outside air temperature.

the outside temperatures; that is, the highest temperature depends on the peak load and the lowest temperature depends on the temperature needs for domestic hot water heating.

The advantages of this supply form are

1. a proven design for the entire district heating system including heat sources, piping system, and customer connections is available;
2. low-cost distribution piping is available;

3. efficient cogeneration with a high power yield is possible (a low electrical sacrifice is possible); and
4. low operation and maintenance costs could be achieved.

It is important that domestic hot water heaters and space-heating systems be connected to the system so that the lowest possible return temperatures are obtained.

Guidelines should be worked out as soon as possible so that the design of the heat exchangers, control valves, heat meters, etc., and principal flow diagrams become uniform. Guidelines prepared by the Swedish District Heating Association could be used as an example.

4.3.2 Michaud, Cooley, Hallberg, Erickson and Associates

The two-phase building conversion study by the Minneapolis engineering consulting firm of Michaud, Cooley, Hallberg, Erickson and Associates (MCHE) was performed to determine the representative costs of connection and conversion of each building to a hot water district heating system.

4.3.2.1 General principles and methods

MCHE performed the study with several principles in mind. The buildings that will be connected to the district heating system will be converted to utilize hot water energy in an efficient manner. The existing building heating systems, consisting typically of radiation, ventilation, and domestic water heating units, will be modified to utilize hot water energy for space heating, domestic hot water, and process loads. Conversion of the building heating systems to hot water will permit more precise control and regulation of the heating system, which increases the comfort of the occupants while it conserves energy. Hot water systems will also permit new energy saving concepts to be implemented as new energy codes are developed.

MCHE applied these principles in each of two study phases. After in-person surveys were made of each of the building heating systems, drawings of the systems were made or obtained from building engineers. Schematic designs showing proposed piping and instrumentation were then drawn in accordance with design methods developed for European hot water district heating systems, allowing a mechanical contractor to prepare a cost estimate for each building conversion.

4.3.2.2 Phase I

The first phase of the MCHE study analyzed the conversion of seven buildings which were specified as typical buildings within the market area. Their heat demands ranged from 750 to 3500 kW(t). Each of the buildings has a different building mechanical system and characteristics which were studied for hot water district heating connection. Table 4.4 presents a summary of each building's heating system characteristics. Study of these systems was intended to provide generic data for buildings with similar characteristics.

Table 4.4. Phase I building information

Building	Demand [kW(t)]	Building's heated area (ft^2)	System age[a] (years)	Building heating system characteristics
Pioletti Hi-Rise (public housing)	750	127,000	Unknown	Hydronic radiation and ventilation heating
Empire Building (commercial)	750	62,000	Unknown	Two-pipe steam radiation and ventilation heating
Hamm Building (commercial)	2,635	312,000	61	Two-pipe steam and part hydronic radiation heating; two-pipe steam ventilation heating with preheating and reheating
YWCA[b] (apartment and athletic facilities)	1,230	118,000	18	Hydronic radiation heating and two-pipe steam ventilation heating with preheating and reheating
St. Paul Companies (commercial)	2,920	443,000	30	Two-pipe steam radiation and ventilation heating with preheating
Dayton's (commercial)	3,370	388,000	18	Hydronic radiation and ventilation heating
Centennial Office Building (commercial)	3,010	323,000	22	Hydronic radiation and two-pipe steam ventilation heating with steam preheating and hydronic reheating

[a]In 1980.
[b]Young Women's Christian Association.

Conversion costs and suggested conversion methods were developed for each of the buildings. Several options for building conversion were considered, where appropriate, to represent the choice of retention or replacement of some existing equipment. A recommended conversion cost was chosen as shown in Table 4.5, which also presents the results on the basis of the unit conversion cost, \$/kW(t) of demand. Table 4.6 presents a breakdown of the recommended cost data for the seven buildings.

An analysis of the conversion methods for each building proved that it was technically feasible to convert the buildings. The Phase I study also demonstrated that lower costs may be feasible if certain heating system equipment (i.e., preheat coils) could be used as is or excluded and not converted to hot water. A large potential for energy savings was also projected because of the energy conservation related to the modernization of the building heating system from conversion.

This relatively in-depth study was encouraging in terms of the unit conversion cost results. However, it was decided that additional buildings should be studied in order to specify conversion cost estimates for various market area buildings.

Table 4.5. Phase I building conversion cost results

(1980 dollars)

Building	Conversion cost[a] ($)	Unit conversion cost[a] [$/kW(t)]	Range of unit conversion costs [$/kW(t)]	Conversion costs per unit area[a] ($/ft^2)
Pioletti Hi-Rise	47,300	63	32.4–63	0.372
Empire Building	28,950	38.6	38.6–79.7	0.468
Hamm Building	151,700	57.5	57.5–85.1	0.486
YWCA	92,500	75.2	52.8–103.2	0.784
St. Paul Companies	93,000	32.0	27.7–53.1	0.210
Dayton's	104,000	30.9	30.9	0.268
Centennial Office Building	145,900	48.5	26.9–73.4	0.452

[a]For the recommended conversion design.

4.3.2.3 Phase II

The second study phase by MCHE was organized on the basis of ten types of building heating systems categorized by the types of perimeter and air-handling ventilation heating subsystems employed. The ten types of heating systems are described in Table 4.7. In contrast to the detailed Phase I study, the Phase II study provided a less detailed and quicker analysis of a larger sampling of buildings. This approach was deemed advisable especially for the significant number of older buildings in the market area. Over 100 buildings were studied in Phase II using the categories in Table 4.7 and other previously established data.

4.3.2.4 Results

Results from Phase II of the MCHE study are presented in three areas: building heating system characteristics, conversion costs, and equipment/labor costs distribution. The building heating system characteristics are summarized in Table 4.8 for the 106 buildings surveyed. (Individual data on all buildings surveyed are presented in Appendix A, Part 2.) Overall, the survey population covers a wide range of types of building heating systems involving practically all combinations of perimeter radiation units and air-handling units. The energy sources for these buildings are predominately gas, oil, or steam district heating; electric heat units and heat pumps are used in only a few buildings in the St. Paul market area. The average peak demand and system age vary widely among the groups. The groups with the highest average system ages—Nos. 2, 4, 5, and 7—all have steam distribution piping. Groups Nos. 6 and 8 have the lowest average peak demands and use only air-handling systems (no perimeter radiation).

Results of the conversion cost estimates are presented in two forms. First, Table 4.8 presents the average conversion cost for each building group; also, the maximum, average,

Table 4.6. Phase I—recommended conversion cost breakdown

(1980 dollars)

Building	Service piping within building	Radiation	Domestic hot water heater	Hot deck and reheat coils	Preheat coils	Miscellaneous piping, controls and related equipment	Total
Pioletti Hi-Rise	3,200	19,700	23,000			1,400	47,300
Empire Building	2,850	8,725	8,650		8,725		28,950
Hamm Building	26,850	68,850	13,900	22,000	14,650	5,500	151,750
YWCA[a]	3,300	16,600	21,400	11,900	27,505	11,750	92,455
St. Paul Company	12,265	33,185	20,295		12,205	15,070	93,020
Dayton's	28,500	38,300	26,200	11,000			104,000
Centennial Office Building	17,280	11,150	10,175	10,450	64,995	31,850	145,900

[a]Young Women's Christian Association.

Table 4.7. Description of building heating systems for Phase II study

System Group No.	Description
1	Hot water radiation—hot water air side Hot water is delivered to radiators and/or induction units within the heated space. In addition, hot water is supplied to heating coils in air-handling units which pass air over the coils and deliver warm air to the space
2	Steam (two-pipe) radiation—no air side Steam in a two-pipe configuration is supplied to radiators and/or induction units within the heated space
3	Hot water radiation—no air side Hot water is supplied to radiators and/or induction units within the heated space
4	Steam (one-pipe) radiation—no air side Steam in a single-pipe configuration is supplied to radiators and/or induction units within the heated space
5	Steam (two-pipe) radiation—steam air side Steam in a two-pipe configuration is supplied to radiators and/or induction units within the heated space. Steam is also supplied to heating coils in air-handling units which pass air over the coil and deliver warm air to the space
6	No radiation—gas-fired air side Gas is burned to directly heat air which is delivered to the space
7	Steam (one-pipe) radiation—steam air side Steam in a single-pipe configuration is supplied to radiators and/or induction units within the heated space. In addition, steam is supplied to heating coils in air-handling units which pass air over the coils and deliver warm air to the space
8	No radiation—steam air side Steam is supplied to air-handling units which pass air over the coils and deliver warm air to the space
9	No radiation—hot water air side Hot water is supplied to heating coils in air-handling units which pass air over the coils and deliver warm air to the space
10	Hot water radiation—steam air side Hot water is delivered to radiators and/or induction units within the heated space. In addition, steam is supplied to heating coils in air-handling units which pass air over the coils and deliver warm air to the space

Table 4.8. Summary of building conversion costs for 250°F maximum-temperature hot water supply

Costs, in 1980 dollars, include modernization of systems

Group No.	Average conversion costs ($)	Unit conversion costs [$/kW(t)]			Conversion cost per unit area ($/ft^2)		
		Maximum	Average	Minimum	Maximum	Average	Minimum
1	94,040	219.2	57.0	22.6	2.33	0.476	0.032
2	171,200	318	140.1	62.4	2.35	1.14	0.56
3	59,220	148	47.4	27.6	1.72	0.333	0.28
4[a]	241,400	1,301	596.2	216.4	10.59	5.89	2.38
5	209,800	462.2	156.3	31.9	6.65	1.14	0.21
6	25,980	300.4	110.6	52.8	2.84	1.92	1.37
7	159,900	891.6	221.6	89.1	8.92	2.56	0.84
8	20,290	708	240.1	172.4	24.5	2.10	0.97
9	33,720	105	55.6	27.6	1.05	0.440	0.19
10	151,300	216.7	73.2	24.0	2.11	0.733	0.45

[a]Nine of the ten buildings in this group require complete system replacement.

and minimum values are presented for the unit conversion cost, in dollars per thermal kilowatt, and the conversion cost per unit area.* These tabulated results give the general trend of the conversion costs for the ten groups of systems surveyed.

Second, the individual building system conversion cost and unit cost are shown as a function of peak demand for all groups except Nos. 4 and 8 in Figs. 4.2 through 4.9. Group No. 4 was not included because nine of the ten systems were of an age or condition such that

*The "average" values are "group" averages; for example, the average unit conversion cost is the total conversion cost for the group divided by the total kW(t) demand of the group.

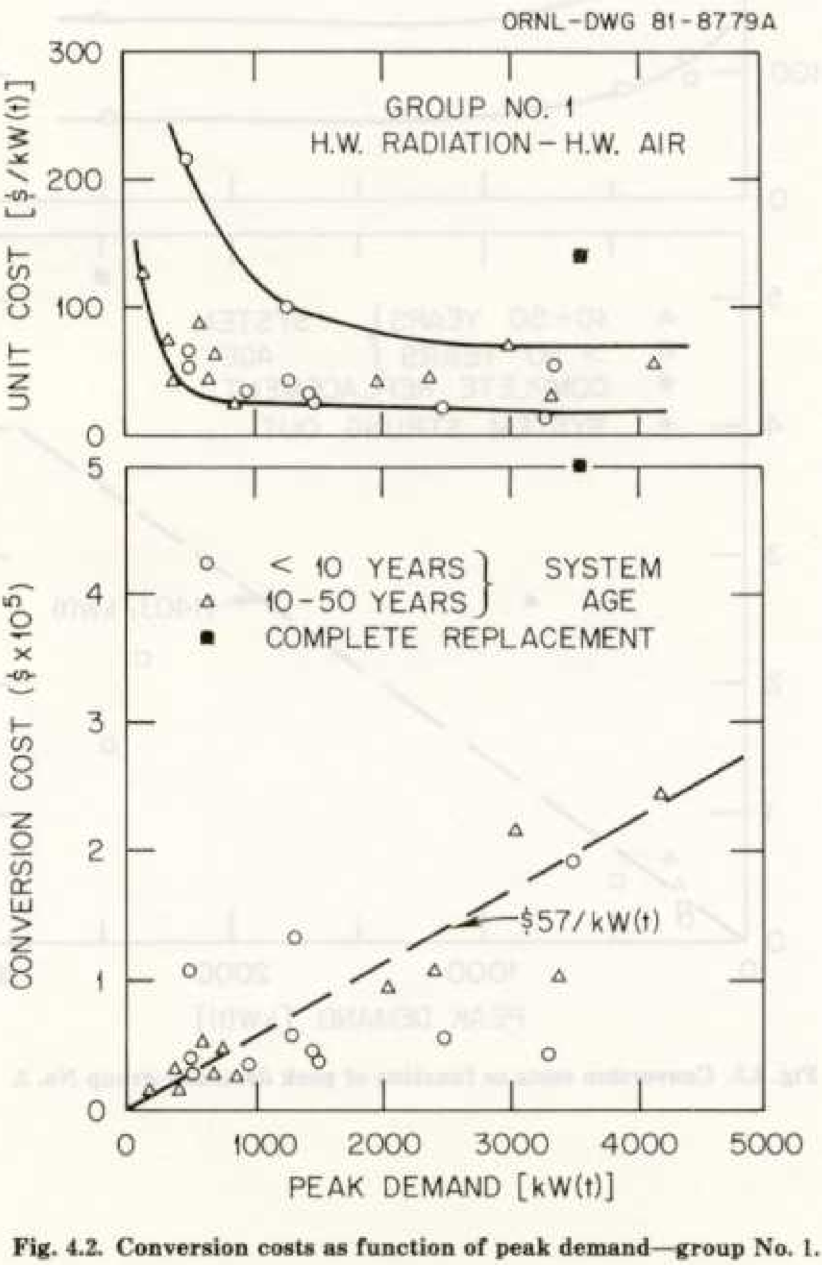

Fig. 4.2. Conversion costs as function of peak demand—group No. 1.

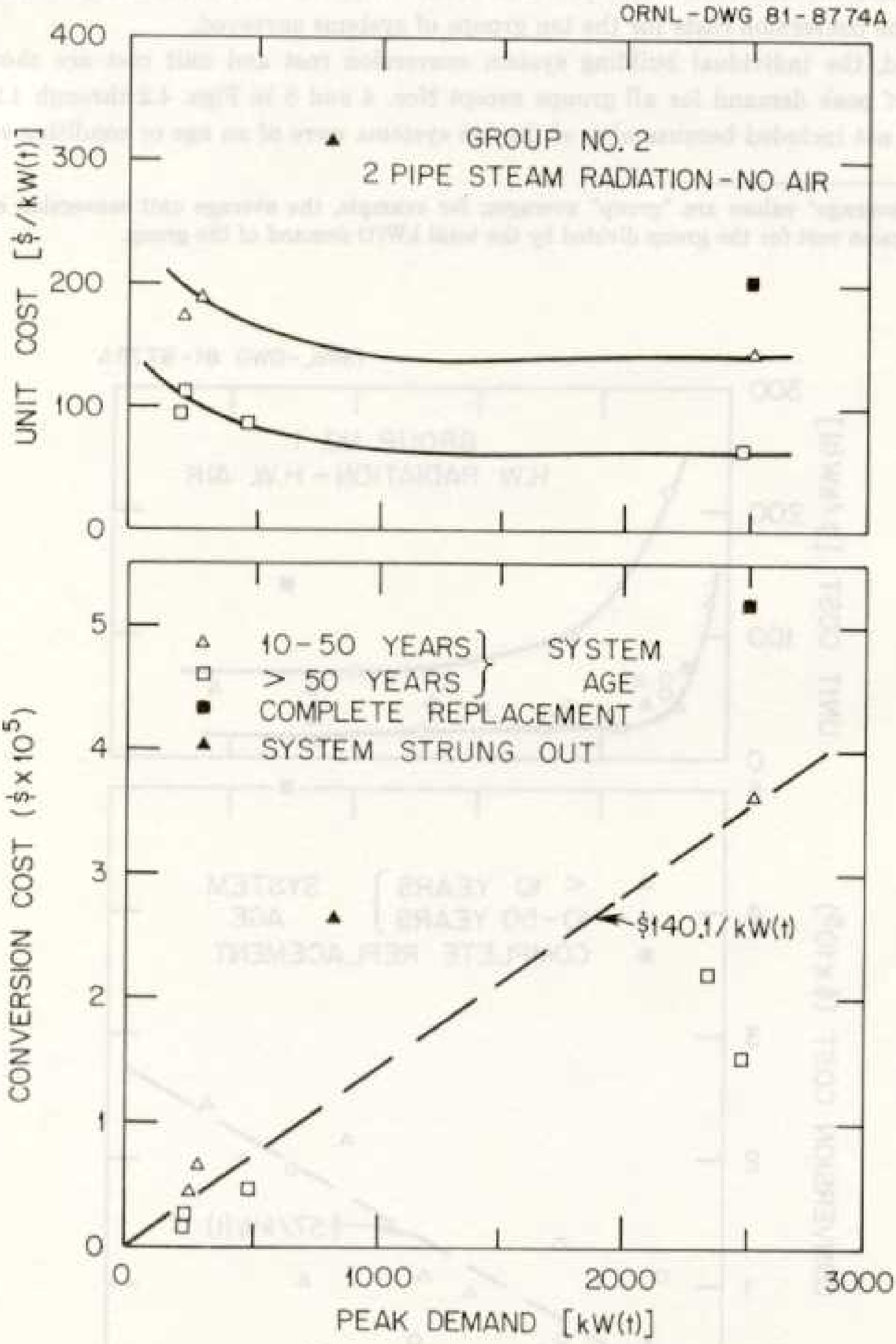

Fig. 4.3. Conversion costs as function of peak demand—group No. 2.

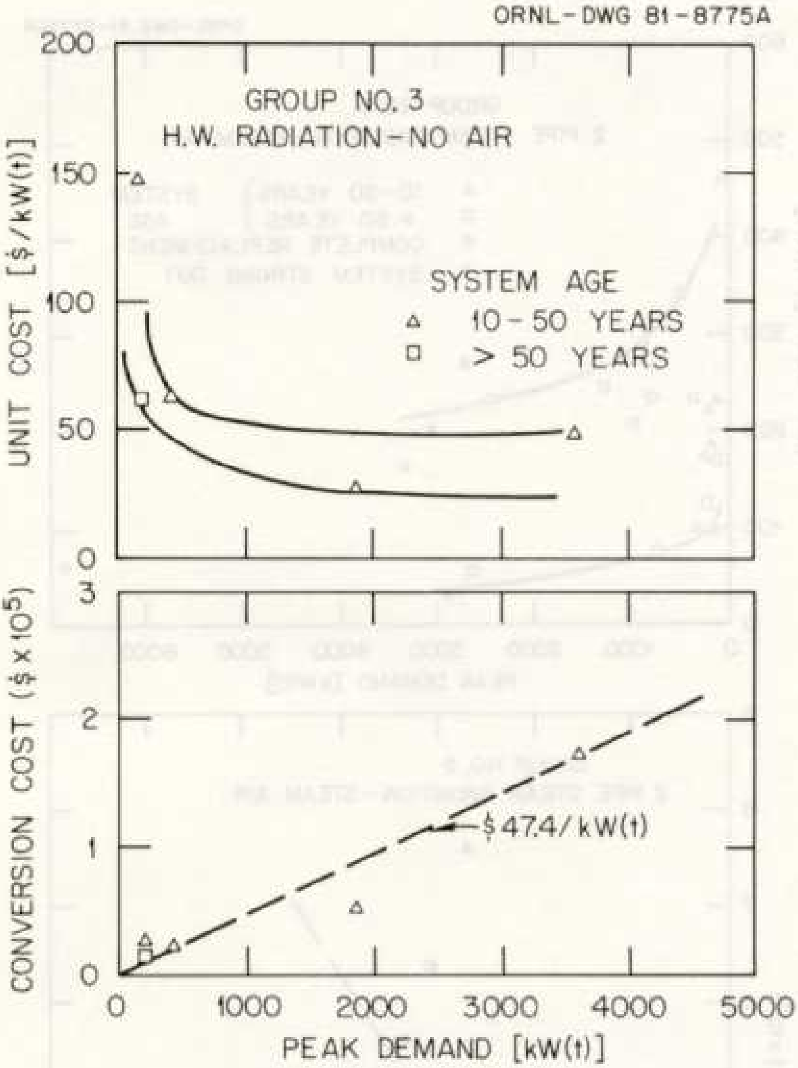

Fig. 4.4. Conversion costs as function of peak demand—group No. 3.

all the piping would require replacement, which makes this group's conversion cost exceptionally high. Group No. 8 has the smallest-sized buildings, which causes the conversion costs to be relatively high and represents only a small segment of the customer market.

The individual cost data have been segregated by system age—less than 10 years, 10 to 50 years, and greater than 50 years—and by systems requiring special treatment. These are systems that required essentially complete replacement because of degraded condition or systems that are "strung out" with long pipe runs to converter units, usually in older buildings that have been modified. The group average value of the unit conversion cost is shown by the conversion cost vs peak demand figures. Also, curves are drawn for the maximum and minimum trends in the unit cost vs peak demand figures. The unit cost of conversion is shown to increase with decreasing peak demand, as was indicated from an earlier study by the Minnesota Energy Agency.[5]

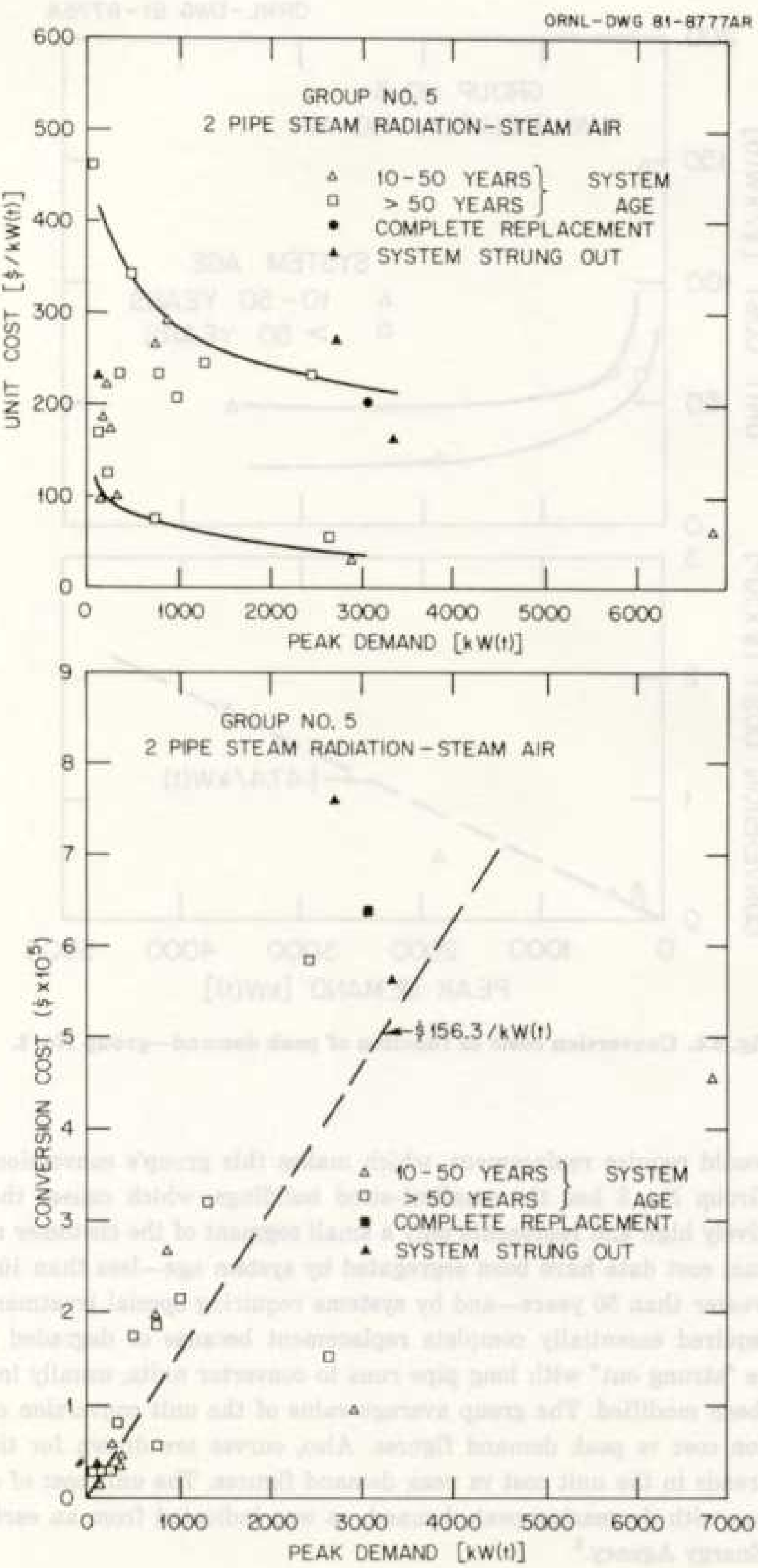

Fig. 4.5. Conversion costs as function of peak demand—group No. 5.

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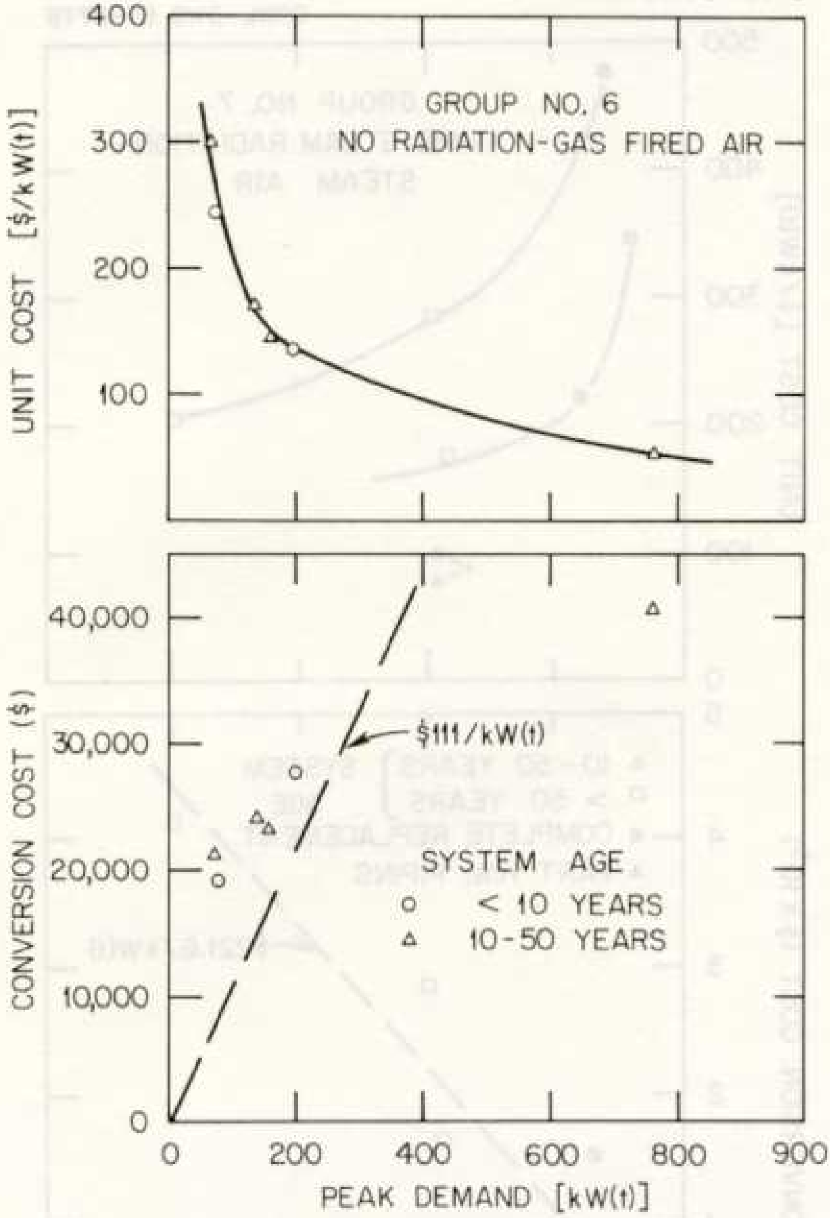

Fig. 4.6. Conversion costs as function of peak demand—group No. 6.

Several general observations can be made from the conversion cost data shown in these figures. First, system ages do not have a consistent effect on unit conversion costs within a group; however, older systems that require essentially complete replacement have relatively high unit costs. Second, the cost vs peak demand plots are widely scattered for most groups except Nos. 3 (hot water radiation—no air side) and 6 (no radiation—gas-fired air side). The resulting band of unit costs at a given peak demand is between \$50 and \$200/kW(t) for steam distribution systems and between \$25 and \$50/kW(t) for hot water distribution systems. By contrast, the conversion cost data for Group No. 6 (gas-fired air system) correlates

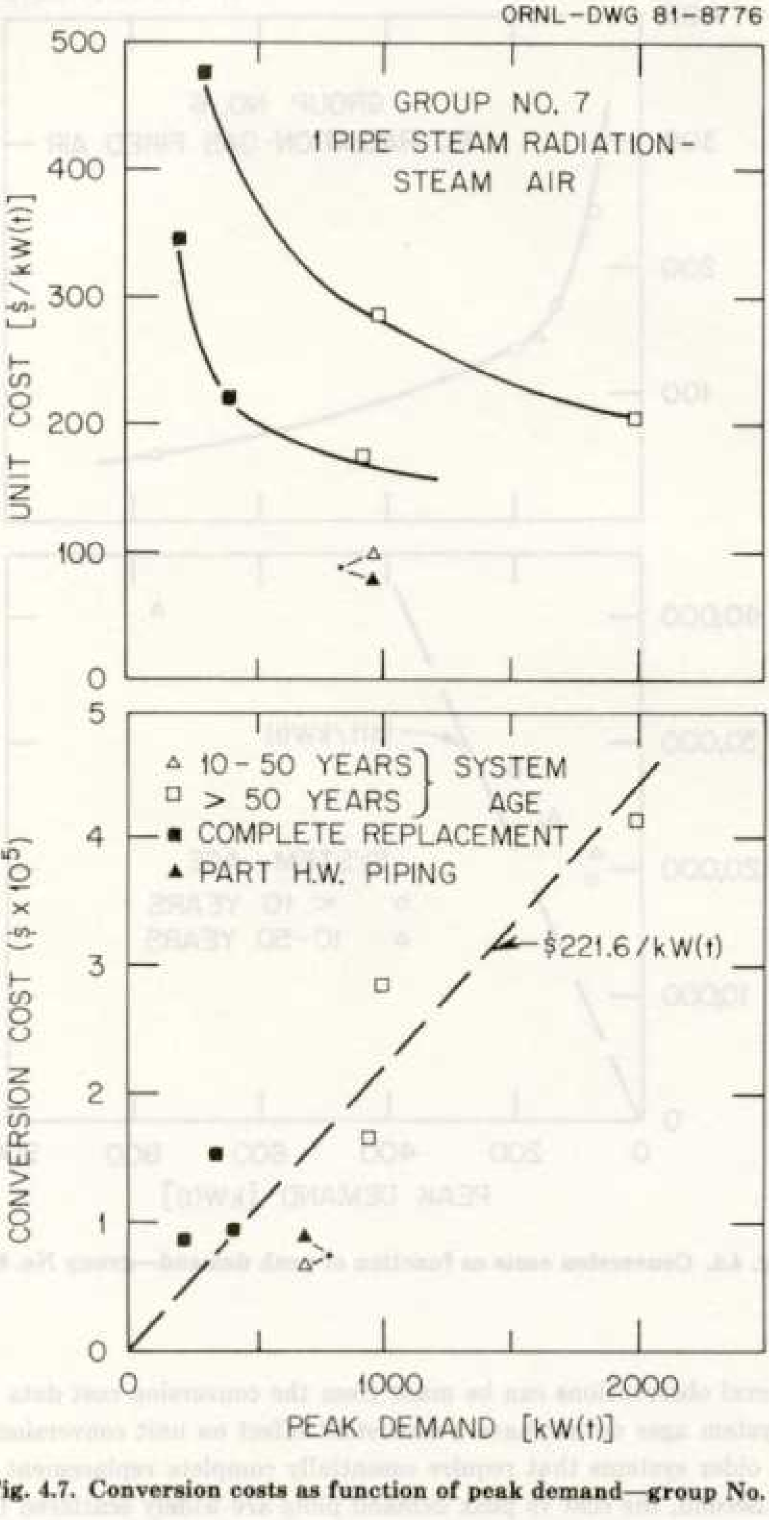

Fig. 4.7. Conversion costs as function of peak demand—group No. 7.

