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FEASIBILITY OF WATER-BASED DISTRICT HEATING AND COOLING

An Assessment in New York City
Volume I: Preliminary Analysis

Energy Task Force
of the Urban Consortium
for Technology Initiatives

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PREFACE

The Urban Consortium for Technology Initiatives was formed to pursue technological solutions to pressing urban problems. The Urban Consortium conducts its work program under the guidance of Task Forces structured according to the functions and concerns of local governments. The Energy Task Force, with a membership of municipal managers and technical professionals from nineteen Consortium jurisdictions, has sponsored over ninety energy management and technology projects in thirty-two Consortium member jurisdictions since 1978.

To develop in-house energy expertise, individual projects sponsored by the Task Force are managed and conducted by the staff of participating city and county governments. Projects with similar subjects are organized into "units" of four to five projects each, with each unit managed by a selected Task Force member. A description of the units and projects included in the Fifth Year (1983-1984) Energy Task Force Program follows:

UNIT -- MUNICIPAL OPERATIONS

Energy used to support public facilities and services by the nation's local governments in 1983 totaled approximately 1.4 quadrillion BTU's. By focusing on applied research to improve energy efficiency in municipal operations, the Energy Task Force helps reduce operating costs without increasing tax burdens on residents and commercial establishments. This Fifth Year unit consisted of five projects:

- Albuquerque, New Mexico - "Analysis of Municipal Bus Operations for the Advancement of Fuel Cell Technology"
- Baltimore, Maryland - "The Hydrate Process for Sewage Sludge Dewatering: Commercialization Assessment"
- Memphis, Tennessee - "Application of Mini-van Technology to Van Pool Services"
- Phoenix, Arizona - "Capacity Optimization of Hydronic Flows: Energy Savings in HVAC Systems"
- Washington, DC - "Facilities Energy Monitoring System: Application in a Large Municipal Government"

UNIT -- MUNICIPAL AND COMMUNITY ENERGY MANAGEMENT

Of the nation's estimated population of 232 million, approximately 60 percent reside or work in urbanized areas. The 543 cities and counties that contain populations greater than 100,000 consumed a total of 49 quadrillion BTU's in 1983. Applied research sponsored by the Energy Task Force helps improve the economic vitality of this urban community by aiding energy efficiency and reducing energy costs for public services and the community as a whole. This Fifth Year unit consisted of five projects:

- Boston, Massachusetts - "Computer-based Preventive Maintenance"
- Cleveland, Ohio - "Coordinating Preventive Maintenance with Energy Management"
- Columbus, Ohio - "Budgetary Incentives for Municipal Energy Management"

- Denver, Colorado - "Municipal Recycling Programs: Potential for Waste Management and Energy Savings"

- Philadelphia, Pennsylvania - "Energy Assistance Program Information System (EAPIS): Coordinating Residential Assistance Programs"

UNIT -- ALTERNATE/INTEGRATED SYSTEMS

Effective use of advanced energy technology and integrated energy systems in urban areas could save from 4 to 8 quadrillion BTU's during the next two decades. Urban governments can aid the realization of these savings and improve capabilities for the use of alternative energy resources by serving as test beds for the practical application of new and integrated technologies. This Fifth Year unit consisted of five projects:

- Chicago, Illinois - "Implementation Methods for an Integrated Energy System"

- Houston, Texas - "Pricing, Regulation and Competition in Cogeneration: A Method for Comprehensive Risk Analysis"

- New York, New York - "Feasibility of Water-based District Heating and Cooling"

- San Antonio, Texas - "Central Energy Systems Application to Economic Development"

- San Francisco, California - "On-site Cogeneration for Office Buildings"

UNIT -- PUBLIC/PRIVATE FINACING AND IMPLEMENTATION

City and county governments often have difficulty in carrying out otherwise sound energy efficiency or alternative energy projects due to constraints in the acquisition of initial investment capital. Many of these investment constraints can be overcome by providing means for private sector participation in innovative financing and financial management strategies. This Fifth Year unit consisted of five projects:

- Hennepin County, Minnesota - "Shared Savings in the Residential Market: Financing Single Family Energy Conservation"

- Kansas City, Missouri - "Street Light Inventory and Maintenance System"

- Pittsburgh, Pennsylvania - "Shared Savings for Energy Conservation: A Model Process for Local Governmets"

- Saint Louis, Missouri - "A Development Strategy for Superinsulated Housing"

- San Diego County, California - "Innovative Financing for a Privately Owned Waste-to-Energy Facility"

Reports from each of these projects are specifically designed to aid the transfer of proven experience to other local governments. Readers interested in obtaining any of these reports or further information about the Energy Task Force and the Urban Consortium should contact:

Energy Program
Public Technology, Inc.
1301 Pennsylvania Avenue, NW
Washington, DC 20004

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ABSTRACT

Although the benefits of district heating are well known, public utility district heating systems in the United States are not prospering. New York City has a large district heating system, owned and operated by Consolidated Edison Company of New York, Inc. ("Con Edison"). This system provides over 27 billion pounds of steam a year for heating and cooling to over 2000 customers. Most of this steam is cogenerated. The system has stabilized following several years of large losses of customers. However, its economic position is still fragile, because the cost of district steam has risen so much that it is marginally competitive with steam that a building owner can produce on site.

It has been suggested that the economics of district heating in New York City could be improved by using hot water, instead of steam, as the medium for distributing heat, and by distributing chilled water for cooling. Water-based district heating systems are widely used in Europe, and on-site water-based heating and cooling are used in many buildings and multi-building complexes in the U.S. The New York City Energy Office (NYCEO) and Con Edison are conducting a joint study to evaluate the use of water-based technology to provide district heating and cooling service to potential new customers.

The approach is presented here for a site-specific study of a water-based district heating and cooling system that may be economically feasible. The first phase of the study was conducted in-house by NYCEO, at low cost. It comprised (1) site inspection, (2) conceptual design, (3) formulation of a scope of work for engineering/economic analysis by a consultant, and (4) consultant selection. These four project elements and the project development methodology are described in Volume I. The next phase -- a preliminary feasibility study -- is being performed by NYCEO with the aid of the consultant, and includes

evaluating design options, comparing the cost of service from the proposed district heating/cooling system with the cost of alternatives available to building owners, and assessing alternative ownership and financing options. Results of the analysis will be presented in Volume II, and recommendations will be provided to aid in developing City policy on district heating, to Con Edison for system planning, and to potential customers for assessing their future plans for energy supply. Since other cities, utilities and energy users face similar problems with existing district steam systems, the results of this study should be broadly applicable.

CHAPTER 1 - INTRODUCTION

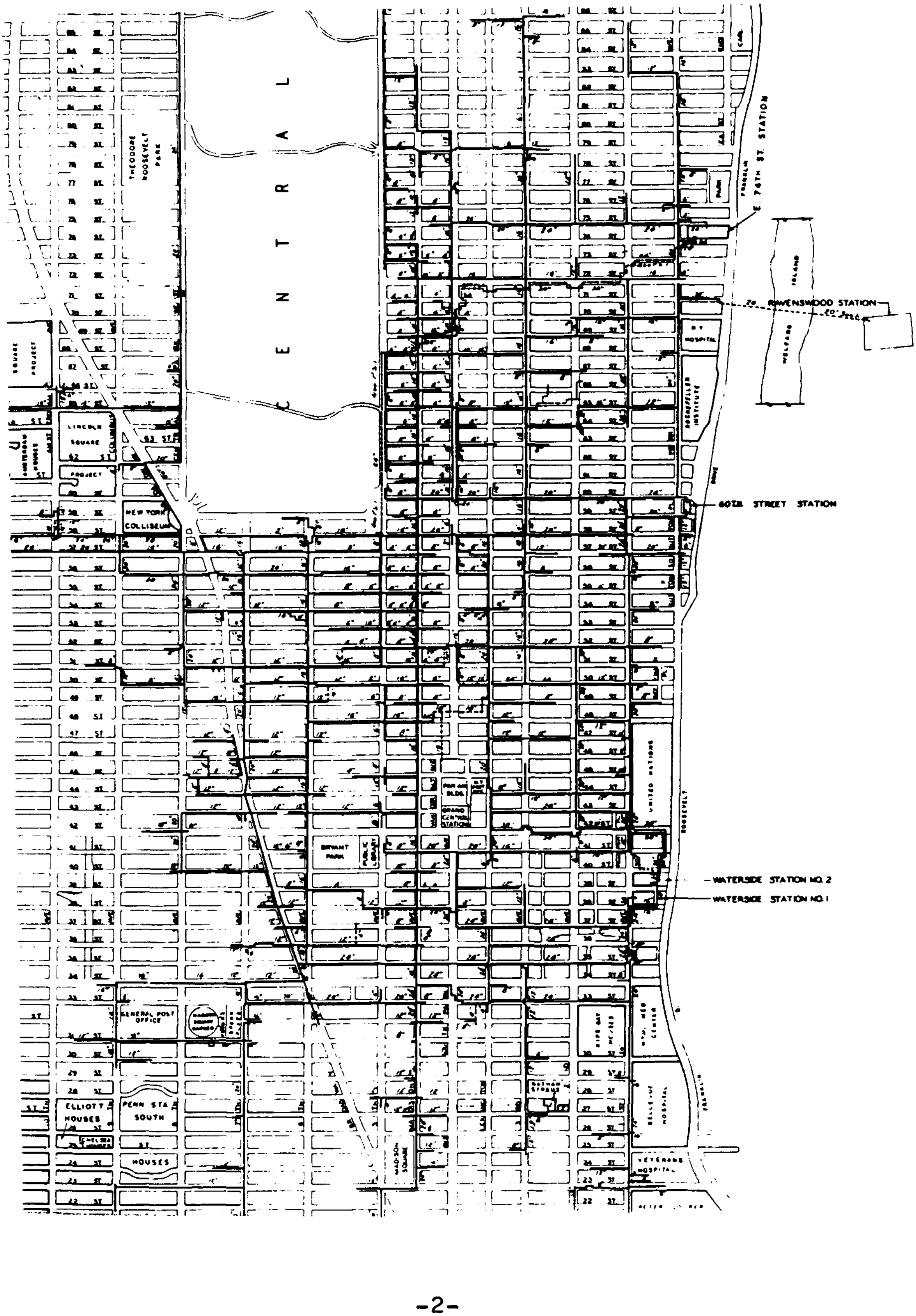
BACKGROUND

The benefits of district heating are well known. The major benefits are reduced fuel consumption, more efficient use of fuel and capital, and reduced emission of pollutants. Other benefits are reduced maintenance costs, reduced truck traffic for fuel deliveries, and release of space in buildings for productive use. The benefits are enhanced by combining district heating with electric power generation ("cogeneration"). A combined plant consumes less fuel, and is cheaper to build and run, than separate plants producing the same amounts of electricity and heat as the combined plant. These benefits translate into lower costs to consumers.

District heating has existed in New York City for over 100 years(1). The Consolidated Edison Company's steam system extends from the southern tip of Manhattan north to 96th Street on the west side of Central Park, and to 89th Street on the east side. It is the largest district steam system in the United States. Most major commercial buildings in Manhattan use Con Edison steam for space heating. Significant quantities are also used for air conditioning and for generation of domestic hot water. Figure 1 is a map of the system(2) and Table 1 shows individual station capacities.

Con Edison's central steam system is an important component of New York City's energy supply. In 1982, the system supplied steam to 2038 customers. Winter peak load was 10,790,000 lbs. per hour and total sendout capability was 13,296,000 lbs. per hour.

Figure 1


CENTRAL
THEODORE ROOSEVELT PARK
E. 74TH ST. STATION
RAVENSWOOD STATION
WELFARE ISLAND
ROCKEFELLER INSTITUTE
LINCOLN SQUARE
NEW YORK COLISEUM
60TH STREET STATION
BRYANT PARK
PUBLIC LIBRARY
GRAND CENTRAL STATION
UNITED NATIONS
WATERSIDE STATION NO. 2
WATERSIDE STATION NO. 1
GENERAL POST OFFICE
ELLIOTT HOUSES
PENN STA SOUTH
HOUSES
MADISON SQUARE
VETERANS HOSPITAL

Total steam sales in 1982 were about 27 billion lbs., of which about 80% was supplied from topping turbines and extraction turbines cogenerating electricity and steam. Revenues were about $347 million. Approximately 56% of the steam was sold for use in office buildings, 24% in residential buildings, 8% in hospitals and 12% to various other customers[3,4].

Table 1.

STEAM GENERATING STATION CAPACITY

	1,000 lbs. Per Hour
STEAM STATIONS	MAXIMUM NET CAPACITY
74th Street Package	762
Ravenswood	888
Woolworth	107
East 60th Street	762
59th Street Package	381
East River South	1,200
Total	4,100
ELECTRIC STATIONS	
Waterside	3,000
Hudson Avenue	2,300
74th Street	1,100
59th Street Annex	830
Intermediate	600
East River Extraction (2000)	1,552*
Total	9,382
Leased Plants	232
Total System	13,714

* THIS CAPACITY DEPENDS ON DOWNTOWN LOAD AND CAN REACH CAPACITY OF 2,000 MLBS/HR.

Although currently stabilized, increasing rates (now averaging $12.72 per 1,000 lbs. of steam) had resulted in a number of customers leaving the Con Edison steam system, starting in the late 1970's. The loss of these customers contributed to increasing costs for the remaining customers, since the fixed costs had to be spread over a reduced customer base. Steam systems in many other cities have faced similar problems. Utilities in Akron and Chicago shut down their district steam systems. Rochester Gas & Electric and other steam utilities are studying plans for system abandonment. In 1983, utilities in ten cities either ended, curtailed or studied the ending of steam sales(5). Yet, during the period 1973 to date, European district heating systems, based on hot water, have been expanding and prospering. A major reason for the economic difficulties of United States central utility district heating systems is the fuel waste inherent in their use of steam as the heat transport medium. Distribution losses range up to 30% of the steam produced (currently 18% for Con Edison) and are in addition to the heat lost by discarding condensate. Also, United States systems do not generally use waste heat from base-load electric plants; instead, additional fuel is burned to supply district heating. These factors tend to offset the potential fuel economies that district heating offers.

Con Edison's rates for steam are now so high that many building owners believe they can produce steam more cheaply with their own boilers. Each time Con Edison's steam rates have been increased, some customers have disconnected and installed their own boilers(1). Yet Con Edison earns a lower return on steam plant investment than on electric plants(1). The results are that Con Edison has little incentive to invest in pursuing more steam sales, and few building owners have an incentive to become customers. New customers are mainly large commercial operators, who often find it more profitable to rent the space that would otherwise be taken up by heating plants on-site.

To keep capital costs down, Con Edison's long-range steam system plan is based on refurbishing old plants and equipment, not building new facilities[2]. This includes increased use of steam-electric plant cogeneration. It is believed that this approach will prevent significant increases in steam rates. The plan concludes that the customer load will remain stabilized and that the load will increase about 0.5% per year over the next 10 years, mainly through addition of new office buildings in the central business district of Manhattan.

The City of New York is concerned with the continued viability of the Con Edison steam system for both energy and economic development reasons. From an energy point of view, central utility cogeneration plants are more fuel efficient by as much as a 20% margin over on-site boilers, and can often utilize cheaper fuels. Moreover, eliminating many small boiler plants can result in improved air quality and other benefits. From an economic development perspective, rapidly escalating energy costs have been a major discouragement for businesses seeking to remain, expand or locate in New York City. To the extent such operating costs can be reduced or stabilized, the costs of doing business in New York City can be held down.

Recent developments in water-based district heating and cooling technology[6-9] may provide an opportunity to reduce the cost, compared to steam, of heating and cooling New York buildings. This reduction would occur by enabling more efficient use of fuel, better utilization of existing equipment, and lower operating and maintenance costs. The water-based option, if applicable to the Con Edison system, might result in the addition of new water-based service loops to the system. This would enable the addition of new customers, which, in conjunction with the more efficient use of existing plant, could have a favorable impact on system-wide economics for both old and new customers. Moreover, building owners considering on-site cogeneration, which might impact negatively on Con Edison ratepayers, might find a less costly hot water-chilled water service to be an option of potentially great interest.

The NYCEO conducted the first phase of the study, described in this volume, to assess the feasibility and market opportunities for water based district heating and cooling systems in New York City. This study phase was conducted over a six-month period. The major tasks were to gather information on water-based district heating and cooling systems, to identify a study area that might be served by Con Edison through a water-based branch of the existing district heating system, and to develop a conceptual design and tasks for a preliminary engineering and economic feasibility study of this site. The latter study, jointly funded by the New York State Energy Research and Development Authority ("NYSERDA") and the Energy Task Force of the Urban Consortium, is expected to be completed in the fall of 1985. It will be described in Volume II. The Scope of Services for that study is given in Appendix G.

