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DOE/CS/20071-1-Exec.Summ.
(DE84006857)

DISTRICT HEATING AND COOLING SYSTEMS FOR
COMMUNITIES THROUGH POWER PLANT RETROFIT
DISTRIBUTION NETWORK, PHASE 2

Final Report for 1 March 1980—31 January 1984

January 31, 1984

Work Performed Under Contract No. AC02-78CS20071

Public Service Electric & Gas Company
Newark, New Jersey

Technical Information Center
Office of Scientific and Technical Information
United States Department of Energy

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Microfiche A01

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DISTRICT HEATING AND COOLING SYSTEMS FOR
COMMUNITIES THROUGH POWER PLANT
RETROFIT DISTRIBUTION NETWORK
PHASE 2

FINAL REPORT
FOR THE PERIOD
1 MARCH 1980 - 31 JANUARY 1984

EXECUTIVE SUMMARY

REPORT DATE: 31 JANUARY 1984

WORK PERFORMED UNDER CONTRACT

DE-AC02-78CS20071

PUBLIC SERVICE ELECTRIC & GAS COMPANY
80 PARK PLAZA
NEWARK, NEW JERSEY 07101

FOREWORD

This is the Final Report of Phase 2 of "District Heating and Cooling Systems for communities through Power Plant Retrofit Distribution Network." It is composed of an Executive Summary and seven volumes:

Executive Summary

Volume I: Detailed Summary

Volume II: Introduction, Load & Service Area Assessment, Institutional Questions, Rates, Financial Considerations

Volume III: Technical Considerations

Volume IV: Cost Estimates, Staged Development Scenarios, Economic Evaluation, Impact on Fuel and the Environment, Alternates to Conventional Heating Systems, Conclusions, Recommendations

Volumes V-VII: Appendices A - C

ACKNOWLEDGEMENTS

The following key personnel contributed to the completion of this report:

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Numerous contributions by other subcontractor and PSE&G personnel are gratefully acknowledged.

EXECUTIVE SUMMARY

INTRODUCTION

PSE&G's involvement in cogeneration and district heating began in the late 1950's with large combined steam and power production and steam transmission through a pipeline to a nearby oil refinery. In 1975, the Company conducted an internal study of the potential for district heating using waste heat from its electric generating stations. This was followed by a survey of potential industrial cogeneration sites in New Jersey.

In late 1978 the USDOE-funded Phase 1 (Preliminary Feasibility) Study of District Heating was initiated. All of PSE&G fossil-fueled electric generating stations were screened (Figure 1.1). Three northern New Jersey stations (Hudson, Essex and Bergen), in the areas of highest thermal load density, were recommended for further study since it was found that there was more than enough potential thermal load within five miles of each of these stations to utilize the available waste heat.

The Phase 2 (Detailed Feasibility) District Heating Study began in 1980 and concentrated on the Hudson Generating Station because of its proximity to the concentrated Jersey City and Newark load areas and the new developments planned for the Hackensack Meadowlands. Initially, the oil-fired Essex Unit No. 1 (Newark) and Hudson Unit No. 1 (Jersey City) were also considered. However it was soon apparent that district heating based on coal would be more viable, and the coal-fired Hudson Unit No. 2 was used as the study basis of a large, regional district heating system for northeastern New Jersey (Figures 1.2 and 1.3).

The potential for district heating was examined in terms of a total (regional) system and two subsystems of overlapping scales. Only systems A and B below were studied in detail.

FIG. 1.1

PSE&G GENERATING STATIONS IN NEW JERSEY

STAGED DEVELOPMENT AND DISPATCH CONCEPT

FIG. 1.2

FIG. 1.3

REGIONAL DISTRICT HEATING SYSTEM - CONCEPTUAL
DATES OF SYSTEM ADDITIONS

- A. A total (regional) system (3.7×10^9 BTU/hr peak) based on Hudson Unit No. 2 supplemented by combustion turbine capacity (Kearny Unit No. 12) and local gas-fired heating and cogeneration plants built up in staged development as in the European model.
- B. A major district heating site (200×10^6 BTU/hr peak) based on a new development or an existing urban housing complex, using landfill gas, natural gas or limited steam extraction from Hudson Unit No. 2.
- C. A "mini" district heating site (on the order of 10×10^6 BTU/hr peak) based on, "stand-alone" cogeneration facilities serving a small number of apartment buildings, and fueled by waste gas, natural gas, or wastes. These sites could serve as the initial nuclei for district heating system development, while being economically viable even if a larger district heating grid (based on a coal-fired central generating station) were not eventually built. The need for this type of small facility emerged late in Phase 2 as capital needs and constraints became apparent. They were thus not studied in detail, but are the subject of on-going PSE&G investigations of district heating options/opportunities for future consideration.