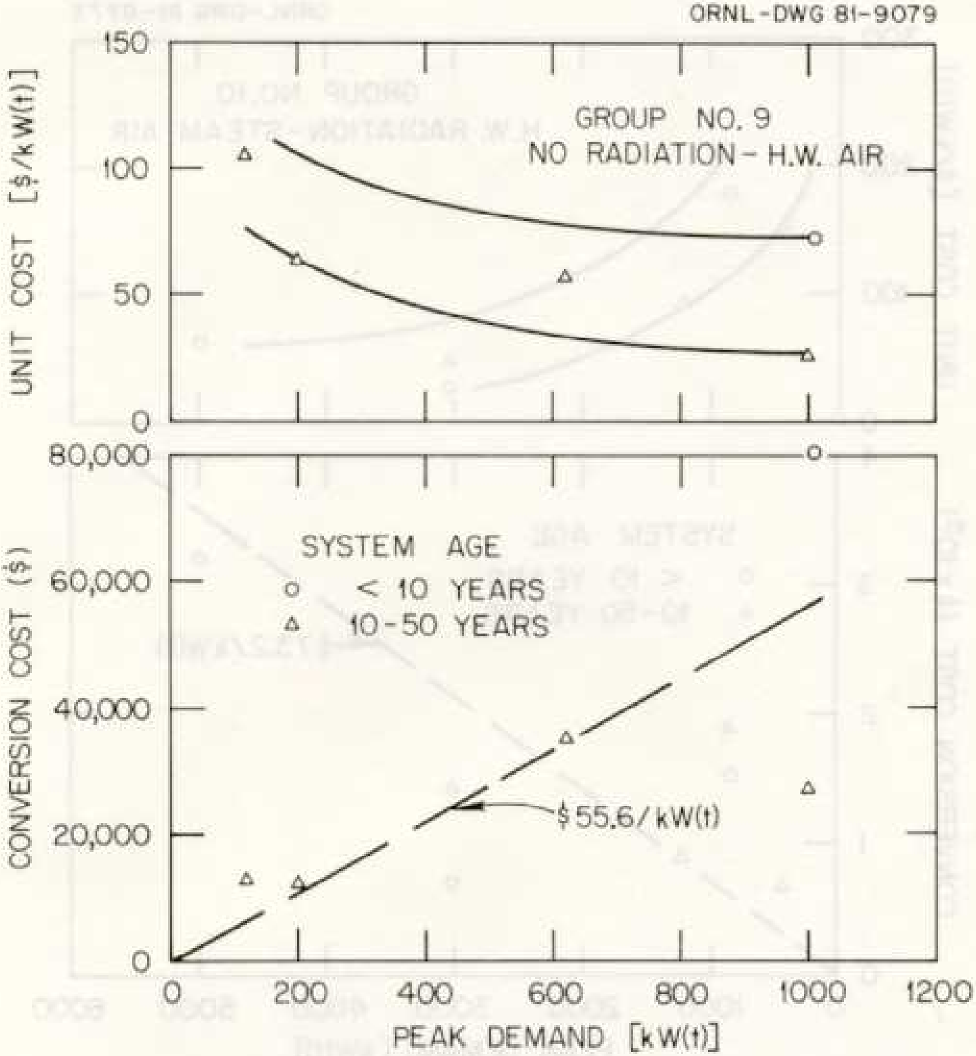

Fig. 4.8. Conversion costs as function of peak demand—group No. 9.

well with peak demand so that the unit cost shows little uncertainty. Third, the steam distribution systems classified as having extended piping have higher than normal ranges of conversion costs. Finally, the unit conversion cost data show an upward trend at decreasing peak demands.

The final result from the MCHE conversion cost survey is in the distribution of cost between materials and labor for the conversion work to be performed. As an overall average, labor accounted for 50.5% and materials for 49.5% of the total cost. When the systems were classified by steam and hot water systems, the labor component rose to 50% for steam systems compared to 48% of the total cost for hot water systems.

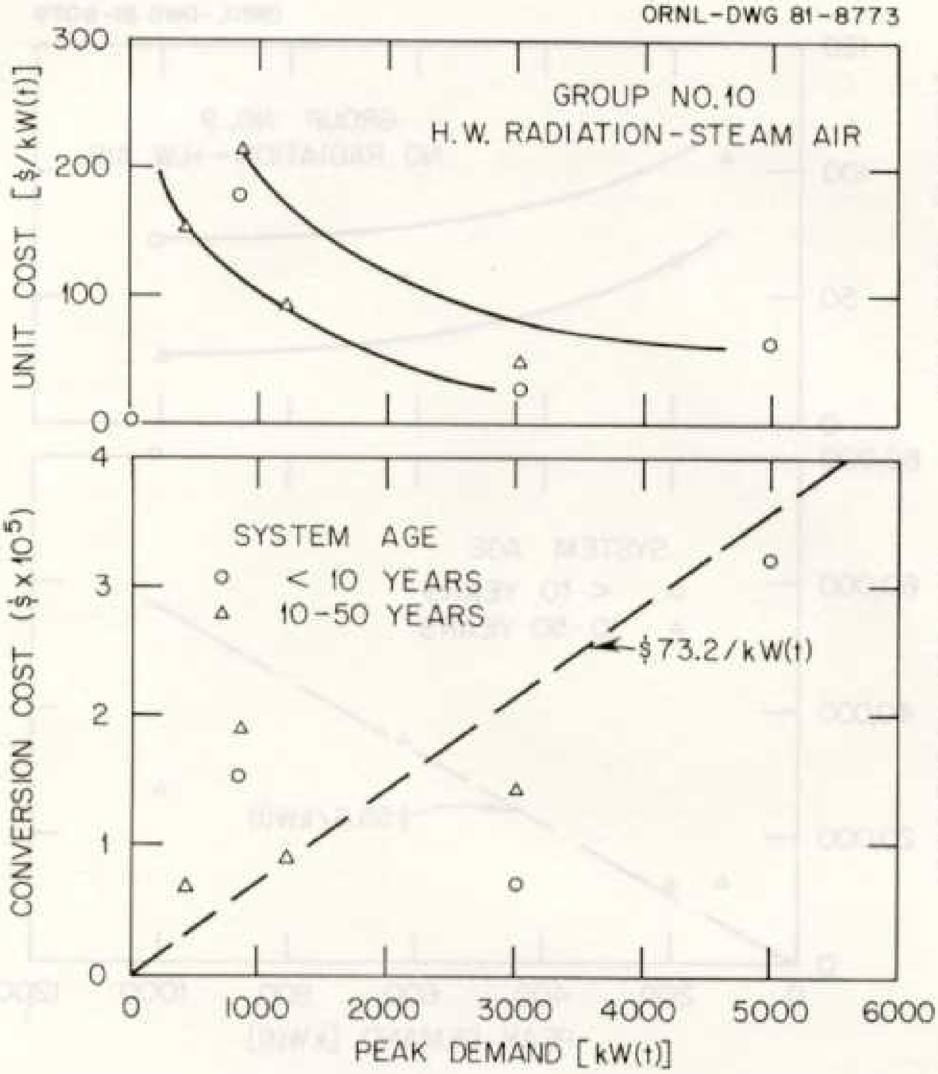

Fig. 4.9. Conversion costs as function of peak demand—group No. 10.

4.3.2.5 Discussion

This study by MCHE covers a broad range of characteristics of building types in terms of (1) function (heating, cooling, humidification, domestic hot water, and process uses), (2) building ages (affecting the type, condition, and configuration of the internal distribution system), and (3) building sizes and heating demands [from 900 to 900,000 ft^2 and 9 to 6,835 kW(t)]. Also, the treatment of costs to both convert and simultaneously modernize a building system for connection to a 250°F hot water district heating system adds a large degree of complexity to establishing building conversion costs.

The modernization and upgrading of the building systems is especially important in the St. Paul central business district because a significant number (30%) of the building systems surveyed in this study are 50 or more years old. A concomitant factor is the high percentage of buildings using low-pressure steam distribution systems. The philosophy behind this study was not to minimize the "first cost" of connection to a hot water supply system but rather to optimize the life-cycle cost of the energy supply and the building distribution systems. The minimum "first cost" strategy requires a hot water supply temperature of about the 300 to 360°F (149 to 180°C) operated year around to supply the existing steam distribution systems. This strategy leads to a lowest initial cost for "adapting" a building system to a hot water heat supply, as is presented in the Minnesota Energy Agency study,[5] but leaves the older steam distribution buildings with a system that is less efficient, more difficult to control, and has higher maintenance costs than has a hot water distribution system.

Therefore, the strategy followed in this study is based on three principles: the hot water supply temperature would be limited to 250°F to reduce the construction and operating costs of the district heating system; steam distribution systems should be converted to hot water distribution in an economical fashion; and, when necessary, degraded or outmoded equipment should be replaced, and an overall system modernization should be included with connection to the hot water district heating supply.

This strategy is restated here because it has a major impact on the results of the building conversion cost survey for buildings with steam distribution. For such systems, a significant part of the conversion cost can be for system modernization and upgrading. This result is illustrated most dramatically by building Group No. 4, which contains the largest percentage of the old steam systems and has the highest unit conversion costs of the groups surveyed. For the other steam distribution systems— Groups Nos. 2, 5, 7, and 8—the average unit conversion costs are from \$40 to \$190/kW(t) higher than for hot water distribution systems—Groups Nos. 1, 3, and 9. These differences in unit conversion costs between steam and hot water building systems are higher than the \$10 to \$20/kW(t) unit cost difference estimated in the Minnesota Energy Agency study. The earlier study analyzed relatively new buildings supplied by 300°F (149°C) hot water and for which system modernization and upgrading changes were not included.

The higher conversion costs for the steam distribution systems are caused by extensive replacement of existing converter units, perimeter radiation units, and connective piping and controls required to operate such systems as hot water distribution systems. In addition to generally higher conversion costs, the modernization and upgrading of the steam systems contributes to the wide variability in the unit conversion costs, as evidenced by the \$200/kW(t) range in unit conversion cost at a given peak demand for Group No. 5. This wide range of unit costs is caused by the wide diversity of systems developed over an 80-year period. Also, the physical condition of the system components and insulation varies greatly and contributes to the diversity in conversion costs for steam distribution systems.

To a certain extent, the conversion costs for individual steam distribution buildings developed in Phase 2 of this study are higher than the costs developed in Phase 1. This difference results from the different approaches taken in the two phases. In Phase 1, a building was chosen to represent typical conversion techniques and costs, so equipment replacement for upgrading and modernization was not included in order to prevent distorting the results. Since Phase 2 was based on a survey of a much larger number of buildings, the upgrading and modernization costs were included on an individual, case-by-case basis. One building, the Empire Building in Group No. 5, was analyzed in both phases of the study.

The conversion costs estimated in phases 1 and 2 for this building were $28,950 and $56,000, respectively, and unit costs were $38.6 and $74.7/kW(t), respectively. The additional cost in the Phase 2 estimate was for replacing all the return piping, as opposed to just the return loop in the equipment room for the Phase 1 estimate. This case is an example of the additional cost for system upgrading and modernization.

For steam distribution buildings served by the existing steam district heating system or local steam boilers, steam-to-steam converter units were replaced by new hot-water-to-hot-water units in the Phase 2 study. This procedure may replace existing converter units that could be usable as hot-water-to-hot-water units because excessive capacity was often provided in the original design. Therefore, additional information about and experience with steam converter units in hot water applications would result in their continued use, thus reducing the conversion cost materially.

4.3.2.6 Conclusions

The study of building conversion costs in St. Paul by Michaud, Cooley, Hallberg, Erickson and Associates has produced a wealth of information, especially in the survey of 106 buildings in Phase 2. The results of this survey have been used by the DHDC to develop general conversion cost estimates for unsurveyed buildings in the DHDC market area. In addition, the results of the survey are the basis for several conclusions relating to the combined effort of system connection, upgrading, and conversion for a 250°F hot water supply system.

Recommended unit conversion costs for the ten types of heating systems established in the Phase 2 survey are presented in Table 4.9. These unit costs were selected as typical

Table 4.9. Recommended building conversion costs
In 1980 dollars

Group	Heating system type	No. buildings	Average peak demand [kW(t)]	Unit costs [$/kW(t)
1	Hot water radiation and hot water air side	22	1826	40
2	Steam (two-pipe) radiation—no air side	10	1223	140
3	Hot water radiation—no air side	4	1517	44
4	Steam (one-pipe) radiation—no air side	7	392	403
5	Steam (two-pipe) radiation—steam air side	21	1351	181
6	No radiation—gas-fired air side	6	235	110
7	Steam (one-pipe) radiation—steam air side	7	823	220
8	No radiation—steam air side	3	172	198
9	No radiation—hot water air side	5	607	56
10	Hot water radiation—steam air side	7	2067	107
	Total	92		

values to represent all buildings in a given group for estimating the total building conversion costs for the DHDC market area. For Groups Nos. 2, 3, 6, 7, and 9, the average unit cost in Table 4.9 is essentially the same as the average value in Table 4.8. However, for Groups Nos. 1, 4, and 8, the average value is reduced by removing several abnormally high-cost buildings from the group data base; conversely, the average values for Groups Nos. 5 and 10 are increased slightly to reduce the influence of several buildings with relatively low conversion costs.

The results of Phase 2 of this study indicate that buildings having existing hot water heating systems on the radiation (perimeter) systems, air-side systems, or both are the most economical to convert to a hot water district supply system. The average unit conversion cost for such systems is \$40/kW(t), with lower costs in the range of \$15 to \$30/kW(t) possible for newer systems requiring little or no upgrading.

By contrast, heating systems with one- or two-pipe steam radiation—Groups Nos. 2, 4, 5, and 7—have the highest unit conversion costs, averaging from \$140 to \$400/kW(t), and, in the case of Group No. 5, the highest range of unit cost, \$200/kW(t), at a given peak demand. These high conversion costs are caused by significant upgrading and modernization required for a hot water or hydronic-heating system. The additional investment to modernize some of the existing steam-heating systems may require incentives to encourage building owners to make such an investment if a clear economic pay back is not evident. Also, the uncertainty in the conversion cost for such buildings, as evidenced by the range of costs found in this survey, indicates that an individual building system survey and cost estimate is desirable to establish the conversion cost for a specific building or potential customer. Therefore, design assistance by the DHDC to potential customers should be considered in the marketing phase of the St. Paul DHDC to provide an incentive for owners of buildings that require significant upgrading and modernization.

4.3.3 The St. Paul Gillette Company

Although many of the buildings in the St. Paul market area were assessed in the MCHE building conversion study, it was decided that special consideration was needed for the system's largest potential industrial customer, the Gillette Company, which presents different conversion concerns. The overall objective of the study was to determine the optimum method of converting a facility from medium-pressure steam to medium-temperature water. The study was important because the economic feasibility of the district heating system depends on the conversion of such systems at low cost and with minimal interruption to business operations.

The engineer consulting firm of Toltz, King, Duvall, Anderson and Associates (TKDA) of St. Paul was chosen by the DHDC to perform such a study on the Gillette Company facility in St. Paul. The specific objectives of the study were to

1. determine an optimum method of converting the heating system from steam to hot water;
2. estimate heating system return water temperature under various conditions;
3. determine the feasibility of converting the process systems from steam to hot water;
4. prepare conceptual drawings and descriptions of changes required for conversion;

5. prepare cost estimates; and
6. prepare a construction plan and schedule.

TKDA summarized this study as follows.

The Gillette Company is an important asset to the city of St. Paul, employing more than 900 people in the manufacture and distribution of the Gillette line of toiletries and other products. The St. Paul facility accounts for about $130 million in product sales per year.

The Gillette Company facility was selected for this study because of its industrial load and because all heating and process energy needs are supplied by a steam district heating system. The district system currently supplies steam to the Gillette facility at a guaranteed minimum pressure of 60 psig.

The Gillette facility is located near Fifth and Broadway streets in St. Paul, as shown on Fig. 4.10. The facility consists of a one-story warehouse, a distribution center of 180,000 ft^2

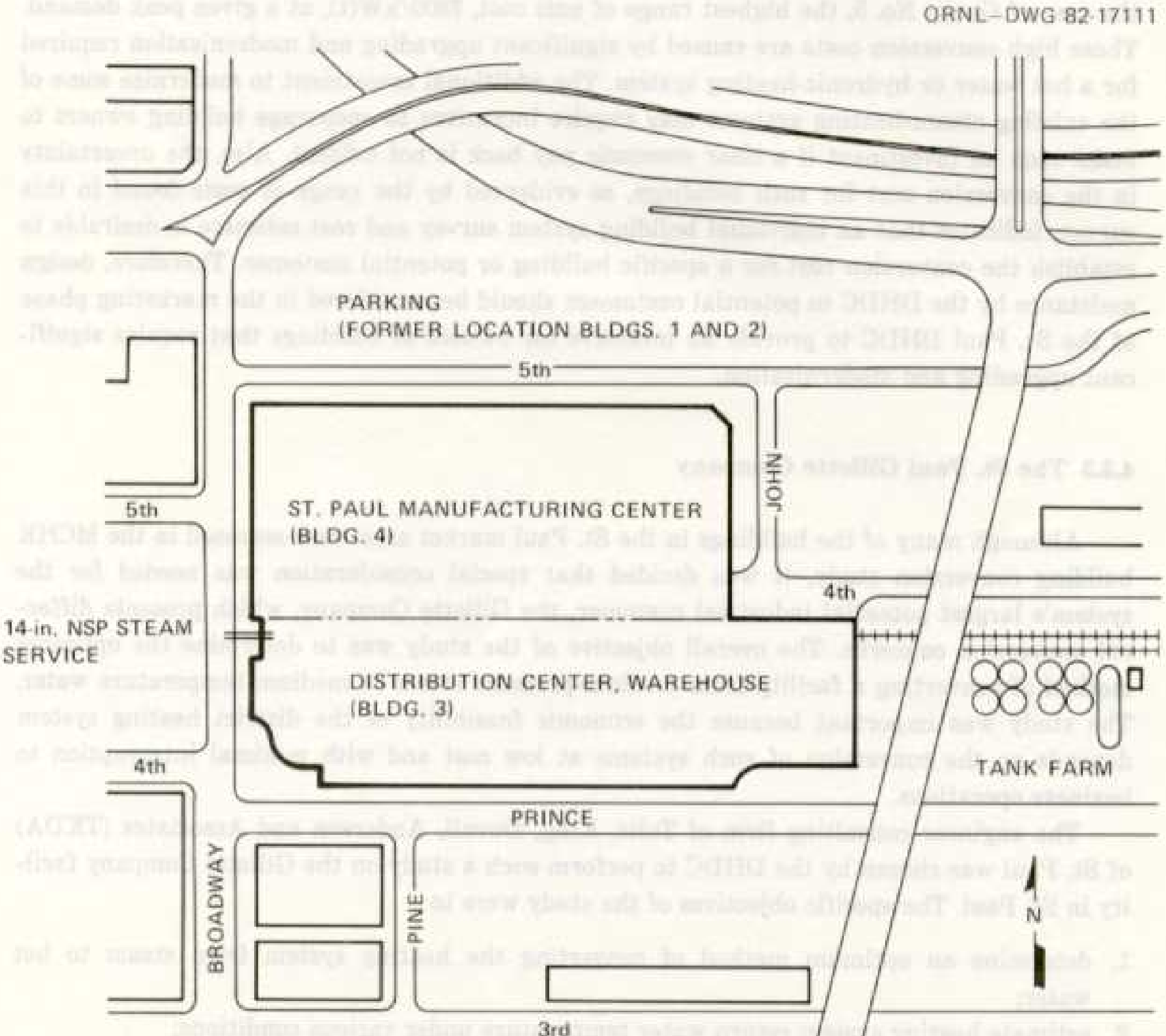

Fig. 4.10. Plot plan of St. Paul Gillette Company.

constructed in 1966, and an adjoining three-story manufacturing center of 660,000 ft^2 constructed in 1970. Annual steam consumption is about 32 million pounds of steam or 38,000 Btu per ft^2 per year. Peak steam demand is estimated to be 29,500 lb/h or 9.2 MW(t). This rate of consumption is probably slightly below normal for this kind of facility.

Conversion of the St. Paul Gillette Company manufacturing plant from the existing district steam heating service to the planned St. Paul Hot Water District Heating System is estimated to cost $740,000. A cost-saving alternative, which should be further investigated, would result in a conversion cost of $520,000. This alternative concerns existing steam coils in air-handling units. If further investigation proves these coils can be converted to use hot water and provide adequate capacity, the largest single expense item, coil replacement, would be eliminated.

From a technical standpoint, converting the 60-psig steam system to a 250°F hot water system is relatively straightforward. However, the conversion to hot water permits some innovative concepts to be incorporated in the design. These include exchanging heat from return water to product water, connecting unit heaters in series to reduce return temperatures, and providing supplementary reheating to achieve temperatures required for special processes (Fig. 4.11). The proposed new hot water system would also provide flexibility of control and eliminate condensate wasted to sewers, which should result in a reduction of energy consumed.

For the purpose of analysis and description, the report and this summary separately describe the space heating-ventilation system conversion from the process systems conversion.

1. Space heating-ventilation conversion. Conversion can be accomplished by replacing steam coils in the air-handling equipment, reusing a major part of existing steam and condensate mains, and dividing the existing system into three circuits, each connected to a district water/heating circuit, plate-type heat exchanger. Two of the circuits are designed as forced circulation, primary-secondary, direct return, hot water heating systems. One serving the warehouse distribution center building is designed as a forced circulation, hot water system arranged for series flow of water through terminal unit heaters. All return water is directed through a heat exchanger in a closed water storage tank to extract additional heat from the hot water.

2. Process heating conversion. Conversion can be accomplished with only one-half day "downtime" to any process area. All existing process equipment can be reused without alteration. A new direct return, forced circulation, hot water piping system will supply each process area from a district water/product water, plate-type heat exchanger. A few process areas will require supplemental electric heating to reach necessary temperatures during the summer when district water temperatures are expected to be reduced.

   A new, closed, water storage tank with a heat exchanger will reduce district return water temperature by exchange of heat with incoming city water supplying product requirements.

   Process heating energy consumption is about 30% of the facility requirement. The peak demand is estimated to be 4500 lb of steam per hour.

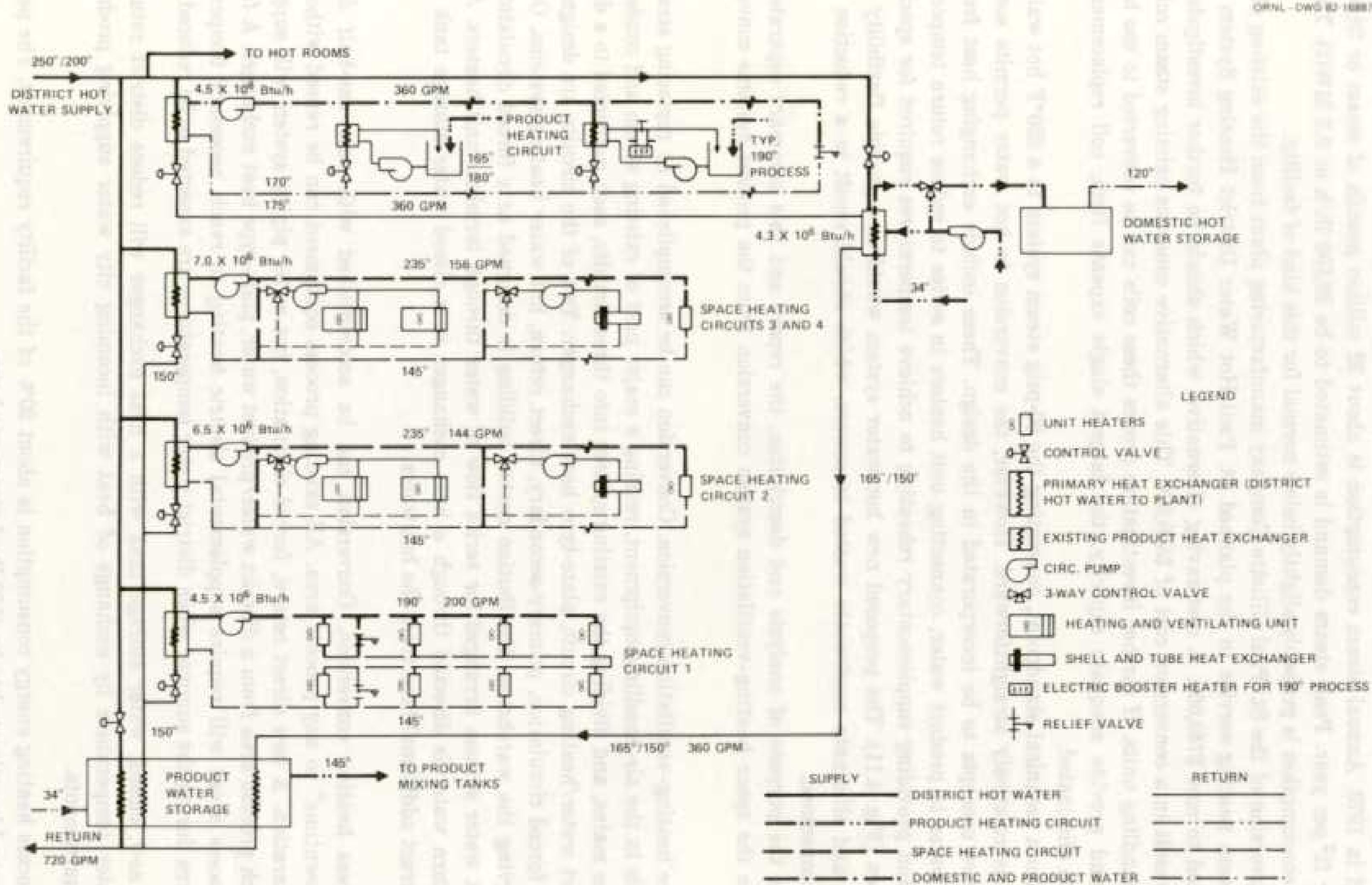

Fig. 4.11. Proposed conversion of Gillette Company to hot water district heating.

4.3.4 Experience with Heating Systems Converted from Steam to Hot Water Operation

Both the MCHE and TKDA studies indicate that building conversion to a district hot water supply is feasible. To document instances in which existing building heating systems and equipment have actually been converted from steam to hot water operation, however, TKDA was commissioned to perform an additional study. The information was documented in a report in order to develop confidence in the associated costs required to accomplish the conversions.

TKDA summarized the results of this study as follows.

Steam was predominately used in heating systems installed several years ago and, therefore, is likely to be found in older buildings. The original decision to use steam was probably the result of steam availability and preference by the owner or designer because of familiarity and common usage at the time, rather than because of any advantage peculiar to steam as a heating medium for the building. In heating systems today, the superiority of water as a heating medium is generally recognized; it is therefore most often selected for new construction and updating of heating systems.

The major components of a heating system—boilers, radiation units, and controllers—are normally manufactured to function with either steam or hot water. Therefore, conversion of a steam heating system to a hot water heating system is not unique. Heating systems have been converted, utilizing all existing components and replacing equipment, because of only a deteriorated condition or outmoded appearance of the components.

Building conversion to hot water heating should generally result in reduced operation costs as well as a marked improvement in comfort. Basically, this is because of the ease of achieving a greater range of operating temperatures in the terminal radiation units, elimination of losses through steam traps, reduced chemical treatment requirements, and a reduction in corrosive effects on the system. The examples in this study are summarized in Table 4.10 and support the advantages of hot water as a heating medium.

4.3.5 Conversion of the Ramsey County Courthouse/St. Paul City Hall

The positive results of the TKDA study of the experience with converting building heating systems from steam to hot water operation were reiterated in a detailed study of an actual, individual building in downtown St. Paul, the Ramsey County Courthouse/St. Paul City Hall. This study, Proposed Conversion to District Hot Water Heating—Ramsey Courthouse/St. Paul City Hall, enclosed as Appendix B, was performed by the engineering consulting firm of Henningson, Durham, and Richardson (HDR) of Minneapolis. The results of the study are summarized below.

The study has shown that the existing steam radiator system in the building can be converted to a hot water heating system by utilizing all of the existing 450 radiators and all but a small portion of the existing piping.

The existing radiation in the building can withstand the static pressure that is required by a hot water system. Adequate heating surfaces are available in the occupied spaces. The purchase of supplementary heating equipment is not needed to compensate for the reduced operating temperature of the hot water system. This is mainly due to the conservation programs at City Hall which have reduced the building's heating demand.