PURPOSE

The purpose of this project is to study and assess the economic and technical feasibility of adapting hot water district heating and cooling to an existing central steam system, and to determine the potential economic impact of such an approach on existing and future steam ratepayers. In order to evaluate the water-based approach realistically, NYCEO and Con Edison are jointly conducting a pre-feasibility study that focuses on a specific potential project for a selected site. The site includes Con Edison's 74th Street Station, which produces steam and some electricity, and includes New York Hospital-Cornell Medical Center and Rockefeller University as potential customers for water-based district heating/cooling service. A conceptual design for such a service has been developed and is being refined and evaluated for economic feasibility.

The outcome of this study will be an assessment of the potential for utilizing water-based district heating and cooling to reduce energy costs in New York City, and a determination whether such an option should be considered further in planning the future of the existing steam system.

The specific project objectives are:

- Assess the engineering, economic and preliminary marketing feasibility of creating a hot water district heating and cooling loop to serve new thermal customers, i.e., a hospital complex and a university.

- Evaluate the economic impact on existing ratepayers of water-based district heating and cooling systems.

- Determine whether proceeding to development and implementation of the project would be economically beneficial, including a definition of the financial and institutional commitments required by the utility, potential customers, City government and other potential participants.

The first step in evaluating the option of a water-based approach is to determine whether it is feasible as an extension of the existing steam system. Since the steam and hot water technologies to be used are well-established individually, the issue is whether these technologies can be combined in an economically attractive way under realistic urban conditions. NYCEO staff formulated a preliminary design concept. We are now proceeding with a sufficient quantitative analysis, with the aid of a contractor, to determine whether the design concept, or some variation thereof, can be made economically attractive to potential customers while justifying the investment required to provide the new services.

If the proposed water-based system can provide lower-cost service to potential customers than either the existing steam system or the use of on-site boilers in individual buildings, this could result in reducing thermal energy costs for building owners and tenants in New York City.

NYCEO's investigation is limited to determining whether the proposed project is technically, economically and institutionally feasible. Project results will help the City develop policy recommendations relative to district heating and cooling in New York City, and should provide guidance for central utility steam systems operating in other cities. The results will also be provided to Con Edison and to potential customers to help guide their energy planning.

The study deals with closely intertwined institutional, legal, technical and economic issues, responsibilities for which are divided between the City and Con Edison. Therefore, NYCEO and Con Edison are conducting this project jointly. This type of joint effort has been one of the essential bases for the much-admired success of water-based district heating development in Europe.

ORGANIZATION OF REPORT

Chapter 2 of this volume describes the development of the project, including the definition of work scope for detailed analytical studies and the process of selecting a consulting firm to perform those studies.

Chapter 3 describes the conceptual system design developed by NYCEO staff for the project.

Chapter 4 discusses the preliminary systems analysis and specifications, and gives some preliminary data.

Chapter 5 reviews results to date and lessons learned from the project.

Volume II will cover the quantitative analyses performed by the engineering/economic consultants, leading to initial conclusions about the feasibility of a water-based district heating/cooling system for the east side of Manhattan.

CHAPTER 2 - PROJECT DEVELOPMENT

GENERAL

The basic study approach was to evaluate the energy and economic effects of supplying potential new Con Edison thermal customers with water-based district heating and cooling service, and to compare these results with both the cost of service from the existing Con Edison steam system and customer on-site systems. Potential new thermal loads were identified. To determine whether such sites could be connected to the central steam system, reviews were conducted of Con Edison generating plants, potential customer energy loads and heating-ventilating-air conditioning (HVAC) systems, and proposed heat transfer and distribution systems.

The outcome of the study hinges on the question: How can water-based district heating/cooling be offered to building owners in the project area at competitive rates while providing an acceptable rate of return on project investment? The study aims to answer this question by carrying out three major tasks:

Task 1 - Technical Analysis: This analysis is based on an NYCEO conceptual design of a district heating/cooling system that optimizes performance and cost and attempts to adapt that design to specific project requirements.

Task 2 - Market Study: This study will determine the characteristics of the thermal loads of two potential customers: Rockefeller University and New York Hospital-Cornell Medical Center.

Task 3 - Economic Analysis: This analysis integrates the output of Tasks 1 and 2 to determine (1) the comparative costs of energy to customers from the proposed project and alternatives; (2) return on investment under various ownership and financing options; and (3) evaluation of the economic feasibility of the project.

THE WATER-BASED APPROACH

Public utility district heating systems were first developed in the United States starting in 1877. Steam was the medium for distributing heat. The steam was propelled by pressure from the boiler house. The system was simple and cheap to build, and needed no pumping power. Moreover, the early prime movers for electric generation were inefficient steam engines exhausting large quantities of useful steam. This exhaust steam was available for heating buildings at very low cost.

The advantages of hot water for district heating became apparent after the development of modern, high-efficiency steam-electric generating plants. These plants utilize high-pressure, high-temperature boilers and multistage condensing steam turbines to produce electricity from fuel with actual efficiencies that approach the thermodynamic limits. In these systems there is no unused steam. The heat rejected from the turbine cycle is discharged in warm water from the condensers, and the spent steam is condensed and recycled as boiler feed-water. To obtain heat for district heating from such a system requires that heat be taken from the turbine cycle, and hence less electricity produced for a given amount of fuel consumed. So the heat is no longer virtually "free" as it was in the old steam-engine days.

There are three major advantages of hot water over steam for district heating: higher fuel efficiency for combined heat and power generation ("cogeneration"), lower losses in the distribution system, and better system control (including load leveling). The higher fuel efficiency comes about because the taking of heat from the turbine cycle in hot water causes a smaller loss of electric generating capacity than when steam is extracted. As much as 20% more fuel must be burned to cogenerate given amounts of electricity and steam heat than to cogenerate the same amounts of electricity and heat when the heat is supplied in hot water(7). Losses in distribution are much lower for water than for steam, because the water is recirculated and leakage is very low. Losses and pumping power requirements total only 0.5% to 3% of thermal power capacity, even for hot water mains up to 30 miles long(6). This compares to losses of up to 30% in steam systems (currently 18% for Con Edison), not counting condensate loss(3), in steam mains less than 2 miles long.

Other advantages of hot water over steam include the following:

- Hot water can be distributed at constant pressure over much longer distances than steam.
- Hot water metering is far simpler and more accurate than steam metering.
- Hot water systems are more reliable and require less maintenance.

These are the main factors that have caused the longevity and continuing growth rates for European hot water district heating systems.

The existing Con Edison district heating system is a steam system, with over 2000 customers. This system represents an investment of several hundred million dollars, and it would be difficult to justify the cost of replacing it immediately with a hot water system. However, when considering extensions of the existing system, use of hot water (and chilled water, for cooling) may be advantageous. Such is the approach of this study.

PLANNING PROCESS

A step-by-step approach was followed to develop the project. This approach is commonly used for handling projects with many initial uncertainties and options.

The major steps include:

1. Problem definition: development of specific quantitative technical and economic requirements that must be met for the project to be feasible, and determination of the physical, legal, institutional, etc., constraints within which a solution to the problem must be sought.

2. Fact-finding: collecting information about the site, available equipment and literature on previous or related projects.

3. Conceptual design: defining a specific case for study that satisfies the general problem requirements and constraints, such that a detailed analysis of this design will lead to determining preliminary project feasibility.

4. Preliminary feasibility study: system analysis of the conceptual design, and possible variations thereof, preliminary sub-system designs and equipment selections, preliminary cost estimates, financing plans and investment analysis, leading to a determination whether the project appears feasible.

5. Feasibility analysis: detailed engineering design, construction, economic and financing analyses, sufficient to arrive at a final decision whether to invest in the project.

6. Design/construction.

Steps 1 through 3 were accomplished by NYCEO staff, and served as the basis for proceeding to Step 4, Preliminary Feasibility Study, which is currently being conducted with the aid of a consultant. The results will help to determine whether to proceed to a formal detailed investment feasibility analysis (Step 5). Con Edison staff supplied technical and economic data on the 74th Street Station and other parts of their district steam system, and staff of Rockefeller University and New York

Hospital supplied data on their energy usage, systems and equipment. A retired vice president for utilities of a major industrial corporation was engaged to assist in evaluating the Con Edison and Rockefeller University facilities and to suggest ways to optimize the conceptual design. He provided the perspective of a major purchaser of district heating and cooling systems, as contrasted to consulting engineering firms and equipment makers who supply and build these facilities.

The Conceptual Design Phase culminated with issuance of an NYCEO Request for Proposal to engineering firms for conducting the Preliminary Feasibility Study Phase (Step 4). The results of the Conceptual Design Phase are described in Chapter 3 and approaches to the Preliminary Feasibility Study Phase are discussed in Chapter 4. The Preliminary Feasibility Study Phase will be completed in 1985 and will be described in Volume II.

Figure 2 lists the critical path elements of the Conceptual Design and Pre-feasibility studies. The center column shows the steps of the Pre-feasibility Study, from solicitation of potential contracts to delivery of final report. The Conceptual Design Study was conducted in parallel, as shown in the right-hand column, and the result was used as a basis for the proposed contractor Scope of Work.

Figure 2. PROJECT SCHEDULE

CRITICAL PATH ELEMENTS

6/18/84	*Preliminary Scope		
6/18/84	*Contractor list		
6/25/84	*RFQ mailed		<u>Conceptual Design</u>
7/16/84	*Review responses		*Inspect 74th & E. 60th St. Stations
7/23/84	*Interviews		*Review possible approaches
7/30/84	*Select top 3		*Inspect Rockefeller University
8/6/84	*Draft RFP	<---	*Select Approach
8/13-9/4	*Review RFP		
9/11/84	*Mail RFP		
10/1-10/5	*Review Proposals		
11/8/84	*Board of Estimate Approval		
11/13/84	*Contractor Kickoff		
	Draft Report		
	Final Report		

*Completed

Project Advisory Committee

A Project Advisory Committee has been established to provide guidance and direction to the study. The Committee is chaired by NYCEO's Director. The other members are the NYCEO Project Director and Project Manager; the New York State ERDA Project Manager; the Vice President for Planning, Chief Generation Planning Engineer and Manager of Steam Planning of Con Edison; the Director of Physical Facilities of Rockefeller University and the Associate Director of New York Hospital. The Committee reviews the progress of the project, provides advice and input to the project team, and insures a complete assessment of local interests and conditions. The Committee will meet three times: first, following appointment of the contractor/consulting firm at the beginning of the Preliminary Feasibility Study, second at the halfway point of the study, and third following completion of the draft final report. A subcommittee was established to provide technical input and assistance to the contractor during the study. This subcommittee includes representatives of the operating staffs of New York Hospital and Rockefeller University, the engineering and operations departments of Con Edison, and the NYCEO Project Manager.

Selection of Consulting Firm/Contractor

Selection of the consulting firm proceeded according to the steps shown in the center column of Figure 2. A list of ten candidate firms (Appendix A) was developed from an initial list of 20 possibilities. A Request for Qualifications (Appendix B) was prepared and sent to the 10 candidates. Eight companies responded, two of them as a joint venture, for a total of seven responses. Of these, three were selected as potentially qualified for this project and were interviewed. Appendix C is the question guide used in the interviews. Since no clear preference emerged from the interviews, all three firms were asked to submit proposals. Appendix D is the Request for Proposal

("RFP"). It includes a tentative Scope of Work and a description of the Conceptual Design developed by NYCEO staff, referred to in Appendix D as the Reference Case. The submitters were encouraged to propose their own ideas, and not to follow the Reference Case uncritically. However the RFP made it clear that the study must be focused on the most promising approaches to the specific project area and requirements, and is not intended as a broad look at all possible approaches.

Appendix E gives the rating scheme used to evaluate the proposals. The critical deciding factors were experience in similar projects, leadership and directly relevant experience of the project team, and the relative probability of success via the proposed approach.

Burns & Roe, Inc. was selected as the consulting firm to perform the Preliminary Feasibility Study.

CHAPTER 3 - PROPOSED CONCEPTUAL DESIGN

The NYCEO Conceptual Design was developed primarily on the basis of prior studies and from design, construction and operating experience of utilities, other firms and government agencies in the U.S. and Europe[6-9, 11-16]. It represents an attempt to select approaches that have reasonably high *a priori* probability of successful application in the proposed project.

THE STUDY AREA

The area selected for study is the east side of Manhattan between 60th Street and 74th Street, east of York Avenue. As shown in Figure 1, this area includes Con Edison's East 74th Street Steam-Electric Station, New York Hospital-Cornell Medical Center and Rockefeller University, adjacent to each other along York Avenue.

This area has many advantages as a subject for this study. The two institutions have a combined steam load of 950 million lbs. per year. This load is suitable as an "anchor" for the project, and minimized the need for extensive building surveys and market studies in this preliminary study. Because the 74th Street Station is nearby, it is likely to be an economical thermal source for the project. The close proximity of the 74th Street Station and the load minimizes the length of transmission and distribution mains that must be installed in streets, generally the most costly part of a district heating project. These costs may be further reduced, since rights of way -- through existing tunnels and along the East River -- may be available, thereby obviating the need for street excavation.

In the same vicinity are several more hospitals and many large, modern apartment houses potentially suitable as additional load for the project. If future expansion requires additional heat, this might be obtained from the Ravenswood Station via a 10-ft.-diameter tunnel from Ravenswood to East 71st Street, which contains a 20-inch steam line (See Figure 1).

CONSTRAINTS

The major constraints on this study of developing a technically and economically feasible water-based extension to the existing central steam system in New York are:

- The fuel is residual oil; use of coal is excluded.
- The load must consist of buildings with HVAC systems that are suitable for connection to a hot water water district heating/cooling system, i.e., systems that can use hot water and chilled water.
- The project approach must maximize efficient use of fuel in electric and heat production.
- The technology and method chosen for adding new customers for heating/cooling service must be technically compatible with the existing Con Edison system, and the incremental costs must be cost-effective relative to the existing Con Edison steam system. No design can be considered that will increase average Con Edison system costs.
- New York City street excavation costs are extremely high, and interferences are many[10]. Innovative approaches for minimizing distribution and piping costs are required.
- The sale of heat by a public utility is subject to certain forms of taxation (e.g., franchise and gross receipts taxes) that are not applied to facility owners who produce heat on site.

PLANT VISITS

As a first step toward developing a conceptual design approach, several plants were visited. Con Edison's 74th Street and 60th

Street Stations, Rockefeller University, and New York Hospital were visited to assess equipment and operations. Public Service Electric & Gas (New Jersey) was visited to review results of a major district heating/cooling study they conducted[13-15], which might be helpful as a guide.

The plant visits included:

- Inspecting equipment: types, condition, age, etc.
- Observing performance data;
- Questioning station personnel about equipment, performance and other matters pertaining to NYCEO's project;
- Obtaining other information required to judge the suitability of the plants and equipment observed for use in the project.

Details of the plant visits are given in Appendix F. Based on this and other information, we determined which plants and equipment were most suitable for the project and identified study approaches that appear the most promising a priori and most worthwhile for detailed economic/engineering analysis. We eliminated study approaches that appeared to have a lower probability of success, and which should be deferred or discarded.

NYCEO CONCEPTUAL DESIGN

The physical elements that were considered most suitable for inclusion in NYCEO's study are as follows:

- Con Edison's high pressure boilers Nos. 120, 121 and 122 at the 74th Street Station. These are modern Combustion Engineering Co. corner-fired boilers, each rated for the production of 500,000 pounds per hour of steam at a pressure of 1250 psig and temperature of 950°F.
- Con Edison's turbine generators Nos. 9 and 10 at the 74th Street station. These are Westinghouse compound condensing turbines, supplied via a common header with steam from boilers 120, 121 and 122. Turbine generator No. 11 is also supplied from this header.

- Unused building space is available in Con Edison's 74th Street Station, sufficient for installing the additional equipment that would be needed for a water-based system.

- The chilled water distribution systems at Rockefeller University, particularly those in the newer buildings (Tower and LARC) may be suitable for both hot water and chilled water.

- The on-site hot water and chilled water systems that supply most buildings in the New York Hospital-Cornell Medical Center complex appear to be suitable for connection to a water-based district heating/cooling system with little modification.

The conceptual design developed is based on a 2-pipe distribution system that would supply hot water for heating in the winter and chilled water for air conditioning in the summer. There are a number of variations that could be explored, but all would have in common the features listed below.

- The source of heat during the winter months would be steam from No. 9 or No. 10 turbine at Con Edison's 74th Street Station. Initial operation on a small scale might be undertaken with minimum investment by taking steam from the crossover line between the high pressure and low pressure turbine casings. This steam could be used either to heat hot water in a heat exchanger or to operate a small back-pressure turbine that would produce both hot water and electricity (13-15). Ultimate development of full capacity and maximum combined heat and power production would require alterations to the turbines to make them suitable for the production of hot water. There are precedents for this type of alteration (11). Backup, if required to meet an emergency, could be steam produced in existing package boilers.