The basis of the economic analysis of district heating was that the utility's electric and gas customers would not be economically burdened by the implementation of district heating, and that any incremental costs due to district heating (e.g. district heating capital and operating costs, replacement electric power, abandonment of unamortized gas mains) would be charged to district heating customers.

RESULTS

The Phase 1 study identified the high-density population areas within the Company's service territory as the most feasible for development of district heating systems. It ended up recommending the concentration of further efforts on the Newark-Jersey City-Hackensack Meadowlands triangle. (See Figure 8.3.1) The Phase 2 study involved a number of issues as summarized below.

Potential thermal load data was obtained in 4 ways: (1) Analysis of statistical data from census and industrial sources; (2) A detailed energy use questionnaire completed in direct interviews with potential customers; (3) A briefer energy/fuel use questionnaire sent by mail to a broader sample of potential customers and (4) Meetings with developers, apartment complex managers and municipal housing authority management.

Approximately 6.5×10^9 BTU/hr of total peak thermal load (space heating and domestic hot water) was identified in the region. A large regional system serving 3.5×10^9 peak BTU/hr - about 50% of the total load - plus 0.2×10^9 peak BTU/hr of transmission losses was conceptually designed and studied. Smaller systems involving the Berry's Creek Center (Bergen County Associates) and Harmon Meadows (typical of a number of Hartz Mountain projects in various stages of construction and planning) were studied. These developments have thermal loads of about 200×10^6 peak BTU/hr.

Cursory examination was also made of small, cogeneration-based "mini-district heating" sites of the size of one or a few apartment buildings (10×10^6 peak BTU/hr).

By considering space heating and domestic hot water loads only, the district heating load estimates are conservative. Industrial process loads can only improve total load density and load factor. However, such loads are extremely site specific and difficult to appraise on a general basis. Any attractive industrial development will need to be examined on a case specific basis.

Three sources of heat were used in the "total system": (1) Extraction of 1.6×10^6 lb/hr of steam from the I.P./L.P. crossover of Hudson Unit No. 2 (coal-fired), (2) Addition of 1.1×10^9 BTU/hr of heat recovery from 196 MWe of the Kearny No. 12 combustion turbines, and (3) 11 local gas-fired heater plants of $200-240 \times 10^6$ BTU/hr peak capacity.

Heat transmission by hot water and system growth by development on the European model was selected. The local heater plants provide both peaking and backup capability equivalent to the largest single heat source on each contiguous portion of the system at each stage of development. Figures 1.2, 1.3, and 8.3.14 give further details of the staged development and system operation concepts. Technical highlights of the system are given in Table ES-I. Table ES-II summarizes the characteristics of the heat sources. Table ES-III summarizes the capital costs of the "total system" in comparison with conventional heating systems in each building.

Figure 10.8 shows the portion of the heat supplied to district heating customers which is provided by each of the 3 heat source categories in the fully developed system: the retrofitted Hudson No. 2, the intermediate plant (Kearny No. 12) and the local heater plants.

On a regional basis district heating was found to result in significant fuel savings. As depicted in Figure ES-1, district heating results in a net 35% decrease in total fuel burned, even after accounting for the additional fuel burned on the Pennsylvania-New Jersey-Maryland (PJM) Interconnection for the generation of replacement electric power to offset the derating of Hudson No. 2 by district heating. The district heating use shows a 36% reduction in natural gas use and a 62% reduction in oil use over the non-district heating case. However, 24.1% of the fuel burned to supply district heating represents an increase in coal use, both at Hudson and on the PJM grid, over the non-district heating use.