Table 4.10. Steam to hot water conversions

Conversion	Date converted	Building size (ft^2)	Annual energy consumption		Peak demand		Cost of conversion ($)	Cost/peak demand [$/kW(t)]	Estimated yearly saving (%)	Comments
			MBtu[a]	MWh	kBtu/h[b]	kW(t)				
Health Service Building, Macalester College, St. Paul	1974	3,800	460	134	271	79	9,000	114	10	Revised existing radiation and piping for new boiler, circulating pump, and hot water accessories
Red Wing City Hall	1977	23,600	763	224	449	131	25,000	191	20	Revised existing boiler, new circulating pump, piping, radiation, and hot water accessories
Halstenson House Boy's Ranch, Austin, MN	1978	7,600	560	164	280	82	12,000	146	15	Revised existing boiler, radiation and steam main. New circulating pumps (3). Supply main and hot water accessories
Minnesota Museum of Art	1974	30,000	1,570	460	920	270	3,500	13	24	Partial conversion of district steam system. Reused piping and radiation. New heat exchanger, circulating pump, and hot water accessories
Vomela Specialty Manufacturing Co., St. Paul	1979	29,000	2,350	689	2,200	626	12,000	19	10	System expansion and conversion of district steam system. Revised piping and radiation. New circulating pump. Additional piping and hot water accessories

[a]Millions of British thermal units.
[b]Thousands of British thermal units per hour.

Except for some mechanical modifications required to connect new hot water heating equipment, the piping network in the building is circuited properly for conversion to hot water. Only a minimal amount of new piping must be installed.

The temperature control equipment must be modified to be compatible with hot water and to improve the operating efficiency of the system and the comfort of the occupants. Existing bare piping will be insulated to conserve energy and to meet the State Energy Code.

The estimated annual energy savings from conversion to hot water distribution and building conservation measures is 7430 M Btu, which is approximately a 40% reduction in annual energy use. The annual energy savings represent sufficient energy to heat 50 homes. Energy savings were estimated for the various steps involved in the building conversion as follows:

1. steam traps eliminated, media temperature reduced, and outdoor/indoor temperature controls implemented: 15-20%;
2. night setback, reduction of ventilation, and insulation of pipes: 20-30%.

Total estimated costs for conversion to hot water are $696,130 (in 1981 dollars). This amount also includes two areas of conservation improvements not related to hot water conversion: nonroutine maintenance by operating personnel ($88,872) and additional energy conservation measures ($65,688). These costs include a 15% contingency fee and a 12% engineering and inspection fee.

The annual saving in thermal energy costs from conservation by converting to hot water distribution and modernization of the system is $70,513 (in 1981 dollars). (This does not include cost savings due to purchase of lower cost hot water district heating.) The simple payback for this investment is 8.62 years.

A second economic analysis examined the costs of continued operation with the existing building heating system supplied from the steam district heating system as compared to the costs of a hot water building heating system supplied by the hot water district heating system.

A computer analysis provided by the St. Paul District Heating Development Company and verified by HDR assumes the total cost of conversion will be amortized over 20 years at a 10% interest rate. The 40% energy savings from conversion is also included. This analysis indicates a positive annual savings cash flow in four years and a cumulative positive savings cash flow in seven years. These cash flows include both the annual energy costs and an annual amortized payment for the conversion to hot water.

Steam condensate from the present steam district heating system currently is drained to the sanitary sewer system. In the hot water building heating system, the water is recirculated, thereby saving 2.25 million gallons of water annually.

Now that these studies are complete, the DHDC has investigated various methods of providing low-cost financing to area building owners to help them finance the resulting conversion cost to the hot water district heating system. These financing options are discussed in Sect. 7.

4.4 Prepare Heat Source Analysis

The thermal energy to be consumed by the initial market area buildings is an important factor in total system development. The objective of this task was therefore to investigate the role of various area heat sources in the initial development and future operation of the system. The analysis in this study is based on the prior extensive studies by Peter Margen et al.[1] and United Engineers and Constructors Inc.[3]

4.4.1 Heat Source Implementation Plan

The basic economics of district heating indicate that existing power plants and other large heat sources in the initial district heating market area should be utilized to the greatest extent possible. For this reason, the heat sources will be existing turbine generator units, proposed for conversion to cogeneration, and existing heat-only boilers. New heat source capacity will be added only as necessary for system reliability and growth.

Various types of existing heat sources are located within or near the initial market area. These include the Northern States Power Company's High Bridge Generating Plant, the Third Street Steam District Heating Plant as well as several large boiler installations at the State Capitol and at United, Ramsey County, and St. Joseph's Hospital power plants.

Three sites—Third Street Plant, State Capitol Heating Plant, and Ramsey County Hospital—were analyzed in considerable detail as likely thermal sources for the St. Paul district heating system in the *St. Paul District Heating System Conceptual Design Study and Report*.[4] The first power plant to be modified would be the Third Street Plant if the system is constructed according to the phasing specified in this report. The Third Street Plant would be used as the system's base load heat source during the first years of construction. During that time, the Third Street Plant would also begin a gradual phase out as the heat source for the steam district heating system. The use of the Third Street Plant as the first heat source postpones the cost of constructing the large transmission line between the High Bridge and Third Street plants until the hot water system load develops.

Since 1979, a major event has changed the DHDC's outlook on potential heat sources. To bring the Third Street Plant into compliance with environmental regulations for particulate emissions, a consent decree had been agreed upon by the U.S. Environmental Protection Agency, the Minnesota Pollution Control Agency and the Northern States Power Company, the city of St. Paul, and the DHDC. The decree stipulated that the Third Street Plant would no longer be fired on coal, and the steam system would be supplied from the High Bridge Power Plant by means of a steam line to the Third Street Plant. Using natural gas and oil, the Third Street Plant would be used as a backup facility for the High Bridge Plant.

The implementation plan for the hot water district heating's heat sources was therefore changed. From the beginning, the High Bridge Power Plant was scheduled to be used for supply of both steam and hot water. When the steam system is phased out, the steam line between the High Bridge and Third Street plants may be used as a hot water line to provide increased capacity for the hot water system. (See Sect. 7.2 for the final resolution of the Third Street Plant particulate emission problem.)

4.4.2 High Bridge Power Plant Retrofit

The High Bridge Power Plant consists of four turbine generator units. Two identical General Electric 50-MW(e) units, T-3 and T-4, were constructed in the early 1940s and have steam conditions of 850 psig and 900°F and a heat rate of 9340 Btu/kWh. Unit T-3 is capable of 62.5 MW(e) at a power factor of 1.0. Turbine unit T-5 was installed in 1956 and has a rated capacity of 91 MW(e) and a heat rate of 8161 Btu/kWh; the steam conditions are 1450 psig and 1000°F, with a single reheat of 1000°F. It was manufactured by Allis Chalmers and is a three-case, tandem-compound, double-exhaust turbine.

Turbine unit T-6 is also a three-case, tandem-compound, double-flow exhaust turbine. It was installed in 1959 and has a rated capacity of 156 MW(e) and a heat rate of 7931 Btu/kWh. Steam conditions are 1800 psig and 1000°F, with a single reheat of 1000°F. The turbine manufacturer is General Electric.

All four units at the High Bridge Generating Plant are fueled with low-sulphur western coal which is supplied by unit train and purchased under long-term contract by Northern States Power Company.

The High Bridge Plant has been the subject of several studies relating to its modification to cogeneration service as a hot water district heating source. The most recent and detailed study was performed by United Engineers and Constructors, Inc. (UE&C), for NSP.[3] UE&C concluded that the large units, T-5 and T-6, are in good condition and suitable for cogeneration. They can be converted to extraction-mode cogeneration by installing a cross-over pipe between the intermediate- and low-pressure turbines. Steam is then directed to a steam-to-hot-water heat exchanger which interfaces with the hot water district heating system. Of the two smaller units, only unit T-3 is suitable for conversion to cogeneration in the back-pressure mode by removal of all low-pressure blading. The electric and thermal production capacities for units T-3, T-5, and T-6 are shown in Table 4.11; a total of 444 MW(t) could be produced by the three units, with permanent loss of only 13.3 MW(e) electrical generating capacity.

The retrofit would start with boilers B-9 and B-10 to supply direct steam to hot water heat exchangers. The conversion of one of the units, probably T-6, could occur in the mid-1980s when hot water sales can economically support the conversion.

An important consideration for retrofitting an existing full-condensing unit such as T-6 to extraction cogeneration operation is the effect of the district heating system load duration on the unit's electrical output. Whenever the unit's electrical output does not follow the

Table 4.11. Cogeneration performance of the High Bridge Generating Station

Unit	Original electrical generating capacity [(kW(e)]	Maximum heat energy [MW(t)]	Maximum simultaneous electrical generation [kW(e)]	Lost electrical generating capacity[a] [kW(e)]
3	62,265	120	48,909	13,356
5	90,900	138	65,873	0
6	156,232	186	109,314	0

[a]Lost capacity on a permanent basis.

economic dispatch of the total electric utility generation system, then additional electrical generation costs are incurred which would be passed on to the thermal customers. These additional costs are called

- replacement energy when the unit output is decreased because of cogeneration operation and the "replacement" electricity must be generated at a higher cost per unit,
- excess energy when the unit output is increased relative to the economic dispatch level. (See Appendix D for a detailed description.)

The T-6 unit has recently operated 1800 to 2000 h/year at an average output of about 120 MW(e). Because the full-extraction mode operation would only decrease the electrical output to 109 MW(e) on the average, the amount of replacement energy, the higher of the two system-related costs, would be relatively low. However, if the electric utility's reserve margin decreases in the future, the cost of replacement energy can increase significantly from two causes: first, the economic dispatch would increase the hours of operation and the output level, thereby increasing the megawatt hours of electricity to be replaced; and, second, the unit cost of the replacement energy would increase since it would be produced at higher cost peaking plants. Therefore, the long-term (20-year) electric utility reserve margin and the cost of peaking electricity can have a significant effect on the cost of cogenerated hot water from a utility-owned turbine.

A method to minimize the influence of the electrical system operation on the hot water system costs is to install a hot water accumulator to be charged at night during off-peak power demand hours. This approach has been used in European hot water systems of sufficient size to justify the capital cost of the accumulator.

4.4.3 Cost of Power Plant Conversions

The total capital cost of converting units T-3, T-5, and T-6 at the High Bridge Plant was estimated to be $9 million in 1978. The total estimated project cost of the peaking and reserve power plant modifications for hot water district heat totals $4,009,500 (in 1980 dollars), as shown in Table 4.12.

4.5 Establish Piping System Design Criteria

Hot water district heating systems offer significant advantages over steam district heating systems. The principal advantages are larger service areas, lower cost piping, more-economical boilers, less electricity production loss in cogeneration, higher efficiency, and lower maintenance costs.

Hot water district heating systems have been used very little in cities and municipalities in the United States. The principal reasons are the historically low costs of oil and natural gas and the ignorance of hot water district heating systems technology among district heating systems planners. In Europe, a number of large and growing hot water district heating systems have demonstrated the characteristics of the technology.

As with steam district heating systems, a number of system types have been used. One classification scheme calls low-temperature water (LTW) systems those with maximum tem-

Table 4.12. Costs of heat source conversions

In 1980 dollars

	Estimated cost[a]
Direct cost	
Third Street Plant	1,938,900
State Capitol	796,300
Ramsey Medical Center	618,200
	3,353,400
Indirect cost	
Engineering	364,500
Construction services	291,600
Total	4,009,500

[a]Contingencies (15%) included.

peratures less than 200°F, high-temperature water (HTW) systems those with operating temperatures above 350°F, and medium-temperature water (MTW) systems those with operating temperatures about 250°F. The principal advantages of higher temperature systems are (1) customers who need high-temperature heat for industrial processes or for operating absorption chillers can be served, (2) higher supply temperatures can make customer's equipment less expensive, and (3) higher sendout temperatures can allow higher energy transmission capacity if the return water is of a suitably low temperature. The principal advantages of MTW and LTW systems are lower cost distribution piping, less electrical sacrifice in cogeneration systems, lower cost heat-only boilers, and lower operating costs. However, as the supply temperature decreases, the pumping power and cost increases as does the cost of heat exchangers at the customer location. The bulk of the hot water district heating systems in Europe are medium-temperature systems.

Hot water district heating systems consist of a network of supply and return pipe pairs. LTW systems typically send out water at 180 to 250°F, and the return temperature varies from 140 to 160°F. The supply water is diverted to the customer's building, gives up heat in a set of heat exchangers, and is fed into the return pipe. The capital cost of a district heating system is determined by the peak heat demand, the difference between the supply and return temperatures, and the maximum system temperature.

The maximum design temperature of the system affects the capital cost of the system. At higher temperatures, heavier gage pipe must be used in addition to more expensive installation and expansion techniques. Below temperatures of about 250°F (120°C), relatively thin-wall (schedule 10) pipe with low-cost polyurethane insulation may be used.

The selection of design temperature for a hot water district heating system involves the characteristics for the whole system: heat sources, piping distribution, and the building heating systems. The functional requirements for supply temperature of the various buildings in the St. Paul market area are diverse. Some buildings require only 180°F for domestic hot water heating; others require up to 400°F for sterilization and other relatively high-temperature processes.

Even the largest energy demand of space heating can require a hot water supply temperature of only 270 to 300°F if the building heating system employs 5 to 15 psig steam as the distribution medium. Space cooling, when provided by an absorption chiller, is usually supplied from steam or hot water in the temperature range of 270 to 400°F for commercially available chiller units. The choice of the hot water supply temperature for a district heating system therefore determines the amount of thermal energy demand and types of end uses that can be served in a given building market. The study of building conversion by the Minnesota Energy Agency for hot water district heating systems with a 300°F supply temperature presents a more detailed description of building conversion techniques.[5]

The 300°F supply temperature approach was used in a feasibility study for a hot water system in St. Paul sponsored by Northern States Power Company. At that time (1978), the higher temperature approach did not seem to be economically feasible.

After preliminary studies were made of the potential heat sources and building conversions for the St. Paul system, a study was performed by Peter Margen from Studsvik Energteknik.[1] The study addressed the water delivery temperatures, return water temperatures, and design pressures. Margen concluded that the 250°F supply temperature was the correct approach for this particular system.

The planned St. Paul system will supply thermal energy at a maximum of 250°F (121°C), with the supply temperature decreasing to 190°F (88°C) as the outdoor air temperature increases, as shown in Fig. 4.1. This type of variable temperature supply schedule is used in many European hot water district heating systems to provide for primarily building heating and domestic hot water heating demands. Reducing the supply temperature as the outdoor air temperature increases and the building heating demand decreases and holding the maximum supply temperature to 250°F will reduce the cost of the piping system and cogenerated thermal energy to the district heating utility. This will also mean reduced long-term costs because

1. the overall efficiency of the cogeneration power plant is improved, and the electric capacity derating is minimized;
2. the low-cost, prefabricated pipe with polyurethane foam insulation conduits can be utilized; and
3. heat losses and corrosion are minimized.

In addition to the supply temperature characteristics described above, a cogeneration heat source district heating system requires the return water temperature to be reduced as much as practical for efficient operation of the power plant. The desired return water temperatures for the St. Paul system range from 150°F to 160°F. The desired return water temperatures and the supply temperature establish the criteria for the size and type of heat exchangers installed at each consumer location.

4.6 Define Piping Distribution System

Since northern European engineers have a great deal of district heating piping system development experience, the services of northern European consultants were engaged in cooperation with American engineering firms to develop the conceptual piping design of the St. Paul system. Using the input from the system design criteria, the team of KVB, Inc., Metcalf and Eddy, Inc., and Fjarrvarmebyran ab performed the conceptual piping design study, "St. Paul District Heating System Conceptual Design Study and Report"—which is Appendix C and printed separately as Vol. II of this report.

The major objectives of the study were to

1. develop a conceptual system design that minimizes construction costs while ensuring a high degree of system reliability and flexibility;
2. develop a system implementation schedule that will provide sufficient revenue return on invested capital during the system's development;
3. prepare cost estimates and an expenditure schedule suitable for inclusion in an underwriter's bond prospectus; and
4. develop a conceptual design of the distribution system in sufficient detail to serve as a basis for the preparation of detailed engineering design and construction bid specifications at a later date.

Overall, the report presents the engineering data necessary to estimate the overall cost of a 270 MW(t) hot water district heating system in downtown St. Paul and the nearby State Capitol Complex.

One of the first priorities of establishing the piping route was the customers' use of steam heat from the Third Street Plant, which will gradually be phased out in the initial hot water district heating development period. To ensure early revenue production for the system, the initial distribution lines will be routed to the steam and high-density heat load customers.

The largest diameter supply and return transmission lines, 28 in., will run between the High Bridge Power Plant and the Third Street Plant. The supply and return transmission lines which will begin near Third Street will be approximately 20 in. in diameter and transport district heating water to and from that point through the dense downtown area to the State Capitol Complex. Smaller diameter, 8- to 10-in., supply and return distribution pipelines will be routed from the transmission piping to the buildings to be served. The transmission and distribution piping will transport hot water at a maximum temperature of 250°F in the winter and about 180°F in the summer to the hot water district heating consumer.

The central system piping will consist of a prefabricated piping conduit buried in the ground. This design has steel inner pipe for the hot water with a larger protective outer polyethylene pipe. The annuli between the pipes are filled with polyethylene foam to produce a structural unit. Pipe sections are prefabricated in standard lengths at the factory and transported to the site where they can be installed quickly because of the minimum amount of field fabrication required.

The following summary of the conceptual design report by KVB et al. details some basic assumptions and procedures which were used to establish the above system criteria.[4]

A hot water district heating distribution network is quite simple in theory. The network is essentially a large loop; hot water is pumped out of the plant on one side of the loop and returned on the other. Customers take the hot water, pass it through heat exchangers located on their premises, and return it to the opposite side of the loop. The system may be compared to the circulatory system of the human body. Like the body, the largest diameter outflow and return conduits are located nearest to the pump; there are principal conduits going to, and returning from, all of the major areas served; the system is closed (that is, the same fluid is constantly being recirculated); there are small conduits serving each user; and the conduits get smaller as they get farther away from the pump.

Prior to evaluating alternative configurations for the St. Paul district heating system, the study team established certain guidelines to be used in the evaluation. To a large extent, these guidelines were based on Swedish experience and practice, but, in effect, the guidelines are not unlike those that might be applied to any mechanical system.

A district heating system must be designed to deliver hot water to its customers even under the most adverse conditions, and if sections must be shut down for repair, those sections should be short and designed with the appurtenances necessary to permit the lines to be safely and rapidly drained. The system should also be designed with an appropriate level of redundancy so that customers can be served by more than one leg of the system. The ideal system, moreover, should be configured to minimize the total length of the larger diameter pipes and, in general, serve the most customers with the shortest possible runs. Following Swedish practice, the following design criteria were also established:

1. maximum sendout temperature of 250°F and a peak system pressure of 15 atm (250 psig);
2. maximum ΔT (temperature difference between supply and return water) of 90°F; and
3. an ideal bulk flow velocity of 2 m/s (6.6 ft/s).

The DHDC provided the study team with peak heating load data for each building within the initial service area. That area, also specified by the DHDC, included the downtown business district between Main Street on the west and Wall Street on the east, and between Kellogg Boulevard on the river side and I-94 on the north. In addition to this downtown business district, the initial service area included the State Capitol Complex, Ramsey County Hospital, and Mount Airy—which, in turn, were clustered into multiblock units. The aggregate peak heating load for each block and each multiblock unit was recorded in the process. A map showing the multiblock clusters and the peak heating load for each cluster is presented in Fig. 4.12. Where significant future growth was expected—as for the 32 MW(t) in Lowertown, for instance—the future peak heating load was estimated and assigned to the cluster. The total estimated heating load was then used in sizing and laying out the distribution system.

Once the multiblock load clusters were established, several distribution networks were laid out, down to 8-in.-diam pipe, serving all identified loads. These rough layouts served the important purpose of allowing for a quick evaluation of alternative network configurations. Using cost-estimating factors, each alternative network was priced. The least expensive alternative, which was roughly 15% less than the next most expensive one, was then used as the basis for developing a more refined network.

At this point, several other factors were reviewed and assessed for each leg of the system:

1. street width,
2. pavement conditions,
3. sidewalk width,
4. location of existing utilities and chambers, and
5. traffic conditions.

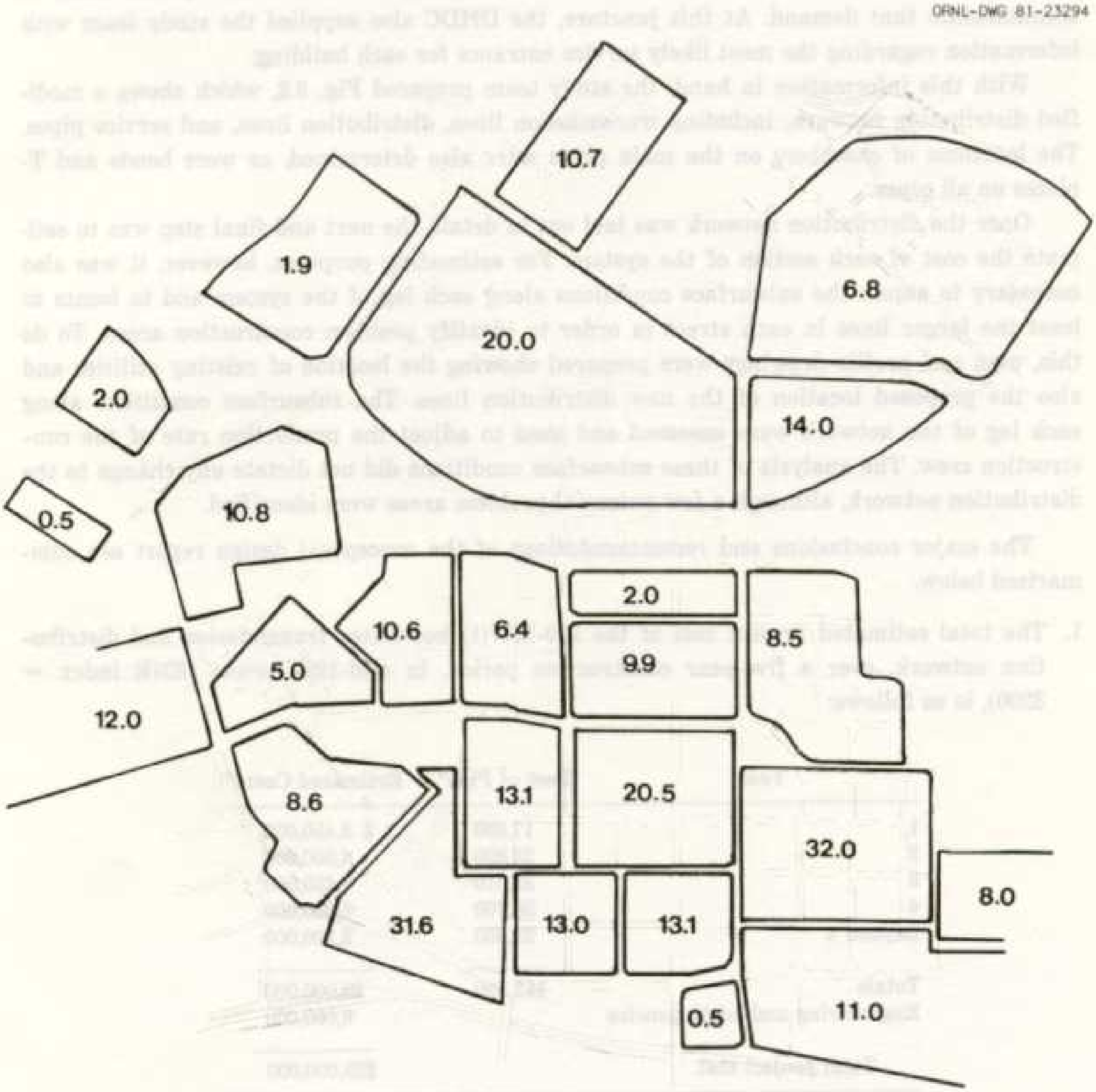

Fig. 4.12. Peak heating loads [MW(t)] for multiblock clusters of the St. Paul hot water district heating market—272.5-MW(t) total.

It was also necessary to assess the network's flexibility and redundancy. This was accomplished by using specially designed computer programs to analyze pressure drops in the system. The system was designed to accommodate a stable (no-growth) demand in all areas except Lowertown, where future demand was estimated and the system sized to accommodate that demand. At this juncture, the DHDC also supplied the study team with information regarding the most likely service entrance for each building.

With this information in hand, the study team prepared Fig. 3.2, which shows a modified distribution network, including transmission lines, distribution lines, and service pipes. The locations of chambers on the main pipes were also determined, as were bends and T-pieces on all pipes.

Once the distribution network was laid out in detail, the next and final step was to estimate the cost of each section of the system. For estimating purposes, however, it was also necessary to assess the subsurface conditions along each leg of the system and to locate at least the larger lines in each street in order to identify problem construction areas. To do this, plan and profile drawings were prepared showing the location of existing utilities and also the proposed location of the new distribution lines. The subsurface conditions along each leg of the network were assessed and used to adjust the production rate of the construction crew. The analysis of these subsurface conditions did not dictate any change to the distribution network, although a few potential problem areas were identified.

The major conclusions and recommendations of the conceptual design report are summarized below.

1. The total estimated project cost of the 270-MW(t) hot water transmission and distribution network, over a five-year construction period, in mid-1980 prices (ENR index = 3200), is as follows:

Year	Feet of Pipe[a]	Estimated Costs[a]
1	17,080	$ 3,450,000
2	22,820	4,500,000
3	32,510[b]	7,450,000[b]
4	58,760	5,500,000
Beyond 4	21,350	2,100,000
Totals	152,520	23,000,000
Engineering and contingencies		6,000,000
Total project cost		$29,000,000

[a]Excludes pipe inside buildings.
[b]Transmission main between the Third Street and High Bridge generating plants includes 10,000 ft of pipe at a cost of $4 million.

2. In general, the installation of pipe within shallow trenches, excavated in the street, was determined to be the most effective technique for all but the very small diameter pipelines. Although a layer of very competent limestone is present at a shallow depth and throughout a widespread area, the cost of its excavation using mechanical means is estimated to be less than the cost of excavating new tunnels or widening existing tunnels.

3. Installation of the hot water mains within existing utility tunnels would be more expensive than installing the pipelines within entirely new tunnels.
4. The cost of excavating new tunnels within the St. Peter sandstone formation is very expensive for the following reasons:

   A. The required tunnel section is large.
   B. The sandstone deteriorates with exposure to heat and humidity and is highly erodable by a high-pressure jet of water; therefore, measures would have to be taken to protect the new as well as existing adjacent tunnels.
   C. The large chambers required for valving and expansion loops would require an elaborate and expensive support system for the cavern roof.
   D. Adequate clearance from existing tunnels and adequate necessary cover will be difficult to achieve in many congested areas.

5. The route which was selected for study for the transmission mains between the High Bridge and Third Street generating plants appears to have poor soil conditions, on the basis of limited available subsurface data. However, this soil apparently has sufficient bearing capacity to support railroad beds, a roadway subject to heavy truck traffic, and numerous utility pipelines. For purposes of this feasibility study, where the objective is to determine the most likely cost of constructing the transmission system between the two plants, it has been judged that construction of the pipelines along this routing can probably be accomplished provided that certain precautions are taken during design and construction. This presumption should be confirmed by a detailed subsurface investigation.
6. The most economical means of conveying the transmission mains across the Interstate Highway to the Capitol Complex area was determined to be the construction of a new pipe-carrier bridge.
7. For small-diameter pipe, 2.5 in. and less, routing from basement to basement appears to be practical. Pipe of this diameter could also be economically installed within existing water tunnels in some locations. These savings are indeterminant and are minor in comparison to the total estimated project cost.
8. Some American-made products, equivalent to those used in European practice, are available.
9. American construction practices can be successfully applied to achieve results similar to those in European practice.
10. Standards more rigorous than those customarily employed in the United States in normal fabrication, quality control, and construction coordination will need to be enforced.
11. It is recommended that, wherever possible, standardized prefabricated and preassembled components be used to ensure quality control, economy, and construction efficiency.

Generalized installed piping costs in mid-1980 dollars from this conceptual design are shown in Fig. 4.13 according to pipe internal diameter. As shown in this figure, significantly higher costs are attributed to trenching in rock conditions; for example, installed costs are 50 to 60% higher in rock conditions at low (≤4-in.-diam) pipe sizes and about 30% higher at large (≤12-in.-diam) pipe sizes.

The conceptual design report detailed a hot water piping system to service all the existing and future heating demands in the service area. The piping diameters and flow capacities were therefore designed to supply the full 270-MW(t) demand in the service area.

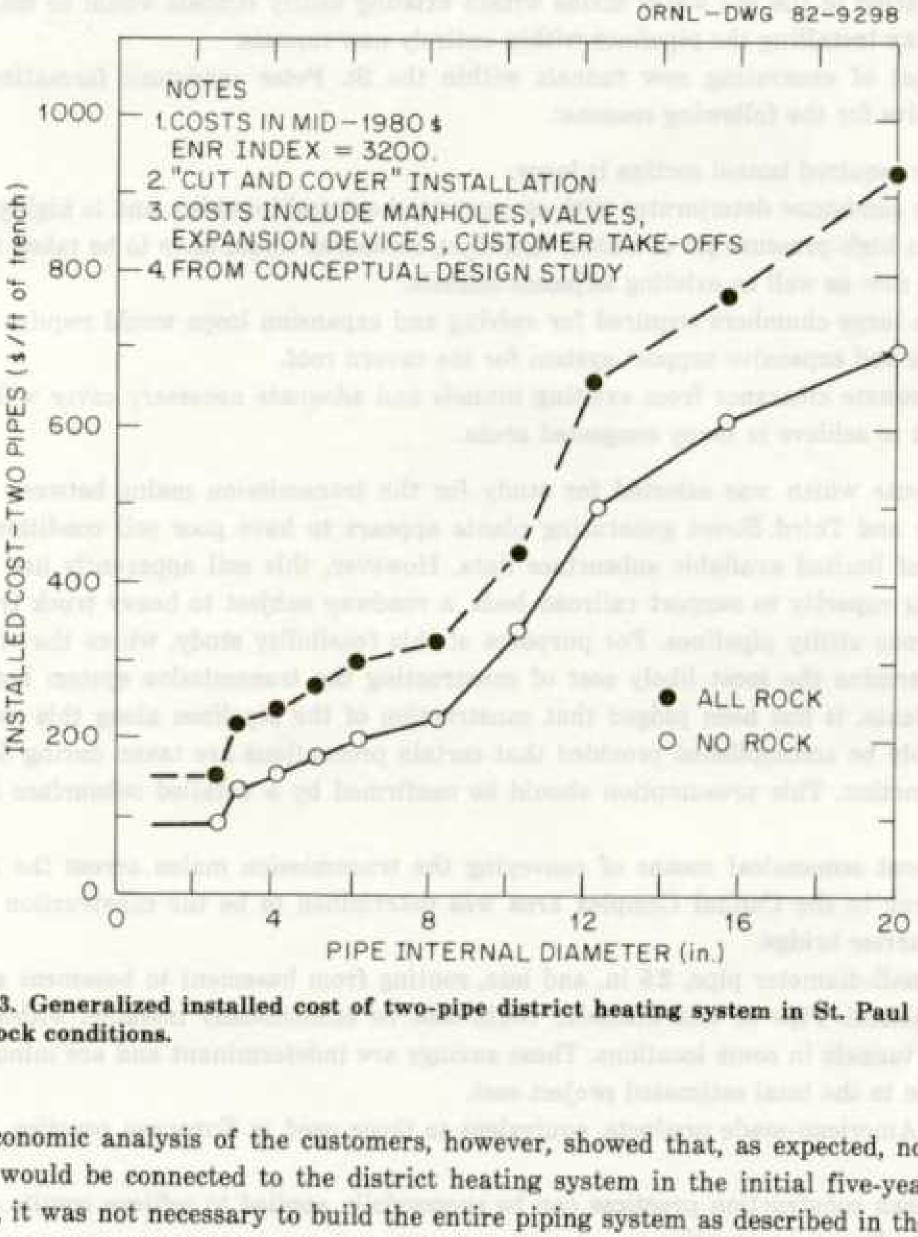

Fig. 4.13. Generalized installed cost of two-pipe district heating system in St. Paul streets for range of rock conditions.