- The source of cooling during the summer months would be new electric-driven centrifugal chillers to be installed at Con Edison's 74th Street Station. The heat sink for these units can be seawater, using the existing intake and discharge systems used for Nos. 9 and 10 turbine condensers.

- The change-over from hot water to chilled water and vice-versa would take place, for example, on May 15 and October 15, following the pattern used in a number of New York apartment buildings.

- Hot and chilled water storage would be provided, possibly using vertical cylindrical tanks but more probably by using underground structures, shaped like swimming pools. The provision of some storage is considered essential, particularly to avoid an inordinate increase in the summer electric peak, but also to permit improved operating economy by shifting the time of load. Chilled water storage during the summer months will make it possible to use lower-cost off-peak power, available at night, rather than the more costly on-peak power. Hot water storage during the winter months will make it possible to cogenerate electric power during the hours it is in greatest demand and can replace power from the highest cost alternative sources.

- The distribution mains would be placed along the river bank, under the existing walkway, in order to minimize excavation of the city streets. Existing tunnels, formerly used for transporting coal from the river to Con Edison's 74th Street Station and to Rockefeller University, might also be used. Other tunnels exist at locations between these two sites.

- Typical western European practice is to install a heat exchanger (and meter) at each building to isolate the main headers from the loops within the building. This practice was established many years ago and has obvious advantages. However it has some disadvantages and its desirability is to be reexamined, giving consideration to today's high energy costs.

- Typical practice in designing hot water district heating systems is to use a flow-main temperature of about 180°F and a return temperature of 110°F, as long as the outdoor temperature is above 20°F. At lower outdoor temperatures the water temperatures are increased to an indicated 240°F when the outdoor temperature is 0°F. However, it may be desirable to design for a maximum of 212°F, at least for the storage portions of the system, so as to avoid the cost of pressurized storage tanks.

- Study is needed to determine the extent of changes necessary in buildings at Rockefeller University and New York Hospital in order to connect them to the hot water/chilled water system. However, many of the buildings inspected appear to be readily connectible without costly changes (See Appendix F).

- It appears at first glance that the replacement of existing steam radiators by hot water radiators would be so costly as to be impractical. Where chilled water distribution systems exist it may be practical to convert them to the use of hot water, at least to carry part of the load.

FACILITIES AND CONCEPTS DISCARDED

Facilities that were studied and discarded were the following:

- Con Edison's 60th Street Station, which has very limited space and contains only package boilers.
- The use of package boilers at Con Edison's 74th Street Station as primary heat sources.
- No. 11 back-pressure turbine generator at 74th Street Station, which is now in cogeneration service and supplying steam to the existing distribution system.
- Those portions of the steam distribution systems at Rockefeller University and New York Hospital required to supply steam for uses other than space heating. Some of this equipment should be retained, to help reduce the cost and complexity of the proposed district heating/cooling system.

There are a great many different design concepts that might be considered. Reasons for initially rejecting some of the other alternatives are given in the list below. The alternatives listed include those that come to mind either because they are applicable to other situations or because they have been described in the literature.

Higher Temperature System

The use of water at a temperature of, say, 275° F. would have the advantage of making it possible to generate low pressure steam in heat exchangers in the buildings served. Thus a larger load could be served at Rockefeller University, which has several old buildings with steam radiators. However, such a system would cogenerate 20 to 25 percent less electric power, and hot water storage would have to be in pressure tanks, requiring a high investment. It is believed that in the 60th to 74th Street area it will be found that a large portion of the heating load can be served without the use of high temperatures. However, this needs to be confirmed by a series of inspections.

Four-Pipe System

There are a number of situations requiring simultaneous heating of one portion of a building and cooling of another portion. The four-pipe system makes this possible. It also makes it possible to provide heat for domestic hot water in the summer and to remove all existing on-site heating and cooling systems. However, the four-pipe system is more costly and requires more space. Two-pipe systems have been widely used and accepted in apartment buildings. It is likely to be more economical to retain portions of the existing plants that now supply summer heating and winter cooling, rather than to convert the entire project to a full-scale four-pipe system, which would be underutilized.

Absorption Chillers

All proposed systems incorporating the regular use of these devices are considered inherently more costly because of high current costs of steam in New York City. Existing units were installed when the cost of making steam was low and because of their simplicity of operation and maintenance. A large portion of the savings obtainable by the proposed system may be derived from the elimination of low-efficiency absorption chillers.

Heat Pumps

It has been suggested that heat pumps be incorporated into a hot water system to reduce the return water temperature, thus increasing the heat carrying capacity of a given line. This system would be inherently less efficient, and it appears doubtful that the benefits of larger line capacity would offset the cost of buying and operating the heat pumps. Normal designs for the application of heat pumps for building heating take energy from a no-cost source, such as the atmosphere, and raise it to the required temperature. For a hot water district heating system, any energy removed from the return water must be replaced at the power house.

CHAPTER 4 - PRELIMINARY SYSTEM ANALYSIS

This chapter discusses the steps taken thus far to conduct the preliminary feasibility analysis. It is based on the conceptual design developed in Chapter 3, and focuses on some of the details described in the Scope of Work (in Appendices D and G). Results of the preliminary feasibility analysis will be given in Volume II, to be published in the fall of 1985.

The analysis is divided into three parts: technical, market, and economic. The technical section identifies potential methods of retrofitting an electric utility plant for hot water district heating and cooling, and for routing new piping in a dense urban environment. The market analysis section addresses the ability of the system to develop a user base. The economic section identifies issues affecting the potential cost of the system, effects upon Con Edison regulated rates, and cost advantages to potential customers.

TECHNICAL ANALYSIS

System development and evaluation will be performed for the key elements of a water-based district heating/cooling project using the conceptual design of Chapter 3 as a starting point. The contractor, under NYCEO direction, will prepare the following:

- Facility and System Design Criteria;
- Preliminary Flow Diagrams;
- General Arrangement Sketches for Major Equipment and Piping;
- Preliminary Equipment List;

- Preliminary Cost Estimates for Engineering Design and for Construction;
- Operations and Maintenance Cost Estimates.

Heat Source

By using hot water as the heat transport medium, steam can be extracted from a turbine at a much lower pressure than if steam were to be the transport medium. As a result, a higher electric output is obtainable in a hot water system. Turbines T9 and T10 at Con Edison's 74th Street Station are of identical design. Both can be converted to cogeneration. Based upon the collection and review of turbine data from Con Edison and Westinghouse, various turbine retrofit schemes will be evaluated that could provide for the cost-effective extraction of heat. Steam can be extracted from the crossover piping between the high pressure (HP) turbine and the low pressure (LP) turbine with minimal retrofit. The exhaust pressure from the HP turbine is 23.7 psia, high enough to produce 230°F hot water. A heat balance of the turbine has to be performed to determine the optimum extraction steam flow, which is dependent on the minimum required steam flow through the LP turbine and the heat load demand. More heat can be extracted by converting the turbine to backpressure operation. This will be considered as a further option for full development of the heat-supply capacity of the turbine. Secondary sources could be the package boilers at 74th Street Station.

Extracted steam can be used to produce hot water for heating in a closed circuit, via a two-stage heat exchanger. The selection of a hot water distribution temperature will be coupled with the development of turbine retrofit schemes. A description of the turbine cycle modifications and additional auxiliary systems (e.g., hot water heat exchangers, new back pressure turbines, etc.) will be prepared, to define the bases of cost estimates for construction and for operation and maintenance.

Domestic Hot Water (Summer)

With the two-pipe system envisioned in the conceptual design, it would be necessary to have provision for transport of hot water for domestic uses in the summer, when the two-pipe system is used to transport chilled water. Several alternatives are available. The domestic hot water could be supplied by separate small hot-water heaters in each building, or by retaining some of the existing boiler capacity in either Rockefeller University or New York Hospital.

Alternatives would be to install a separate hot water boiler at the 74th Street station, or to extract steam from the existing boilers there, with additional small-size piping for the buildings using domestic hot water. (These hot water connections could be used year round with the turbine hot water system by-passing the boiler in winter.) The second method may be helpful in preventing cross-contamination of the domestic water with building heating water. The reduction in cost of end-user piping connections may also offset the cost of the additional piping to the buildings.

Chilled Water System

Electrically-driven centrifugal compressors are commonly used for large chilled water systems because of their high efficiency. For this project, a potential electricity source is the existing generating units at the 74th Street Station. In addition, there is a possibility of using excess steam from the plant's boilers to operate a turbine-driven centrifugal chiller. The amount of available excess steam has to be determined. The exhaust steam from the turbine could then be used for other purposes, such as to produce hot water for heating elsewhere. Another possibility is to use excess low-pressure steam from the boilers to operate some existing absorption chillers, to carry part of the cooling load. For this project, it is not necessary to scrap all the existing equipment at the customers' plants. It may be economical to use part of it in order to achieve an overall optimal cost-effective system. We have already mentioned possible retention of some on-site boiler capacity for summer heating and hot-water needs.

Selection of Supply and Return Temperatures

In winter, low temperature hot water would be produced. The supply water temperature would probably be 230°F and below. Such low temperature systems are commonly used because they result in higher steam cycle efficiency than a higher temperature hot water system. The capital cost for piping is usually lower, too, because high-temperature insulation is not required. The return water temperature would be approximately 140°F. These are the temperatures often used for systems of this type. The possibility of employing higher temperatures is being reviewed. At higher temperatures more heat is delivered per unit mass flow, and therefore pipes and other equipment can be smaller, which reduces cost. However, if a two-pipe year-round system is used, the pipes may be oversized anyway, in order to accommodate the lower temperature differential for chilled water (40°F supply, 55°F return).

Final selection of operating temperatures will be based on balancing all factors together.

Thermal Storage

The provision of thermal storage of hot or chilled water has a leveling effect on thermal and electric peaks. As a result, the turbines can operate at near maximum efficiency most of the time. Thermal storage would be accumulated during low electrical demand and released during electric peaks in order to level electric generation. Cooling capacity can be provided in the liquid phase or solid phase (ice). After the volume and the type of storage vessels required are determined, locations for storage facilities can be investigated. Possible locations include sub-basements and tunnels within the customer facilities, vaults under streets and sidewalks, and the 74th Street Station.

Distribution System

The distribution system is usually the largest element of capital cost in a district heating system. The special requirements and special cost-saving measures applicable to this project have been discussed earlier. Numerous proven design approaches, types of pipe, insulation, etc. are available. Before specific approaches can be developed further, the configuration of the rest of the system has to be established more clearly and the potential rights of way inspected. This is being done by the contractor.

Connections to Buildings

Where hot water and chilled water systems are currently being used, as is the case in many buildings at New York Hospital, the retrofit work required is limited to addition of a heat exchanger, or modification of the existing system with controls and piping to provide for a primary-secondary piping system.

In the case of forced air systems, a heat exchanger is also necessary in order to use the hot water as a heating medium. Although there is a drop in efficiency when heat exchangers are used, this can be minimized by use of a plate heat exchanger, for example. Use of heat exchangers isolates the primary water distribution system from the various customers' systems. This is the preferred practice in western Europe and the United States.

Direct connection between the district heating system and the customers' heating systems is used in Eastern Europe. It is cheaper than use of heat exchangers and saves some energy. Where buildings can be directly connected between the district heating system and the customer's heating system, hot water from the district heating system mixes with the return water from the radiators in a mixing valve before return to the main. This results in no sacrifice of energy efficiency.

A key objection to direct connection is the danger of contaminating the district heating supply water with air, and possibly with impurities, from the customers' piping systems, which could cause corrosion in the main supply piping. (This is also the reason for the absence of condensate return in district steam systems.) Other objections to direct connection are hazards of high pressure and problems of water hammer. Because of the need to conserve costly energy, the possibility of designing a safe, clean direct-connection system is being reviewed.

MARKET ANALYSIS

Rockefeller University and New York Hospital constitute major potential loads for the proposed project. Preliminary inspections of these facilities are described in Appendix F. The managements of both institutions have stated that they prefer to buy the energy they use rather than to invest in on-site facilities. They do not wish to be in the utility business. Therefore, they are good candidates as loads for the proposed project, provided the cost of district heating and/or cooling is attractive.

The capacity of the 74th Street Station to supply a district heating load economically may exceed the load available at Rockefeller University and New York Hospital. A rough calculation of heat send-out capacity of the 74th Street Station, assuming full conversion of one turbine to a hot water system, indicates that a peak load of 90 MW (thermal) could be carried. This compares with peak demand of 40 MW for Rockefeller University and New York Hospital combined.

This is not to say that the full capacity would have to be utilized to develop an economical project. Nevertheless, to account for the possible need for additional load, the characteristics of heating and cooling systems in east side Manhattan buildings were reviewed. Appendix H describes types of heating and cooling systems in buildings in the area. Many of these buildings have modern heating systems that are found connected to hot-water district heating systems elsewhere(6). However, the number of buildings in the area which could actually be connected to a water-based district heating and cooling system would have to be determined by observation.

In order to obtain data on specific building systems in the area, a sample of HVAC drawings was requested from the New York City Buildings Department for buildings in the project service area. Six samples were requested, including one of a building at New York Hospital. Three of the requested sets of drawings were found, the others could not be found. One set of drawings, for New York Hospital, showed that a steam system had been retrofitted to one building in 1968. Drawings for the other two samples, a large apartment house and an office building, were incomplete and in poor condition.

We conclude that we can not rely on Building Department records to determine suitability of buildings for connection to the district heating/cooling system. Drawings and data must be obtained from the building owners or the HVAC engineers who designed the systems, and building inspections must be conducted for verification. However, this is not necessary for the current preliminary study. If the results of this study are favorable, a building survey would be recommended for the next phase.

ECONOMIC ANALYSIS

A preliminary economic analysis of the proposed district heating and cooling system is being performed from both system and customer points of view. This analysis includes estimated capital costs, operating and maintenance (O&M) costs, financing approaches, phasing of the project development and relevant laws, rules, regulations and procedures applicable to capital investments by regulated utilities in New York City. With regard to this last statement it should be noted that, while Con Edison is a private utility and is currently regulated with respect to the sales of electricity, natural gas, and steam, hot water district heating is not regulated in New York State.

The first step in the economic analysis is to formulate a proposed district heating/cooling project for the study area. Specific New York Hospital and Rockefeller University buildings selected in the Market Analysis are being analyzed with respect to:

- Heating and cooling load and load profiles (daily, seasonal, annual);
- Geographic location and distribution system routing.
- Impact of HVAC system retrofit on operating and maintenance costs.
- Total system heating and cooling loads in relation to equipment and distribution characteristics.
- Description and schematics for major equipment and piping including modifications at 74th Street Station.
- Estimated total system performance based upon composite load curves. Fuel and electric power consumption values for the project are being calculated for a typical year.
- Capital cost estimates for the new central plant facility and distribution systems, based upon data from equipment vendors for major equipment and piping and in-house data for balance of plant equipment. Installation costs are being verified by contact with local contractors.

- A proposed schedule of implementation for the construction of the project.
- Capital requirements for building connections.

The economic analyses performed from the system point of view (return on investment) uses a required-revenue approach. The analysis will determine the annual costs for each investment phase, the composite costs and the unit cost of heat and chilled water. The annual costs needed to support the district heating/cooling investment are calculated based on return rates, book life, tax information and insurance rates applicable to each ownership option under consideration. The method used in the analysis will develop the total system costs comprising fixed costs and operating expenses, and compare these costs to the total quantity of heat and chilled water sold, to determine the minimum required cost of district heating and cooling. The fixed costs are calculated from the required return on invested equity, interest on debt, depreciation, applicable taxes and insurance. The operating expenses are calculated from O&M labor, O&M material, fuel costs, energy costs, pumping cost, penalties associated with electric capacity loss, if applicable, and taxes. A sensitivity analysis will be performed with respect to capital cost changes, load factor, fuel cost changes, etc. A computer program will be used that is capable of modeling a district heating system of any ownership option chosen and any number of development phases required. An example of the output of the computer model is given in Table 2.