Fig. 8.3.14

FULL DISTRICT HEATING SYSTEM
LOAD AND CAPACITY EXPANSION
1984-2011

TABLE ES-I

DH SYSTEM TECHNICAL HIGHLIGHTS

I. SYSTEM AND SUBSYSTEM	Thermal Capacity Btu/hr* (Peak)	Equivalent Heating Load No. of Typical Dwellings***
A Total DH System	3,700 x 10 ⁶ **	185,000
B Major DH Site	200 x 10 ⁶	10,000
C Mini DH Site	10 x 10 ⁶	500
II. THERMAL SOURCES		
A - Hudson 2 Steam Unit - 600 MW _e (electric capacity without DH) Coal Fired		
Peak DH Output - 1,600 x 10 ⁶ Btu/hr (86 MW _e derating by DH use)		
- Kearny 12 Gas Turbines (GT) - 196 MW _e Oil/Gas Fired		
Peak DH Output - 1,100 x 10 ⁶ Btu/hr		
B - Package Boilers - 50 x 10 ⁶ Btu/hr Unit Gas Fired		
Peak DH Output - 200 x 10 ⁶ Btu/hr with 25% back-up		
C - Cogeneration Units - (1.2 x 10 ⁶ Btu/hr + 316 KW _e) /Unit		
Types - Diesel, IC Engine, Combustion Turbine		
Peak DH Output - 1.2 x 10 ⁶ Btu/hr/Unit base load		
10 x 10 ⁶ Btu/hr peak thermal load (Multi-Unit)		

III. THERMAL EXTRACTION

- A - Hudson 2 - Steam extraction at IP/LP Crossover (80 psia)*
 - Hot Water Sendout: 223°F, Return: 165°F (Peak Load)
- Kearny 12 - Heat recovery from exhaust gases
 - Hot Water Sendout: 261°F
- B - Package Boilers - Hot Water Sendout: 293°F
- C - Cogeneration Units - Hot Water Sendout: 290°F (Nominal)

*3.4 x 10⁶ Btu/hr = 1MW_{th}

**Annual load: 8.8 x 10¹² Btu

***20,000 Btu/hr peak thermal load

TABLE ES- I

DH SYSTEM TECHNICAL HIGHLIGHTS - (Continued)

IV THERMAL CONVEYANCE (Regional System)

Transmission piping: 16" - 42" diameter; 118,600' length

Carbon Steel/Polyurethane/Polyethylene

Distribution piping: 1 1/2" - 12" diameter; 984,000' length

Carbon Steel (primary) and PVC (Secondary) Foam glass or Polyurethane/Polyethylene

Hydraulic pressure in grid: 70 - 230 psig

DH Flow Rate: 58,700 gpm

*Expanded to 30 psia and 12 psia through turbines for 2-stage heating.

V. CUSTOMER'S SITE**

Hot Water: Space Heating and domestic uses

20,000 Btu/hr per typical dwelling

T_{lm} (DH loop - User's loop) = 56°F

Cooling: 1.5 tons of refrigeration per typical dwelling

35×10^3 Btu/hr at 230 - 290°F for absorption cooling

Steam: 8.5 psig steam from 243°F DH water

Higher steam grades with on-site heat pump

**Typical Dwelling Assumptions

Heating: Outside T - 0°F, inside T - 70°F, 5200 Heating Degree Days

Cooling: Outside T - 77°F Wet Bulb, Inside T = 75°F, 1100 Cooling Degree Days

94°F Dry Bulb

Domestic Hot Water: 140°F year round

TABLE ES- II

FULLY DEVELOPED DISTRICT HEATING SYSTEM

 3.7×10^9 BTU/HR PEAK OUTPUT

THERMAL ENERGY SUPPLY ELEMENTS

Plant	Peak output 10 ⁶ BTU/hr	entering leaving peak water temp. of	
Hudson #2	1600	167	223
Kearny #12	1100	223	259
Total of 11 heater plants	1000	259	295
(installed capacity)	(2300)		

TABLE ES-III
SUMMARY OF CAPITAL COSTS
FULLY DEVELOPED DISTRICT HEATING SYSTEM
VS.
CONVENTIONAL HEATING SYSTEMS

		<u>Million \$ (1983)</u>	<u>Million \$ (current)</u>
<u>DISTRICT HEATING</u>			
11 heater plants		61.6	10.9%
Natural gas service to heater plants		.77	
Kearny #12 retrofit		11.7	2.0%
Transmission lines	59.		
River crossings	8.	68.0	11.8%
Hudson retrofit		93.3	16.3
Distribution			
New developments	40.0		
Jersey City	131.5		
Newark	136.5	308.0	53.5%
Sub-total		543.37	94.5
Landfill gas & distr.		7.7	1.3
		551.07	95.8
Customer conversion			
New Developments	N/A		
Jersey City	9.5		
Newark	14.0		
Metering	.63	24.13	4.2
Total/DH System cost		575.20	2,335. 100.0
<u>CONVENTIONAL HEATING SYSTEMS</u>		72.6	334.