An economic analysis of the customers, however, showed that, as expected, not all the buildings would be connected to the district heating system in the initial five-year period. Therefore, it was not necessary to build the entire piping system as described in the conceptual design report. Also, it is not economically prudent to invest in a piping installation which could not provide sufficient economic return.

The DHDC, however, is dedicated to future expansion of the system and to providing service to all the buildings in the service area. Therefore, the piping diameters specified for the 270-MW(t) demand will not be changed in the final, detailed design. The system will be reduced in physical size, however, by omitting piping to buildings which will not be connected during the initial five years. The omitted piping merely reduces the number of buildings that could be serviced and, in this manner, reduces the system demand (system size) to approximately 165 MW(t). The 165-MW(t) specification was determined by the Touche Ross & Co. preliminary economic feasibility study (Sect. 6.2) which incorporated economic limitations as well as the market analysis for potential connection to the system. The basic system design capacity of 270 MW(t) can be achieved when necessary, however, by installing the omitted pipelines.

5. MARKET ASSESSMENT

5.1 Analyze Market Characteristics

The characteristics of the downtown St. Paul market area play a significant role in the development of a marketing plan for the hot water district heating system. These characteristics are detailed in Sect. 4.1 and are summarized in Tables 5.1 and 5.2.

For the preliminary economic feasibility study, specific characteristics on each building were incorporated from data that had been developed in previous engineering studies. This list of building information is included in Appendix A, Part II. By analyzing this and other

Table 5.1. Market survey results for existing energy sources and building heating systems (1980) in the St. Paul central business district

Energy source	Percent of load	Heating system medium	Percent of load
Interruptible gas	49	Steam	43
Firm gas	12	Steam + hot water	43
District steam	31	Hot water	12
Oil	1	Air	2
Electricity	1		
Unknown	6		

Table 5.2. Summary of building types in the St. Paul central business district

Market	Peak demand [MW(t)]	No. of buildings
Identified		
Government buildings & hospitals	90	30
Large buildings [>500 kW(t)]	91	55
Small buildings [<500 kW(t)]	4	21
Planned development (1980–85)	40	14
Subtotal	225	120
Unspecified		
Small buildings [<500 kW(t)]	20	~140
Large buildings	40	
Total	285	

data, three major areas of concern were identified as important in the marketing strategy: customer type, existing energy sources, and building characteristics.

Within these areas, the DHDC specified items which would have to be taken into consideration when developing the marketing plan:

1. small customers and/or nonprofit organizations do not have the economic base to finance conversions;
2. large institutions have inherently long approval processes that may slow the marketing progress;
3. gas customers who traditionally have had relatively low-cost energy may find it hard to accept that, although gas may be less expensive initially, hot water district heating will be less expensive in the long run;
4. steam district heating customers who will eventually be phased out of the steam system may feel resentment because they feel forced into hot water district heating (even though it is only one of several options);
5. buildings with old steam systems which have high conversion costs will have to be convinced that increased building efficiency and energy savings resulting from conversion will make the investment worthwhile; and
6. buildings with present hot water systems may not require as much attention and emphasis in the marketing program because of relatively lower conversion costs.

As a result, the DHDC realized that a diverse marketing plan and detailed pricing policy were needed to effectively and appropriately contact all potential customers.

5.2 Develop Pricing Policy

The first step in developing a pricing policy for district heating (thermal energy) was to analyze alternative energy prices in the market area.

5.2.1 Alternative Energy Prices

Alternative energy prices were calculated using the actual prices in 1980 dollars which were escalated to reflect projected real price increases (where applicable) and the assumed general inflation rate. Alternative fuels and thermal energy sources had the following unit prices in St. Paul in 1980:

Steam, firm	\$8.15/MBtu
Steam, interruptible	\$5.22/MBtu
Natural gas, firm	\$2.90/1000 ft^3
Natural gas, interruptible	\$2.15/1000 ft^3
No. 2 fuel oil	\$1.04/gal
No. 6 fuel oil	\$0.55/gal

Steam rates for 1980 were based on current average steam prices adjusted for a 15% temporary rate increase allowed by the St. Paul City Council's Energy, Utilities, and Environment Committee. Natural gas prices were average commercial rates based upon NSP's current rate schedule. Fuel oil prices for No. 2 and No. 6 oils were based on the May 9, 1980, projection of commercial distillate and residual prices by the MEA.

These alternative 1980 energy prices have been converted to end-use prices in \$/MBtu using the following formula:

\$/MBtu = cost per unit ÷ Btu per unit ÷ end-use conversion efficiency factor. The assumed MBtu conversion factors are

Natural gas	1.0 MBtu/1000 ft^3
No. 2 fuel oil	138,805 Btu/gal
No. 6 fuel oil	152,325 Btu/gal

Assumed annual average, end-use conversion efficiencies are 0.55 for No. 2 and No. 6 oil, 0.60 for natural gas, and 1.00 for steam. Individual boiler efficiencies vary with age and condition of equipment and, therefore, comparison of specific customer alternative energy costs may require adjustment for actual conditions. A city franchise fee of 8.7% was also added for steam and natural gas.

Alternative energy prices were escalated to reflect the following projected real and inflationary price increases:

- Steam prices were assumed to escalate at the general inflation rate.
- Natural gas and No. 2 and No. 6 oil price escalations were assumed to include real price increases according to the MEA's May 9, 1980, commercial gas, distillate, and residual projections, added to the assumed general inflation rate.
- The general inflation rate was assumed to be 12% for 1981–82; 10% for 1983–84; and 8% for 1985–2000.

The projected end-use prices in current dollars per million Btu from these 1980 values are shown in Fig. 5.1.

5.2.2 Customer Hookup Analysis

The customers' hookup analysis assumed that in choosing between district heating and current energy sources, customers would minimize their out-of-pocket cash outlays. In general, it was also assumed that smaller customers would insist upon receiving some benefit from district heating within five years of hookup, since forecasted benefits beyond that period would likely be perceived as less certain and of marginal value in justifying hookup.

Each customer's projected out-of-pocket district heating costs were calculated as (1) cost of thermal energy and (2) principal and interest payments on the customer's conversion equipment. With this in mind, it was assumed that the steam rates were an upper limit for the initial hot water rates.

Financing for customer heating system conversions was assumed to be provided by separate bond issues each year equal to the required conversion expenditures plus financing costs (computed as 2.65% of the issue amount for that year). The interest rate was assumed initially to be 10% per year. Conversion bonds were assumed to be 20-year tax-exempt bonds secured by liens on the district heating customers' property (Sect. 5.3.2).

The average conversion cost for customers needing less than 8 MW(t) was calculated at \$1.96/MBtu. The cost for customers whose demand is larger than 8 MW(t) (an annual energy use of more than 50,000 MBtu) was equivalent to \$2.37/MBtu.

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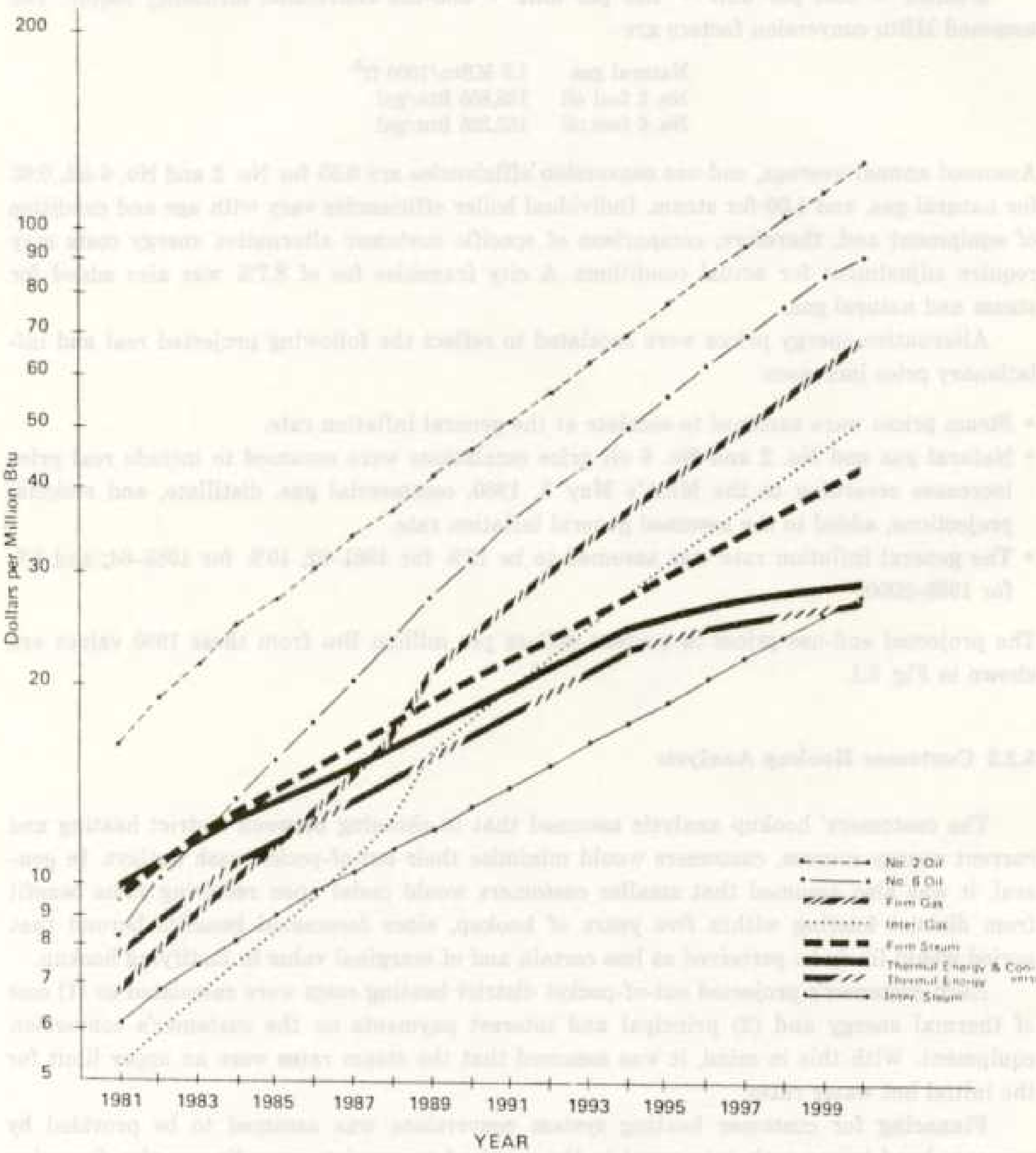

Fig. 5.1. Projected end-use prices for hot water thermal energy and alternatives in St. Paul in current $/MBtu.

5.2.3 Pricing Alternatives

The two principal alternatives for pricing district heating services are cost-based rates and competitive service–based (market) rates.

Cost-based rates are generally superior to market-based rates in achieving objectives relating to

- providing revenues equal to costs (revenue sufficiency),
- ease of administration,
- customer acceptance, and
- minimizing subsidizing customers.

Cost-based rates are based on the concept that the utility is entitled to recover all costs of operations and capital costs, while market-based rates are set by substitute prices. With respect to administration of the rates, cost-based rates are relatively easy to administer due to the objective nature of the base. Cost-based utility rates are possibly best understood and accepted by consumers because consumers generally perceive that they will not have to subsidize other users if costs have been objectively defined.

A significant characteristic of market-based rates is that assuming current fuel price projections, such rates would result in lower revenues in early years and higher revenues in later years of the project. Cost-based rates appear to have the opposite effect. In fact, based on preliminary data, a strict cost-based rate approach for the hot water district heating service results in rates which are noncompetitive in the marketplace.

Market-based pricing requires definition of the standard which defines the "market" price; alternative "market" prices include:

- the average price of thermal energy paid by all customers,
- the lowest price of thermal energy paid by any customer, and
- the actual price of thermal energy paid by each customer.

Difficulties in implementing market-based prices include

- selection of market price definition,
- customer acceptance (because customers may desire the flexibility to change sources of fuel as relative prices change),
- lack of incentive to commit to taking service for customers whose current prices are lower than the average for all customers,
- potential revenue losses for the district heating operation if the lowest market price is used, and
- perception of price discrimination if actual prices are used.

Although there are problems in implementing market-based prices, market prices for alternative fuels nevertheless impose a price constraint for thermal energy prices which are cost based. Customers are not likely to pay more for thermal energy from a hot water district heating system than they would pay for alternative sources of heat.

Neither cost-based rates nor market-based rates appear to simultaneously satisfy the objectives of (1) providing revenues equal to costs and (2) encouraging hookup. Preliminary economic analysis indicates that cost-based rates would be higher than prices for alternative fuels in the early years of the project. Therefore, the prices for alternative fuels probably establish a maximum price for new hot water district heating services.

The St. Paul hot water district heating system requires the expenditure of a significant amount of the total system investment in the early years of the project. This results in high fixed costs in the early years which cannot be "spread" over sufficient sales units to provide prices which are at or below market prices for alternative fuels. If prices are set to fully recover costs (including capital costs), it is unlikely that the resulting market penetration (hookup rate) will result in revenues covering costs. If prices are set at the market price for alternative fuels, the utility will likely generate revenues that fail to cover costs.

5.2.4 Thermal Energy Price

Because of the considerations previously discussed, it was decided that the district heating revenue requirements be determined based on the costs expected in each year adjusted for a forecast level of facilities utilization. In other words, customers would initially be charged prices which reflect current utilization of the system and all other costs would be deferred. At such time that the market constraint is in excess of actual operating and capital costs, accumulated deferred costs would be amortized and recovered from the increased customer base.

The initial average price of thermal energy in 1981, including an 8.7% franchise fee, is $7.28/MBtu or $24.85/MWh (1980 equivalent of $6.50/MBtu) and is inflated at the assumed general inflation rate through 1988. Figure 5.1 shows the average thermal energy price in current dollars/MBtu through the year 2000 along with the alternative energy prices for natural gas, fuel oil, and district steam.

In 1989, prices are projected to be determined using a cost-based rate formula when the formula costs are projected to be less than the previously assumed market constraint prices. The cost-based rate formula provides that revenues from customers be equal to the sum of 10% rate of return on net investment, operating costs, and amortization of deferred costs. (See Sect. 6.2 for a more detailed discussion of system costs and revenues.)

Separate demand and energy rates (Table 5.3) have been designed to generate the revenues shown in projected financial statements, given the assumptions used in the preliminary economic feasibility analysis of Sect. 6.2. These rates assume full variable cost recovery in the energy charge and demand charges that recover fixed costs over the 20-year projection period.

5.3 Analyze Market Penetration

The ability of the DHDC to successfully penetrate the heating market in downtown St. Paul depends significantly on the market buildings' characteristics and economics.

5.3.1 Market Characteristics Considerations

The market area buildings (see Sects. 5.1 and 5.2) are quite varied. Some buildings have old, one-pipe steam heating systems which are rapidly deteriorating; others have relatively new hot water systems which are readily compatible with hot water district heating.

Table 5.3. Recommended demand and energy rates for hot water thermal energy[a]

Year	Demand [$/kW(t)]	Energy ($/MBtu)
1982	$21.52	$4.44
1983	23.64	5.01
1984	25.98	5.85
1985	28.54	5.79
1986	31.36	6.11
1987	35.54	6.43
1988	38.82	6.87
1989	42.42	7.34
1990	43.95	7.84
1991	45.53	8.58
1992	47.17	8.96
1993–2000	48.88	

[a]Dollars are current.

These factors will affect the customers' economics. If conversion of the building heating system will require substantial customer investment, the economics of a customer's conversion are diminished. It is expected to be more difficult to penetrate this segment of the market compared to those buildings which require a much smaller conversion investment.

It is also expected to be more difficult to penetrate the natural-gas-customer market. Gas is now relatively inexpensive, but its cost is expected to increase rapidly in the next three to five years as deregulation of well-head prices occurs. Customers already using the more costly energy sources, oil and steam district heat, are likely to shift to hot water heating service. To obtain present gas customers, the DHDC will have to demonstrate its competitiveness with natural gas—particularly in the long run.

Since St. Paul's steam district heating system is planned to be phased out by September 30, 1985, in favor of hot water district heat, these customers may find the new system most attractive. Converting to any other heating system would mean that the customer would have to purchase a boiler, install a stack, and make other preparations in order to burn gas, oil, or coal. This segment of the market is projected to be more penetrable because of the essential lack of uncomplicated or less expensive alternatives.

5.3.2 Customer Economics Analysis

The DHDC realizes that, although a customer's decision to take or not take district heating may be influenced by emotional or political factors, it must eventually be grounded in sound economics. Individual customer economics have therefore been used to indicate whether a potential customer is likely to take district heating service.

Although mainly intended for internal analysis purposes, the individual customer economics may be a strong external marketing tool—particularly because of the effective computer program which was developed. The major assumptions for the economic analysis are

1. projected hot water district heating thermal energy prices,
2. projected competitive energy prices,

3. conversion cost amortization, and
4. building owner's income tax bracket.

The projected hot water district heating prices are discussed in Sect. 5.2. It will be emphasized to the customers that the customer's cost for district heating decreases with the addition of customers to the system.

The energy price projections have a significant effect on the cost effectiveness of conversion to district heating. The faster and more extensive the increases in other energy prices, the better hot water district heating will look in comparison.

Because the majority of customers will incur conversion costs, assumptions have been made for conversion cost amortization. Financing with 10%, tax-free loans for a 20-year period was initially assumed but isre subject to change according to bond market conditions. Rates will be developed in coordination with the St. Paul Port Authority, which is preparing a conversion financing package. The most recent (June 1982) financing conditions are 30-year loans with a 12% per year rate.

After a survey of the market areas in both St. Paul and Minneapolis, an income tax bracket of 35% was assumed for all nonexempt buildings. There may be income tax advantages for tax-paying building owners. The estimate will be adjusted on an individual basis as more detailed information becomes available.

With these general assumptions in mind, the following information was gathered from previous studies or was estimated:

1. the existing fuel type and consumption for each building,
2. boiler efficiency, and
3. building conversion costs.

All information for each customer was input into a data-based computer program which is detailed in Appendix A, Part III. The program analyzed the economics for each customer to convert from its present system to the hot water district heating system. Using the factors described above, the program compares the building's conversion cost plus district heating costs to the building continuing with its present heating system. The computer prints out this analysis as the building's cash flow after conversion including a discount factor for future costs and savings. The program includes inflated costs and begins its analysis in the year the building is assumed to be connected to the system, based on the preliminary construction schedule from the conceptual design study. (See ref. 6 for more detailed descriptions.)

Some buildings with low conversion costs have been shown to have a payback period, based on the time to reach a positive cumulative cash flow, within as little as three years because of the significant energy cost savings. Buildings with very high conversion costs [>$300/kW(t) of demand] can have discounted pay-back periods of 10 to 15 years. The customers with payback periods of less than five years are considered to be the most penetrable portion of the market.

The DHDC has discovered that different building owners or companies may have their own rate of return stipulations. These specific concerns are being dealt with during the final marketing effort.

5.4 Develop Marketing Plan

The DHDC's marketing approach has announced and stressed to each potential customer the long-term economic benefits of conversion to hot water district heating. Providing reliable rate projections, conversion cost estimates, and suitable financial assistance packages are critical elements in this process. Emphasis is placed on the benefits to the building owner of reduced heating system space requirements, the reduced fuel costs, and—where applicable—increased system and building heating system efficiency. The use of the economic analysis computer program (Sect. 5.3.2) is expected to play a major role in emphasizing the economic benefits of the system.

An on-going, three-phase marketing plan has been developed: phase I—Market Awareness; phase II—Customer Contact; and phase III—Contract Negotiations. Phase I began simultaneously with DHDC's incorporation, phase II began in late March 1981, and phase III began in June 1981.

During phase I, project awareness was created primarily through the local news media and general large-group presentations with assistance from the city of St. Paul, the St. Paul Building Owners and Managers Association, and the St. Paul Area Chamber of Commerce. General informational brochures were prepared and distributed, and a folder with the district heating logo was also developed.

In the immediate weeks before phase II marketing began, key presentations and contacts were intensified to large, influential community groups. A major part of these presentations was a sound and color slide production prepared specifically for large group presentations. The 10-min production explains the need for district heating in St. Paul, the hot water district heating concept, and the purpose of the St. Paul DHDC. It also was made available to customers for use within their organizations.

During phase II, direct customer contacts were made through meetings held with the individual building owners. The DHDC explained to each customer the benefits of district heating, the computer economic analysis, and the proposed terms and conditions of taking district heating service. To implement phases II and III, the DHDC selected a Director of Marketing, who was responsible for attaining and maintaining customer contacts. Because of the density of the downtown area, the marketing director was familiar with the downtown area and its social/business climate.

A customer contract, discussed in the following section, was developed by the DHDC and its consultants during phases I and II. It was presented to the building owners during phase III. The object of phase III is to obtain the necessary number of signed contracts—at this point totaling approximately 165 MW(t)—to make the hot water system economically feasible for obtaining approval by a bond rating agency and subsequent sale of a bond issue.

5.5 Generate Customer Contract

Representatives from the DHDC management team, legal counsel, bond counsel, and the Board of Directors have formulated a draft customer service contract which must be finalized by phase III of the marketing program. A 30-year "take and pay" contract was initially written to satisfy the concerns of the bond counsel; initial review of the contract by a sample of prospective customers indicated that some concerns exist from a customer viewpoint.

To satisfy the requirements to receive an A-rated bonding, the contract terms were seller-oriented and provided less flexibility for the customer than for the district heating company. The highlights of the original draft contract terms are enumerated below.

1. Term of agreement—30 years
2. Agreement can be terminated by DHDC with 30-d notice for
   a. failure to pay,
   b. failure to abide by rules,
   c. insolvency—bankruptcy of customer,
   d. destroyed building, or
   e. delivery service to customer becoming unlawful.
3. Agreement can be terminated by customer with 30-d notice if
   a. bonds for the DHDC are not issued by a certain date, yet to be determined,
   b. building is destroyed and not repaired in 18 months,
   c. building is taken by eminent domain, or
   d. reception of service from DHDC becomes unlawful.
4. Customer, at its own expense, will convert its building to utilize hot water from DHDC.
   a. Customer must comply with any performance specifications of DHDC.
   b. DHDC will attempt to obtain low-interest financing of customer's conversion costs.
5. Rates will be composed of an energy rate with a fuel cost adjustment provision and a demand rate.
   a. *Energy Rate* will be determined for a given period by dividing the projected variable costs by the total thermal energy sales of all customers.
      - Variable costs will include purchased energy costs, DHDC energy production costs, and operating and maintenance costs of the distribution system.
      - Adjustments will be made as necessary to the energy rate to cover variable costs.
   b. *Demand Rate* will be determined so that the sum of each customer's demand multiplied by the demand rate will equal the total amount of fixed costs. Adjustments can be made as necessary to cover fixed costs.
      - Customer's initial demand for the first two years of service will be determined by dividing the normalized annual thermal energy used by 1700.
      - Normalized annual thermal energy used will be determined by the formula:

$$(\text{June-August MW(t) hours}) \times 4 + \frac{8159}{\text{actual heating degree days}} [\text{total MW(t) hours} - 4(\text{June-Aug. MW(t) hours})] .$$

      - MW(t) hours will be determined by the annual pounds of water flowing through the customer's heat exchanger times the difference in the inlet and outlet water temperature across the heat exchanger divided by 3,400,000.

- During the first two years of use, the customer demand can be increased by a set percentage for each °F the leaving water temperature returning to the district heating system is above 176°F.
- After two years of use, the customer demand rate can be increased for each degree above 168°F. DHDC will deliver hot water at a temperature 260°F or less.
- Prior to January 1, 1989, DHDC will try to defer fixed costs so that the sum of the customer's demand and energy rate will be no greater than the cost of energy the customer would have experienced had he not converted to the DHDC system.
- After January 1, 1989, DHDC will recover any deferred costs and also accumulate an expansion reserve for the district heating system.
- DHDC may modify its method of determining demand and energy change.

6. Metering—DHDC shall own and maintain the meter, but the customer will provide and pay for any electricity required for the meter.
7. No customer shall provide heating service from its building heating system to any other building.
8. Customer shall hold harmless and indemnify the DHDC for anything on the customer's property except for negligence by the DHDC.

The contract terms were substantially revised to reflect acceptable changes proposed by the customer base. The revisions were accepted in 1982 by the project bond underwriters, E. F. Hutton Co.; bond counsel, Briggs and Morgan; and the rating agency, Standard and Poors. The highlights of the final contract terms as presented to the customer market in May of 1982 are listed below.

1. Form of agreement—All provisions are included in the contract itself, rather than in Rules and Regulations. The contract terms cannot be amended without approval by a majority of customers, both by number and by megawatts of demand, and the trustee of the system bonds.
2. Customer representation—To reflect the interests of current customers and long-term system concerns, the contract provides that DHDC shall have a seven-member board, including three members elected by customers according to demand categories, three publicly appointed members, and a seventh member with appropriate qualifications selected by the other six.
3. Term—The contract is effective from the time of signature and remains in effect until 30 years after hot water service to each customer begins, subject to the following provisions:
   - Sufficient customers must be signed, building conversion financing arranged, and system feasibility demonstrated by September 30, 1982, or the contract becomes null and void.
   - Financing for system construction must be in place by December 31, 1982, or customer may terminate the agreement.
   - Agreement may also be terminated if customer's building is destroyed, if DHDC becomes unable to deliver hot water on an on-going basis, or if certain conditions exist.
   - Every five years, customer has option to terminate without cause, provided such termination would not put system below level of customer load required for economic feasibility.

4. Hookup—The date of hookup is specified in each contract. An extension of up to 60 d is possible if completion of building conversion is delayed for reasons totally beyond customer's control.
5. Demand and energy charges—Each customer's demand will be set initially by contract and adjusted annually thereafter according to the previous year's hot water use. Demand charge rates during the first three years of system operation will be set so that the total district heating charges are at or below price projections for natural gas. Thereafter, cost-based demand charges will be set annually to recover fixed costs, including debt service coverage, plant operating and maintenance costs, work capital, and administrative costs. Energy charges will be set to recover annual fuel and electricity costs, which vary directly with energy sales.
6. Billing—Monthly statements will be issued and are due upon receipt. Annual demand charges will be billed in 12 equal installments, with energy charges billed according to actual monthly use. A 5% discount will be applied to all bills paid within 10 d of receipt. Any excess or underage of costs at the end of each fiscal year will be charged or credited proportionately to all customers based on usage.
7. Contingent customer obligation—Customers may vary their district heating use, and their demand will be automatically adjusted each year. However, if total system demand falls below the demand required for economic feasibility, each customer shall bear its proportionate amount of the demand charge based on the higher or current use level of original contract demand.
8. Expansion—The system is designed to expand to adjacent areas as economically feasible. An expansion reserve will be funded to enhance the economics of future growth. A customer's direct contribution to expansion is limited to a set percentage that cannot be increased or changed. Thus, DHDC customers, unlike other utility customers, are protected from excessive or unknown charges resulting from utility expansion.
9. Assignment of the contract—The contract can be assigned to third parties if customer's building is sold and third party assumes in writing, fully and enforceably, all contract provisions.

6. ECONOMICS AND FEASIBILITY

For the St. Paul District Heating Demonstration Project to continue from the early "study" phase into the implementation phase involving final design, financing, and customer marketing, positive results were required from a detailed, preliminary economic feasibility analysis. This analysis, performed in the second half of 1980, was based on the results of early engineering studies and the market assessment that determined system costs and revenue potential. Additional considerations for the analysis included financing rates, which were determined by the exact form of the DHDC corporate structure and the type of debt financing chosen, and the cost of heat from the potential heat sources for hot water production, mainly the NSP High Bridge Plant and the Third Street Plant. These considerations, plus other important project strategy issues, are discussed in Sect. 7. As a basis for the economic feasibility analysis, the DHDC developed a scenario for thermal energy production to meet the planned construction and connection of the new hot water district heating system market in the central business district of St. Paul.

6.1 Determine System Thermal Energy Requirements

The basic scenario which was evaluated in late 1980 assumed that all thermal energy would be purchased from NSP's High Bridge Plant or produced at the Third Street Plant. Initial assumptions were that hot water and steam would be produced from High Bridge boiler units B-9 and B-10 and transmitted to the Third Street Plant through new hot water and steam transmission lines to be completed in 1982.*

Cogenerated thermal energy from High Bridge turbine unit T-6 was assumed to be available in 1984. The Third Street Plant was assumed to be operated by NSP under terms to be negotiated and would be used to produce only steam through 1982, as production of hot water at High Bridge was projected to be adequate to meet system needs through 1983. Beginning in 1984, the Third Street Plant would simultaneously provide steam and hot water during scheduled or unscheduled interruptions of hot water production at High Bridge. Backup production plants at Third Street, the State Capitol, and the St. Paul Ramsey County Hospital are required because the High Bridge heat source is subject to interruption based on the NSP electrical system requirements. It has been assumed that 10% of thermal energy will be provided by backup plants and 90% from High Bridge based on anticipated interruptions after 1983.

*The construction of new steam and hot water transmission lines from High Bridge to the Third Street Plant was a possibility under the January 1981 Consent Decree negotiated between the EPA Region 5 Enforcement Branch and NSP in concert with the DHDC (see Sect. 7.2). However, the DHDC has been able to retain the Third Street Plant as the base heat source for both the existing steam and the new hot water district heating systems. Hence, only the hot water transmission lines will be constructed to High Bridge, as had been originally planned.

From the conceptual system construction schedule and the customer economic analyses, the annual district heating demand and energy requirements were forecasted. Table 6.1 presents the annual energy requirements for the Third Street and High Bridge Plants developed from this forecast. In this regard, it is important to schedule the units to be converted to hot water heat sources only when the load is great enough to economically justify the conversion.