The economic analysis that is performed from the customer point of view will use the district heating and cooling rate determined above, combined with customer-specific investment costs, operating and maintenance costs, insurance costs and other costs to determine total district heating and cooling costs. These costs will be compared against existing on-site energy costs, operating and maintenance costs, and other costs, to determine the net impact of district heating/cooling, and payback

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Table 2

ECONOMIC ANALYSIS OF DISTRICT HEATING

Start of Evaluation	1985		Economic Factors			
Unit Costs	1984	Escalation	Preferred Stock Ratio	0	Book Life - Yrs	30
			Return on Preferred Stock - %	0	Income Tax Rate - %	0
Electricity - $/MWh	30	7.5	Common Stock Ratio	0	Tax Credit - %	0
Pumping Power-$/MWh	30	7.5	Return on Common Stock - %	0	Tax Life - Yrs	30
O&M Labor -$/ManYr	30000	7.5	Debt Ratio	1	Accel. Tax Deprec.	0
O&M Materials -% Cost	----	7.5	Debt Cost - %	7	Insurance Rate - %	0
Property Taxes - %	0	2.5	Weighted Cost of Capital - %	7	Gross Receipts Tax-%	5
Steam - $/1000 Lbs	2.07	1				

Year	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
A. Annual Quantities										
1. District Heat - MBtu/yr	125051	125051	125051	125051	125051	125051	125051	125051	125051	125051
2. Electricity Loss - MWh/yr	5350	5350	5350	5350	5350	5350	5350	5350	5350	5350
3. Pumping Energy - Mwh/yr	795	795	795	795	795	795	795	795	795	795
4. Steam - 1000 Lbs/yr	17600	17600	17600	17600	17600	17600	17600	17600	17600	17600
5. O&M Labor - ManYr/yr	2	2	2	2	2	2	2	2	2	2
6. O&M Material-% year's Inv	1.42%	1.42%	1.42%	1.42%	1.42%	1.42%	1.42%	1.42%	1.42%	1.42%
B. Unit Costs										
1. Replacement Elec. - $/MWh	32.25	34.67	37.27	41.27	44.36	47.69	55.91	60.10	64.61	69.46
2. Pumping Electricity-$/MWh	32.25	34.67	37.27	40.06	43.07	46.30	49.77	53.50	57.52	61.83
3. O&M Labor - $1000/ManYr	32	35	37	40	43	46	50	54	58	62
4. Steam - $/1000 Lbs	2.09	2.11	2.13	2.15	2.18	2.20	2.22	2.24	2.26	2.29
C. Investments - $1000	3197	0	0	0	0	0	0	0	0	0
D. Annual Carrying Charges-$1000/yr										
1. Return on Preferred Stock	0	0	0	0	0	0	0	0	0	0
2. Return on Common Stock	0	0	0	0	0	0	0	0	0	0
3. Interest	224	216	209	201	194	187	179	172	164	157
4. Book Depreciation	107	107	107	107	107	107	107	107	107	107
5. Tax Depreciation	107	107	107	107	107	107	107	107	107	107
6. Income Taxes	0	0	0	0	0	0	0	0	0	0
7. Deferred Taxes	0	0	0	0	0	0	0	0	0	0
8. Property Tax	0	0	0	0	0	0	0	0	0	0
9. Insurance	16	16	16	16	16	16	16	16	16	16
Sub- Total	346	339	331	324	317	309	302	294	287	279
E. Operating Expenses - $1000/yr										
1. Replacement Electricity	173	185	199	221	237	255	299	322	346	372
2. O&M Labor	65	69	75	80	86	93	100	107	115	124
3. O&M Materials	45	49	52	56	61	65	70	75	81	87
4. Pumping Cost	26	28	30	32	34	37	40	43	46	49
5. Steam Cost	37	37	38	38	38	39	39	39	40	40
Sub- Total	345	368	393	427	457	488	547	586	627	672
F. Gross Receipts Tax-$1000/yr	67	66	66	66	66	67	68	69	69	70
G. Required Revenues- $1000/yr	758	773	791	817	839	864	917	948	983	1021
H. Unit Cost of Heat - $/MBtu										
1. Fixed Expenses	$2.77	$2.71	$2.65	$2.59	$2.53	$2.47	$2.41	$2.35	$2.29	$2.23
2. Replacement Electricity	$1.38	$1.48	$1.59	$1.77	$1.90	$2.04	$2.39	$2.57	$2.76	$2.97
3. Operating Expenses	$1.38	$1.46	$1.55	$1.65	$1.75	$1.86	$1.98	$2.11	$2.25	$2.40
4. Gross Receipts Tax	$0.53	$0.53	$0.53	$0.53	$0.53	$0.53	$0.54	$0.55	$0.55	$0.56
5. Reinvestment Fund	$0.67	$0.69	$0.70	$0.73	$0.75	$0.77	$0.81	$0.84	$0.87	$0.91
	$6.73	$6.87	$7.03	$7.26	$7.46	$7.68	$8.15	$8.43	$8.73	$9.07

periods for the customer. Where applicable, other impacts on revenues, such as release of space for revenue producing purposes will be assessed. In addition, the costs of service from the proposed district heating/cooling system will be compared with other options available to the building owners, such as:

- Con Edison steam for heating and cooling.
- Con Edison steam for heating, Con Edison electricity for cooling.
- New on-site plants for heating and cooling.
- New on-site plants for heating, Con Edison electricity for cooling.

The economic analysis for the customer will also be performed using a computer model. This computer model takes into consideration district heating investments with or without financing, taxes, escalation, expensing deductions, depreciation, multiple fuel use and other factors as dictated by a specific customer. Once the basic model is set up for a specific customer the input can be modified to determine the effect of alternative financing schemes and to perform sensitivity analyses of different factors on the payback period. The analysis is designed to present comprehensive results on an annual basis for a 20 year period. (Examples of the customer analysis are shown in Table 3.) The results of the economic analysis from both the system and the customer points of view will be presented graphically. Life-cycle costs of on-site equipment and supply/distribution equipment will be determined. Comparative cost analyses will be performed using both rate-of-return and present-worth-of-expenditures methods.

Ownership and Financing Analysis

There are several operator/ownership options potentially available to the district heating system, and each will have specific institutional and economic characteristics that must be

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TABLE 3

COST COMPARISON FOR:

PRESENT YEAR:	1984
HOOKUP YEAR:	1985
TOTAL CONVERSION COST (PRESENT YEAR):	$6,500
ESCALATION RATE:	6.50%
TOTAL CONVERSION COST (HOOKUP YEAR):	$6,923
PERCENT FINANCED:	100%
CASH INVESTMENT:	$0
TERM OF LOAN (YEARS):	15
INTEREST RATE:	9.00%
ANNUAL PAYMENT:	$859
TAX RATE:	50%
EXPENSING DEDUCTION:	$5,000
YEARS OF DEPRECIATION:	5
ACCELERATED DEPRECIATION? (1=YES,0=NO):	1
POTENTIAL END USE ENERGY SAVINGS FROM CONVERSION:	13%
ESTIMATED CURRENT BOILER EFFICIENCY:	60%
HEATING EQUIPMENT TYPE:	GAS BOILER

		------------ CURRENT ANNUAL FUEL USE ------------			
		PRIMARY	BACKUP	BACKUP	TOTAL
FUEL TYPE:		GAS			
CONSUMPTION (MILLION BTU):		1143			1143
ESTIMATED DH CONSUMPTION (MILLION BTU):					537
CURRENT FUEL RATE ($/MILLION BTU):	5.68				
FUEL ESCALATION RATE:	7.50%				

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 ($)	CUMULATIVE SAVINGS ($)	ENERGY COST SAVINGS ($)
1985	6.11	8.00	6979	4298	236	623	5156	1615	3438	3438	2681
1986	6.56	8.27	7503	4443	257	602	5302	-1018	1184	4621	3060
1987	7.06	8.56	8065	4599	280	579	5457	-1242	1366	5987	3467
1988	7.59	8.96	8670	4813	305	553	5672	-1450	1548	7535	3857
1989	8.15	9.31	9320	5001	333	526	5860	-1695	1766	9301	4319
1990	8.77	9.70	10019	5211	363	496	6070	-2156	1793	11094	4809
1991	9.42	10.42	10771	5598	395	463	6457	-2355	1960	13054	5173
1992	10.13	10.90	11579	5856	431	428	6714	-2648	2217	15270	5723
1993	10.89	11.42	12447	6135	470	389	6994	-2962	2492	17762	6312
1994	11.71	11.98	13381	6436	512	347	7295	-3299	2787	20549	6945
1995	12.58	12.42	14384	6672	558	301	7531	-3706	3148	23697	7712
1996	13.53	13.09	15463	7032	608	250	7891	-4090	3482	27179	8431
1997	14.54	13.81	16623	7419	663	196	8278	-4504	3841	31020	9204
1998	15.63	14.60	17870	7843	723	136	8702	-4945	4222	35242	10026
1999	16.81	15.44	19210	8295	788	71	9153	-5422	4634	39876	10915
2000	18.07	16.36	20650	8789	0	0	8789	-5931	5931	45807	11862
2001	19.42	17.34	22199	9315	0	0	9315	-6442	6442	52249	12984
2002	20.88	18.41	23864	9890	0	0	9890	-6987	6987	59236	13974
2003	22.44	19.56	25654	10508	0	0	10508	-7573	7573	66809	15146
2004	24.13	20.30	27578	11174	0	0	11174	-8202	8202	75011	16404

PAYBACK (NO FINANCING) 2 Years

PAYBACK (WITH FINANCING) 3 Years

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factored into the analyses. As a preliminary step in the economic analyses, various options will be identified. These options will be reviewed, and certain options will be selected for detailed analysis. Operator/ownership options could include the following:

- Con Edison to finance, own and operate the hot water district heating system.
- Formation of a new subsidiary by Con Edison to finance, own and operate the district heating system and purchase the hot water and chilled water from the 74th Street Plant under a long term contract.
- Con Edison to form a new independent company with financing separate from the present company.
- A joint venture with an independent company and Con Edison to finance, own and operate the district heating system with heat purchased from the 74th Street plant.

In case the rate of return on the proposed system is much lower than the return on electric plant investment, innovative financing methods would become important. In such a case, the system might be subdivided into different operating entities with different owners taking advantage of a combination of innovative financing schemes. Innovative financing schemes that may apply include:

- Leverage Lease - The assets or a portion of the assets of the project would be sold to a buyer interested in the associated tax benefits and leased back by the original owner who may not be able to use such tax benefits.
- Privatization - A private concern would be given primary responsibility for the design, financing, and building of all or part of the system. The system would then be operated by the private party under a long term service contract, or the system or part of the system might be leased to Con Edison or another party that will operate it. This type of arrangement often saves substantial time and thus money in the development of the system.
- Floating Rate Bonds - This innovation allows the bond issuer to pay a lower rate than established for conventional long term bonds while investors earn more than

they would for short-term instruments with a maturity date the same as the first put date.

- Certificates of Participation - The certificates represent a proportionate interest in a lease and option to purchase. The party issuing the certificates pays rent on the leased property equal to the principal and interest payments. When all rental payments are completed or at the issuers option and for a predetermined price the issuer may purchase the property.

Other Factors

The following factors, which would ordinarily be included in a full-scale economic analysis of a proposed project for a public utility, have been deferred from consideration in the present study:

- Rate design - electric, steam, hot water, chilled water; to be compatible within applicable rules and procedures;

- Allocation of capital costs between different plants and different services;

- Apportionment of revenue credits between different plants and different services;

- Analysis of the effect of economic dispatch rules and procedures on the district heating/cooling system.

These matters do not directly affect the preliminary feasibility analysis. They can be taken up in a subsequent phase, should the proposed system prove to be economically, technically, and institutionally viable.

CHAPTER 5 - RESULTS AND LESSONS LEARNED

In developing the project, the following principles and procedures were important to making progress.

1. We worked in partnership with Con Edison in developing the the project, keeping in mind the differences in objectives and operating philosophies between a public utility and a municipality. While NYCEO carried lead responsibility and did most of the work, Con Edison contributed in essential ways. This included:

   - Suggesting specific plants as heat sources, and arranging plant inspections.
   - Providing essential data on the existing steam system.
   - Participating in development of the Scope of Work.
   - Participating in the selection of the contractor/consulting engineer to perform the study analyses and calculations.

2. New York City government, like municipalities generally, has little expertise in power generation and supply, because that has been the responsibility of public utility companies, not cities. In order to develop the project, we had to develop in-house expertise, so as not to become captives of the consulting firms hired to do the detailed technical work. We did this by drawing on NYCEO staff experience in industry, by reviewing related work by Public Service Electric & Gas (N.J.) and other utilities, and by engaging a retired senior industrial executive with experience as a buyer of district heating/cooling cogeneration systems to advise us. In this

way, the project development was based largely on first-hand experience of similar projects.

3. Investor-owned utilities are managed on the basis of allowable return on investment. It is difficult to increase Con Edison's district heating revenues enough to make the return on steam system investment match the return on electric plant investment. Further increases in steam rates would give steam customers a greater incentive to disconnect, and to install their own boilers, thereby increasing costs still further to customers remaining on the system. This kind of downward spiraling collapse of the customer base has been a factor in the discontinuance of district heating systems elsewhere in the U.S. The project includes study of innovative financing approaches to help avoid this problem.

4. The development process included the following steps, which have been used in similar sequences for other government study project procurements in the United States. This methodology may prove useful to other local governments who are engaged in district heating and cooling development projects.

   - Limited first-hand investigation of potential project sites and concepts, leading to in-house selection of preferred project site and preliminary conceptual design.

   - Preparation of a site-specific Scope of Work based on the preliminary conceptual design.

   - Parallel development of a list of potential contractors and a Request for Qualifications.

   - Evaluation of qualifications of potential contractors, from documentation submitted and from interviews.

   - Development of a Request for Proposals, for the potential qualified contractors, incorporating the Scope of Work.

   - Selection of the contractor/consultant, through independent evaluations by NYCEO and Con Edison, followed by comparison of results.

We selected the candidate contractor whose proposed innovative approaches seemed most likely to lead to cost-effective solutions to the technical and financing issues. Based on customary procedure, the next step would be an investment-level feasibility study, culminating with a prospectus for financing. Normally such a detailed feasibility study would be conducted by potential developers or investors in the proposed system.

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GLOSSARY

Absorption chiller (absorption air-conditioner): A refrigerator in which the driving power is supplied by heating (e.g., low pressure steam) instead of by mechanical compression.

Back-pressure turbine: (See topping turbine). A turbine in which the pressure at the end, or "bottom", of the steam cycle is above atmospheric, still high enough to supply mechanical power. Also called a "non-condensing" turbine.

Cogeneration: Colloquial contraction for combined heat and electric power generation.

Common header: A main pipe line that receives fluid (steam, water, etc.) from several sources and from which fluid is tapped off to branch lines serving various areas or pieces of equipment.

Condensing turbine: A steam turbine designed for maximum utilization of steam energy to produce shaft power, especially in order to drive an electric generator with maximum efficiency. At the "bottom" of the condensing steam cycle, the spent steam is condensed to liquid water at a pressure far below atmospheric (usually measured as a few inches on a water manometer).

District heating: A system of producing heat at a central station and distributing it to buildings in a city or neighborhood. The distribution medium may be steam or water. Often combined with cogeneration at the central plant.

Extraction turbine: A turbine from which steam is extracted, for use elsewhere, at an intermediate pressure and temperature in the turbine cycle, between the "top" and the "bottom". Only a portion of the steam at the extraction point is taken out; the rest impinges on turbine blades, to produce more shaft power.

Heat rate: In a steam-electric plant, the amount of heat required to produce a kilowatt hour of electricity.

Package boiler: A factory-assembled boiler, shipped as a complete system. Contrasts with field-erected boiler, which is constructed on site.

Psia: Pounds per square inch absolute, i.e., the actual pressure.

Psig: Pounds per square inch gauge, i.e., pressure above atmospheric.

Topping turbine: A steam turbine from which steam is taken, for use elsewhere, at the lowest temperature and pressure of the turbine operating cycle, after the steam, initially at higher temperature and pressure, has transferred energy to the turbine blades, producing shaft mechanical power. The term "topping" denotes the high temperature part ("top") of the steam cycle, as contrasted to the low temperature part ("bottom") of the cycle, where the steam is taken off.

APPENDIX A

CANDIDATE CONSULTING FIRMS

ASEA - Stal, Inc.
525 Executive Boulevard
Elmsford, New York 10523

EBASCO Services, Inc.
2 World Trade Center
New York, NY 10048

Stone & Webster
One Penn Plaza
New York, NY 10119

Burns & Roe, Inc.
700 Kinderkamack Road
Oradell, NJ 07649

Amman & Whitney
2 World Trade Center
New York, NY 10048

C.T. Main Corporation
Southeast Tower
Prudential Center
Boston, MA 02199

American Hydrotherm Corp.
470 Park Avenue South
New York, NY 10016

Carlson & Sweatt P.C.
275 7th Avenue
New York, NY 10001

Bechtel, Inc.
15740 Shady Grove Road
Gaithersburg, MD 20877

Danpower Inc.
1000 Connecticut Ave., NW
Washington, DC 20036

APPENDIX B

NEW YORK CITY ENERGY OFFICE

REQUEST FOR QUALIFICATIONS

June 19, 1984

New York City Hot Water District Heating and Cooling Feasibility Study

Introduction

The New York City Energy Office (NYCEO) in cooperation with Consolidated Edison Company of New York, Inc. ("Consolidated Edison") and the New York State Energy Research and Development Authority, requires a qualified consulting firm to assist the NYCEO in assessing the preliminary economic and engineering feasibility of hot water district heating technology at certain sites within the Con Edison central steam system service area.