FIGURE 10.8

FULL DISTRICT HEATING SYSTEM THERMAL ENERGY SUPPLIED—BY DIRECT SOURCE 1984–2011

**THERMAL ENERGY SUPPLIED BY FUEL TYPE
WITHOUT
DISTRICT HEATING
1984-2011
(ASSUMING PRESENT N.J. MIX OF OIL AND GAS USAGE
FOR RESIDENTIAL HEATING)**

146×10^{12} BTU OF FUEL CONSUMED

**TOTAL DISTRICT HEATING SYSTEM
THERMAL ENERGY SUPPLIED BY FUEL TYPE
(INCLUDING EFFECT ON ELECTRIC SYSTEM OPERATION)
1984 - 2011**

94×10^{12} BTU OF FUEL CONSUMED

**FUEL SAVINGS
 52×10^{12} BTU**

FIGURE ES-1

District cooling was initially considered. However, it was found that distribution of chilled water would require a 4-pipe instead of a 2-pipe transmission and distribution system, increasing already high T&D capital costs. The use of hot water from a central thermal source to drive absorption chillers was found unfeasible as the loss in electric generation from the retrofitted central heat source (Hudson No. 2) would exceed the electricity needed to drive compression chillers at the customers' sites. It would also derate Hudson No. 2 at the time of the Summer electrical peak, and require a District Heating water sendout temperature higher than would otherwise be needed. However, local, site specific absorption cooling needs could technically be served from the local heater plants and/or the Kearny No. 12 heat recovery unit. These would need to be assessed for any economical advantage on an individual basis.

A regional district heating system was found to have a negligible-to-positive environmental impact and no insurmountable barriers to its development were encountered. The key economic findings are summarized in the Conclusions. Table 5-I lists the ownership/financing options examined in the financial analysis, and Table 5-II lists the financial assumptions used in that analysis.

CONCLUSIONS

- (1) Small localized district heating systems in new developments, each with a peak demand in the order 200×10^6 BTU/hr and supplied by centralized package boilers, appear economically preferable to conventional natural gas-fueled individual-building heating systems. The Levelized Annual Minimum Revenue Requirements (LAMRR) advantage of district heating ranges from 22% (natural gas) to 34% (landfill gas) savings over the conventional system (Table 9-II).*

* References correspond to main body of report

Table 5-VI shows the projected cost of heat from district heating of such a new development (using landfill gas) compared with conventional heating. District heating is initially more expensive due to front-end capital loading, but shows a growing cost advantage after the fourth year. Site specific analyses will however be required to confirm these findings.

- (2) A small, localized district heating system (200×10^6 BTU/hr peak) supplied by a limited retrofit of coal-fired Hudson No. 2 seems economically equivalent to the package-boiler alternative described above. It would thus be difficult to justify the higher capital investment of a limited retrofit of Hudson No. 2 relative to the package boiler option. (Table 9-1).
- (3) A combination of district heating supplies from package boilers and limited retrofit of Hudson No. 2 into one system (400×10^6 BTU/hr load) results in an advantage of 9% with natural gas and 17% with landfill gas (Table 9-III). This is less than for two smaller district heating systems fueled totally by natural gas as in (1) above. Thus, the retrofit of Hudson No. 2 and associated transmission piping cannot be justified in this case.
- (4) There is no real economic incentive to accelerate the development of a regional (3.7×10^9 BTU/hr) district heating system based on retrofitting coal-fired Hudson No. 2 and constructing associated thermal transmission facilities (Fig. 9-IV) over what a gradual market penetration (using package boilers) would dictate. This is shown in Table 9-IV (levelized analysis) and Table 5-IV (price of heat).
- (5) Distribution piping facilities account for the largest item (16%) of the Levelized Annual Minimum Revenue Requirements for the fully-developed system, due primarily to the urban locations for the pipe installations.

Concentrating on new developments, with one-third less the distribution piping cost of established areas, could significantly improve district heating economics. Use of innovative technology to reduce piping installation costs could have a similar effect.