Table 6.1. Total plant energy requirements (in MBtu)

Year	Third Street Plant			High Bridge Plant				Total
				B-9 + B-10			T-6 hot water	
	Steam	Hot water	Total	Steam	Hot water	Total		
1980	499,000	0	499,000	0	0	0	0	499,000
1981	551,000	0	551,000	0	0	0	0	551,000
1982	357,000	0	357,000	160,000	94,600	254,600	0	661,000
1983	0	0	0	423,000	430,000	853,000	0	853,000
1984	31,000	80,000	111,000	276,000	545,000	821,000	173,000	1,105,000
1985	21,000	100,630	121,630	185,000	201,260	386,260	704,410	1,212,300
1986	21,000	104,330	125,330	185,000	208,660	393,660	730,310	1,249,300
1987	21,000	104,650	125,650	185,000	209,300	394,300	732,550	1,252,500
1988	0	104,650	104,650	0	209,300	209,300	732,550	1,046,500

6.2 Determine Cost of Thermal Energy

Although NSP will not be building the district heating system, it is taking a cooperative role in the development of hot water district heating in St. Paul by agreeing to provide the system with thermal energy from some of its power plants. During the first half of 1980, NSP and the DHDC worked together to define the cost of thermal energy. Although the electric utility business is regulated, district heating is not; thus, the Minnesota Public Service Department has also been involved in the determination of the effect of cogeneration and subsequent sale of thermal energy on the cost of electricity. An outline of the cost allocation procedure is shown in Appendix D, Part 1. Preliminary review by the Public Service Department has been positive.

Costs of thermal energy production by NSP represent an estimate of a "cost plus" contract which is anticipated to be entered into between DHDC and NSP. Some of the anticipated provisions in this contract are:

- full recovery of operating costs attributable to the generation of steam or hot water energy sold to DHDC,
- rate of return on investment and recovery of plant retrofitting expenditures at High Bridge financed by NSP, and
- automatic escalators to provide for fixed cost recovery in the event that thermal sales vary from projected levels and to adjust for variations in fuel or other variable costs.

A more detailed explanation of the cost of thermal energy methodologies is presented in Appendix D, Part 2.

Average production costs for hot water were estimated by NSP for the High Bridge Plant and by the DHDC for the Third Street and the Ramsey County Hospital plants. These costs (Table 6.2) include general inflation rates of 12% for 1981-82, 10% for 1983-84, and 8% for 1985-2000.

The hot water costs from High Bridge (Table 6.2) include preliminary estimates for the electric-system-related costs. These preliminary estimates assumed that current turbine load factors (for which the electric system costs were minimal) would continue. Later evaluations by NSP included pessimistic assumptions concerning the electric system reserve margin beyond 1987. For such situations, the additional costs for replacement and excess energy could exceed the cost savings from cogeneration if hot water were purchased on a firm rather than an interruptible basis. Since some important factors affecting the NSP electric system reserve margin could not be reliably predicted by NSP, a long-term contract for firm hot water production at High Bridge has not been negotiated between NSP and DHDC. However, NSP has agreed to continue negotiations for hot water production on an "oil interruptible" basis. Under this arrangement, the High Bridge turbines retrofitted to extraction cogeneration would return to maximum electrical output whenever the first oil-fueled gas turbine units—currently the Pathfinder Plant—would be required to meet the electric system demands.

Table 6.2. Projected thermal production quantities and costs (in current dollars)

Year	Third Street Plant Quantity (MBtu)	Third Street Plant Cost ($/MBtu)	High Bridge B-9 and B-10 Quantity (MBtu)	High Bridge B-9 and B-10 Cost ($/MBtu)	High Bridge T-6 Quantity (MBtu)	High Bridge T-6 Cost ($/MBtu)	Total Quantity (MBtu)	Total Average cost ($/MBtu)
1981	0		0		0		0	
1982	0		94,600	3.87	0		94,600	3.87
1983	0		430,000	4.43	0		430,000	4.43
1984	80,000	17.43	545,000	3.93	173,000	3.79	798,000	5.25
1985	100,630	18.77	201,260	4.90	704,410	3.39	1,006,300	5.23
1986	104,330	20.90	208,660	5.09	730,310	3.43	1,043,300	5.49
1987	104,650	23.09	209,300	5.28	732,550	3.49	1,046,500	5.81
1988	104,650	23.41	209,300	6.59	732,550	3.63	1,046,500	5.94
1989	104,650	25.85	209,300	6.84	732,550	3.80	1,046,500	6.61
1990	104,650	28.56	209,300	7.07	732,550	3.99	1,046,500	7.06
1991	104,650	33.38	209,300	7.36	732,550	4.19	1,046,500	7.74
1992	104,650	34.49	209,300	7.68	732,550	4.41	1,046,500	8.07
1993	104,650	37.90	209,300	8.05	732,550	4.69	1,046,500	8.68
1994	104,650	41.65	209,300	8.47	732,550	5.24	1,046,500	9.32
1995	104,650	45.78	209,300	8.93	732,550	5.24	1,046,500	10.03
1996	104,650	50.32	209,300	9.44	732,550	5.57	1,046,500	10.82
1997	104,650	55.31	209,300	10.01	732,550	5.95	1,046,500	11.70
1998	104,650	60.81	209,300	10.59	732,550	6.35	1,046,500	12.64
1999	104,650	66.85	209,300	11.26	732,550	6.77	1,046,500	13.68
2000	104,650	73.50	209,300	12.01	732,550	7.25	1,046,500	14.83

6.3 Determine Economic Feasibility

The preliminary feasibility study was based on the results from all the previous engineering and marketing areas. Since the pricing policy and the cost of thermal energy are areas which have a particularly substantial influence on the economics of the system, they have been described separately in Sects. 5.2 and 6.1, respectively.

The Minneapolis office of Touche Ross & Co. performed the preliminary economic study and compiled the November 1980 "Preliminary Feasibility Report" and its March 23, 1981, revision. Touche Ross worked closely with the DHDC using the following study scope:

1. analysis of the economic impact of alternative construction plans, construction phasing, customer hookup plans, and district heating pricing assumptions,
2. review of business plan assumptions,
3. assistance in identifying business plan alternatives,
4. development of competitive fuel price projections,
5. development of an approach to rate setting,
6. review of customer economics performed by the DHDC management, and
7. identification of rate design issues and design of specific demand (fixed charges) and energy rates and automatic rate escalator provisions for the first 20 years of operation.

6.3.1 Summary of Major Results

The Touche Ross study resulted in a business plan which, based upon the facts available in mid-1980, minimizes projected construction costs, financing costs, and the price of thermal energy while maintaining debt service coverage requirements for an "A"-rated bond offering.

Specific study results are as follows:

1. Based on current cost and financing assumptions, DHDC needs customers under contract of about 165 MW(t) in simultaneous peak demand or load* to have an economically feasible project.
2. At a customer load of 165 MW(t), implemented over a four-year period, a debt service coverage ratio of 1.5 or greater, as required by the bond rating agency for a revenue bond, is projected in the first years when thermal energy sales peak under this load assumption. A customer load in excess of 165 MW(t) results in lower thermal energy rates by reducing the individual demand charge. For example, a load of 180 MW(t) increases the cash flow available in early years by more than a million dollars. Figure 6.1 presents the cash flow available for debt service and the debt service requirements for the 165 MW(t) market during the first ten years of assumed system operation; Fig. 6.2 shows the corresponding debt service coverage ratio over the same time period.
3. Based upon alternative fuel cost projections:
   - A. long-term customer economic benefits support district heating;
   - B. short-term customer economics will likely make customer hookup commitments difficult to obtain.

*Customer "load" is based on the total peak demand—in MW(t) or MBtu/h—for a specific market with no reduction for noncoincidence in demand.

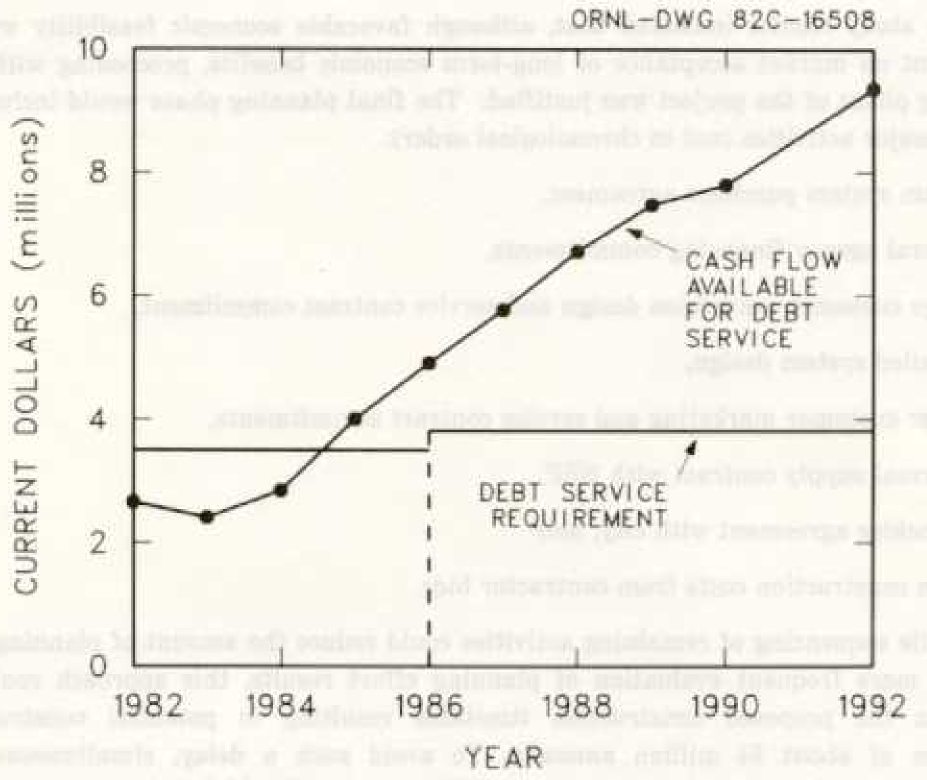

Fig. 6.1. Comparison of cash flow available for debt service and debt service requirements for a 165-MW(t) St. Paul district heating market.

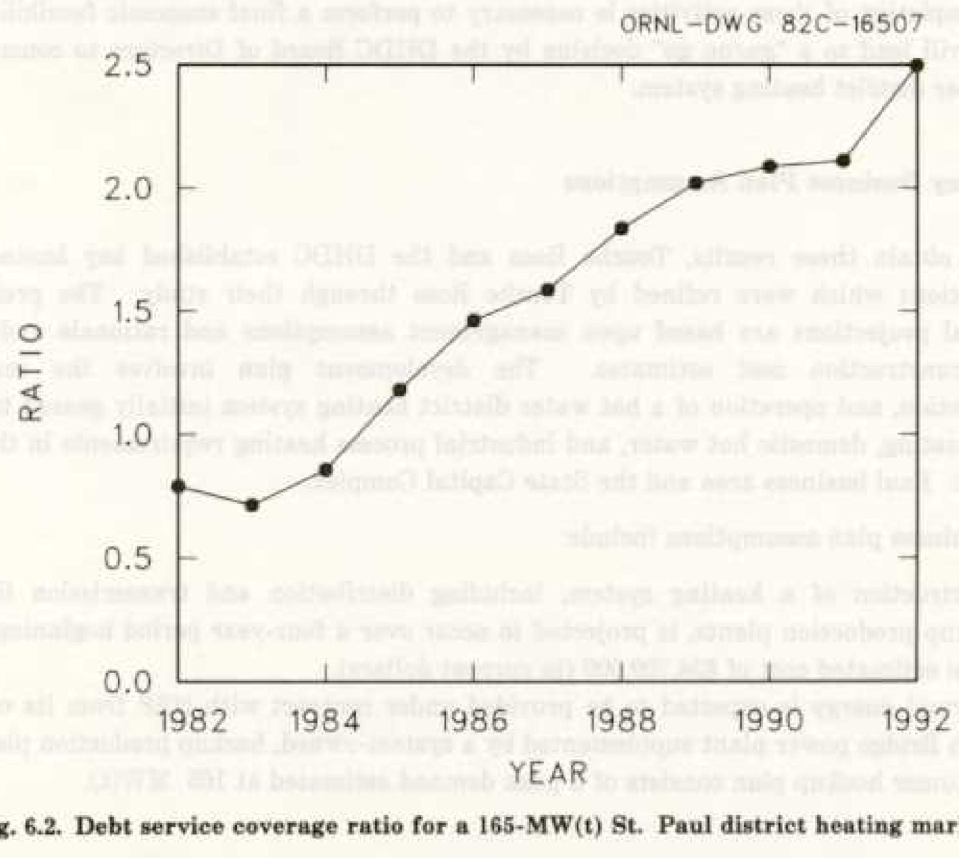

Fig. 6.2. Debt service coverage ratio for a 165-MW(t) St. Paul district heating market.

The study results indicated that, although favorable economic feasibility was heavily dependent on market acceptance of long-term economic benefits, proceeding with the final planning phase of the project was justified. The final planning phase would include the following major activities (not in chronological order):

- steam system purchase agreement,
- federal agency financing commitments,
- large customer conversion design and service contract commitment,
- detailed system design,
- other customer marketing and service contract commitments,
- thermal supply contract with NSP,
- franchise agreement with city, and
- firm construction costs from contractor bids.

While sequencing of remaining activities could reduce the amount of planning money at risk by more frequent evaluation of planning effort results, this approach could cause a delay in the proposed construction timetable resulting in potential construction cost increases of about $4 million annually. To avoid such a delay, simultaneous work on remaining activities may be appropriate. High priority should be given to large customer conversion design and service contract commitments representing approximately 60 MW(t) of customer load.

Completion of these activities is necessary to perform a final economic feasibility study which will lead to a "go/no go" decision by the DHDC Board of Directors to construct the hot water district heating system.

6.3.2 Key Business Plan Assumptions

To obtain these results, Touche Ross and the DHDC established key business plan assumptions which were refined by Touche Ross through their study. The preliminary financial projections are based upon management assumptions and rationale and preliminary construction cost estimates. The development plan involves the marketing, construction, and operation of a hot water district heating system initially geared to satisfy space heating, domestic hot water, and industrial process heating requirements in the downtown St. Paul business area and the State Capital Complex.

Key business plan assumptions include:

1. Construction of a heating system, including distribution and transmission lines and backup production plants, is projected to occur over a four-year period beginning in 1981 at an estimated cost of $34,709,000 (in current dollars).
2. Thermal energy is expected to be provided under contract with NSP from its coal-fired High Bridge power plant supplemented by a system-owned, backup production plant.
3. Customer hookup plan consists of a peak demand estimated at 165 MW(t).

4. Hot water transmission lines from the High Bridge power plant have a design capacity of 300 MW(t), which provides expansion capability. Capital investment required for expansion may be financed, in part, by cash generated by thermal energy sales. Cash generated in excess of working capital requirements is assumed to be dedicated for debt repayment, equipment replacement, and system expansion.
5. Table 6.3 presents a breakdown of the financing by how it will be used. Costs to be borne by NSP and the customers are also included. With the addition of these costs, the system will cost an estimated $77 million.
6. Customer heating system conversion costs, estimated at $23,586,000, inflation escalated, are assumed to be financed through annual sales of bonds during the construction period. This debt is expected to be an obligation of users, not the development company.
7. During the first ten years of the projection period, thermal energy rates are projected to be below full cost, which results in a cost deferral of $12,162,000 representing unrecovered depreciation and a portion of net interest cost of debt. This cost deferral is projected to be recovered during the second ten years of the projection period when full cost-based rates are projected.

Table 6.3. Financing sources and project uses
(in current dollars)

DHDC		
Sources		
Debt financing	34,600,000	
HUD/UDAG loan	7,500,000	
City loan	2,300,000	
		44,400,000
Uses		
Construction cost	34,709,000	
Debt service reserve and financing costs	4,729,000	
Working capital, construction interest and cash operating losses	4,962,000	
	44,400,000	
NSP		
High Bridge conversion		9,000,000
Building owners		
Building conversion		23,600,000
		77,000,000

6.3.3 Projected Capital Investment

The major components of the proposed hot water district heating system are

- retrofitted Third Street Plant capable of producing hot water,

- retrofitted High Bridge power plant capable of producing hot water in a cogeneration mode,
- natural gas/oil-fired boilers for backup capacity located at the St. Paul Ramsey County Medical Center and the State Capitol,
- transmission, distribution, and service piping to deliver hot water to the customers, and
- conversion of potential customers' heating systems to use hot water as a heat source.

The preliminary design of the district heating production and distribution components includes capacity for expansion beyond the assumed core system. The hot water transmission line to High Bridge has a design capacity of 300 MW(t), and, for economic planning purposes, a 165-MW(t) system load is assumed.

Table 6.4 includes estimates of construction costs of the hot water system, as provided by project management and design engineers. The costs in Table 6.4 in 1980 dollars are also restated to reflect current escalated prices for the year in which they are anticipated to occur. The applicable rate of construction cost escalation is assumed to be: 11% for 1981, 10% for 1982–84, and 8% for 1985–2000.

These rates of construction cost inflation reflect the general inflation rate over the projection period. During the first two years, however, the rates are lower than the general inflation rates to reflect that construction costs have recently escalated more slowly than the general inflation rate.

Third Street Plant. It was assumed that the DHDC will purchase the Third Street Station plant facilities and steam distribution system from NSP in early 1981. The plant will be

Table 6.4. Projected capital investment[a]

	Cost in 1980 $ (in thousands)							Total cost restated current (escalated) dollars
	1981	1982	1983	1984	1985	1986	Total	
Third Street station, hot water conversion		2,918					2,918	3,561
Transmission lines		5,045					5,045	6,155
Distribution system	823	7,260	4,789	4,329			17,201	22,596
St. Paul Ramsey conversion		740					740	903
State Capitol conversion		952					952	1,161
Service equipment	300						300	333
Total	1,123	16,915	4,789	4,329			27,156	
Total cost restated in current (escalated) dollars	1,246	20,638	6,418	6,407				34,709
Customer conversions[b]								
—In 1980 dollars		5,495	6,547	4,099	898	352	17,391	
—In current (escalated) dollars		6,704	8,773	6,067	1,437	605	23,586	
—In current dollars with financing costs		6,887	9,011	6,232	1,476	622	24,228	

[a]Totals may not agree exactly with detail due to rounding.
[b]Exclusive of building conversion cost and distribution system for State Capitol complex.

used to provide base load steam generating capacity into 1982, when parallel steam and hot water transmission lines are assumed to be completed, providing base load steam and hot water capacity from the retrofitted High Bridge power plant. It was further assumed that the Third Street Plant will be available to provide steam and hot water backup capacity for scheduled or unscheduled interruptions in High Bridge production beginning in 1983. The DHDC plans to construct the steam and hot water transmission lines, Third Street hot water conversion equipment, and hot water system pumps to be located at the High Bridge plant.

The DHDC was assumed to continue operating the steam distribution system, using steam capacity provided both by the Third Street Plant and High Bridge facilities. However, steam production was assumed to decrease from 499,000 MBtu in 1980 to 206,000 MBtu in 1987, because of assumed conversions of steam customers to hot water district heating. Revenues from the sale of steam in each year are assumed to fully offset the production and distribution costs attributable to the steam operation. Thus, the capital investments attributable to steam production are not reflected in Table 6.4, nor are the revenues or operating costs attributable to continued steam sales included in the financial projections.

Distribution System Construction. The construction scenario and related costs were based upon estimates of market penetration and preliminary cost estimates for various components provided by project management and design engineers (see Table 6.4). Transmission and distribution system construction costs were based on estimates in the *St. Paul District Heating Conceptual Design Study and Report* (Appendix C) adjusted to reflect a reduction in size of the system. Construction costs, estimated in 1980 dollars, are restated to current escalated prices for the year in which they are anticipated to occur over a three-year period as lines are constructed.

Customer Heating System Conversions. Costs for conversions of customer heating systems to hot water district heating were based upon preliminary cost estimates for 98 buildings provided by the engineering firms of Michaud, Cooley, Hallberg, Erickson, & Associates, Inc. (MCHE) and Toltz, King, Duvall, Anderson, and Associates, Inc. (TKDA). The MCHE estimates were summarized by conversion type, and extrapolations to the remaining 150 buildings were computed. Conversion cost estimates by building were increased by 6% for detail design costs; the total cost per building was escalated at the construction cost escalated rates detailed above to reflect the cost of conversion during the anticipated year of hookup (see Table 6.4).

Service Equipment. Unspecified service equipment, consisting of vehicles, tools, and test equipment (but excluding construction equipment) was assumed to be required to sustain normal operations. The initial cost of such equipment was assumed to be $300,000 in 1980 dollars and was assumed to escalate at the construction cost escalation rates detailed above. Additional service equipment and replacements were assumed to be required every five years.

6.3.4 Projected Financing Sources and Costs

Financing in the amount of $44,400,000 would be required for the project uses shown in Table 6.3. The sources of financing were assumed to be a combination of HUD/UDAG and city of St. Paul loans and borrowed funds in the amounts shown in Table 6.3. The terms and costs of three financing sources are discussed below.

HUD/UDAG Loan. $7,500,000 of funds from the U.S. Department of Housing and Urban Development, Urban Development Action Grant program were assumed to be available for system construction during 1982. Principal and interest on this loan are assumed to be payable at such time that sufficient funds are generated by project revenues. Interest, at a rate of 5%, was assumed to be accrued and added to the principal balance of the loan until 1992 when level principal and interest payments are assumed to begin. Repayment is assumed to be complete by the year 2000. The accrued interest expense is reflected together with interest expense on bonds as "Interest Expense" on the income statement in Appendix E. Cash flow statements reflect repayments of HUD principal and interest as a separate cash outflow.

City Loan. A loan of $2.3 million was assumed to be provided by the city of St. Paul to supplement the HUD/UDAG loan. The repayment of this loan would be on the same basis as the HUD/UDAG loan.

*Private Debt Financing.** Financing for working capital requirements, initial operating losses, Third Street Plant conversion, and system construction not funded by HUD or the city was assumed to be provided by a single issue of 30-year tax-exempt revenue bonds sold in 1982. The bonds were assumed to bear an interest rate of 10% per annum. The amount of this issue is sufficient to maintain a positive cumulative cash balance, given the other assumptions described herein, and to provide funds sufficient to complete construction. Underwriter fees of 2.65% of the issued amount were assumed to be paid from the proceeds and amortized over the life of the bonds. A debt service reserve equal to the highest annual principal and interest payment on the bonds was assumed to be funded from bond proceeds.

A five-year moratorium was assumed on principal repayment of this debt issue; interest only was paid from 1981-1985. Level debt service was assumed from 1986-2010. Principal and interest payments appear on the cash flow statement in Appendix E under the headings "Debt Retirements" and "Interest Paid," respectively.

6.3.5 Revenue, Thermal Sales, and Price Projections

Projected thermal revenues (Table 6.5), have been determined using projected energy sales at $6.50/MBtu in 1980 dollars escalated at the assumed general inflation rate through 1988, and on a cost basis starting in 1989, reduced by large customer hookup incentive allowances.

Quantities of thermal energy sold to customers are projected based upon estimated potential energy sales for buildings in the proposed market area that were assumed to hook up to the system. The DHDC has identified a potential load of 225 MW(t) along its planned and future distribution lines. A summary of these potential customers is shown by type in Table 6.6. Approximately 60 MW(t) of customers are unspecified potential load.

It was assumed that 83% of the identified potential customer load of 198 MW(t) on planned distribution lines would be connected to the system between 1982 and 1987 resulting in an assumed system load of 165 MW(t). Six large customers—Bethesda Hospital, St.

*Additional discussion of debt financing options considered is presented in Sect. 7.4.

Table 6.5. Projected thermal revenues, sales quantities, and prices
(in current dollars)

	Purchase requirements (MBtu)	Average system line loss	Quantity sold (MBtu)	Average price[a] ($/MBtu)	Gross revenues[b]	Large customer hookup incentive allowances	Net thermal revenues[b]
1981	0	0	0		0	0	0
1982	94,600	9%	86,025	8.15	701,000	86,000	616,000
1983	430,000	8%	394,553	8.97	3,539,000	413,000	3,126,000
1984	798,000	7%	738,943	9.87	7,294,000	783,000	6,511,000
1985	1,006,300	7%	940,491	10.66	10,026,000	923,000	9,104,000
1986	1,043,300	7%	974,858	11.51	11,220,000	692,000	10,528,000
1987	1,046,500	7%	978,242	12.43	12,159,000	461,000	11,698,000
1988	1,046,500	7%	978,242	13.42	13,127,000	231,000	12,896,000
1989	1,046,000	7%	978,242	14.49	14,176,000	0	14,176,000
1990	1,046,000	7%	978,242	14.97	14,644,000	0	14,644,000
1991	1,046,500	7%	978,242	15.78	15,441,000	0	15,441,000
1992	1,046,500	7%	978,242	17.56	17,177,000	0	17,177,000
1993	1,046,500	7%	978,242	18.11	17,718,000	0	17,718,000
1994	1,046,500	7%	978,242	18.68	18,279,000	0	18,279,000
1995	1,046,500	7%	978,242	19.36	18,937,000	0	18,937,000
1996	1,046,500	7%	978,242	20.25	19,813,000	0	19,813,000
1997	1,046,500	7%	978,242	21.19	20,730,000	0	20,730,000
1998	1,046,500	7%	978,242	22.16	21,677,000	0	21,677,000
1999	1,046,500	7%	978,242	23.24	22,737,000	0	22,737,000
2000	1,046,500	7%	978,242	24.47	23,942,000	0	23,942,000

[a]Excluding large customer hookup incentive allowances.

[b]Totals may not agree exactly with detail due to rounding.

Table 6.6. Summary of potential customer thermal loads in the St. Paul central business district

	Planned distribution lines [kW(t)]	Future distribution lines [kW(t)]	Total [kW(t)]
Identified potential load			
Government buildings and hospitals	79,761	10,855	90,616
New development, 1980-85	32,610	6,980	39,590
Other large buildings [>500 kW(t)]	80,451	7,596	88,047
Other small buildings [<500 kW(t)]	5,526	760	6,286
	198,348	26,191	224,539
Unspecified potential load			
Small buildings			20,000
Growth after 1985			40,000
			284,539

Joseph's Hospital, St. Paul Ramsey County Medical Center, United Hospital, Gillette Company, and the State Capitol complex—comprise 36% of the 165 MW(t) load; the individual demand and annual energy usage data for these customers is shown in Table 6.7.

Cash flow, income statements, and balance sheets were developed using the assumed load of 165 MW(t) and revenue, thermal sales, and price projections and are presented in Appendix E. These financial results reflect all of the above criteria and the projected financing sources—revenue bonds, HUD/UDAG loan, and a city loan.

Table 6.7. Large customer data for St. Paul central business district

	Peak demand MW(t)	Annual usage (MBtu)	Assumed original year of hookup
Bethesda Lutheran Medical Center	7.9	51,256	1982
St. Joseph's Hospital	8.2	53,297	1983
St. Paul Gillette Company	4.4	32,000	1984
St. Paul Ramsey Medical Center	13.5	87,571	1983
State Capitol Complex	14.8	85,881	1982
United Hospitals, Inc.	10.3	82,165	1983
Total	59.1	392,170	

7. IMPLEMENTATION STRATEGY

While preliminary feasibility studies were being made, system implementation and operational strategies had to be developed. Because permit requests can often be complex and time-consuming, permits for construction and operation were seen as key issues. The Minnesota Environmental Quality Board issued a key approval of the project when it declared that an Environmental Assessment Worksheet (EAW) was sufficient and an Environmental Impact Statement (EIS) would not be required for the project.

The future organizational form and subsequent expansion of the system are critical areas for system planning. Financing sources and the marketing acceptance greatly rely on who will own and operate the system and how the system will be implemented. From local experience and investigation of financing alternatives, it was decided that the company should retain its private nonprofit status when it becomes operational. The operational company has already been given a charge to expand the system and its benefits as soon as economically feasible.

7.1 Identify and Prepare Permits

Permit approvals for system construction and operation were needed before each phase of the project could proceed. The following list of necessary permits was developed:

1. EIS—or EAW stating that the EIS is not necessary,
2. operating franchise permit from the city of St. Paul,
3. National Pollutant Discharge Elimination System (NPDES) permit,
4. utility permit from the Minnesota Department of Transportation,
5. utility installation permit from the St. Paul Public Works,
6. building permits, and
7. construction approval from the State Capitol Area Architectural and Planning Board.

The EIS issue was considered the most immediate and significant of the above permits. As a result, it was agreed in the spring of 1980 that the environmental department staff of the MEA would develop an EAW (see Appendix F) to determine if an EIS would have to be developed for the five-year district heating development plan. Upon completion of the EAW in May 1980, the MEA recommended to the Minnesota Environmental Quality Board that an EIS would not be needed because of the following generalizations:

1. Soil suitability. The urban nature of the area indicates a general suitability for development. A study by the Minnesota Geological Survey and U.S. Department of Transportation concludes that the soils present, though variable, are generally easy to excavate, with the exception of some soils near the High Bridge and Third Street plants.

2. Steps to minimize soil erosion. Exposure of soils will be minimized during construction by phasing construction activities and rapidly removing excess soil. Erosion will not take place after construction since the site will be restored to preconstruction condition.

3. Groundwater appropriation. Because the project's hot water pipeline network is designed as a closed system, water appropriation demands will be low. It will essentially replace the city's aging open-ended system that presently condenses steam in each building and discharges it into the city's sewer system and thereby into the Mississippi River. Because these discharges will not occur from the proposed hot water system, implementation of the project will have a net positive effect on local groundwater supplies.

4. Water quality. Studies by ORNL indicate that the use of cogeneration at the High Bridge plant would reduce the amount of river surface area affected by excess water temperatures by a factor of ~2. By reducing the excess temperatures, district heating may have an overall beneficial effect in minimizing existing impacts from the plant's cooling water system.

5. Air quality. Indications are that the project will have an overall positive effect on local air quality because (1) emissions will come from two central sources with greater stack height rather than from numerous small pollution sources and (2) centralized sources will facilitate closer supervision of emissions and use of higher-grade pollution abatement devices.

   Using conservative assumptions and available preliminary project information, an analysis of emissions showed a 79% reduction of particulates and a 20% increase in SO_x. It should also be noted that estimated SO_x and particulate emissions for the existing systems result from the burning of fuels for heating purposes only. Most of the fuel required for the district heating proposal, however, produces both thermal and electrical energy via the cogeneration process at High Bridge. Therefore, SO_x and particulate emissions attributable to the project soley for heating purposes are substantialy lower than those estimated above.

   An update of project information relating to system configuration, fuel displacement, and generating plant allocation has resulted in a revised estimate of emissions. The particulate reduction remains at approximately 50%. The SO_x emissions are now, however, projected to be reduced by over 20% from current levels.

6. Fuel conservation. For a 200-MW(t) system with input of 1.3×10^{12} Btu per year, the district heating system will require an additional 22,400 tons of coal to be burned each year. However, it will eliminate the annual consumption of approximately 3,600,000 gal of oil and 925,000,000 ft^3 of natural gas—both of which are in more limited supply. The project will thus have a net savings of oil and gas fuels of approximately 1.0×10^{12} Btu per year.