It has been established through previous studies that use of a hybrid steam-hot water system may be a promising approach toward bringing district heating service to additional customers in United States urban areas. Existing district steam systems have great difficulty attracting new customers in competition with on-site boilers. However, if steam at a steam generating plant is used to produce heat for new hot water loops, it is possible in some cases to distribute this hot water to buildings economically.

Background

The Consolidated Edison steam district heating system is the largest in the United States, extending from the southern tip of Manhattan north to 96th Street on the west side of Central Park, and north to 89th Street on the east side. Most of the major commercial buildings in Manhattan use Consolidated Edison steam for space heating, with substantial quantities utilized for air conditioning and hot water production. As a major source in satisfying New York City's energy supply, the system supplied 27 billion pounds of steam to 2,038 customers in 1982. A major part of this steam came from steam turbines in electric generating plants.

Although currently stabilized, high costs had resulted in a number of customers leaving the Consolidated Edison steam system. These customer losses have led to escalating costs for remaining customers. Hot water-based district heating and cooling systems could potentially reduce costs for transmission and distribution piping, improve efficiency, lower plant equipment costs, provide greater potential for heat storage and offer great potential for use of moderate temperature waste heat from other sources. Consolidated Edison has agreed to explore the feasibility of such systems with NYCEO.

The basic study approach will be to evaluate the energy and economic effects of potentially supplying new Consolidated Edison thermal customers with hot water district heating and cooling service and to compare these results with the present costs of the service from the existing Consolidated Edison steam system and customer on-site systems. Potential new thermal loads will be identified. To determine whether such sites could be connected to the central steam system, Consolidated Edison generating plants, potential customer energy loads and HVAC systems and proposed heat transfer and distribution systems will be evaluated. The technology and methods chosen for adding new customers must be technically compatible with the existing system, i.e., existing generating facilities must be utilized and the incremental costs of the new technology must be cost-effective relative to the existing Consolidated Edison steam system. No design will be considered which will increase average Consolidated Edison system costs. Potential loads may be, for example, institutions, large apartment houses or commercial buildings.

Existing Consolidated Edison plants will be studied as potential heat sources, for example, the East 74th Street and East 60th Street Stations.

Locations and designs for one or more hot water transmission and distribution systems will be studied, possibly considering installation in streets, sidewalks or private rights of way.

Purpose of the Study

The purpose of the study is to assess the technical and economic feasibility of adapting hot water district heating and cooling technology to one or more sites on Manhattan's east side. The study will provide a basis for determining the potential for renovating an existing central district heating system and the economic impact of alternative system technologies on Consolidated Edison steam ratepayers. Project results will also help the City develop policy recommendations relative to district heating and cooling in New York City.

Procedure for Selection of Consultants

Firms interested should submit their qualifications in writing. Firms deemed best qualified will be invited for interviews to be conducted during the second half of July, 1984, preceding issuance of Request for Proposals ("RFP") in August 1984. RFPs will be sent only to firms deemed best qualified under this procedure.

No specific format is required for submissions. Submissions should include, but not be limited to, the following, which may be presented in any order, and in any combination, to bring out your firm's background and capabilities in the relevant fields most clearly.

Related Projects Completed or in Progress

Specify whether study, design, or construction.

If in progress, give status.

If construction complete, is plant operating?

Give name and telephone number of client representative for at least one project of each type (study, design, construction) listed.

Projects of interest are primarily district heating and cooling. Other projects, such as industrial cogeneration, utility steam and power, are also of interest if they have features relevant to district heating and cooling.

Types of Work

Give examples to illustrate:

- Experience in analysis, feasibility studies, design and construction of steam-electric combined heat and power projects in the United States, both utility and industrial;

- Experience in analysis of public utility management, rates, investment, regulation, marketing and related matters, especially relationships between electric and heat rates;

- Capability and experience in all analytical, cost-estimating, scheduling, financial analysis, investment analysis, rate-setting, legal and other specialties pertinent to organizing, financing and marketing district heating heat-only and cogeneration ventures;

- Experience in design of large-scale steam and hot-water systems for heat transmission and distribution;

- Experience with design of steam plants burning coal, oil and gas, and with environmental controls and regulations pertinent to such plants;

- Demonstrated knowledge of both United States and European district heating practices pertinent to the project;

- Capability and experience in all mechanical, electrical, structural and other engineering specialties and sub-specialties required to analyze performance and design of steam-generating and steam-electric cogenerating plants used by public utilities;

- Any other specific experience in district heating projects;

- Demonstrated resourcefulness in solving problems.

Massive detail is unnecessary and undesirable. You may use standard project descriptions.

Company brochures should be included, for general background.

Project Organization and Resumes

Indicate briefly how you usually organize a small study project on district heating (less than $100,000), for example, by a typical organization chart showing positions and functions.

Give resumes of personnel who will be employed on the project and specify the function of each. Give enough detail to qualify each individual for this project. You may submit your standard resumes and briefly supplement each with added material on district heating, etc.

If your submission is for a team comprising more than one firm, indicate whether you have worked together before and the role of each firm in prior projects.

Scope of Services

The following outline of the Scope of Services indicates possible areas of work. A detailed Scope of Services will be included in the RFP.

The Scope of Services to be included in the RFP will include, but not be limited to, the following areas:

- Review of current capital and operating costs, and future plans, of the steam utility;

- Analysis of all relevant types of equipment for applicability to the project;

- Collection of data and analysis of selected customer heating and cooling requirements, systems and costs;

- Analysis of heat source and transmission systems on the Consolidated Edison system;

- Assessment of costs and benefits of alternative hot water technologies to the customer, compared to existing Consolidated Edison steam and to the customer's existing system;

- Assessment of promising system designs for functional and economic feasibility;

- Analysis of applicable rate structures;

- Development of cash flow, income and balance sheet projections;

- Development of financing plans;

- Analysis of overall impact on utility revenues, costs and rate structure; and

- Evaluation of regulatory constraints.

Location of Contractor's Project Office

Give the location of your project office or offices that would conduct the project, if awarded. A project office location in New York City is desired but is not the major criterion for selection.

APPENDIX C

QUESTION GUIDE FOR INTERVIEWING PROSPECTIVE CONTRACTORS

1. Of your projects, which were built? Operating? Performance? What role did you play? Study? Design? Construction? Start-up? (Projects most closely related to hot water district heating.)

2. Of your projects that did not lead to construction, what were the tangible results? Benefits to the client? Benefits to others?

3. How were results of your feasibility studies verified? Designs reviewed? Cost estimates and heat charges to customers reviewed? By whom? Did they agree with your figures?

4. References (names and phone numbers) if not supplied earlier.

5. The project goal is to extend an existing steam DH system by adding hot water loops. Do you have an opinion about the probability of success? If so, based on what experience?

6. Have you been late or run over budget on projects listed in your submittal?

7. Sample reports that illustrate qualifications for this project?

8. Contract experience with NYC?

9. Experience with Con Edison?

10. Would you use computer modeling? Valid for this project? Programs available?

11. <u>Accomplishments</u> in specific technical areas that relate to the project:

    a. Hybrid steam - hot water district heating (DH) systems.

    b. Hot water DH systems.

    c. Transmission/distribution/piping. The high cost of these systems is a major obstacle. How reduce cost? Design, construction, water temperature and pressure? Are your opinions based on practical results? In which projects?

d. Role of foreign technology and equipment? Western European? Eastern European? Familiarity: First-hand?

e. Multi-building systems, supplied by public utility or on-site plants.

f. Connection of DH to buildings, including all types of HVAC, modern and out-moded.

g. Public utility combined-heat-and-power and heat-only generating plants.

12. Accomplishments in business areas:

a. Comparing cost of investment with cost of non-investment to achieve same result (life-cycle cost), e.g., DH vs. on-site boilers.

b. Utility planning of DH projects, including electric and heat load management, cost allocation, rate proceedings, permitting, testimony, arguing regulatory cases, raising financing (prospectuses).

c. Market analysis: Market share vs. cost, projection of capacity needs.

d. Selling DH to building owners: Analysis of efficiency of owners' use of DH supply, literature, presentations to owners.

APPENDIX D

NEW YORK CITY ENERGY OFFICE

REQUEST FOR PROPOSAL

September 11, 1984

New York City Hot Water District Heating and Cooling Feasibility Study

ERRATA and ADDENDA

PROPOSAL REQUIREMENTS

Page 2, paragraph 6, line 4, after "additional", insert: "terms, conditions and provisions required".

Page 3, last line, "condition" should be "conditions"; "provision" should be "provisions".

SCOPE OF WORK

Page 4, paragraph 1c), after "summer", add: "and design of systems for annual changeovers from heating to cooling and vice versa".

Page 4, after paragraph 1g) add: "h) Provision for supplying heat during forced outages".

APPENDIX A

Paragraph (b), line 5, after "71MW" add: "60 Hz".

Paragraph (b), line 9, after "36MW" add: "25 Hz".

APPENDIX B

Last paragraph, lines 3, 4 and 6, change "deck" to "duct".

PROPOSAL REQUIREMENTS

1. Qualifications

The qualification brochure you previously submitted will be incorporated into your proposal by reference and distributed to reviewers with your proposal. Therefore you need not submit resumes, descriptions of prior projects, or any other material already submitted in the qualification brochure.

2. Approach

Give a concise discussion of the work your firm will undertake to accomplish each Task of the Scope of Work. Your discussion should indicate your understanding of the scope and purpose of the project, and should describe your approaches to the various Tasks of the Scope of Work by referring to your specific experience comparable to, or applicable to, each item discussed. If such experience has been described in your qualification brochure, refer to the appropriate items in the brochure; do not repeat material in the brochure. If such experience was not described in your qualification brochure, describe it briefly or attach an appendix that describes it (such as copies of pages from prior reports, etc.). Include in your discussion any exceptions you take or modifications you desire to any item of the Scope of Work or schedule, and state whether any exception you take is essential, in your opinion.

If you propose major changes to the Scope or Schedule, document or otherwise justify them in detail by reference to experience in prior projects of your team or others.

Your discussion may also include suggestions for rewording or rearranging portions of the Scope of Work to make the Scope of Work clearer. Suggestions for rewording or other minor changes need not be justified in detail.

The Reference Case described in the Scope of Work was developed by NYCEO on the basis of the results of prior studies, by NYCEO staff and others, and from design, construction and operating experience of utilities, other firms and government agencies in the U.S. and Europe. It seeks to focus on proven approaches that have reasonably high *a priori* probability of successful application in the proposed project, and to avoid approaches that have proven unsuccessful in the past.

Proposers are free to make whatever use they can of the Reference Case, in accordance with their experience and judgement. Proposals based solely on study of the reference case and proposals based on alternative proven approaches that satisfy the same requirements and constraints are equally acceptable.

3. Level of Effort and Management Plan

The estimated effort required to complete the project is nine person-months. Describe your work management plan, preferably using a diagram. Show how all tasks and functions will be covered, and identify all personnel who will perform project work, and their functions. Distinguish principal or lead personnel from specialists and support personnel. Give a breakdown of hours by individual and by function or task, e.g. by a matrix. Provide an estimated time table to show the sequences in which you would perform the items listed in the Scope of Work and The Schedule of Key Dates.

4. Estimated Accuracy

Estimate the anticipated accuracy of the results (e.g. capital cost estimates, rate of return on investment, rates to be charged to heating and cooling system customers) you would expect to provide for the estimated effort, e.g. ± 10%, ± 25%, etc. Explain the basis for your accuracy figures, for example by giving references to prior work by your team or by others that supports your accuracy estimates.

5. Cost

Price the project, in accordance with New York City, Office of Management and Budget, Certificate CS-29C, Section V, Fee Standard for Study - Type Contracts, a copy of which is attached. Give a breakdown of cost to carry out Tasks 1 and 2 combined and a separate cost for Task 3. Note that the amount of detail given on a task or subtask in the Scope of Work is not proportionate to NYCEO's estimate of the relative efforts required for the different tasks. Include a warranty that the price quoted in this proposal does not exceed that charged or quoted others for services of similar nature and duration. Provide a payment schedule tied to the work management plan and time table.

6. Certain Contract Provisions

Part of the funding for this work is from a cost sharing agreement with the New York State Energy Research and Development Authority. In accordance with the cost sharing agreement, the City's Standard Contract shall include certain additional under the agreement, dated March 12, 1984, between the New York State Energy Research and Development Authority ("NYSERDA") and the City of New York, which terms, conditions and provisions include, without limitation, a requirement to provide insurance covering NYSERDA, the State of New York and the City of New York as insureds except for worker's compensation policies, or their respective interests may appear, as follows:

(a) Worker's compensation insurance as required by the laws of the State of New York;

(b) Employers liability or similar insurance for damages arising from bodily injury, by accident or disease, including death at any time resulting therefrom, sustained by employees engaged in performing this work, in an amount not less than $500,000;

(c) Comprehensive general liability insurance for bodily injury liability, including death, and property damage liability, incurred in connection with the performance of this work, with minimum limits of $1,000,000 in respect of claims arising out of personal injury or sickness or death of any one person, $5,000,000 in respect of claims arising out of personal injury, sickness or death in any one accident or disaster, and $1,000,000 in respect of claims arising out of property damage in any one accident or disaster;

(d) Comprehensive automobile liability insurance in respect of motor vehicles owned, licensed or hired, for bodily injury liability, including death and property damage, incurred in connection with the performance of this Agreement, with minimum limits of $500,000 in respect of claims arising out of personal injury or sickness or death of any one person, $1,000,000 in respect of claims arising out of personal injury, sickness or death in any one accident or disaster and $500,000 in respect of claims arising out of property damage in any one accident or disaster.

The City's Standard Contract also shall be subject to the relevant terms, condition and provision of the said agreement.

SCOPE OF WORK

INTRODUCTION

The background and general scope of the project are described in the Request for Qualifications.

The assignment for the consultant firm under this contract is to conduct a preliminary "pre-feasibility" or "phase zero" study in order to help New York City Energy Office (NYCEO) and Consolidated Edison to determine whether it is worth while to proceed with a full scale engineering/economic analysis of a water-based district heating/cooling project. The study will cover analysis of technical, economic, environmental and institutional feasibility. The study area will extend roughly from 74th Street to 60th Street on the East Side of Manhattan, focusing on buildings of Rockefeller University and New York Hospital - Cornell Medical Center.

The major constraints are:

(1) The fuel is primarily oil; use of coal is excluded.

(2) The load must consist of buildings with HVAC systems that are suitable for connection to a water district heating/cooling system, i.e. systems that can use hot water and chilled water.

(3) The project approach must maximize efficient use of fuel in electric and heat production.

(4) The technology and method chosen for adding new customers for heating/cooling service must be technically compatible with the existing Con Edison system and the incremental costs must be cost-effective relative to the existing Con Edison steam system. No design will be considered that will increase average Con Edison system costs.

(5) New York City street excavation costs are extremely high, and interferences are many. Innovative approaches for minimizing distribution and piping costs are required.

REFERENCE CASE

The reference case is an exemplary limiting case of minimum cost/ maximum revenue within the major constraints. The reference case is as follows:

A 2-pipe distribution system connected to Con Edison's 74th Street Station will supply hot water for heating in the winter and chilled water for air conditioning in the summer. There may be many variations that could be explored, but most would have in common the features listed below.

1. Sources of heating and cooling:

1.1 The source of heat during the winter months would be steam from T10 turbine at Con Edison's 74th Street Station. This unit is described in Appendix A. Initial operation on a small scale might be undertaken with minimum investment by taking steam from the crossover line between the high pressure and low pressure turbine casings. Ultimate development of full capacity, and maximum combined heat and electric power production, would require alterations to the turbine to make it suitable for the production of hot water. To obtain the most favorable economic result, both the electric and hot water capacities of the turbine would be utilized.

1.2 The source of cooling during the summer months would be new electrically-driven centrifugal chillers to be installed at Con Edison's 74th Street Station. The heat sink for these units can be seawater, using the existing intake and discharge systems.

1.3 Thermal storage would be provided in water, possibly using vertical cylindrical tanks (the European practice), but more probably by using underground structures, shaped like swimming pools. The provision of some thermal storage is considered important to avoid an increase in the summer electric peak and to permit improved operating economy by shifting the time of load.

1.4 The changeover from hot water to chilled water and vice-versa would take place in May and October, following the pattern used in many New York apartment buildings, college campuses and other locations with two-pipe systems.

1.5 Typical practice in designing hot water district heating systems is to use a flow main temperature of about 180 F and a flow return temperature of 110 F, as long as the outdoor temperature is above 20 F. At lower outdoor temperatures, the water temperatures are increased to an indicated 240 F when the outdoor temperature is 0 F. However, it may be desirable to design for a maximum of 212 F, at least for the storage portions of the system, so as to avoid the cost of pressurized water storage tanks.