In June 1980, the Minnesota Environmental Quality Board supported the results of the EAW and ruled that an EIS would not be required for the project because of its overall positive environmental effects.

The other permits will be requested as the project comes closer to the construction stage.

7.2 Owner/Operator Options and Federal Emission Standard Compliance for the Third Street Plant

The Third Street Steam District Heating Plant became very important to the project in the fall of 1980. Third Street's owner, NSP, was facing a December 15, 1980, deadline with the Environmental Protection Agency to bring the plant into compliance with federal standards for particulate emissions.

Several compliance methods which NSP was considering would have adversely affected the DHDC project. As a result, NSP and the DHDC began negotiations to find a solution which would be most favorable for the future growth of hot water district heating in St. Paul and bring Third Street into compliance. To achieve the compliance, it was concluded that a steam line to supply the steam district heating system would be installed between the High Bridge and Third Street plants to eliminate the use of the Third Street boilers. This method was shown to be more cost-effective than retrofitting the existing boilers to incorporate additional pollution controls.

It was agreed by NSP and the DHDC that there should be only one owner of the steam and hot water district heating systems to avoid potential conflicts of interest. As a result, NSP agreed to sell the Third Street Plant and steam distribution system to the DHDC. The DHDC could then appropriately phase out the steam system and replace it with a hot water system without any conflicts with NSP.

Upon assuming ownership of the Third Street Plant in July of 1981, the DHDC conducted a testing program on Nos. 2, 3, and 4 boilers with an improved coal and also upgraded the existing centrifugal dust collectors. As a result, compliance with Minnesota and federal particulate emission regulations was demonstrated, and the need to construct a steam line to High Bridge to serve the steam system was removed. Therefore, the DHDC has achieved two important positions: first, control of the existing steam district heating market; second, the flexibility to use the Third Street Plant with coal fuel for the beginning phase of the hot water system operation without the need for construction of a transmission line to High Bridge before the customer load justified such an expenditure.

7.3 Determine Organization of Operating Company

The major ownership decision for district heating systems is whether the organization should be a private or municipal type of ownership. The major decision factors are

1. the cost of capital associated with the organizational form,
2. the long-term goals of the city of St. Paul and the potential users of the system, and
3. potential of the organizational form to implement hot water district heating.

Potential private organizations were identified as a private investor-owned utility, a private nonprofit corporation, or a cooperative association. Potential municipal organizations were identified as a new city department or incorporation into an existing city department and establishment of a new energy authority under state legislation. The two most viable of these alternatives—private nonprofit and municipal ownership—were analyzed.

7.3.1 Private Nonprofit Corporation

Authority. The St. Paul City Charter allows for the construction and operation of a private hot water district heating utility. Such a district heating utility must obtain a city franchise which is presently limited to 20 years. A vote of the electorate or charter amendment is required for a 30-year franchise.

Financing. A private, not-for-profit, IRS 501(c)(3) organization can issue tax-exempt revenue bonds. An Internal Revenue Service (IRS) ruling may be required which applies to a hot water district heating system. There are significant legal problems with other private organizational forms being able to issue tax-exempt revenue bonds. The nonprofit status of the owner could be jeopardized, however, if the owner desired to enter into a management contract for system operation with a for-profit entity.

Operational Aspects. A small organization has the greatest flexibility in personnel, hiring, and overall management and is best suited for implementing a project which is in the development stage. Some arguments can be made for the confidence of the potential users in private organizations which are viewed to be more efficient and less susceptible to political intervention. The mandate for continued economical expansion of the St. Paul district heating utility would appear both in the franchise from the city and the articles of incorporation of the not-for-profit corporation.

7.3.2 Municipal Entity

Authority. The St. Paul City Charter, Chap. 15, allows for the city to own and operate a district heating system if the proposition to acquire or construct the system has been approved by a majority of the electorate.

Financing. St. Paul could issue tax-exempt general obligation bonds to finance the system. These bonds require "full faith and credit to the city." Issuance of revenue bonds under Minnesota Statute Chap. 452 requires approval by the electorate for the issuance of revenue bonds which are limited to 20 years.

Since the city had been prohibited by the Minnesota Legislature from increasing its bonding authority, the municipal ownership option did not appear to be viable.

Operational Aspects. The district heating system could be organized similar to or integrated with the efficient St. Paul Water Department where there is great similarity in the service to be provided.

There is significant potential for cost saving due to the possibility for sharing of information, personnel, expertise, and equipment. The significant level of federal financial input and public interest for expansion of the system would be recognized. Further, municipal utilities have a significant record of providing efficient and economical service.

7.3.3 Summary and Conclusions on the Organization of the Operating Company

The private, nonprofit organization was considered the most viable for the St. Paul hot water district heating organization. One of the main arguments against the municipal ownership was that it will be a long time—perhaps 10, 20, or 30 years—before the district heating utility would become a true "public" utility in comparison with water, sewer, and telephone services such as the promunicipals believe. With such extensive use of the underground portion of city streets, a franchise for such use is more desirable than a simple street use permit.

Preliminary contact with the market base shows that the status of the company will be enhanced by removing the possibility of another government-business relationship. The downtown business and industry users will feel much more comfortable working and cooperating with a private, nonprofit operation rather than continuing to expand government operation into providing more and more services.

Facing a multicustomer market, local competition from natural gas, and introduction of hot water technology, St. Paul has a challenge which could be a major indicator of the future of district heating in the United States. Continued efforts to remove unnecessary institutional and operational restraints can only benefit an already complex yet progressive project.

The DHDC, as an operating company, must be composed of a small force of highly competent persons, each having broad experience in a number of disciplines. They must be flexible and have the freedom to make decisions on most matters very quickly during the design, construction, and initial operational phases. The project cannot be buried with paper work requirements other than those necessary for a well-run, small, private business.

Neither can it be run by committees, boards, agencies, etc., delving into other than major questions of policy during the development years. It must be flexible, innovative, imaginative, and able to break with traditional practices, always ensuring that all customers and suppliers are treated fairly and equitably.

The selection of the right persons to serve this small company during its building years is probably the most difficult part of the management's organizational responsibilities. The future of the project, once feasibility and financing have been proven, will depend primarily on the capability of people. The flexibility afforded in employing, advancing, and dismissing people under private operation is of tremendous value, especially in the first decade of operation.

With these factors in mind, the DHDC Board of Directors, on October 2, 1980, passed the following resolution which ensures that the owner and operator of the hot water district heating system in St. Paul will be the private, nonprofit DHDC.

> RESOLVED, That the District Heating Development Corporation should undertake the detailed design, construction, and implementation of the district heating development project presently estimated to include 270 megawatts of thermal energy.
> FURTHER RESOLVED, That the District Heating Development Corporation, a Minnesota Non-Profit Corporation, shall own and operate the district heating development project.
> FURTHER RESOLVED, That the District Heating Development Corporation establishes hereby a firm, unequivocal policy authorizing and directing the appropriate officers, employees and agents of this Corporation to develop the necessary financial and management plans to ensure that the district heating system will expand beyond the Downtown and Capitol Project Areas to serve other customers within the City of St. Paul in an economically feasible manner.

7.4 Develop Financial Package

The financing of the St. Paul hot water district heating system is proposed to be via government assistance and tax-exempt bond financing.

7.4.1 Building Conversion Financing

A special feature of the financial package is the separate financing to be made available on a voluntary basis to customers for their building conversion costs. This financing is being developed with the St. Paul Port Authority which can provide the underlying security for the conversion bonds through its Common Revenue Bond Fund and Reserve, thus reducing the financing costs to the customers. The conversion bonds are expected to be for 30 years and have a Standard & Poor's "A" rating. The availability of such lower-cost conversion loans is especially important to the marketing effort because of the high interest rates prevailing during 1981 and 1982.

7.4.2 HUD/UDAG Loan

Financial support from the federal government has been approved in the form of a $7.5 million Department of Housing and Urban Development (HUD), Urban Development Action Grant (UDAG). The grant was awarded to St. Paul in March 1981; St. Paul will loan the money to DHDC at a low interest rate for use during construction.

Principal and interest on this loan are assumed to be payable at such time that sufficient funds are generated by project revenues. Interest, at a rate of 5%, is assumed to be accrued and added to the principal balance of the loan until 1992 when level principal and interest payments are assumed to begin. Repayment is assumed to be complete by the year 2000.

7.4.3 City Loan

To supplement the $7.5 million loan from the HUD/UDAG funds to the city, St. Paul approved an additional loan of $2.3 million to the DHDC since the original request for the UDAG was for $10 million. This loan would be combined with the UDAG loan and repaid with the same interest and on the same schedule as the UDAG loan. The ability of St. Paul to provide a loan for a small part of the new St. Paul district heating system financing was based on declining bonded indebtedness of the city in 1981.

7.4.4 Tax-Exempt Bond Financing

Tax-exempt bond financing options considered for the system construction and heat source retrofit costs were general obligation bonds, municipal revenue bonds, industrial development bonds (IDBs), and state general obligation bonds with loans or loan guarantees to district heating utilities. The following is a brief description of the individual features and restrictions of these financing options.

General Obligation Bonds. These bonds provide the lowest-cost financing available since they are backed by the full faith and credit of the municipality. The use of these bonds may be limited by the existing overlapping debt burden of the municipality and requirements for the municipality to own and operate the district heating system. The City Charter may require a general referendum for the city to own and operate a district heating utility.

Municipal Revenue Bonds. These bonds are secured by revenues from the system operation and require that the system be owned by an exempt entity. Exempt entities are either nonprofit corporations or quasi-municipal agencies.

The bond underwriters require several other major accomplishments before the revenue bonds are issued. DHDC is completing its marketing, piping design, and economic feasibility study. Marketing results should show that a sufficient number of customers have signed a contract for hot water district heating service. The piping design costs must also be bid before inclusion in a final economic feasibility study. The economic study must show that the system is economically feasible on the bases of marketing results and the piping bid.

Industrial Development Bonds. These bonds are limited to a $10 million project ($20 million with a HUD/UDAG loan) for a nonexempt facility. Section 103(b) of the IRS code lists the exempt facilities for which unlimited IDBs may be issued. Recently, Congress revised the list of exempt facilities to include construction of hot water district heating facilities. These bonds are primarily secured by the revenue generated by the project and may have additional security provided by the issuing agency (i.e., the St. Paul Port Authority). The debt service for the IDBs is payable solely from the revenues received by the issuing agency under its agreement with the district heating utility. The bonds are not counted as part of the debt burden of the municipality, no referendum is required for their issuance, and the municipality is not liable for the repayment of the principal and interest for the bonds. The bond rating that IDBs receive is dependent upon the security provided and the financial statements of the organization for which the bonds are issued.

The DHDC's bond council is preparing a request to the IRS for a ruling on the tax-exempt status for these bonds. Tax exemption is being sought via two paths:

1. District heating is the local furnishing of water; therefore, district heating qualifies as an exempt facility [reference: Sect. 1.103(b)(2) of the Internal Revenue Code (IRC)].

2. Since the bonds do not meet the trade or business test and the security interest test, the bonds are therefore tax exempt [reference: Sect. 1.103-7(b)(5) of the IRC]. If both of these tests are met, the bonds are classified as IDBs.

The trade or business test is satisfied if all or a major portion of the proceeds of the bonds are to be used in a trade or business carried on by a nonexempt person. A nonexempt person is anyone other than a governmental unit or an organization described in Sect. 501(c)(3) of the IRC.

The security interest test is satisfied if payment of principal or interest is secured by an interest in property used in a trade of business. The output contracts test—a special trade or business test and security interest test that may be applied to electric energy, gas, or water facilities—is satisfied if the use of a major portion of the output of those facilities has the effect of transferring to nonexempt persons the benefits of ownership and responsibility of the debt service. The output contract test is satisfied if:

> One nonexempt person pursuant to a contract to take, or take or pay for, a major portion (more than 25%) of such a facility; or two or more nonexempt persons, each of which pays annually a guaranteed minimum payment exceeding three percent of the average annual debt service with respect to the obligations in question, agree, pursuant to take, or to take or pay for, a major portion (more than 25%) of the output of such a facility.

State General Obligation Bonds with Loans and Loan Guarantees for District Heating Utilities. A number of potential and existing district heating systems in Minnesota began pursuing legislation in 1980 to enable the state to issue general obligation bonds to finance hot water district heating systems. The funds would be loaned to the district heating utility. An alternative plan being considered was for the state to provide a limited guarantee of the "early losses" of the district heating system. For the first few years of start-up of a district heating system, the revenues are not adequate to pay for the operating costs and debt service. Therefore, the initial shortage of adequate revenue is capitalized and amortized. Repayment of these losses could be guaranteed by the state up to an amount proportional to the revenue bond issue.

Special advantages of State General Obligation Bond financing are that the state has a better credit rating than any municipality in the state, which therefore lowers the financing cost. Further, the legislation can be structured so the loans are not considered part of the municipalities' overlapping debt structure.

Although a state bonding request was made during the 1980 Minnesota State legislative session, the request was not granted. However, a district heating bonding bill for up to $50 million in state bonding authority was passed by the 1981 State Legislature and signed by Minnesota Governor Quie in May 1981.

The state bonds can be used to finance up to 50% of the cost of hot water district heating systems that are either municipally owned or under control of a municipality. Therefore, for the state bonds to be available for the St. Paul system financing, the ownership structure of the DHDC would have to be changed to fit the requirements of municipal control under the state bonding law.

7.4.5 Summary of Financing Status

The general concept was to combine government-assisted financing with tax-exempt debt financing. This somewhat unusual blend of financing types and sources, which includes a significant amount of government assistance in providing bonding authority and loans, is necessary because the capital-intensive nature of initiating a sizeable, new district heating system over a relatively short (~5 years) time period precludes any self-financing.

The award of the "energy" HUD/UDAG to St. Paul in March 1981 became the foundation for the system financing which was soon followed by a pledge for a loan from the city. The project plans to acquire the balance of the required financing through the tax-exempt revenue bonds issued through the St. Paul Housing and Redevelopment Authority which must be secured by signed 30-year contracts for hot water district heating service. The fate of the revenue bond financing is therefore directly tied to the success of the DHDC contract negotiation and customer marketing program which began in July 1981.

An attempt is also being made by the DHDC's bond counsel to arrange for a "sale and lease-back" agreement with a private investor to acquire the investment tax credits allowed under the 1981 Tax Law. This strategy could reduce the amount of revenue bonds required and, hence, the size of the customer market required to be under contract. However, IRS approval for this arrangement appears doubtful as of July 1982.

The activities listed in Table 7.1 detail the numerous steps required to proceed to the sale of a revenue bond issue. The DHDC plans to make its presentation to the bond rating agency (Standard & Poor's) in November 1982 for a Bond Closing in December 1982.

Table 7.1. Financing timetable, responsibilities, and status (July 1982)

Action	Party
Selection of investment banker, economic feasibility consultant, bond counsel, and general counsel	DHDC (completed)
Organizational meeting to review district heating project description, discuss timetable, and discuss outstanding legal and financing-plan structuring questions	DHDC, bond counsel, U/W,[a] U/W counsel, consulting engineer (completed)
Apply for IRS ruling for tax-exempt status of bond	DHDC, bond counsel (completed)
General provisions of underlying contracts discussed and determined— construction and completion contract, heating supply contract, hot water purchase contract, and building conversion loan agreement	DHDC, U/W, consulting engineer, user's counsel (completed)
First drafts of underlying contracts distributed to all parties	Bond counsel (completed), user's counsel, U/W (completed)
Negotiations of hot water purchase contracts with building owners/users; begin preliminary rate estimates	DHDC (completed)
Preliminary engineering and economic feasibility studies	Consulting engineer, Touche Ross (completed)
Develop detailed engineering design specifications for the district heating system.	Consulting engineer, DHDC (completed)
Prepare construction contract bidding specifications and Request for Proposal	DHDC, bond counsel, consulting engineer (completed)
Negotiate heat supply contracts—NSP	DHDC, U/W (in progress)
Solicit system construction contractor and evaluate competing bids	Consulting engineer, DHDC (completed)
Obtain commitments for DOE grants and HUD/UDAG loans	DHDC, city of St. Paul, state of Minnesota, U/W (completed)
Incorporate comments on drafts of underlying contracts from all parties	Bond counsel, U/W counsel

Table 7.1 (continued)

Action	Party
Complete final economic and engineering feasibility study	Consulting engineers, economic consultants (in progress)
Select project construction contractor and execute construction and completion contract	DHDC
Complete negotiations with building owners/ users and execute hot water purchase contract and building conversion loan agreements	DHDC, U/W, consulting engineer, local relations counsel
Prepare and distribute initial drafts of financing documents— bond resolution, U/W documents, and preliminary official statement	Bond counsel, U/W counsel, U/W
Commence discussions with rating agencies	U/W
Discuss and develop any required performance bond and debt insurance policies	U/W
Incorporate comments on drafts of financing documents	Bond counsel, U/W counsel
Select bond issue trustee	DHDC
Initiate steps for approval of project bond issues by the issuing authority	Bond counsel, U/W counsel
Prepare rating agency presentations	DHDC, consulting engineer, U/W
Make rating presentations	DHDC, bond and U/W counsel, consulting engineers, U/W
Mail preliminary official statement and commence presale marketing efforts; form underwriting syndicate	U/W
Finalize terms of bond issues and execute bond purchase agreement	DHDC, U/W
Prepare and mail final official statements	U/W bond counsel, U/W counsel, DHDC, consulting engineers
Prepare list of closing documents	Bond counsel, U/W counsel
Bond closing	DHDC, bond counsel, U/W, U/W counsel, trustee
Investment proceeds of heating system bonds pending disbursement for construction expenditures	Trustee
Begin conversion of building owners heating systems and make conversion loans	DHDC

[a]U/W = underwriters.

8. CONCLUSIONS

Since the St. Paul project began in July 1979, substantial progress has been made toward the development of a hot water district heating system in St. Paul. Pending the completion of system marketing, final design, economic feasibility, financing, and construction, St. Paul will have developed one of the first hot water systems in a major U.S. city.

Because district heating systems are innately capital intensive, it is important that a district heating company be structured so as to qualify for low-cost system financing. Therefore, DHDC's ability as a nonprofit corporation to use tax-exempt revenue bonds for system financing, plays a critical role in the project's structure and success. Another option would be a municipal entity; however, customers are known to respond negatively to this alternative. The city also has credit constraints which might hamper issuance of general obligation bonds for system financing.

In a city like St. Paul, which has many older buildings interspersed with newer buildings, district heating can also be capital intensive for the building owner. A significant number of older buildings with internal steam systems require an expensive retrofit to be compatible with the system. Conversely, new developments are able to design for compatibility initially and connect to the system at little extra expense or, in some cases, with a capital savings. For those buildings which will incur conversion expenses, the St. Paul Port Authority will make low-cost, long-term (20- or 30-year) financing available.

Information on all buildings within the market area is stored in a central computer data base. With the information, DHDC compares the short- and long-term cost advantages of converting to district heating rather than remaining with an alternative fuel or heat source. These comparisons are an important ingredient to the marketing program.

8.1 Status as of July 1982

Of the main project tasks yet to be completed, marketing encompasses the broadest area. To make the project economically feasible, enough customers must sign up. The converse is that unless the customers know the system is economically feasible and will be less expensive than gas and oil, they will not sign up. This task's difficulty is increased by the necessary stringent stipulations set by the bond underwriters. To obtain system financing, the DHDC's underwriters require that the DHDC acquire a firm construction bid for the system and sufficient customer contracts binding for the 30-year term of the bonds and that DHDC complete an economic feasibility study which justifies proceeding with construction.

Because the customer service contract must provide security for the bonds, the most stringent stipulations are inherent in the 30-year customer contract. The customers' confidence in all other areas of the project—that is, building conversion, system ownership, thermal energy prices as compared with alternatives such as natural gas over the next 20 years—thus becomes even more critical in order to enhance the project's salability.

With a thorough preliminary conceptual piping design completed and a final piping reference design essentially completed, a firm construction bid, which is within the original estimate, has been determined. However, the optimum reference design with respect to customer take-offs cannot be determined until a sufficient number of customers sign service contracts.

Despite the difficulties involved in finalizing a district heating project, it is necessary to expedite this development because of steadily rising fuel prices. Much may be learned from the St. Paul data. Other new systems will not have to redo what has been done but instead may adapt the information to a specific situation.

The energy dependence of cities throughout the United States may play a critical role in their ability to revitalize and redevelop. District heating systems will enable cities to keep energy costs more reasonable, thus making the city more attractive for business growth. With the prevailing economic situation, such a benefit could help prevent the regression of the central core areas of some U.S. cities. Demonstration of a municipal district heating development is, therefore, important as a future energy option for cities. Although the institutional and marketing issues are time-consuming and often difficult to control or predict, the St. Paul project is successfully addressing these issues.

8.2 Final Project Status

On September 30, 1982, the DHDC passed the key milestone that will allow the project to proceed to a bond sale by December 1982. The primary ingredients of this milestone are as follows:

1. Customer contracts for 137 MW(t) of load have been signed. Additional customer negotiations in the final stage could build the contracted load to 150-165 MW(t).
2. A bid of $19,999,000 has been accepted by the Board of Directors for construction of the 280-MW(t) piping distribution system (which includes service connections of 165 MW(t) of customers but excludes the transmission line between the Third Street and High Bridge plants). The bid is in current dollars over a three-year period, 1983-1985.
3. The 30-year revenue bond issue will have a Standard and Poor's "A" or "AA" rating and a 10%/year interest rate, according to the DHDC bond counsel. In addition to the 30-year customer contracts, this bond issue will be secured by two St. Paul banks providing a "floating demand" security for the first ten years of the issue.
4. The final economic feasibility study, performed by Gilbert/Commonwealth, was accepted by the DHDC Board of Directors. The study concluded that a customer load of 135 MW(t) is required to meet the debt service requirement of the bond issue.

Thus, the three requirements of the bond underwriters have been met. With the sale of this bond issue, construction of the St. Paul hot water system will begin in the early spring of 1983.

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Appendix A

ST. PAUL BUILDINGS' DATA

PART I: DHDC BUILDING SURVEY FORM

PART II: RESULTS OF THE ST. PAUL BUILDING SURVEY OF THE CENTRAL BUSINESS DISTRICT

PART III: ST. PAUL DISTRICT HEATING DEVELOPMENT COMPANY, INC., COMPUTER ANALYSIS EXPLANATION

Appendix A, Part I

DHDC BUILDING SURVEY

Interviewer________________________________ Date________________

☐ in person

☐ by telephone

Building________________________________ No.________________

Address________________________________ Blk________________

Ph.No.________________________________

Contact____

Title____

Ph. No.________________________________

Bldg. Engr.____

Ph. No.________________________________

Building Owner/Manager________________________________

Ph. No.________________________________

Building Use____

Total floor area________________________________

No. of stories above ground________________________________

No. of stories below ground________________________________

Average floor-to-floor height________________________________

Volume____

Age of Building________________________________

Age of heating system________________________________

Notes____

____

____

RADIATION

☐ Steam pressure__________ ☐ one pipe

☐ Hot water temperature________ ☐ two pipe

☐ Other____________________________________

☐ Cast iron

☐ Steel-finned

AIR HANDLING UNITS

☐ Preheat coils

☐ Steam pressure__________

☐ Hot Water temperatures-in___ out___

☐ Other____________________________________

☐ Other coils____________________________________

☐ Steam pressure__________

☐ Hot water temperatures-in___ out___

☐ Other____________________________________

☐ Fossil fueled

Could coils in air handling units be eliminated if outside air quantities are reduced?____________________________________

____

REHEAT COILS (IN DUCTWORK)

☐ Steam pressure

☐ Hot water temperatures-in___ out___

☐ Other____________________________________

Number____________________________________

BOILER

☐ Steam pressure________

☐ Hot water temperature______

No. of boilers____________________

Capacity of each___________________ (units)_____input/output

Notes____

____

AIR CONDITIONING

☐ None Tons

☐ Window units ____X____ea

☐ Direct expansion - reciprocating compressor ________

☐ Water chiller - reciprocating compressor ________

☐ Electric centrifugal water chiller ________

☐ Steam absorption water chiller-stm press_____ ________

☐ Ht Wtr absorption water chiller-wtr temp_____ ________

☐ Other____ ________

HUMIDIFICATION

☐ None

☐ Steam

☐ Water

No. of units____

Description of equipment_____________________________________

____

Water treatment____

____

FURNACE

☐ Inside

☐ Rooftop

Number ____________________

Locations

☐ Together in ____________________

☐ Dispersed-describe ____________________

____

AIR CONDITIONING

	Tons
☐ None	
☐ Window units	___X_____
☐ Direct expansion - reciprocating compressor	_____
☐ Water chiller - reciprocating compressor	_____
☐ Electric centrifugal water chiller	_____
☐ Steam absorption water chiller-stm press ______	_____
☐ Ht wtr absorption water chiller-wtr temp ______	_____
☐ Other ____________________	_____

HUMIDIFICATION

☐ None

☐ Steam

☐ Water

No. of units ____________________

Description of equipment ____________________

____

Water treatment ____________________

____

NSP STEAM

☐ HP ☐ interruptible pressure(from street)

☐ LP ☐ interruptible pressure(from street)

Notes____

AIR CONDITIONING

☐ None Tons

☐ Window units ______X__________ea

☐ Direct expansion - reciprocating compressor __________

☐ Water chiller - reciprocating compressor __________

☐ Electric centrifugal water chiller __________

☐ Steam absorption water chiller-stm press________ __________

☐ Ht wtr absorption water chiller-wtr temp________ __________

☐ Other________________________________ __________

HUMIDIFICATION

☐ None

☐ Steam

☐ Water

No. of units______________________________________

Description of equipment__________________________

Water treatment___________________________________

DOMESTIC WATER HEATERS

Fuel	Number	
☐ Gas	______	
☐ Oil	______	
☐ Gas/Oil	______	
☐ Electric	______	
☐ Steam	______	pressure________
☐ Hot water	______	
☐ Other	______	______________________________

Comment ____

____

Locations

☐ Mech. Eq. Room

☐ Other____

If more than one:

☐ Located together

☐ Dispersed - Describe_______________________________________

____

____

Temperatures____

____

FUEL (heating and air conditioning only)

☐ Gas - firm

☐ Oil #_____

☐ Gas - interruptible

☐ Oil standby #_____

☐ Other standby ____________________________________

☐ NSP steam - HP ☐ interruptible

☐ NSP steam - LP ☐ interruptible

☐ Electric

☐ Other____

ANNUAL CONSUMPTION

	Year__________	Year__________
Gas - MCF	__________	__________
Oil - Gal	__________	__________
Steam - Mlb	__________	__________

DEMAND

Max BTU/hr____

Other____

Has an energy conservation program been implemented in the last few years?______ What percent reduction of heating and cooling energy was achieved?__________________________________

____

Is there an energy conservation program planned in the future? ______ What percent reduction of heating and cooling energy is anticipated?____

____

Is any major remodeling planned in the future?

☐ Heating system

☐ Other

Describe____

KITCHEN

☐ Dishwasher

☐ Steam booster pressure__________

☐ Electric booster

☐ Steam cookers pressure__________

☐ Steam tables pressure__________

PROCESS

Describe____

____

____

____

____

☐ Steam pressure______ Annual consumption____________

☐ Hot water Temperature____ Annual BTU/year____________

☐ Other____

SIDEWALK HEATING

Area - sq. ft.____

Annual BTU/year____

TENANTS

Building____

	A	B
Tenant 1	___	___
Tenant 2	___	___
Tenant 3	___	___
Tenant 4	___	___
Tenant 5	___	___
Tenant 6	___	___
Tenant 7	___	___
Tenant 8	___	___
Tenant 9	___	___
Tenant 10	___	___
Tenant 11	___	___
Tenant 12	___	___
Tenant 13	___	___
Tenant 14	___	___
Tenant 15	___	___
Tenant 16	___	___
Tenant 17	___	___
Tenant 18	___	___
Tenant 19	___	___
Tenant 20	___	___

A Tenant's heating system is part of main building system.

B Tenant has separate heating system not part of main building system.

List only street level tenants unless tenants on other floors have separate heating systems.