2. Distribution:

The distribution mains would be placed along the East River drive, for example, under the existing walkway, in order to minimize excavation of city streets. There are existing tunnels, formerly used for transporting coal at Con Edison's 74th Street Station and at Rockefeller University, which may also be used. It is believed that other tunnels exist at various locations between these two sites.

3. Load:

   3.1 Most buildings of New York Hospital - Cornell Medical Center have hot water heating and chilled water cooling, and should be connectible to a district heating/cooling service with little modification. Appendix B indicates the variety of HVAC systems at Rockefeller University, some of which are suitable for connection to the study system.

   3.2 Some study is needed to determine the extent of changes necessary in order to use the hot water-chilled water system. For example, in the Tower Building at Rockefeller University (See Appendix B), the present design, a dual-duct hot air/cool air system, particularly the centralized locations on each floor and the chilled water distribution system, is such that the extent of changes required appears to be reasonable. A report on the types of heating and cooling systems in the buildings in the study area is available, and will be provided to the contractor.

   3.3 It appears that the replacement of existing steam radiators by hot water radiators would be so costly as to be impractical. Where chilled water distribution systems exist, it may be practical to convert them to the use of hot water, at least to carry part of the load.

   3.4 An additional potential for energy savings may be derived from eliminating older, less efficient types of steam absorption chillers. This should be studied to assess the market potential for these applications as well as new construction.

   3.5 Typical European practice in connecting a building to a hot water district heating system is to install a heat exchanger (with meter) at each building, to isolate the main headers from the loops within the building. This practice was established many years ago and has obvious advantages. However it has some disadvantages with respect to energy efficiency and its use needs to be reexamined, giving consideration to today's high energy costs.

TASKS

The contractor will perform the following tasks, only to the extent, and in sufficient detail, required to provide NYCEO and Con Edison with data and other information to help judge whether to conduct a full-scale detailed engineering/ economic study with a view to eventual design and construction.

Task 1 Technical Fact-Finding and Analysis

Collect necessary data, perform necessary analyses, and prepare descriptive designs of a district heating/cooling system, using the Reference Case described above as a guide, including preliminary estimates of construction costs and operation & maintenance costs, including but not limited to:

a) Conversion of turbine T10 at Con Edison's 74th Street Station in order to serve a hot water district heating loop while providing optimum combined electric and heat generation.

b) Installation of central electrically-driven centrifugal chillers to provide chilled water for a district cooling loop.

c) Provision for domestic hot water in summer.

d) Hot water and cold water storage, to help level the thermal and electric peaks.

e) Selection of suitable sendout and return temperatures for both heating and cooling, compatible with optimum performance, system efficiency, economy and safety.

f) Location and design of distribution mains to minimize street excavation and interferences.

g) Determine the types of changes necessary in the candidate buildings for possible connection to the proposed water district heating/cooling system, excluding major replacement of HVAC systems in buildings.

Task 2 Market Analysis

a) Assist NYCEO and Con Edison to define the study area to be served.

b) Review data on identities and locations of buildings potentially suitable for connection to the proposed system. NYCEO will assist in obtaining the data, including arranging visits to Rockefeller University and other sites.

c) From results of 2a, 2b, and other data that may be available, estimate the potential loads for the proposed system: heating load, cooling load, increment or decrement to electric load, in terms of the physical possibilities for connection to the proposed system. (Note: No market surveys will be conducted as part of this study.)

Task 3 Economic Analysis

a) Coordinate data on the three major elements of the proposed system (heating/cooling sources, distribution mains, loads) in the study area, and define a reasonable total economic venture, utilizing the whole or portions of each such element studied in tasks 1 and 2. This analysis will include, without limitation, estimated capital costs, financing approaches, O&M costs, phasing of the project development if constructed, and all relevant laws, rules, regulations and procedures applicable to capital investments by regulated public utilities in New York City.

b) Estimate the return on investment from the proposed system, using the costs developed in the Technical Analysis, Task 1 and the estimated net electricity and steam revenues to be obtained by means of the proposed system. This review may cover one or more phases of development of the proposed system, whatever is necessary to achieve the project objective.

c) Estimate the cost to potential building owners of service by the proposed system, including, without limitation:

(1) rates for heating and/or cooling service,

(2) savings or increases in current energy costs,

(3) operating and maintenance costs,

(4) investment costs for connection,

(5) other impacts on costs, such as fire insurance,

(6) other impacts on revenues, such as release of space for revenue - producing purposes.

d) Compare the costs of service from the proposed district heating/cooling system with the costs of other possible options for a building owner, such as:

(1) Con Edison steam for heating and cooling,

(2) Con Edison steam for heating, Con Edison electricity for cooling,

(3) on-site boiler for heating and cooling,

(4) on-site boiler for heating, Con Edison electricity for cooling,

e) Define applicable "innovative" financing methods, and estimate the effects of each such method on the estimates developed under Tasks 3a to 3e. "Innovative" financing may include any mode of financing that differs from common practices employed in financing public utility and private real estate ventures.

Items to be delivered

1. Monthly letter progress reports, limited to no more than two pages.

2. Reports on completed work segments, as produced.

3. Draft Project Report, comprising the reports on work segments referred to in 2. above, with revisions, if any, plus additional appropriate material.

4. Final Project Report.

The Final Project Report will include, without limitation, the following:

- Executive Summary
- Sections reporting on completed work segments, which shall encompass all items of the Tasks in the Scope of Work, but not necessarily presented in the same order as they appear in the list of tasks.
- Conclusion: a determination whether the Reference Case, any variation thereof, or any other case that may have been considered by the contractor, is a suitable basis for a district heating/cooling project under criteria normally used for evaluating proposed public utility ventures. The conclusion shall be justified by reference to the contractor's investigation and any relevant references to other work.
- Recommendations: either

  a) If the conclusion is positive, identify the steps, studies, etc. needed to proceed with the next step of project development.

  b) If the conclusion is negative, state whether any steps, changes, studies, etc., might be effective to change the evaluation to positive, and if so, identify them.

SCHEDULE

Key dates are as follows:

Approval to proceed	October 26, 1984
Kickoff	November 5, 1984
Draft Report	March 15, 1985
Final Report	May 15, 1985

The draft report will be circulated for comments by NYCEO for a planned 30-day period, after which the contractor will have 30 days to complete and deliver the report. Interim reviews will be conducted by NYCEO and Con Edison, as appropriate, based on contractor's monthly reports and other material produced as the project proceeds.

In order to adhere to the schedule, it is anticipated that sections of the final report will be prepared as portions of the work are completed. Preparation of the Draft Report will therefore consist largely of assembling and revising material already at hand.

APPENDIX A. 74th Street Station

Consolidated Edison Company's 74th Street Plant, located on the East River, contains the following:

(a) Three Combustion Engineering corner-fired boilers, Nos. 120, 121 and 122, installed in 1962, having a gross capacity of 520,000 lbs./hr. each at 1250 psig and 950 F, and connected to a common header. Net station steam sendout capacity from these boilers is 1,101,000 lbs./hr.

(b) Three turbines for electric generation, designated as T9, T10, and T11. T9 and T10 are Westinghouse compound condensing turbines, supplied via the common header with steam from boilers 120, 121, and 122. Turbine T9 was installed in 1959, and is rated at 71MW in condensing mode. The particulars on turbine T10 are similar except that it was installed in 1956. Turbines T9 and T10 have been used very little and have no provision for supplying steam outside the plant. Turbine T11 rated at 36MW was built by General Electric Company and installed in 1962. This is a topping turbine, inlet steam pressure and temperature being 1250 psig and 950 F respectively, supplied from the common header, and topping parameters of 185 psig and 550 F.

(c) Six (6) package boilers, which were installed in 1978, and which are capable of producing, net, 762,000 lbs./hr. of 200 psig pressure steam.

In 1982, 441, 783,000 lbs. of steam were produced by the six (6) package boilers of the East 74th Street plant. In addition, the topper line produced 4,281,649,000 lbs. of steam. The fuel for the East 74th Street plant is residual oil.

This plant receives oil by pipeline from storage facilities on the east side of the East River. A tunnel, formerly used for coal, connects the plant to the waterfront at the East River.

APPENDIX B. Heating and Cooling Systems at Rockefeller University

The following brief account conveys an idea of the various systems on the campus. It is believed that a similar diversity of systems exists in the other large institutions in the area, most of which contain buildings and equipment of widely varying ages. Enough of these systems are believed suitable for connection to a hot water district heating/cooling system to constitute a significant additional load for Con Edison.

The central plant at Rockefeller University contains three Babcock and Wilcox oil-fired boilers, rated at 23,000 lbs./hr. each, at 250PSI. Steam is sent out at 110 PSI, and reduced in each building to 60 PSI for sterilizers, distilling, kitchen etc. uses. Most of the steam is used at 110 PSI to operate turbine-driven machines, such as pumps and compressors and some reciprocating engines. Exhaust steam from these machines is the primary source of low-pressure steam for heating and cooling buildings. Many of the machines in use are very old.

Direct steam from the boilers is used for peaks. On a typical day in July, 635,000 lbs. of steam were delivered, of which 35,000 lbs. consisted of direct steam. The range of direct steam is 5% to 15% of the total delivered. Total steam capacity is 1,582,000 lbs. per day, which includes 121,000 lbs. of direct boiler steam.

Lost steam in the system varies from 22% to 30%, which includes both unaccounted-for steam and steam required to run auxiliaries.

The most modern buildings are the Tower Building and the animal research building. The Tower Building has a thousand tons of absorption air conditioning capacity in 2 Carrier machines of 500 tons each, installed in 1970. These machines are operated by steam generated in the Central Plant at 110 PSI and reduced in the building to 10 PSI. The Tower Building was once on Con Edison steam.

The Tower Building contains laboratories that require an unusually high rate of fresh air intake. It is heated and cooled by a dual-duct air system. The hot deck of the system uses steam in the winter, outside air in the summer. The cold deck uses chilled water in the summer and outside air in the winter. The hot-deck air is heated to 45 F in one stage and 85 F to 90 F in a second stage. Both hot and cold air are delivered to each room, and mixed in a plenum chamber in the ceiling above the room for delivery into the room. There is a mechanical room on each floor of the Tower Building. 110 PSI steam and chilled water are delivered first to the top of the building, and the low-pressure steam and/or chilled water travel downward into the mechanical room on each floor. The system is shut down and drained in November and April. The dual-duct system is not being run at design conditions, which are to use year-round steam and chilled water to adjust the temperature.

In the older buildings, heating is provided by vacuum steam radiators, operated at 5PSI. Cooling is provided independently through McCray air-circulating units, cooled by internal coils. These coils were designed for water but are now being used for steam. By combining chilled water and steam, the proper temperature is obtained.

Steam for the older buildings is supplied by exhaust steam from machines in the central plant, as noted above. Chilled water for cooling is supplied by a 400-ton absorption chiller, a 400-ton electrically-driven centrifugal compressor and two 60-ton reciprocating compressors driven by steam turbines. Cooling is accomplished in two stages, first with freon and then with brine.

A new residential building, to be constructed over the East River Drive, will provide heating and cooling through heat pumps in every room. A Con Edison steam connection will be used for heat when the temperature drops below 20 F.

Steam consumption in 1982 was 247 million lbs. from on-site boilers, 249 million lbs. total including 2 million lbs. of Con Edison steam used during peaks and shutdowns. In 1983 the corresponding figures were 257 and 266 respectively, and in 1984 the figures were 291 and 302 respectively. All figures are for the fiscal year ending June 30. Peak electric load is 3,599 KW and average electric load is 2,910 KW. The summer steam load exceeds the winter steam load, due to extensive use of absorption chillers.

The system in the Tower Building, and a similar system in the animal facility, appear to be suitable for connection to a hot water district heating/cooling system.

There is a system of distribution tunnels under the campus, connecting all buildings to the central plant. Another tunnel, formerly used for coal, connects the central plant to the East River drive.

APPENDIX E

GUIDELINES FOR EVALUATION OF PROPOSALS

1. Project Approach: District heating/cooling/engineering/design to minimize capital construction and operating costs. Includes heating and cooling sources, distribution system, connection to load.

   Rating Basis: Degree of understanding of, and responsiveness to, project requirements; internal consistency; credibility as demonstrated by related experience. Experience in projects that were constructed carries the most weight.

2. Knowledge and Experience in district heating/cooling, public utility power plants, cogeneration: utility and non-utility.

   Rating Basis: This item gives credit for district heating/cooling knowledge and experience other than that already included in Item 1 as being directly related to Approach; other experience in public utility power plant projects (design, construction, operations services) for Con Edison and for other utilities; experience with industrial and other on-site cogeneration projects, as well as utility cogeneration experience.

3. Experience and Approach to HVAC Systems: On-site steam and hot water, chilled water, district steam, retrofits, comparative costs.

   Rating Basis: Greatest weight will be given to practical experience and knowledge of in-building systems connected to, connectible to, or retrofitted to, district heating and/or cooling systems, with little or no investment in building system conversions. Credit will be given for both technical experience and capability in estimating comparative costs of different heating/cooling options for building owners.

4. Experience in public utility investment analysis, rate design, financing, allocation of costs and allocation of revenues between different plants and between different services (electric, steam, gas, hot water, chilled water).

   Rating Basis: Greatest weight will be given to practical experience in utility planning for investment in new facilities, analyzing revenues from proposed projects, developing utility rate structures, and financing projects, all within accepted practices and regulations that govern the public utility business.

5. Other

Public utility market analysis experience;
Knowledge of U.S. and European technology;
Project team qualifications in general;
Price;
Management Plan and Schedule.

APPENDIX F

PLANT VISITS

Con Edison 74th Street Station

The station contains three turbine generators, a group of package boilers, and gas turbines for peaking; as shown in Figure 3.

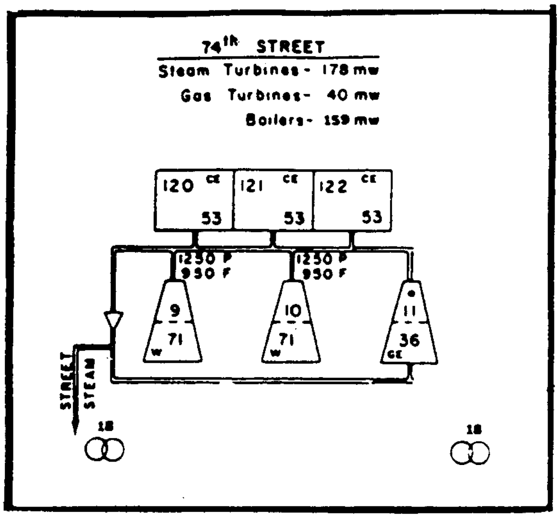

Figure 3. Steam generators and turbines at 74th Street Station. Units 9 and 10 are 60Hz units; Unit 11 generates 25Hz power.

Unit #9 is being considered by Con Edison for conversion from a condensing unit to a topping unit. Either a new turbine may be installed or the existing turbine may be modified for back-pressure operation. Con Edison expects to gain 22 MW electric generating capacity thereby. They would then use the package boilers less. It is now uneconomical to use the condensing turbines as such, because of high heat rates. Unit #9 has been used a total of about 4,000 hours since it was installed in 1962. Brown Boveri has quoted on a new turbine, operating at 300 psig back-pressure, for $2-1/2 million. Total project cost is estimated at $8 million. Maximum load is experienced 30% of the time.

There is an express main to 57th Street and 5th Avenue delivering 1.2 million lbs. per hour. The converted topping turbine would serve this express main, according to the plan.

All steam is dispatched from the energy control center at West 66th Street.

Water for the steam system has to be 100% made up, because there is no condensate return. The water is demineralized using caustic soda and sulfuric acid. The condensate from auxiliary equipment is 18% recirculated. The cost of city water is $5.80 per thousand cubic feet. Most of the water cost is in treatment, not raw water. If a new hot water loop were installed, the condensate from steam used to heat it would be recovered at the plant, adding to the economy. The package boilers at 74th Street and 60th Street Stations, and the package boilers at Ravenswood, are secondary sources. Most steam sold comes from the topper line.

All steam lines are buried. There is an oil line along the FDR Drive for oil from Ravenswood coming across 71st Street. There is a vertical shaft at the end of the tunnel from Ravenswood at the Hospital for Special Surgery.

The oil used is #6, 0.3% sulfur, supplied continuously by pipe line from Ravenswood. Consumption is 3 million to 4 million gallons per month. Storage at the site totals 80,000 gallons. The major supply is stored in Astoria.

There is ample space for a 30-by-30 foot heat exchanger for hot water at East 74th Street Station. This is the type of equipment that would be used for a hot water system.