Appendix A, Part II

RESULTS OF THE ST. PAUL BUILDING SURVEY OF THE CENTRAL BUSINESS DISTRICT

GOVERNMENT BUILDINGS AND HOSPITALS

Bldg. #	Blk. #	Building Name	M C 1-2	Hgt. System Type Group#	KW	MW hrs.	Conversion Cost	Hookup Year	Existing Fuel Type	Line Location
253	000	Capitol Complex	1	10	14,802	25,163	$2,000,000*	1982	Inter.	A
252	000	Bethesda Hospital			7,904	15,018	1,400,000*	1982	Inter.	A
	86	Auditorium		5	1,311	2,200	319,000	1982	HP Steam	
220	000	United Hospitals		10	10,350	24,074	780,000*	1983	Inter.	A
225	000	St. Paul Ramsey Hospital		10	13,504	25,658	2,000,000*	1983	Inter.	A
88	78	St. Joseph's Hospital	2	10	8,219	15,616	1,257,060	1983	Inter.	A
258	86	Civic Center	2	5	7,000	7,072	450,000	1982	HP Steam	A
	91	Civic Center Parking Ramp		5	217	347	25,000	1983	Gas	B
257	84	Landmark Center	2	10	1,200	1,900	155,300	1982	LP Steam	A
116	7	Science Museum	2	1	1,451	2,466	44,850	1982	LP Steam	A
2	8	Arts & Science Center	2	1	2,400	3,240	111,381	1982	HP Steam	A
105	60	City Hall	3	5	2,480	4,217	585,000	1982	HP Steam	A
52	60	City Hall Annex		5	1,092	1,856	80,200*	1982	Inter. HP Steam	A
263	92	New Jail	2	1	500	850	110,000	1982	LP Steam	A
110	2	Public Health Center	3	10	457	778	69,700	1982	Inter.	A
106	89	St. Paul Public Library		1	600	1,021	42,000*	1982	HP Steam	A
84	89	Hill Reference Library		5	250	300	31,625	1982	HP Steam	A

*Estimated conversion cost

GOVERNMENT BUILDINGS AND HOSPITALS

Bldg. #	Blk. #	Building Name	M C 1-2-3	Hgt. System Type Group#	KW	MW hrs.	Conversion Cost	Hookup Year	Existing Fuel Type	Line Location
229	86	Senior Citizen Center		2	81	138	16,200*	1983	Oil	A
138	3	Capitol Square Office Building		5	1,000	1,600	178,800*	1983	Inter.	A
111	64	U.S. Federal Courthouse		1	1,520	2,585	98,800*	1984	HP Steam	A
157	45	Minnesota Department of Economic Security		9	670	1,139	35,500*	1984	Gas	A
115	14	Juvenile Center		1	190	305	12,530*	1984	Gas	A
113	91-9	Ramsey County Morgue		2	233	397	46,600*	1984	Gas	B
75	74	U.S. Post Office	2	5	2,780	4,580	761,420	1985	Inter.	A
112	75	Post Office Annex		3	83	141	24,900*	1985	Gas	B
108	000	Valley Apartments		1	915	1,739	66,430*	1987[o]	Inter.	B
237	000	T V I		5	2,062	3,506	165,000*	1987[o]	Inter.	B
107	000	Ravoux Hi Rise		5	693	1,317	155,000*	1987[o]	Inter.	B
103	10	Police Annex	3	5	350	500	80,200	1987[o]	Inter.	B
104	4	Public Safety	3	5	502	854	171,600	1987[o]	Inter.	B
259	000	Mt. Airy		6	5,800	11,020	2,146,000*	1987[o]	Gas	B
No. of Bldgs.:	30	Totals			90,616	161,697	$13,420,096			

*Estimated Conversion Cost
oAssumed hookup 1987 or later

NEW DEVELOPMENT

Bldg. #	Blk. #	Building Name	M C 1-2	Hgt. System Type Group #	KW	MW hrs.	Conversion Cost	Hookup Year	Existing Fuel Type	Line Location
	83	St. Paul Co. (addition)	2	10	1,850	3,150	72,000	1982	Steam	A
	7	Gallery Towers			1,670	2,840	66,000 *	1982		A
	000	Budget Inn (addition)			480	815	12,000*	1982		B
	88	St. Paul Hotel			3,000	5,100	120,000*	1981		A
	100	100 Summit (Miller)			2,580	4,390	103,000*	1982		A
	17	Haskins			1,730	2,940	43,000*	1983		A
	100	Austin-King			1,110	1,890	28,000*	1982		A
	46	Block 40			3,000	5,100	120,000*	1983		A
	86	Civic Center Hotel Complex			6,625	11,260	166,000*	1984		A
	65	Block L			3,900	6,630	98,000*	1984		A
	16	Robert Hall			125	210	3,100*	1983		A
	6	Farmer's Market			3,000	5,100	125,000*	1984		B
	36	Minnesota Mutual Life Insurance	2	1	3,200	5,440	42,000	1982	Steam	A
	34	Radisson Plaza	2	1	2,500	4,250	57,000	1982	Steam	A
	26	Town Square	2	1	3,500	5,950	195,000	1982	Heat pump	B
	000	Children's Hospital			720	1,300	18,000*	1982		A
	17	KSJN-Old building and addition			600	1,020	15,000*	1982		A
No. of Bldgs.:	14	Totals			39,590	67,385	$1,283,100			

*Estimated conversion cost

OTHER LARGE BUILDINGS

Bldg. #	Blk. #	Building Name	M C 1-2	Hgt. System Type Group#	KW	MW hrs.	Conversion Cost	Hookup Year	Existing Fuel Type	Line Location
100	83	St. Paul Companies	1	5	3,011	5,118	93,020	1982	HP Steam	A
70	61	Degree of Honor Bldg.	2	9	618	1,053	35,316	1982	HP Steam	A
210	61	Radisson Hotel		5	3,910	6,256	312,800*	1982	HP Steam	A
49	50	Lowry Square Apts.	2	?	2,191	4,163	152,800	1982	Inter. HP Steam	A from City Hall Annex
50	50	Lowry Square Medical Building	2	1	4,310	2,540	413,900	1982	HP Steam	A
51	50	Lowry Garage	2	10	173	294	16,170	1982	Inter. HP Steam	A
87	92	West Publishing	2	5	4,000	6,800	458,000	1982	Steam	A
22	35	Twin City Federal	2	1	1,043	1,774	31,980	1982	Inter.	A
199	42	Northwestern Skyway		6	952	1,619	238,000*	1982	Gas	A
154	27	Donaldson's		5	1,309	2,225	261,800*	1982	Inter.	A
96	14	Exchange (Piolette) Hi Rise	1	1	750	1,425	25,000	1982	Inter LP Steam	A
85	90	Northwestern Bell	2	3	3,615	6,147	179,000	1982	HP Steam Inter.	A
121	000	American Linen		2	617	1,050	61,700*	1983	Inter.	
53	51	Old NSP Building	2	1	632	1,075	27,722	1983	HP Steam	A
43	42	Osborn Building	2	1	3,025	7,329	216,760	1983	HP Steam	A
19	27	Woolworth's	2	5	332	566	31,910	1983	LP Steam	A
63	32	Wabasha Court	2	3	174	296	27,580	1983	LP Steam	A

*Estimated conversion cost

OTHER LARGE BUILDINGS

Bldg. #	Blk. #	Building Name	M C 1-2	Hgt. Type	System Group#	KW	MW hrs.	Conversion Cost	Hookup Year	Existing Fuel Type	Line Location
98	32	Hamm Building	1		3	2,704	4,597	151,700	1983	Inter.	A
12	15	Central Towers	2		1	2,047	3,940	92,850	1983	HP Steam	A
24	35	Bremer Tower	2		2	320	550	57,200	1983	LP Steam	A
23	35	Bremer Building	2		2	1,000	1,440	269,300	1983	LP Steam	A
54	51	Minnesota Mutual Life Ins.	2		1	863	1,468	25,400	1983	HP Steam	A
55	52	Minnesota Federal Bank	2		1	348	592	26,500	1983	LP Steam	A
101	33	Dayton's	1		5	2,300	2,900	104,000	1983	Inter.	A
254	59	Gillette Company	3		10	4,400	8,800	740,000	1984	HP Steam	A
97	54	Empire Building	1		5	755	1,284	48,000	1983	Inter.	A
99	62	YWCA	1		10	1,183	2,011	92,455	1983	HP Steam	A
98	32	Hamm Building	1		3	2,704	4,597	151,700	1983	Inter.	A
65	55	Burlington Northern	2		5	3,370	3,840	569,217	1984	HP Steam Inter.	A
72	67	Monarch Studios	2		2	300	500	43,400	1984	LP Steam	A
25	37	Mears Park Place	2		1	1,700	3,230	58,280	1984	HP Steam	A
181	63	Kellogg Square	3		10	5,000	9,500	330,000	1984	Inter.	A
46	45	Farm Credit Bank	2		3	1,859	3,160	51,311	1984	HP Steam	A
164	24	Gambles State Bank	3		5	800	1,400	183,600	1984	Inter.	A
81	86	Minnesota Club	2		7	1,000	1,600	165,000	1984	HP Steam	A
231	15	Schubert Apt.	3		4	617	1,049	133,520	1984	Gas	A

*Estimated conversion cost

OTHER LARGE BUILDINGS

Bldg. #	Blk. #	Building Name	M C 1-2	Hgt. Type	System Group#	KW	MW hrs.	Conversion Cost	Hookup Year	Existing Fuel Type	Line Location
74	73	American Center Bldg.	2		1	523	890	33,800	1985	Gas heat pump	A
44	44	American National	2		1	1,307	2,223	131,404	1985	Gas	A
67	38	Park Square Court	2		1	572	970	50,500	1985	LP Steam	B
20	28	Metro Square	2		2	2,500	4,100	363,900	1985	Inter.	A
214	11	Rossmor Building	3		2	2,346	3,989	218,050	1985	Inter.	A
167	10	Goodyear Tire	3		6	765	1,301	40,400	1985	Gas	B
71	62	Minnesota Building	2		9	733	1,248	27,699	1985	Inter.	A
227	000	Sears			1	967	1,644	62,855*	1987[o]	Inter.	B
59	53	First National Bank	2		1	3,486	6,081	504,200	1987[o]	LP Steam	A
68	61	Commerce Building	2		5	1,010	1,200	211,000	1987[o]	HP Steam	A
5	9	Capp Towers	2		5	664	1,062	211,200	1987[o]	Inter.	A
174	000	Holiday Inn			9	908	1,462	51,240*	1987[o]	Gas	B
244	30	Union Gospel Mission			5	908	1,545	272,400*	1987[o]	Inter.	B
56	52	St. Paul Athletic Club	2		5	3,100	4,213	637,100	1987[o]	HP Steam	A
	42	Northern Federal Building			7	1,706	2,900	40,400*	1987[o]	Electric	B
	000	Allied Printing Trades Council			1	900	1,530	45,000*	1987[o]	Unknown	B
66	57	North Central Life Insurance	2		2	870	1,475	363,100	1987[o]	LP Steam	B
60	54	Pioneer Endicott Building	2		2	2,554	4,312	519,500	1987[o]	Inter.	B
57	52	St. Paul Dispatch	2		7	1,000	1,719	288,600	Demolished	Inter.	
No. of Bldgs.	55	Totals				90,751	150,052	$9,949,239			

*Estimated conversion cost
[o]Buildings hooked up 1987 and later

SMALL BUILDINGS < 500KW

1

Bldg. #	Blk. #	Building Name	M C 1-2	Mgt. System Type Group#	KW	MW hrs.	Conversion Cost	Hookup Year	Existing Fuel Type	Line Location
16	24	G & M Lunch Bar	2	2	227	386	25,800	1982	LP Steam	A
41	41	Garrik Ramp	2	9	200	420	12,800	1982	LP Steam	A
123	82	The Attic		9	75	128	4,125*	1982	Oil	A
1	1	555 Wabasha Bldg.	2	3	200	267	16,700	1982	Gas	A
80	85	Commercial State Bk.	2	5	203	345	37,900	1983	LP Steam	A
38	41	Snyder Drug	2	5	83	140	13,500	1983	LP Steam	B
28	57	Fourth Street East Building	2	3	410	700	25,700	1983	Steam	A
42	51	Victory Ramp	2	8	202	481	45,000	1983	HP Steam	A
4	9	Hanover Building	2	1	407	692	18,500	1983	LP Steam	A
191	5	Mike's Downtown Standard		6	21	36	7,770*	1983	Oil	B
30	38	Custom Display	2	5	269	457	45,000	1984	Oil	A
135	46	Butwinick's Outlet		4	55	95	27,500*	1984	Oil	A
130	39	B & M Furniture		2	40	69	10,730*	1984	Gas	B
153	76	Dier's KO Station	2	6	33	57	12,210	1984	Oil	B
27	38	Wood's Chocolate Shop	2	2	130	220	18,600	1984	LP Steam	B
29	38	Railroader Printing	2	2	250	423	43,400	1984	LP Steam	B
117	5	Alcoholics Anonymous		3	149	268	7,450*	1985	Gas	B

*Estimated conversion cost

SMALL BUILDINGS < 500KW

Bldg. #	Blk. #	Building Name	M C 1-2	Hgt. System Type Group#	KW	MW hrs.	Conversion Cost	Hookup Year	Existing Fuel Type	Line Location
45	44	American National Bank Annex	2	7	350	540	75,759	1985	LP Steam Gas	A B
206	10	Pedro's Luggage		1	54	93	3,780*	1987°	LP Steam	A
7 & 8	12	Bird & Cronin	2	6	85	135	19,200	1987°	Gas	A
26	37	AAA-37	2	1	139	240	77,600	1987°	LP/Steam	
No. of Bldgs.:	21	Totals			1,582	6,084	$549,024			

*Estimated conversion cost

°Buildings hooked up 1987 and later

Appendix A, Part III

ST. PAUL DISTRICT HEATING DEVELOPMENT COMPANY, INC., COMPUTER ANALYSIS EXPLANATION

Attached is a sample output from the computer program with explanation of how the various numbers are derived. The numbers which are circled on the output come from the building data base and are unique for each building. Numbers with squares around them come from the utility data base. All are entered at the time of the run and are the same for all buildings in a run.

All numbers which do not have a circle or square around them are computed by the program. The attached sheet shows how each number is computed. The number before each formula corresponds to the hand written number beside each printed number on the output.

Also attached is a section of the utility data base showing the energy prices which are used. The specific numbers used in the formulas attached are circled with the number of the formula indicated.

EXPLANATION OF COMPUTED NUMBERS*

(1) $$\frac{\text{1980\$}}{621{,}545} \times \frac{\text{Escal. factor}}{1.25} = \frac{\text{1982\$}}{776{,}931}$$

(2) $$\frac{\text{1982\$}}{776{,}931} \times \frac{\text{Amort. factor}}{.117460} = \frac{\text{Annual pmt.}}{91{,}258}$$

(3) $$\frac{\text{1982\$ \quad Years}}{776{,}931\ /15} = \frac{\text{\$/yr. depreciation}}{51{,}795}$$

(4) $$\frac{\text{MMBtu}}{9{,}000}\ \frac{\text{Conv.factor}}{/\ 3.413}\ \frac{\text{Utilities}}{/\ 1700}\ \frac{\text{Conv.factor}}{\times\ 1000} = \frac{\text{KW}}{1551.16}$$

(5) $$\frac{\text{DH MMBtu}}{(9000}\ \frac{\text{DH Energy Rate}}{\times\ 5.01)} + \frac{\text{KW}}{(1551.16}\ \frac{\text{DH Demand Rate}}{\times\ 23.67)} = \frac{\text{DH Cost}}{81806}$$

$$\frac{\text{DH Cost}}{81806}\ /\ \frac{\text{MMBtu}}{9000} = \frac{\text{Avg.\$/MMBtu}}{9.09}$$

(6) $$\frac{\text{Current MMBtu}}{15000} \times \frac{\text{Fuel Rate}}{10.94} \times \frac{\text{Franchise Fee}}{1.087} = \frac{\text{Current fuel cost}}{178377}$$

(7) $$\frac{\text{DH Cost}}{81806} \times \frac{\text{Franchise fee}}{1.087} = \frac{\text{DH cost incl. fee}}{88923}$$

(8) $$\frac{\text{Annual amort.}}{91258} - \frac{\text{Int. rate}}{(.10\ \times}\ \frac{\text{Unpaid Conv. balance}}{(776931\ -\ 13565\ )} = \frac{\text{Principal amt.for year}}{14921}$$

(9) $$\frac{\text{Int. rate}}{.10} \times \frac{\text{Unpaid conv. balance}}{(776931 - 13565)} = \frac{\text{Int. amt. for year}}{76337}$$

(10) $$\frac{\text{DH Cost}}{88923} + \frac{\text{Principal amt.}}{14921} + \frac{\text{Int. amt.}}{76337} = \frac{\text{Total DH Cost}}{180181}$$

(11) $$\left(\frac{\text{DH Cost}}{88923} + \frac{\text{Int. amt.}}{76337} + \frac{\text{Depreciation}}{51795}\right) \cdot \frac{\text{Tax rate}}{0}\Big) -$$

$$\left(\frac{\text{Current fuel cost}}{(178377} \cdot \frac{\text{Tax rate}}{0}\right) = \frac{\text{Tax effect}}{0}$$

(12) $$\frac{\text{Current fuel cost}}{178377} - \frac{\text{Total DH Cost}}{180181} + \frac{\text{Tax effect}}{0} = \frac{\text{DH savings for year}}{-1804}$$

(13) $$\frac{\text{DH savings to date}}{(-8745)} + \frac{\text{Current year savings}}{(-1804)} = \frac{\text{Cumulative savings to date}}{-\ 10549}$$

*Note: Throughout this section, "MM" should be read as "10^6."

1 105 60 33 May 7, 1981

ST. PAUL DISTRICT HEATING DEVELOPMENT COMPANY

SAMPLE

CUSTOMER INFORMATION FOR CITY HALL

YEAR OF HOOKUP: 1982
TOTAL CONVERSION COSTS(1980 DOLLARS): $ 621545 (INCLUDES 12% DESIGN FEE)
TOTAL CONVERSION COSTS(1982 DOLLARS): $ 776931. (1)
LEVEL AMORTIZATION PAYMENT: $ 91258 (2) OVER 20 YEARS AT 10% PER ANNUM
TAX RATE: 0%
STRAIGHT LINE DEPRECIATION: 15 YEARS AT 51795 (3) $/YR
TAX CREDIT IN FIRST YEAR: 0 %
ENERGY COSTS INCLUDE: 8.7% FRANCHISE FEE EXCEPT OIL
PEAK LOAD: 1551 (4) KW
ESTIMATED UTILIZATION HOURS: 1700
ENERGY SAVING FROM CONVERSION: 40%

	FUEL USE PRIMARY	BACKUP	TOTAL
	NSP STEAM	NONE	
ANNUAL HEATING CONSUMPTION(MILLION BTU)	15000.	0	15000.
ESTIMATED DH CONSUMPTION(MILLION BTU)			9000.

YEAR	CURRENT FUEL RATE $/MMBTU	DH FUEL RATE $/MMBTU	CURRENT ENERGY COSTS	DISTRICT HEATING ENERGY COSTS	DISTRICT HEATING CONVERSION AMORTIZATION PRINC	DISTRICT HEATING CONVERSION AMORTIZATION INTER	DISTRICT HEATING TOTAL COSTS	TAX EFFECTS ($)	DISTRICT HEATING SAVINGS ($)	CUMULATIVE SAVINGS ($)
1982	9.95	8.15	162235	79722	13565	77693	170980	0	-8745	-8745
1983	10.94	9.09 (5)	178377 (6)	88923 (7)	14921 (8)	76337 (9)	180181 (10)	0 (11)	-1804 (12)	-10549 (13)
1984	12.04	10.34	196312	101137	16414	74844	192395	0	3917	-6632
1985	13.00	10.73	211965	104934	18055	73203	196192	0	15773	9141
1986	14.04	11.54	228922	112904	19860	71398	204162	0	24761	33901
1987	15.17	12.56	247347	122629	21846	69412	214037	0	33260	67161
1988	16.38	13.58	267076	132834	24031	67227	223922	0	43154	110315
1989	17.69	14.41	288435	140986	26434	64824	232247	0	58189	168504
1990	19.10	15.14	311426	148158	29078	62180	239414	0	72011	240515
1991	20.63	16.13	336372	157756	31985	59273	249014	0	87358	327873
1992	22.28	16.73	363275	163915	35184	56074	255177	0	108099	435972
1993	24.07	17.84	392461	174550	38702	52556	265808	0	126653	562625
1994	25.99	18.55	423787	181496	42573	48685	272754	0	151013	713637
1995	28.07	19.34	457681	189225	46830	44428	280483	0	177198	890836
1996	30.32	20.22	494368	197834	51513	39745	289092	0	205276	1094112
1997	32.74	21.20	533828	207421	56664	34594	298679	0	235146	1329258
1998	35.36	22.25	576545	217683	62330	28928	308951	0	267593	1596851
1999	38.19	23.39	622688	228846	68564	22885	320104	0	302584	1899435
2000	41.24	24.67	672418	241368	75420	15836	332626	0	339792	2239227

○ = in building database
□ = in utility database or entered for each run

THE FOLLOWING NUMBERS ARE THE FUEL PRICES AND COST FACTORS USED BY THE PROGRAM. FOR EACH ITEM, THERE ARE TWO LINES OF DATA: 1981-90 AND 1991-2000. THE ORDER IS:

1. FIRM NSP STEAM
2. INTERRUPTIBLE NSP STEAM
3. FIRM NATURAL GAS
4. INTERRUPTIBLE NATURAL GAS
5. ELECTRICITY
6. #2 OIL
7. #6 OIL
8. HOT WATER DISTRICT HEATING (AVERAGE)
9. BUILDING ESCALATION RATES
10. DISTRICT HEATING DEMAND RATES
11. DISTRICT HEATING ENERGY RATES

8.86	9.95	10.94	12.04	13.00	14.04	15.17	16.38	17.69	19.10
20.63	22.28	24.07	25.99	28.07	30.32	32.74	35.36	38.19	41.24
5.89	6.37	7.01	7,71	8.33	8.99	9.71	10.49	11.33	12.24
13.21	14.27	15.41	16.65	17.98	19.42	20.97	22:65	24.46	26.42
4.06	4.89	5.71	6.52	8.44	10.32	11.51	13.22	15.74	17.50
19.55	22.14	25.07	28.61	32.14	35.93	40.09	44.55	49.35	55.06
4.06	4.89	5.71	6.52	8.44	10.32	11.51	13.22	15.74	17.50
19.55	22.14	25.07	28.61	32.14	35.93	40.09	44.55	49.35	55.06
8.63	9.20	9.58	10.15	10.82	11.78	12.73	13.37	14.83	16.00
17.28	19.38	20.15	21.70	23.53	25.40	27.43	29.63	31.98	34.55
8.95	10.76	12.37	14.06	15.82	17.17	19.01	21.02	23.29	25.70
28.64	32.33	36.45	41.10	45.70	50.56	55.81	61.51	67.53	74.80
5.35	6.80	7.70	8.84	9.93	10.89	12.20	13.69	15.27	16.93
18.99	21.69	24.65	28.34	31.76	35.27	39.16	43.33	47.66	52.97
7.28	8.15	8.97	9.87	10.66	11.51	12.43	13.42	14.26	14.74
13.94	15.86	17.83	18.51	19.20	19.92	21.01	22.05	23.14	24.39
1.12	1.25	1.38	1.52	1.64	1.77	1.91	2.06	2.23	2.41
2.60	2.81	3.03	3.28	3.54	3.82	4.13	4.46	4.81	5.20
20.00	21.52	23.67	26.04	28.64	31.51	35.54	38.82	41.03	42.38
43.76	45.23	47.59	47.59	47.59	47.59	47.59	47.59	47.59	47.59
4.00	4.44	5.01	5.85	5.75	6.11	6.43	6.87	7.34	7.84
8.58	9.96	9.64	10.35	11.14	12.02	13.00	14.05	15.19	16.47

Appendix B

PROPOSED CONVERSION
TO
DISTRICT HOT WATER HEATING

Ramsey County Courthouse/St. Paul City Hall
St. Paul, Minnesota

by

Henningson, Durham, and Richardson
Minneapolis, Minnesota
May 1981

ON MICROFICHE — SEE INSIDE BACK COVER

Appendix C

ST. PAUL DISTRICT HEATING SYSTEM CONCEPTUAL DESIGN STUDY AND REPORT

ORNL/TM-6830/P10/VII

January 1982

ON MICROFICHE — SEE INSIDE BACK COVER

COPIES ALSO AVAILABLE FROM

National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161

Appendix D

NORTHERN STATES POWER COMPANY'S BASIS FOR COST ALLOCATION

PART I: PRELIMINARY DRAFT OUTLINE OF APPLICATION FOR DETERMINATION OF DISTRICT HEAT REVENUE CREDIT

PART II: COST OF THERMAL ENERGY METHODOLOGIES

Appendix D, Part I

PRELIMINARY DRAFT OUTLINE OF APPLICATION FOR DETERMINATION OF DISTRICT HEAT REVENUE CREDIT

I. Statement of Need for PSC Determination

II. Overview of Proposal

III. Description of Proposed St. Paul District Heating System

- A. Type and Conditions of Service
- B. Service Area and Schedule of Development
- C. Operating Organization and Legal Responsibility

IV. Description of High Bridge Generating Plant

- A. Physical
- B. Present and Projected Electric Operation
- C. Proposed Modification to Provide Thermal Energy

V. Discussion of Impact on NSP Electric System from Supplying Thermal Energy to the D.H.D.C. from the High Bridge Generating Plant

- A. When Equipment is Scheduled for Electric Service
- B. When Equipment not Scheduled for Electric Service

VI. Basic Philosophy on Determining Incremental Cost to Serve Thermal Requirements. Cost Determined on Projected Increment Cost Plus Adder

VII. Calculation of Incremental Cost of Thermal Energy

- A. Incremental Fuel Costs
- B. Incremental Maintenance Costs
- C. Incremental Operating Costs
- D. Incremental Auxiliary Cost
- E. No Load Maintenance, Operating and Auxiliary Cost
- F. Added Fuel Costs for Flame Stability
- G. Credit for Reduced Cold Starts on Boilers
- H. 15 Percent A&G Adder
- I. Replacement Energy Costs
- J. Annual Revenue Requirements for Capital Investment for Plant Modifications
- K. Cost of Electric System Derate for Firm Thermal Energy
- L. Estimated Aggregate Cost of Thermal Energy
    1. Firm Basis
    2. Interruptible Basis
    3. Oil Interruptible Basis

VIII. Recognition of Increment Cost to Serve Thermal Through Revenue Credit for Ratemaking Purposes

Appendix D, Part II

COST OF THERMAL ENERGY METHODOLOGIES

Methodology for Determining Cost of St. Paul District Heating Steam from #9 & #10 Boiler - High Bridge

District heating steam costs are determined on the basis of the difference in costs of providing steam to both the heating system and the electrical system compared to the cost of providing steam to the electrical system only. The cost difference is heating steam cost.

To establish a basis of comparison, an electrical system operating profile of #9 and #10 boiler and associated turbines #3 and #4 was prepared for the years 1982-1987. The profile included hours on line, hours banked, number of cold starts, MW hours output and load duration curve on an hourly basis. Both historical data and System Planning Department projection of capacity factors were used in developing the profile.

The cost of district heating steam for hours the boilers would normally be in service for the electrical system include:

1. Incremental Fuel Costs

   Fuel costs for steam delivered from the boiler including boiler efficiency. Estimated from fuel procurement data.

2. Incremental Maintenance Costs

   Maintenance expenses for labor and materials on #9 and #10 boiler. Calculated from plant data.

3. Incremental Operating Costs

   Operating expenses for labor and supplies associated with #9 and #10. Calculated from plant data.

The cost of district hating steam for the hours the boilers are not in service for the electrical system include:

1. Incremental Costs

   As determined above.

2. No-load Maintenance Operating and Auxiliaries Cost

   Costs associated with boilers #9 and #10 to keep boilers in cold stand-by condition.

   The cost per hour for no-load boiler operation was obtained from plant records. No load hours were determined by assuming 2 boilers would be available 90% of the time and one boiler would be available 100% of the time. (Note: if simultaneous outages occur on both boilers, no steam will be available). No load hours chargeable to district heating were computed by hours in a month x 2 boilers x 90% availability less (the hours on line for electrical generation plus the banked hours for electrical generation).

3. Added Fuel Costs for Flame Stability

   Additional costs when using oil or gas torches to maintain stable coal burner flame at light loads on boilers #9 and #10.

   In order to minimize the amount of oil or natural gas for torches when the boilers on a light load (roughly below 30% of boiler capacity) coal burners are operated with torches for flame stability.

   This added fuel cost was determined for no electrical load operating hours of the boilers as in no load, maintenance, operating and auxiliary hours.

   By examining plant records it was determined that oil is used for torches for 6 months (October to April) and natural gas for 6 months (May to September).

4. Credit for Reduced Cold Starts on Boilers #9 and #10.

   Cost credit to heating system for the reduction in cold boiler starts when boiler(s) are needed for electrical service and are on line supplying steam to the heating system.

   The reduction of cold boilers starts is due to one boiler being on line constantly for district heating and as available for electrical generation. An examination of 1979 operating log sheets indicate 50 less cold starts annually and cost per start-up taken from plant data.

   An additional cost which occurs during hours boilers are or are not in electrical service is "Administrative and General Expenses Including Undetermined Expenses."

Other Costs:

1. Replacement Energy Costs

   Whenever the district heating load on boilers #9 and #10 limits the electrical capability of #3 and #4 turbine needed to supply the normal (without heating load) system electrical requirements, the electrical requirements must be supplied by other less efficient units within the electrical system. The cost of the replaced energy is chargeable to district heating steam.

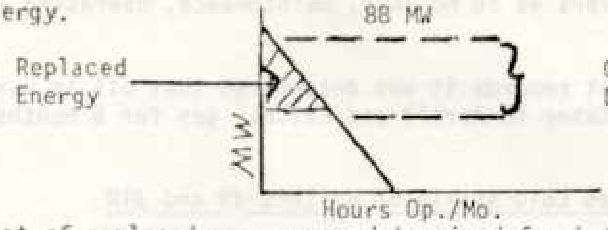
   The MWe hours of replacement energy was determined as the boiler steam to the heating system limits the electrical capacity of the turbines and the energy normally generated on #3 and turbine must be generated on other units. The procedure used is as follows:

   Capacity reduction was determined by determining the MWe equivalent to the MWt monthly peak of the heating system. The MWe equivalent above was reduced by the ratio of:

$$\frac{\text{MWt monthly heating system peak - MWt monthly heating system peak at time of electrical system peak}}{\text{MWt monthly heating system peak}}$$

A load duration curve was plotted for #3 and 4 turbine based on historical data. The annual capacity factor on the historical data was 20.1% and compares to a projected capacity factor of 20.5% predicted by system planning for the years 1982 to 1987.

The district heating load duration curve was developed from the St. Paul and Minneapolis district heating system load profile. The MW hours of replaced energy was determined by reducing the capability of turbines 3 & 4 (88 MWe) by the MWe equivalent of the capacity reduction for heating steam. The MWHe above the reduced capacity as shown on the load duration curve is replaced energy.



Cost of replaced energy was determined for both coal and/or oil or coal only. This cost is the difference between what it would cost to generate the electricity on #3 or #4 turbine as compared to other coal or oil units in the electrical system. With the above information, the replacement cost of energy per month for years 1982-1987 was determined for both coal and/or oil and oil interruptible.

2. Annual Revenue Requirements for Capital Investment

   It will be necessary to install piping, controls, heat exchangers, etc., to make available #9 and #10 boiler steam to the district hot water heating system. The annual revenue requirements to support the capital investment is chargeable to district heating system.

3. Cost of Electrical Systems Derate for Firm Steam

   When firm steam is required for district heating, the cost of replacing the electrical capacity lost to the electrical system is chargeable to district heating.

   The derate is the MWe equivalent for the heating system MWt peak. The MWe equivalent was replaced by the estimated cost per MW for a new coal fired plant in the 800MW capacity range.

In order to supply firm steam to the District Heating System the electrical capacity of the turbines supplied with steam from #9 and #10 will be reduced. The reduction of capacity (derate) is determined as follows:

$$\frac{\text{MWe equivalent of MWt (summer peak)+MWe equivalent of MWt (winter peak)}}{2}$$

Summer peak is defined as May through October. Winter peak is defined as November through April. This could change if NSP becomes winter peaking.

The cost of the electrical derate is the MWe derate determined x the cost per MW of a new coal fired plant in the 800 MW capacity range. It was determined that interruptible steam with DHDC providing peaking was the economic choice.

Methodology for Determining Cogenerated Cost of St. Paul District Heating Steam from #6 Turbine - High Bridge

District heating steam costs are determined on the cost of providing cogenerated heating steam and electrical energy as compared to the cost of providing non-cogenerated electrical energy. The cost difference when like amounts of electrical energy are produced in the electrical system is heating steam cost.

To establish a basis of comparison, an electrical system operating profile #6 Unit (#12 boiler and #6 turbine) was prepared for the years 1981-1987. The profile included hours on line, hours banked, number of cold starts, MW hours output, boiler efficiency, turbine heat rate curve, and hourly load duration curve. Both 1979 historical plant data and and System Planning Department projection of capacity factors were used in developing the profile. Similarily, the DHDC provided a projection of hourly demands and monthly consumption of district heating steam for the years 1982-1987.

Two separate costs of cogenerated steam were determined: the steam costs when #6 Unit is required for the electrical system and when #6 Unit would not be required for the electrical system.