60th Street Station

Con Edison's 60th Street Station contains a number of package boilers operating on gas. Oil is burned occasionally (three times last year). There is no space for additional equipment. The plant must shut down an average of 5 times per year when the wind blows from east to west, because an adjacent apartment house is higher than the stack. 60th Street Station burns gas, #2 oil or kerosene delivered by truck. Costs are $5.20 per million BTU for #6 oil, $6.20 per million BTU for kerosene and $4.00 per million BTU for gas.

Rockefeller University

Figure 4 shows the property. Steam is supplied by three Babcock and Wilcox boilers, rated at 23,000 lbs. per hour each, 250 psig. Steam is sent out at 110 psig, and reduced in each building to 60 psig for sterilizers, distilling, kitchen etc.

The Tower Building has a thousand tons of absorption air conditioning capacity in two Carrier machines of 500 tons each, installed in 1970. These machines are operated by house steam generated in the central plant at 110 psig and reduced in the building to 10 psig. The Tower Building was once on Con Edison steam.

The Laboratory Animal Research Center (LARC) was formerly on Con Edison steam, and now has a Con Edison stand-by connection, used during plant shut down and for satisfying peak demand. Normally LARC is cooled by two 500-ton absorption air conditioners operated by 10 psig steam.

The central cooling system for the old buildings consists of a 400-ton absorption machine, a 400-ton electrically-driven centrifugal compressor, and two 60-ton reciprocating compressors driven by steam turbines. This is a two-stage system. The primary coolant is freon; the secondary coolant is brine.

Direct steam from the boilers is used for peaks. On a typical day in July, 635,000 lbs. of steam were delivered, of which 35,000 lbs. consisted of direct steam. The range of direct steam is 5% to 15% of the total delivered. The rest is exhaust steam from turbine drives and reciprocating engines used to operate equipment in the plant. Total steam capacity is 1,582,000 lbs. per day, which includes 121,000 lbs. direct boiler steam.

The old buildings are heated by steam radiators, operated at 5 psig. The Tower Building is heated by a dual-duct hot air system. The hot duct of the system uses steam in the winter, outside air in the summer. The cold duct uses chilled water in the summer and outside air in the winter. The hot-duct air is heated to 45°F in one stage and 85° to 90°F in a second stage. Both hot and cold air are delivered to each room, and mixed in a plenum chamber in the ceiling above the room for delivery into the room. There is a mechanical room on each floor of the Tower Building. 110 psig steam and chilled water are delivered first to the top of the building, and the low pressure steam travels downward into the mechanical room on each floor. The system is shut down and drained in November and April.

The dual-duct system is not being run at design conditions, which are year-round steam and chilled water.

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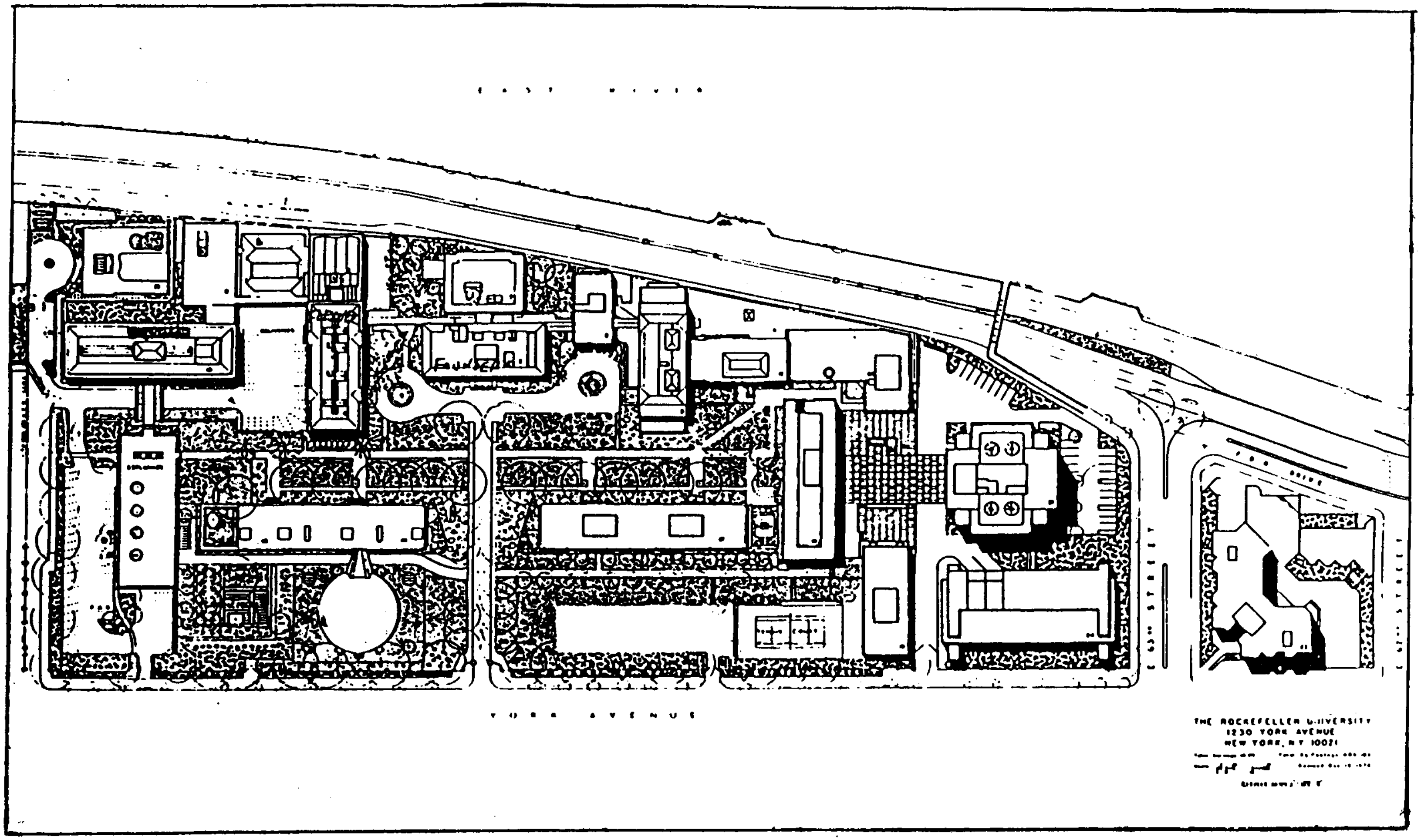


Figure 4

This plant consumes 2,400,000 gallons per year of #6 oil in a 10% water emulsion. Cost is 76 cents per gallon. Oil is delivered by tank truck. The emulsion is claimed to produce a cleaner, shorter flame, entailing less boiler fouling. Oil is stored in two 20,000-gallon and two 18,500-gallon tanks. The boilers are oil-fired, and were installed in 1955. The absorption machines are Carrier models; the newest machine was installed in 1965.

The oldest cooling system, using brine, serves the oldest buildings. The central absorption chilled water system serves buildings of intermediate age, and the absorption system on the roof of LARC serves the newest building.

The system is currently fully loaded, and a fourth boiler will be needed soon. Fuel cost is currently estimated at $6.63 per thousand pounds of steam, $9.00 total cost of steam.

Steam consumption in 1982 was 247 million lbs. from on-site boilers, 249 million lbs. total including Con Edison steam. In 1983 the corresponding figures were 257 and 266 respectively, and in 1984 the figures were 291 and 302 respectively. All figures are for the fiscal year ending June 30. Peak electric load is 3,599 KW and average electric load is 2,910 KW.

In the old buildings, heat is provided by vacuum steam radiators. Cooling is provided independently through McCray air circulating units, cooled by internal coils. These coils were designed for water but are now being used for steam. By combining chilled water and steam, the proper temperature is obtained.

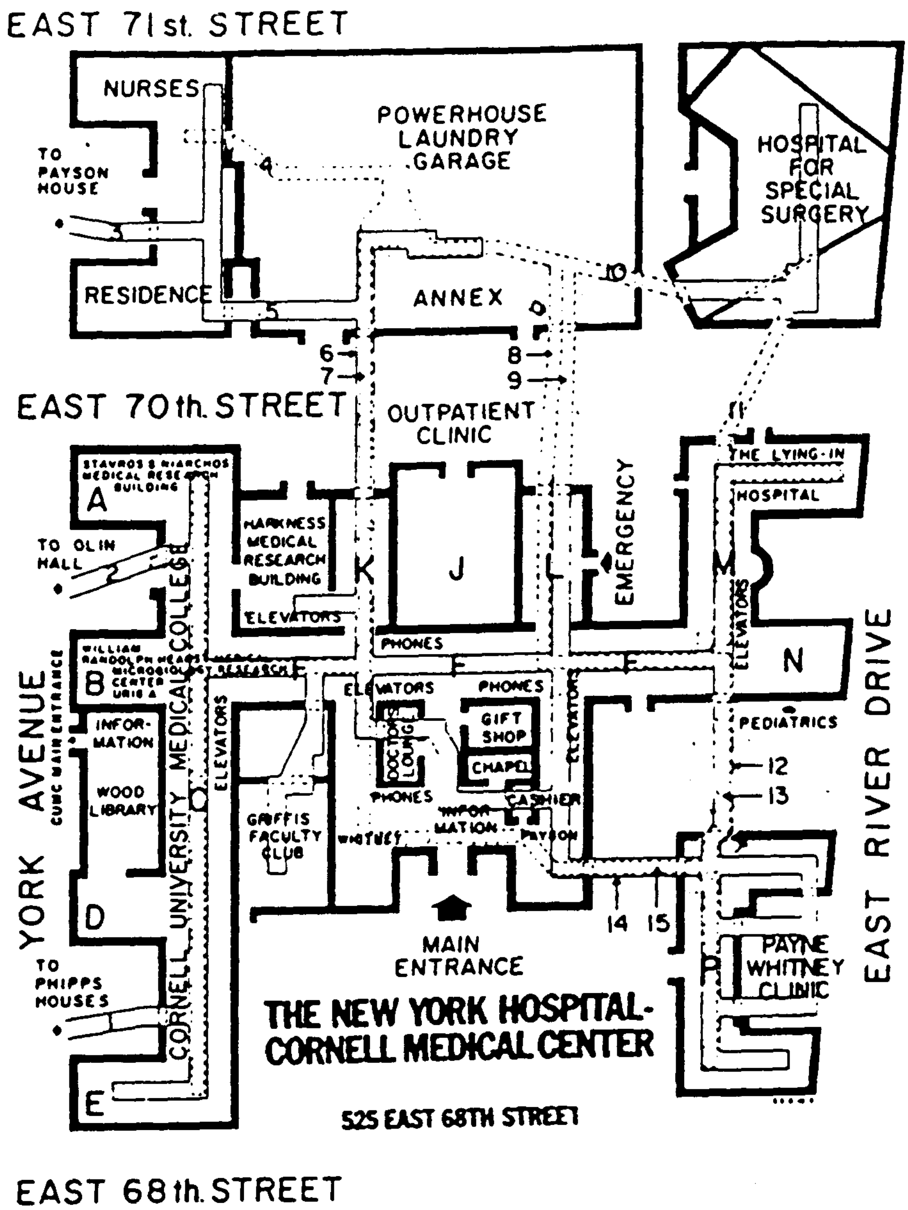
Lost steam in the system varies from 22% to 30%, which includes both unaccounted-for steam and steam required to run auxiliaries.

The new residential building to be constructed over the East River Drive will provide heating and cooling through heat pumps in every room. A Con Edison steam connection will be used for heat when the temperature drops below 20°F.

New York Hospital-Cornell Medical Center

Figure 5 shows the plant. Steam is provided by two 125,000-lbs./hr. Combustion Engineering boilers. Steam is delivered at 185 psig, 380°F, and reduced to 60 psig, 30 psig, and <5 psig for use in buildings. 90% of the steam is delivered for use at 4 psig and 180°F. Three 60,000-lbs./hr. Combustion Engineering boilers are on cold standby, have not been used for several years. Cooling is provided by the following machines: one 1,250-ton electric centrifugal compressor, one 1,500-ton

Figure 5


EAST 71st. STREET
NURSES
POWERHOUSE
LAUNDRY
GARAGE
HOSPITAL FOR SPECIAL SURGERY
TO PAYSON HOUSE
RESIDENCE
ANNEX
EAST 70th. STREET
OUTPATIENT CLINIC
STAVROS S NIARCHOS MEDICAL RESEARCH BUILDING
TO OLIN HALL
HARKNESS MEDICAL RESEARCH BUILDING
ELEVATORS
EMERGENCY
THE LYING-IN HOSPITAL
PHONES
GIFT SHOP
CHAPEL
CASHIER
INFORMATION
PEDIATRICS
YORK AVENUE
CORNELL UNIVERSITY MEDICAL COLLEGE
WOOD LIBRARY
GRIFFIS FACULTY CLUB
TO PHIPPS HOUSES
MAIN ENTRANCE
PAYNE WHITNEY CLINIC
EAST RIVER DRIVE
THE NEW YORK HOSPITAL-CORNELL MEDICAL CENTER
525 EAST 68TH STREET
EAST 68th. STREET

electric centrifugal compressor, one 2,500-ton steam-driven backpressure compressor, and one 1,000-ton steam-driven compressor operated by waste steam from the 2,500-ton turbine. The chilled water distribution temperature is 45°F at a discharge pressure of 115 psig and delivery pressure of 60 psig. In addition there are 2,000 window air-conditioners on the site. Steam from the non-condensing turbines is used to operate 600 tons of absorption refrigeration. 80% of the steam produced in the plant is returned as condensate. A four-pipe system is used for distributing hot water and chilled water. Peak load is 2 million lbs. of steam per day. Steam consumption in the year ending June 30, 1984 was 653,832,396 lbs. Details are given in Table 4. The fuel bill is $4 million per year of #6 residential oil, purchased currently at 77 cents per gallon. Fuel oil is burned to produce heat, at 80% boiler efficiency. Electric energy consumption is 50 million KWh per year. The peak load is 9 MW; the average load is 6.5 MW. No electricity is generated on site. Four 1,000-KW Waukesha diesel generators are installed for emergency power.

Table 4

ANNUAL STEAM CONSUMPTION AT NEW YORK
HOSPITAL-CORNELL MEDICAL CENTER

JAN	1984	62,031,504 lbs.
FEB	1984	57,298,500 lbs.
MAR	1984	66,993,000 lbs.
APR	1984	40,744,500 lbs.
MAY	1984	44,533,500 lbs.
JUNE	1984	57,708,000 lbs.
JULY	1983	66,669,500 lbs.
AUG	1983	68,725,000 lbs.
SEPT	1983	49,735,500 lbs.
OCT	1983	38,331,000 lbs.
NOV	1983	41,668,500 lbs.
DEC	1983	59,393,892 lbs.
TOTAL		653,832,396 lbs.

SUMMER PEAK LOADS		
JUNE	1984	57,708,000 lbs.
JULY	1984	51,555,000 lbs.
AUG	1983	68,725,000 lbs.
SEPT	1983	49,735,500 lbs.
OCT	1983	38,331,000 lbs.
TOTAL		266,054,500 lbs.

WINTER PEAK LOADS		
DEC	1983	59,393,892 lbs.
JAN	1984	62,031,504 lbs.
FEB	1984	57,298,500 lbs.
MAR	1984	66,993,000 lbs.
TOTAL		245,716,896 lbs.

Public Service Electric & Gas Company (N.J.)

Public Service Electric & Gas Company of New Jersey (PSE&G) recently completed a 5-year study of a proposed major district heating system for Newark, Jersey City and other areas of urban northern New Jersey[17], at a cost of $1 million. The system would extract heat from existing steam turbines that now operate in condensing mode to produce electricity. Heat would be distributed by a hot water system.

The PSE&G project is similar to NYCEO's project in that it contemplated retrofitting a hot water loop to an existing condensing turbine. Major differences were:

- PSE&G has no existing district heating steam service.
- The proposed retrofits were to base-load units, and, accordingly, entail a penalty for lost electric generating capacity.
- The proposed project was very large, entailing service over a wide area and distribution mains many miles long.
- The number of individual potential customers was very large and diverse.

With these differences in mind, the following are some pertinent observations. Details are given in the PSE&G report[17]. PSE&G recommended extracting steam from the I.P.-L.P. crossover at 80 psig, and dropping the pressure to 15-30 psig through a small back-pressure turbine before going to a heat exchanger to supply heat to a hot-water loop. This reduces electric generating penalty loss. They also recommended trying to reduce the electric generation loss through redesign, working with the turbine manufacturer. They recommended some innovative technology for piping. They recommended study of fluidized bed coal and waste-fired plants to improve district heating economics.

In the PSE&G study[17], replacing on-site heating with district heating results in a net 30% decrease in total fuel burned, including the effect of additional fuel burned for replacement electricity. The reductions: 36% in gas, 62% in oil; increase 24% in coal.

They excluded serving buildings which now have steam heating, because this would require high temperature water (290°F). They did not calculate the economics for producing steam; this project considered only hot water for district heating.

Use of hot water from a central station to drive absorption chillers was found unfeasible due to excessive electric capacity loss, especially derating in the summer peak. Cooling was eliminated from the project because of low (28%) load factor for the large central system. But dispersed regional cooling plants could raise the load factor enough to become economical.

The project plan contemplated use of dispersed heating plants in stage 1 of the development, which could be used also as cogenerators, and then become peaking units when the full system is completed. The economic analysis showed that the cost of on-site heat is less than the cost of district heating for the first five years of operation, then the relationship begins to reverse. This takes account of innovative financing such as third-party five-year depreciation, and a tax-free transmission and distribution system.

APPENDIX G

Scope of Services

Burns and Roe, Inc. shall perform and progress the work and professional services necessary and appropriate to perform a study of the feasibility of water-based district heating and cooling systems at certain facilities on the East Side of the Borough of Manhattan, City of New York. The sources of energy for district heating and cooling to be considered in the study shall be facilities of Consolidated Edison Company of New York, Inc., ("Con Edison") such as the 74th Street Station. The district heating and cooling loads to be considered in the study shall be the New York Hospital-Cornell Medical Center and Rockefeller University. The work and professional services shall include, without limitation, the following:

Task 1 - Technical Fact-Finding and Analysis

Collect necessary data, perform necessary analyses, and prepare conceptual designs of a district heating/cooling system, including preliminary estimates of construction costs and operation and maintenance costs, including but not limited to:

1.1 Central Heating Source

a) Identify potential heat sources. For example, convert turbine T10 at Con Edison's 74th Street Station to serve a hot water district heating loop while providing optimum combined electric and heat generation, or extract steam from existing district steam lines.

b) Analyze turbine performance in district heating mode.

c) Determine operating requirements of heat sources and load profiles.

d) Determine retrofit requirements on the heat source. Develop budgetary capital and installation cost estimates for retrofitting the heat source.

1.2 Central Cooling Source

a) Evaluate energy requirements of new central electrically-driven centrifugal chillers installed, for example, at 74th Street Station, based on heating/cooling load assessment in Task 2. Develop budgetary capital, installation and operating cost estimates for the chillers.

b) Evaluate the alternative of using turbine-driven chillers, using excess steam from the boilers. Determine steam required. Determine energy recovered from exhaust steam of turbine for hot water production. Estimate capital installation and operating cost for turbines and chillers.

c) Evaluate the use of absorption chillers to carry part of the air conditioning load. Determine steam required. Estimate capital, installation and operating costs for absorption chillers.

1.3 Domestic Hot Water (Summer)

a) Develop budgetary capital, installation and operating cost estimates for local hot water heaters.

b) Develop budgetary capital, installation and operating cost estimates for centralized supply of domestic hot water.

1.4 Thermal Storage

a) Determine quantity of energy to be stored, based on load profiles of the turbines and capital cost estimates of storage facility. This is performed on a trial and error basis on steps (a) through (c).

b) Based on sub-task 1.4(a), determine size and configuration of storage facility, such as above ground tank, underground pool, etc. Sizing is based on effective storage capacity.

c) Develop budgetary capital and installation cost estimates for the storage facility.

1.5 Selection of Suitable Supply and Return Temperatures. Selection will be compatible with optimum performance, system efficiency, economy, and safety.

1.6 Transmission and Distribution Piping Assessment

a) Develop conceptual designs of a transmission and distribution piping system, after studying underground utility piping drawings for the appropriate city streets and other possible routings, such as East River Drive and existing tunnels. Location and conceptual design of distribution mains will attempt to minimize street excavation and interferences.

b) Size the pipes and determine accessories for the piping system.

c) Develop budgetary capital and installation cost estimates for the piping system.

1.7 Customer Retrofit Assessment

a) Investigate type of heating/cooling system existing in customer's premises.

b) Identify and classify buildings in the proposed service area in terms of relative difficulty and cost of retrofit. Based on this work, recommend compatible retrofits that require the least modification to the system and are cost effective.

c) Develop budgetary capital and installation cost estimates for the retrofits.

Task 2 - Market Analysis

2.1 Heating/Cooling Load Assessment

a) Assist NYCEO and Con Edison to define the study area to be served.

b) Locate buildings suitable for district heating/cooling.

c) Review fuel and electric consumption data of Rockefeller University and New York Hospital.

d) Evaluate heating/cooling equipment.

- Determine conditions of heating/cooling equipment.
- Based on sub-task 1.5, estimate efficiencies of such equipment.

e) Integrate the above Sub-tasks to arrive at a realistic heat load, cooling load, increment or decrement to electric load.

Task 3 - Economic and Financial Analysis

3.1 Coordinate data from the analyses of the thermal source, distribution mains and end user loads to define a reasonable total economic venture. This will involve developing a few different system arrangements for which analysis can be performed.

3.2 Develop and refine capital and operating cost estimates for the system arrangement developed in Task 3.1.

3.3 Identify and analyze the ownership/operation options available. This analysis will include, without limitation, estimated capital costs, financing approaches, O&M costs, phasing of the project development if constructed etc., applicable to capital investments by regulated public utilities in New York City and other potential owners/operators.

3.4 Develop alternative financing strategies to be used along with the ownership/operation options identified by Burns and Roe and approved by the Con Edison-New York City Energy Office management team. The strategies will represent conventional and innovative financing presenting worst and best case economics respectively.

3.5 Develop a conceptual financing and development plan for the system arrangements being studied.

3.6 Using the results of tasks 3.1 through 3.5, the estimated electrical production by the system and the estimated thermal energy consumption by the end users, perform a financial cash flow analysis for a 20 year planning period of the proposed system(s) with the end results being the determination of rates for district heating and/or cooling, and the determination of return on investment.

3.7 Based on the results of tasks 1,2 and 3.6, perform an economic analysis to estimate the cost to potential building owners of service by the proposed system. A specific analysis will be performed for each major customer. The end user economic analysis will include without limitation:

- Rates for heating and/or cooling service.
- Savings or increases in current energy costs.
- Operating and maintenance costs.
- Investment costs for connection.
- Other impacts on costs, such as fire insurance.
- Other impacts on revenues, such as release of space for revenue - producing purposes.

3.8 Compare the costs of service from the proposed district heating/cooling system with the costs of other possible options for a building owner, such as:

- Con Edison steam for heating and cooling.
- Con Edison steam for heating, Con Edison electricity for cooling.

. On-site boiler for heating and cooling.
. On-site boiler for heating, Con Edison electricity for cooling.

Task 4 - Reports and Meetings

Burns and Roe, Inc. shall furnish, without limitation, the following reports:

1. progress during the period;

2. planned progress in the future;

3. identification of problems;

4. planned solutions;

5. ability to meet schedule, reasons for any slippage in schedule;

6. percentage of effort completed and projected percentage to be completed in the following period; and

7. comparison of contract cost with rate of expenditure.

b) Interim reports submitted on completed work tasks.

c) A draft study report shall be prepared incorporating the interim reports and all other project results.

d) A final study report shall be prepared incorporating comments and requested revisions to the draft project report and shall include:

. Executive Summary

. Sections reporting on all project tasks

. Conclusion: a determination whether any conceptual design(s) considered by the contractor, is (are) a suitable basis for an economic district heating/cooling project. The conclusion shall be justified by reference to the contractor's investigation and any relevant references to other work.

- Recommendations: That either
  a) if the conclusion is positive, identify the steps, studies, etc. needed to proceed with the next step of project development; or

  b) if the conclusion is negative, state whether any steps, changes, studies, etc., might be effective to change the evaluation to positive, and if so, identify them.

Burns and Roe, Inc. shall be available throughout the term of this agreement for periodic meetings with the New York City Energy Office to review the status of the study and project requirements.

APPENDIX H

HEATING AND AIR CONDITIONING SYSTEMS: MANHATTAN EAST SIDE

Distribution systems within buildings in this area are as follows:

1. All-Air Systems (Usually used in institutions, located in the basement or sometimes on the roof).

   a) Single-duct, constant-volume air flow, low-velocity (1500 to 1800 ft./min.)

   These systems are inexpensive, but provide the same air to all, so do not provide the most comfort. A system consists of a plenum chamber with filter, cooling coil, heating coil controlled by thermostat, fan, and distribution duct. Distribution air temperature in winter is 100° to 110°F; Summer 55° to 60°F. A refinement is to add a reheat coil on branch ducts, for more comfort control in individual spaces. To prevent freezing in winter a preheat coil can be added on the outside air intake before the cooling coil. Heat is supplied by steam in most installations. (Hot water would require pumps, and thus cost more to install). Cooling is by chilled water.

   b) Single-duct, variable-volume air flow. This is essentially the same as 1a in the plenum, but adds a thermostatically-controlled damper in the discharge duct to each space, and a return fan interlocked with the supply fan, to balance the amount of air on both supply and return.

   c) Dual-duct system. This is usually a high velocity system with 2 ducts to each room, 1 for hot air, 1 for cold air. The two air streams are mixed by a thermostatically controlled damper on the amount of cold air used.

   d) Multizone System. This is usually a low velocity system. A duct at the exit from the heating coil is divided into several ducts, with thermostatically-controlled dampers on each duct.

2. Air-Water Systems

   a) Fan coil units are simple primitive systems, and with proper controls are hard to beat for energy efficiency. Filters on individual units are not designed to do a good job of removing dirt in the air. Each unit could be supplied with clean, humidified air from a central point.

One way is to use the building corridors to distribute air. Fan coil units are essentially all-water systems and are widely used in apartment buildings. They are also being used more and more in office buildings because of comfort. A fan coil system consists of a sheet metal enclosure with air intake grill and filter, water coil, fan and an outlet grill. The fan is the motive power to draw air across the coil and discharge it to the room. The fan is usually 3-speed, for control of air flow. Each space unit can have thermostatic control on the coil. In summer, chilled water enters the coil at about 45°F and returns to a central (roof or basement) refrigeration unit at 55°F. In the winter, the water supply temperature to room units is 120°F and return about 100°F. A central heat exchanger could be used.

- In summer, the primary distribution is 45°F out, 55°F return, and secondary 55°F out, 60°F return.

- In winter, the primary distribution is 180°F out, 160°F return, and secondary 120°F out, 100°F return.

b) Induction units are often used in hotels. They have an enclosure with a grill, coil and fan. The fan forces air through nozzles, which induces air flow from the room into the unit, through the cooling coil that is thermostatically controlled. It is necessary to have air flow at all times for the unit to work. These systems cost more today, and do not deal with the problem of taking odors out of the air.

c) Radiant Panel Systems

These are best for comfort but are also the most expensive. They use water pipes in panels in a hung ceiling. In winter the water temperature is up to 120°F. In summer the cooling water temperature should be kept 1° to 3° above the design dew point (to avoid condensation). They should use a wet bulb sensing device. Radiant panels are often used in hospitals.

d) Unitary Self-Contained Air Conditioning Unit

This has a sealed refrigeration compressor in each unit for cooling, plus heating through a heating coil of steam, hot water or electric heating from a central supply. The advantage is that it provides heating or cooling only where it is needed. The total operating hours for self-contained units are usually less than for a central system, thus operating costs for cooling are reduced. Self-contained units usually discharge heat from the refrigeration cycle to the outside through louvres on the unit. It is possible to send the heat to a central cooling tower and even reuse the heat for building hot water. Even though installed horsepower is more than for central systems, actual horsepower used is usually less. One problem with central units is that it is not easy to turn large motors on and off; the problem with small units is to keep all units well maintained.

3. Direct Expansion (D X) Systems

These are found in older apartment buildings. These systems have a sheet metal box that fits in a window or wall. It has a compressor with a condenser coil outside and an evaporator coil inside. Heating is usually provided by a separate steam or water system. These units are simple, have very few controls, and the primary advantage is -- they can be turned on and off. Disadvantages are: inefficient, noisy, drafty, no humidity control. Supermarkets and stores often use a D X roof-top unit with a self-contained heater (electric or gas fired). A duct comes from the roof into the space below. The only problems are the quality of units and the maintenance required.

Characteristics of Building Sources of Heat

On the east side of Manhattan, there are many smaller apartment buildings 40 to 50 years old, and 6 or 7 stories high. Furnaces in these smaller buildings are usually gas or oil fired and either 1) heat air that is circulated by a fan to rooms, or 2) heat hot water that is pumped to radiators or connectors.

Many of the buildings that had boiler plants in the area served by Con Edison steam stopped using their own plant and tied in to Con Edison steam because of the problems of operating personnel. When using Con Edison steam there is less maintenance involved, since they do not have boilers, fuel tanks, etc.

Today, because of rising costs of Con Edison steam, there has been a trend back to using boilers in apartment buildings. Con Edison steam prices increased from less than $3/M lbs. in 1965 to $8.50/M lbs. in 1977, and to $12.72/M lbs. (average) in 1984.

Most of the older 4 to 6 story buildings in the area of 74th Street Steam Station have their own boilers, oil fired (or converted from coal to oil), and steam radiators that are not easily converted to hot water. On the other hand, most of the newer apartment buildings (built since 1950) in the area have air-water, two-pipe, fan coil systems. This was a period of providing for air conditioning as well as heating. Until recently, building owners would elect Con Edison steam instead of installing a boiler. The typical installation would be to pipe Con Edison steam to a meter and pressure-reducing valves. If two reducing valves are used, one goes from 125 psig to 40 psig for domestic hot water and a heat exchanger, and one valve goes from 40 psig to 5 psig. If only one reducing valve if used, it would probably be from 25 psig to 15 psig steam.

There is usually no attempt to store hot water or condensate to even the load. The condensate is sometimes put through a coil in the domestic hot water but usually is cooled only to the temperature permitted to enter the sewer.

The pressure in the distribution piping for the building air conditioning and heating system will be determined by the height of the building: 1) for buildings 22 stories (265 ft.) or less, 125-psig-rated valves and pipe are used; 2) for buildings 40 to 45 stories (480 to 500 ft.), 250-psig rated valves are used. In the tall buildings, the floor units will be put on two separate circuits so that the individual units can use the 125-psig-rated valves.

If older buildings wanted to modernize and add air conditioning, they usually added an absorption unit, increased boiler pressure to 15 psig (to get 12 psig for absorption) and probably took out old steam radiators and added fan coil units. Use of electric central compressors for refrigeration was initially discouraged in the 50's by the availability of cheap steam ($1.25/M lbs. in summer) and by New York City regulations which required a licensed operator for electric refrigeration but not for absorption units. (This is still the license situation in New York City.)

Some buildings have put in high pressure steam to turbines at 125 psig and extract at 12 psig to an absorption machine. Absorption machines have a water rate of 20 lbs./ton hour, turbines have a water rate of 15 to 16 lb. The combined water rate is 12 to 13 lb., which is more efficient. Most building owners will not buy the more expensive condensing-type turbines to give a 10 to 12 lb. water rate. A typical large building will have several machines divided into the various zones or time demand periods to meet the building's needs.

New York owners have emphasized keeping the capital cost of the system down, and thus have sacrificed some efficiencies. New York City has a shortage of space, tougher building codes, and has grown more sporadically than other cities. Most buildings do not have space to provide storage for water tanks to even out peak loads. Roof or underground installations are very expensive.

Many buildings have absorption refrigeration units, because steam was cheap when they were installed. These units are now at the age where they may need to be replaced. At today's costs and the poor efficiency of absorption units, it may pay to go to electric refrigeration. Absorption machines take about twice the space that electric refrigeration units require. The electric unit requires licensed personnel, but the difference in wage rates between licensed and unlicensed operators has narrowed, so this is not as much an economic factor as in years past.

Central distribution of chilled water is very efficient for large systems. It has been used in Hartford over a five mile loop. Chilled water runs around 38°F on the primary loop and either is 1) bled off to a secondary loop or 2) goes to a heat exchanger for the secondary loop. Primary and secondary systems are kept as separate loop systems to improve control and performance.

University systems often are dual, 1) a chilled water system for interior spaces that may need year-round cooling (when the outside temperature is above 35°) and 2) a hot water system for heating perimeter spaces in winter. Most offices, factories, schools, hospitals, department stores (but not apartments) will have interior spaces which need cooling in winter.

There has been very little failure in the commercial or institutional heating and cooling systems. In apartments it is not uncommon to have an outage of 1 or 2 days for repairs (or due to low voltage). Apartment buildings usually have no preventive maintenance programs.

REPORT AND INFORMATION SOURCES

Additional copies of this report, "Feasibility of Water-Based District Heating and Cooling: An Assessment in New York City - Volume I", are available from:

Publications and Distribution
Public Technology, Inc.
1301 Pennsylvania Avenue, NW
Washington, D.C. 20004

For further information on the materials presented in this report, the status of continuing efforts in New York City toward implementation, or for more information on the other energy management efforts of the New York City Energy Office, please contact:

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