The cost of cogenerated district heating steam during the hours the unit would normally be in service for the electrical system include:

1. Cost of Cogenerated Steam

   Cost of cogenerated steam = cost of cogenerated electrical energy ($) including excess energy plus the cost of cogenerated heating steam ($) minus the cost of non-cogenerated electrical energy ($) (without excess energy) - Cost of excess energy ($). Excess energy occurs when the electrical energy demand for the electrical system is not adequate to cogenerate the steam heating demand, and it is necessary to operate the unit with additional electrical load (excess energy) to supply the heating demand. Calculations were made from the following information, data, and assumptions:

   a. Incremental cost of boiler steam to the turbine was determined from incremental fuel cost, operating cost, maintenance cost, auxiliaries cost, and boiler efficiency.

   b. The turbine heat rate (non-cogenerating) was taken from manufacturers' data.

   c. The relationship between available cogenerated steam and electrical load while maintaining necessary minimum steam flow to the low pressure section of the turbine (for cooling purposes) was determined from manufacturers' data and data from United Engineers #6 Cogeneration Retrofit Study. The relationship is plotted on Exhibit 1.

d. The relationship of turbine heat and cogenerated electrical and heating steam energy was determined from the same sources as in (c) above and is plotted on Exhibit 2.

e. The relationship between the cogenerated electrical energy requirements from #6 for the electrical system and the steam heating requirements was determined as follows (a sample load curve is attached as Exhibit 3):

(1) An hourly electrical load curve for a typical work day, Saturday, and Sunday was prepared for #6 unit based on 1979 plant data and projected operation for each month for years 1982 to 1987.

(2) An hourly cogenerated steam heat load curve for a typical weekday, Saturday, and Sunday was prepared for cogenerated district heat based on DHDC data for each month for years 1982 to 1987..

(3) (1) and (2) above were compared to each other to determine the number of hours each month of the co-generated electric and steam loads.

(4) Cost calculations were made for each combination of cogenerated electrical and steam load.

(5) The cost of heating steam for each month was determined by the weighted average of hourly costs and hours of operation at each cost.

(6) The annual steam heating cost was determined by the weighted average of monthly costs and monthly steam heating load.

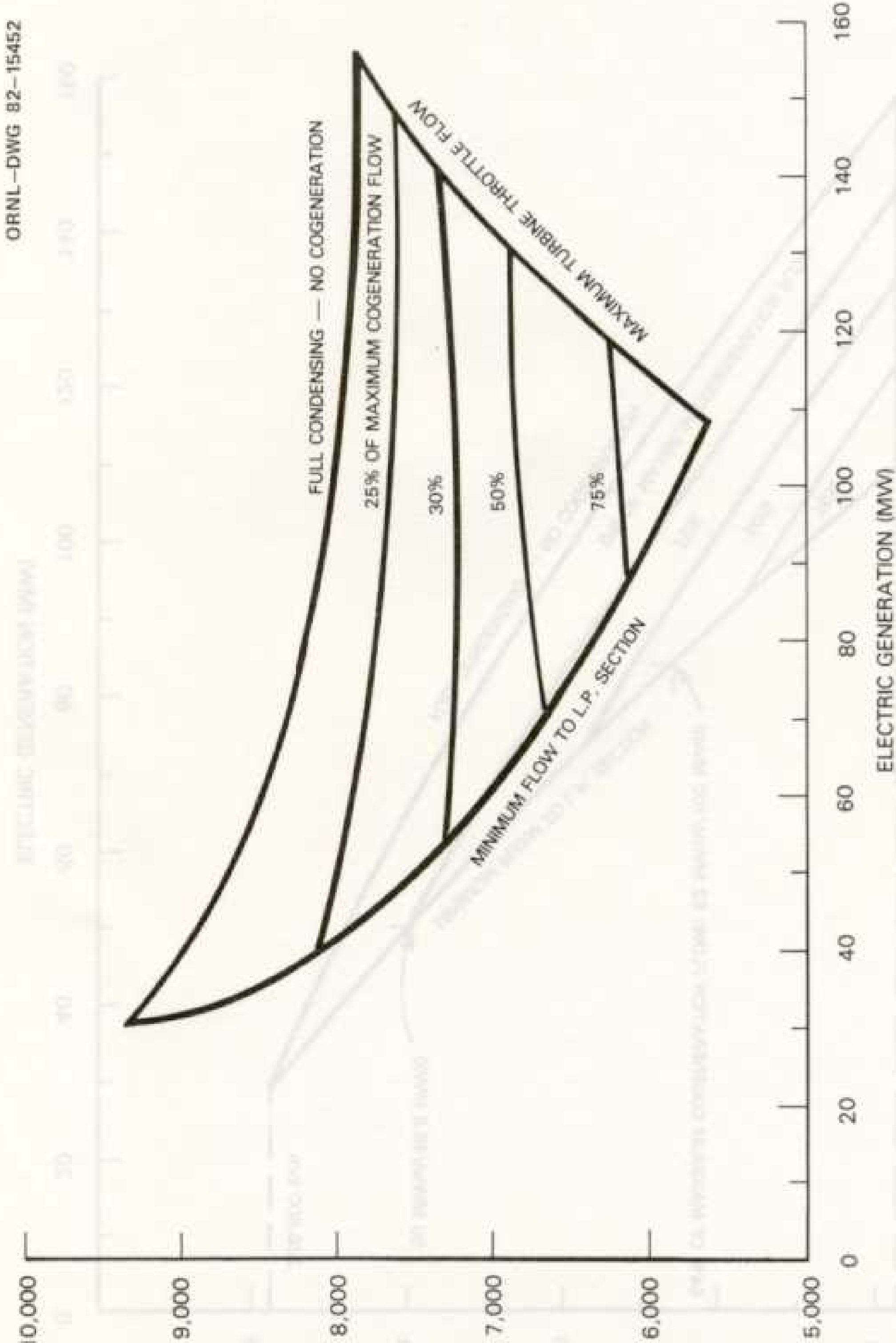

ORNL–DWG 82–15452
FULL CONDENSING — NO COGENERATION
25% OF MAXIMUM COGENERATION FLOW
30%
50%
75%
MAXIMUM TURBINE THROTTLE FLOW
MINIMUM FLOW TO L.P. SECTION
HEAT RATE (Btu/kWh)
10,000
9,000
8,000
7,000
6,000
5,000
0
20
40
60
80
100
120
140
160
ELECTRIC GENERATION (MW)

EXHIBIT 1

ORNL–DWG 82–15450

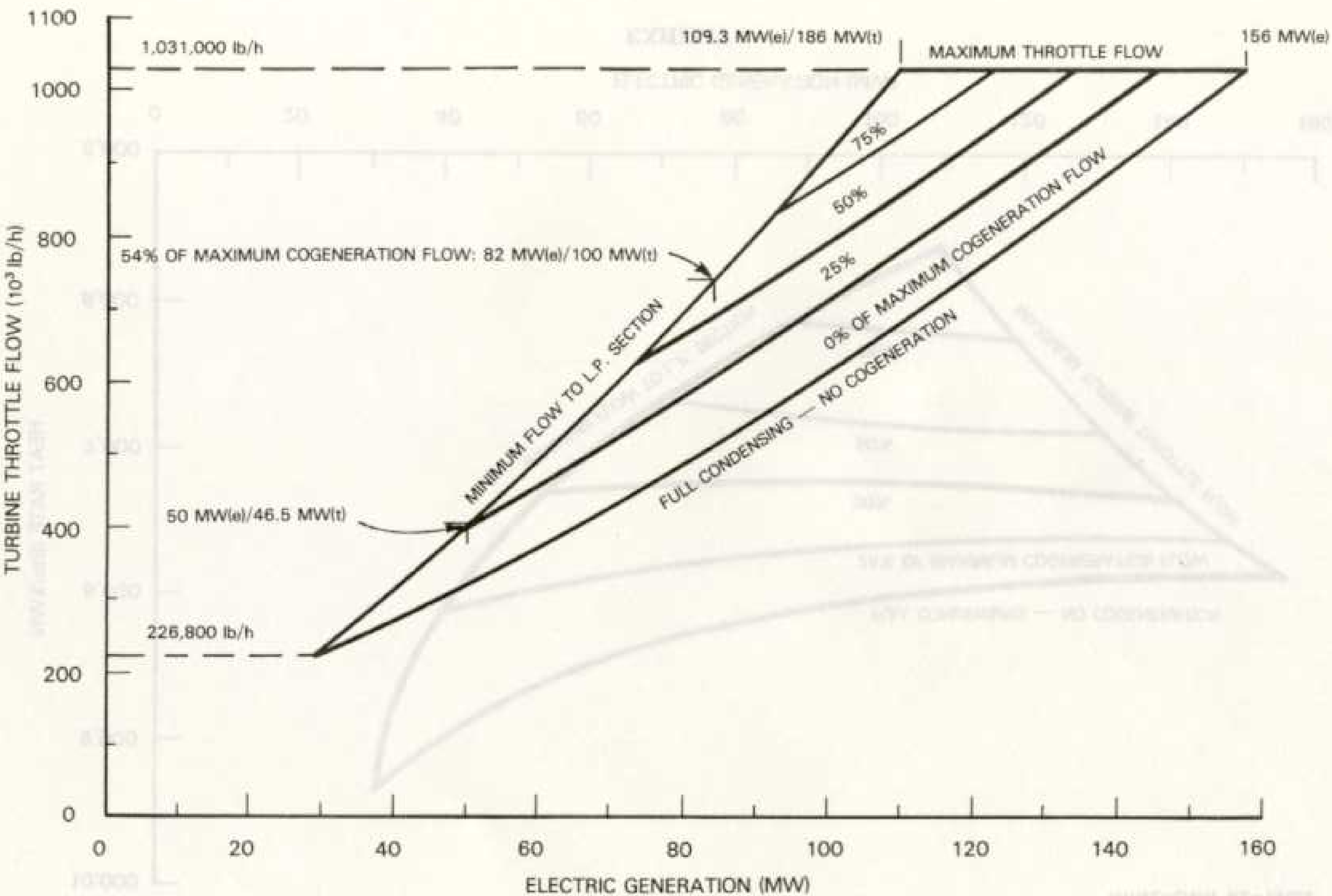
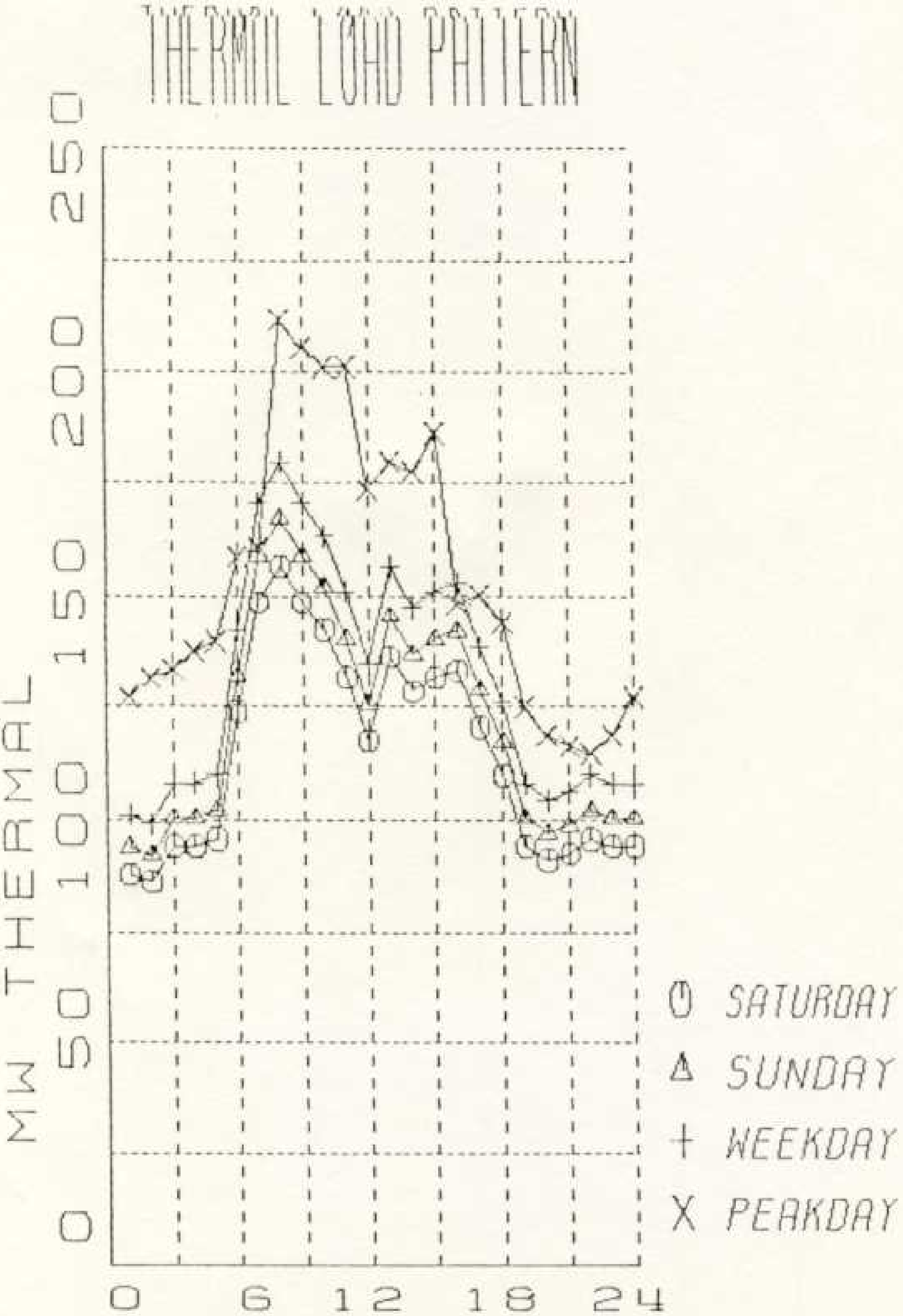


EXHIBIT 2



JANUARY, 1987

EXHIBIT 3

Appendix E

FINANCIAL STATEMENTS OF THE ST. PAUL ECONOMIC FEASIBILITY STUDY

SAINT PAUL DISTRICT HEATING DEVELOPMENT COMPANY, INCORPORATED
PROJECTED CASH FLOW STATEMENT
(THOUSANDS OF DOLLARS)
FOR THE CALENDAR YEARS ENDING DEC 31

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
CASH INFLOW										
OPERATING INCOME										
BEFORE DEPR	$ <475>	$ 350	$ 1,301	$2,675	$3,504	$4,191	$4,935	$5,432	$5,310	$5,185
INTEREST INCOME	3,106	1,792	1,035	514	516	576	665	862	1,092	1,333
FRANCHISE FEES	54	272	566	792	916	1,018	1,122	1,213	1,255	1,318
CASH FLOW AVAIL FOR DEBT SERVICE	2,685	2,414	2,902	3,981	4,936	5,785	6,722	7,507	7,657	7,836
BORROWED FUNDS	34,600	0	0	0	0	0	0	0	0	0
CONTRIBUTED FUNDS	9,800	0	0	0	0	0	0	0	0	0
INCREASE IN A/P	136	211	304	152	74	60	57	69	75	106
TOTAL CASH INFLOW	47,221	2,625	3,206	4,134	5,011	5,845	6,779	7,577	7,732	7,942
CASH OUTFLOW										
DEBT RETIREMENTS	0	0	0	0	0	352	387	426	468	515
INTEREST PAID	3,460	3,460	3,460	3,460	3,460	3,451	3,415	3,375	3,332	3,284
DEBT SERVICE	3,460	3,460	3,460	3,460	3,460	3,803	3,802	3,801	3,800	3,799
CAPITAL EQUIP EXPENDITURE	21,884	6,418	6,407	0	0	558	0	0	0	0
HUD/CITY PRINCIPLE AND INTEREST	0	0	0	0	0	0	0	0	0	0
FRANCHISE FEES	54	272	566	792	916	1,018	1,122	1,213	1,255	1,318
FINANCING COSTS	917	0	0	0	0	0	0	0	0	0
DEBT SERV RES	3,812	0	0	0	0	0	0	0	0	0
FUNDED DEPN, EXP, AND REPL FUND	0	0	0	0	0	612	1,629	2,338	2,518	2,593
INCREASE IN										
CASH	182	281	406	203	99	80	76	92	99	141
A/R	77	314	423	324	178	146	130	131	59	90
TOTAL CASH OUTFLOW	30,305	10,744	11,263	4,779	4,653	6,217	6,779	7,577	7,732	7,942
NET CASH FLOW	$16,836	$<8,119>	$<8,057>	$<646>	$ 357	$<372>	$ 0	$ 0	$ 0	$ 0
DEBT SERV COVERAGE	0.78	0.70	0.84	1.15	1.43	1.52	1.77	1.98	2.02	2.06

SAINT PAUL DISTRICT HEATING DEVELOPMENT COMPANY, INCORPORATED
PROJECTED CASH FLOW STATEMENT
(THOUSANDS OF DOLLARS)
FOR THE CALENDAR YEARS ENDING DEC 31

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
CASH INFLOW										
OPERATING INCOME										
BEFORE DEPR	$6,491	$6,284	$6,018	$5,752	$5,488	$5,360	$5,154	$4,888	$4,623	$4,361
INTEREST INCOME	1,439	1,556	1,724	1,880	2,024	2,129	2,172	2,281	2,373	2,654
FRANCHISE FEES	1,474	1,526	1,576	1,634	1,700	1,788	1,877	1,970	2,076	2,193
CASH FLOW AVAIL FOR DEBT SERVICE	9,405	9,366	9,317	9,266	9,213	9,277	9,203	9,139	9,072	9,208
BORROWED FUNDS	0	0	0	0	0	0	0	0	0	0
CONTRIBUTED FUNDS	0	0	0	0	0	0	0	0	0	0
INCREASE IN A/P	62	100	105	117	128	142	153	167	185	201
TOTAL CASH INFLOW	9,467	9,467	9,422	9,383	9,341	9,419	9,356	9,306	9,257	9,409
CASH OUTFLOW										
DEBT RETIREMENTS	567	623	686	754	830	913	1,004	1,104	1,215	1,336
INTEREST PAID	3,231	3,173	3,109	3,039	2,962	2,876	2,783	2,680	2,567	2,442
DEBT SERVICE	3,798	3,796	3,795	3,793	3,791	3,789	3,787	3,784	3,781	3,778
CAPITAL EQUIP EXPENDITURE	819	0	0	0	0	1,206	0	0	0	0
HUD/CITY PRINCIPLE AND INTEREST	2,088	2,088	2,088	2,088	2,088	2,088	2,088	2,088	2,088	0
FRANCHISE FEES	1,474	1,526	1,576	1,634	1,700	1,788	1,877	1,970	2,076	2,193
FINANCING COSTS	0	0	0	0	0	0	0	0	0	0
DEBT SERV RES	0	0	0	0	0	0	0	0	0	0
FUNDED DEPN, EXP, AND REPL FUND	981	1,849	1,752	1,629	1,496	232	1,273	1,107	913	3,002
INCREASE IN										
CASH	82	133	140	156	171	190	204	223	247	268
A/R	225	74	71	84	95	126	127	134	152	168
TOTAL CASH OUTFLOW	9,467	9,467	9,422	9,383	9,341	9,419	9,356	9,306	9,257	9,409
NET CASH FLOW	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0
DEBT SERV COVERAGE	2.48	2.47	2.46	2.44	2.43	2.45	2.43	2.41	2.40	2.44

SAINT PAUL DISTRICT HEATING DEVELOPMENT COMPANY, INCORPORATED
PROJECTED INCOME STATEMENT
(THOUSANDS OF DOLLARS)
FOR THE CALENDAR YEARS ENDING DEC 31

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
THERMAL REVENUES	$ 616	$ 3,126	$ 6,511	$ 9,104	$ 10,528	$ 11,698	$ 12,896	$ 13,947	$ 14,422	$ 15,146
OPERATING EXPENSES										
PURCHASED ENERGY	367	1,905	4,182	5,264	5,748	6,075	6,484	6,919	7,387	8,099
PUMPING	15	70	137	182	204	221	238	258	279	300
MAINTENANCE	44	67	114	159	172	229	247	267	288	311
GENERAL AND ADMINISTRATIVE	664	734	777	823	900	983	993	1,072	1,158	1,251
	1,090	2,776	5,210	6,428	7,024	7,507	7,962	8,515	9,112	9,961
OPERATING INCOME BEFORE DEPRECIATION	<475>	350	1,301	2,675	3,504	4,191	4,935	5,432	5,310	5,185
OTHER INCOME <EXPENSE>										
DEPRECIATION	<882>	<1,096>	<1,310>	<1,310>	<1,310>	<1,348>	<1,348>	<1,348>	<1,348>	<1,348>
INTEREST INCOME	3,106	1,792	1,035	514	516	576	665	862	1,092	1,333
INTEREST EXPENSE	<3,705>	<3,962>	<3,987>	<4,014>	<4,041>	<4,062>	<4,056>	<4,049>	<4,039>	<4,026>
FINANCING COSTS AM	<31>	<31>	<31>	<31>	<31>	<31>	<31>	<31>	<31>	<31>
	<1,512>	<3,296>	<4,293>	<4,840>	<4,865>	<4,865>	<4,770>	<4,565>	<4,325>	<4,071>
INCOME BEFORE SPECIAL ITEMS	<1,986>	<2,946>	<2,992>	<2,165>	<1,361>	<673>	165	867	985	1,114
DEFERRED COSTS	1,986	2,946	2,992	2,165	1,361	673	0	0	0	0
AMORTIZATION OF DEFERRED COSTS	0	0	0	0	0	0	0	0	0	0
EXPANSION AND REPL PROVISION	0	0	0	0	0	0	165	867	985	1,114
NET INCOME	0	0	0	0	0	0	0	0	0	0

SAINT PAUL DISTRICT HEATING DEVELOPMENT COMPANY, INCORPORATED
PROJECTED INCOME STATEMENT
(THOUSANDS OF DOLLARS)
FOR THE CALENDAR YEARS ENDING DEC 31

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
THERMAL REVENUES	$ 16,945	$ 17,538	$ 18,110	$ 18,779	$ 19,542	$ 20,553	$ 21,572	$ 22,642	$ 23,858	$ 25,203
OPERATING EXPENSES										
PURCHASED ENERGY	8,442	9,082	9,746	10,493	11,317	12,238	13,226	14,308	15,511	16,820
PUMPING	325	350	379	409	441	477	515	556	601	649
MAINTENANCE	336	363	392	423	457	494	533	576	622	672
GENERAL AND ADMINISTRATIVE	1,351	1,459	1,576	1,702	1,838	1,985	2,143	2,315	2,500	2,700
	10,454	11,254	12,092	13,027	14,054	15,193	16,418	17,755	19,234	20,841
OPERATING INCOME BEFORE DEPRECIATION	6,491	6,284	6,018	5,752	5,488	5,360	5,154	4,888	4,623	4,361
OTHER INCOME <EXPENSE>										
DEPRECIATION	<1,400>	<1,400>	<1,400>	<1,400>	<1,400>	<1,478>	<1,478>	<1,478>	<1,478>	<1,478>
INTEREST INCOME	1,439	1,556	1,724	1,880	2,024	2,129	2,172	2,281	2,373	2,654
INTEREST EXPENSE	<3,906>	<3,777>	<3,639>	<3,491>	<3,332>	<3,161>	<2,977>	<2,779>	<2,567>	<2,442>
FINANCING COSTS AM	<31>	<31>	<31>	<31>	<31>	<31>	<31>	<31>	<31>	<31>
	<3,897>	<3,652>	<3,346>	<3,042>	<2,738>	<2,540>	<2,313>	<2,007>	<1,702>	<1,297>
INCOME BEFORE SPECIAL ITEMS	2,594	2,633	2,672	2,711	2,750	2,820	2,840	2,881	2,921	3,065
DEFERRED COSTS	0	0	0	0	0	0	0	0	0	0
AMORTIZATION OF DEFERRED COSTS	1,347	1,347	1,347	1,347	1,347	1,347	1,347	1,347	1,347	1,347
EXPANSION AND REPL PROVISION	1,247	1,286	1,324	1,364	1,403	1,472	1,493	1,534	1,574	1,718
NET INCOME	0	0	0	0	0	0	0	0	0	0

SAINT PAUL DISTRICT HEATING DEVELOPMENT COMPANY, INCORPORATED
PROJECTED BALANCE SHEET
(THOUSANDS OF DOLLARS)
FOR THE CALENDAR YEARS ENDING DEC 31

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
PLANT AND EQUIPMENT										
PLANT	$ 3,438	$ 3,438	$ 3,438	$ 3,438	$ 3,438	$ 3,438	$ 3,438	$ 3,438	$ 3,438	$ 3,438
PEAKING FACILITIES	2,064	2,064	2,064	2,064	2,064	2,064	2,064	2,064	2,064	2,064
DISTRIBUTION SYSTEM	16,016	22,434	28,841	28,841	28,841	28,841	28,841	28,841	28,841	28,841
SERVICE EQUIP	366	366	366	366	366	558	558	558	558	558
	21,884	28,302	34,709	34,709	34,709	34,901	34,901	34,901	34,901	34,901
ACCUMULATED DEPR	882	1,978	3,288	4,598	5,907	6,889	8,237	9,586	10,934	12,282
NET PLANT AND EQUIP	21,002	26,324	31,421	30,112	28,802	28,012	26,664	25,316	23,968	22,620
CURRENT ASSETS										
CASH	17,018	9,180	1,529	1,086	1,543	1,251	1,327	1,419	1,519	1,660
ACCOUNTS RECEIVABLE	77	391	814	1,138	1,316	1,462	1,612	1,743	1,803	1,893
TOTAL CURRENT ASSETS	17,095	9,571	2,343	2,224	2,859	2,713	2,939	3,163	3,322	3,553
OTHER ASSETS										
FUNDED DEPN,EXPANSION, AND REPLACEMENT FUND	0	0	0	0	0	612	2,241	4,579	7,097	9,691
DEBT SERVICE RESERVE	3,812	3,812	3,812	3,812	3,812	3,812	3,812	3,812	3,812	3,812
UNAMORTIZED DEFERRED COSTS	1,986	4,933	7,925	10,090	11,451	12,124	12,124	12,124	12,124	12,124
UNAM FINANCING COSTS	886	856	825	795	764	734	703	672	642	611
	$44,781	$45,494	$46,326	$47,032	$47,688	$48,007	$48,403	$49,666	$50,964	$52,411
CAPITALIZATION										
LONG TERM DEBT	34,600	34,600	34,600	34,600	34,600	34,248	33,861	33,435	32,967	32,452
HUD/UDAG LOAN	10,045	10,547	11,075	11,628	12,210	12,820	13,461	14,134	14,841	15,583
RESERVE FOR EXPANSION AND REPLACEMENT	0	0	0	0	0	0	165	1,032	2,017	3,131
RETAINED EARNINGS	0	0	0	0	0	0	0	0	0	0
TOTAL CAPITALIZATION	44,645	45,147	45,675	46,228	46,810	47,068	47,407	48,601	49,825	51,166
CURRENT LIABILITIES	136	347	651	804	878	938	995	1,064	1,139	1,245
	$44,781	$45,494	$46,326	$47,032	$47,688	$48,007	$48,403	$49,666	$50,964	$52,411

March 23, 1981

SAINT PAUL DISTRICT HEATING DEVELOPMENT COMPANY, INCORPORATED
PROJECTED BALANCE SHEET
(THOUSANDS OF DOLLARS)
FOR THE CALENDAR YEARS ENDING DEC 31

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
PLANT AND EQUIPMENT										
PLANT	$ 3,438	$ 3,438	$ 3,438	$ 3,438	$ 3,438	$ 3,438	$ 3,438	$ 3,438	$ 3,438	$ 3,438
PEAKING FACILITIES	2,064	2,064	2,064	2,064	2,064	2,064	2,064	2,064	2,064	2,064
DISTRIBUTION SYSTEM	28,841	28,841	28,841	28,841	28,841	28,841	28,841	28,841	28,841	28,841
SERVICE EQUIP	819	819	819	819	819	1,206	1,206	1,206	1,206	1,206
	35,162	35,162	35,162	35,162	35,162	35,549	35,549	35,549	35,549	35,549
ACCUMULATED DEPR	13,124	14,524	15,925	17,325	18,725	19,384	20,861	22,339	23,817	25,295
NET PLANT AND EQUIP	22,038	20,638	19,238	17,837	16,437	16,166	14,688	13,210	11,732	10,255
CURRENT ASSETS										
CASH	1,742	1,876	2,015	2,171	2,342	2,532	2,736	2,959	3,206	3,474
ACCOUNTS RECEIVABLE	2,118	2,192	2,264	2,347	2,443	2,569	2,696	2,830	2,982	3,150
TOTAL CURRENT ASSETS	3,860	4,068	4,279	4,519	4,785	5,101	5,433	5,789	6,188	6,624
OTHER ASSETS										
FUNDED DEPN, EXPANSION, AND REPLACEMENT FUND	10,671	12,520	14,273	15,901	17,397	17,629	18,901	20,009	20,922	23,924
DEBT SERVICE RESERVE	3,812	3,812	3,812	3,812	3,812	3,812	3,812	3,812	3,812	3,812
UNAMORTIZED DEFERRED COSTS	10,777	9,430	8,083	6,736	5,389	4,041	2,694	1,347	<0>	<1,347>
UNAM FINANCING COSTS	581	550	520	489	458	428	397	367	336	306
	$51,740	$51,018	$50,204	$49,294	$48,278	$47,177	$45,926	$44,534	$42,990	$ 43,573
CAPITALIZATION										
LONG TERM DEBT	31,886	31,262	30,577	29,823	28,993	28,080	27,077	25,973	24,758	23,422
HUD/UDAG LOAN	14,170	12,686	11,128	9,492	7,774	5,970	4,077	2,088	0	0
RESERVE FOR EXPANSION AND REPLACEMENT	4,378	5,663	6,988	8,351	9,754	11,227	12,720	14,254	15,828	17,545
RETAINED EARNINGS	0	0	0	0	0	0	0	0	0	0
TOTAL CAPITALIZATION	50,433	49,612	48,692	47,666	46,521	45,278	43,873	42,314	40,586	40,967
CURRENT LIABILITIES	1,307	1,407	1,512	1,628	1,757	1,899	2,052	2,219	2,404	2,605
	$51,740	$51,018	$50,204	$49,294	$48,278	$47,177	$45,926	$44,534	$42,990	$ 43,573

Appendix F

ENVIRONMENTAL ASSESSMENT
HOT WATER DISTRICT HEATING SYSTEM
FOR
SAINT PAUL, MINNESOTA

Saint Paul Department of Planning and Economic Development

April 1980

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MARKET ASSESSMENT AND ECONOMIC ANALYSIS OF THE ST. PAUL DISTRICT HEATING SYSTEM

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