- (6) The economic viability of district heating is heavily dependent on fuel prices. Higher fuel price escalations would favor district heating and lower price escalations tend to favor a conventional system (see Tables 9-IV and 9-VII).
- (7) Because of landfill gas supply limitations (several hundred million BTU/hr) in the study area, landfill gas could have only a small but positive effect on the economics of a regional district heating system (3.7×10^9 BTU/hr peak), by reducing the natural gas consumption required for such a system (Table 9-IV). The effect of landfill gas becomes quite significant for smaller systems (see (1) above).
- (8) Reasonable variations in capital costs of thermal energy supply facilities (i.e., district heating plant) have a minimal effect (about 5%) on the overall economics (see Tables 9-IV and 9-VI).
- (9) The alternative financing and ownership options evaluated in the study do not greatly affect the levelized economics of district heating. They do, however, affect cash flow, breakeven period, internal generation of capital and competitive pricing (see Tables 5-III and 5-IV).
- (10) The small, localized, 200×10^6 BTU/hr district heating system described above in (1) has a higher capital requirement than the conventional alternative.

However, its 71% internal generation of capital meets the minimum corporate requirement of 50% (see Table 5-V).

- (11) The 13% Gross Receipts and Franchise Tax (GR&FT) significantly affects the viability of district heating. If this charge were to be eliminated by legislation, all district heating alternatives would be viable with advantages over conventional systems of 10% (regional district heating system) to 41% (district heating of Berry's Creek with landfill gas). This is shown in Tables ES-IV which summarizes the (levelized) economic analysis of all scenarios, with and without GR&FT.

RECOMMENDATIONS

The major conclusion of this study was that small dispersed district heating systems in conjunction with new developments can be viable, and these should be pursued by looking for specific opportunities in northeast New Jersey and other areas with similar characteristics. These dispersed, small systems could provide the underpinning of large regional district heating systems of the future.

A number of major barriers to district heating implementation identified in the current study are listed in Table 13-I. Major recommendations derived from this study are listed below.

1. District Heating development requires a utility to make a fundamental corporate decision and commitment as to whether it wishes to become involved in district heating as a new business area, if and where it is proven profitable.

If the answer is positive then the following steps are appropriate:

- a. The utility should decide if it wishes to own and operate the entire system (including T&D), sell heat to another T&D entity or build and

operate all or part of the system for another owner (e.g., the customer(s) or a third party).

- b. Specific small (10×10^6 BTU/hr) and intermediate (200×10^6 BTU/hr) scale district heating opportunities should be identified. Consideration of large (3.7×10^9 BTU/hr) systems should be deferred for the present.
 - c. A small-scale economically viable, district heating/cogeneration project (e.g., in a new development) should be identified and carried through study to demonstration in a cooperative effort between the utility, the customer(s), the municipality and private investors. Contingent commitments based on cost estimates of gradually increasing accuracy should be utilized.
 - d. The use of transportable heater plants (as in Europe) to reduce district heating start-up costs and improve initial cash flow should be investigated.
 - e. The feasibility of reducing the generation loss resulting from the limited retrofit of a major generating station should be pursued with the manufacturer and the utility operating departments.
 - f. District heating distribution cost estimates for an urban site should be done on a "street-specific" basis due to large variations in costs from the interferences with other underground utilities.
- 2. R&D on the utilization and development of innovative technology to reduce the installed cost of district heating piping in the transmission and distribution sectors should be pursued.
 - 3. Studies should be done of the potential of coal and waste-fired (fluidized bed) cogenerating heating plants to improve district heating economics.

4. New developments/redevelopments now being planned for urban areas in the nation (e.g., Meadowlands and River waterfronts of New Jersey) should be the focus of attention for district heating implementation because of the lower distribution system installation cost (about two-thirds of built-up areas).
5. Case specific studies of industrial development opportunities in conjunction with district heating should be considered.

PROJECT TEAM

PSE&G

Research and Development - Project Management and Coordination

System Planning - Economic and Financial Analysis, Cost of Heat

Gas Transmission and Distribution - Piping system design and costs

Engineering and Construction - Review of cost estimates and designs

Customer and Marketing - Load survey

Rates and Load Management - Tariffs

Law, Finance, Environmental Affairs - Topical issues

Subcontractors:

Stone & Webster Engineering Corp. - Powerplant retrofit, detailed engineering design and cost estimates

Transflux International Ltd. - Load determination, conceptual design of district heating systems and heating plants

Stone & Webster Management

Consultants, Inc. - Load assessment questionnaire design, analysis of responses

Westinghouse Electric Co.

and

General Electric Co.

- Steam turbine retrofit

Coopers & Lybrand Inc.

- Assessment of financing and ownership
options

Trenton State College

- Air quality modeling calculations

N. J. Department of Energy

- Fuel and energy use data

Desert Reclamation Industries Inc.

- Aquifer thermal storage consultant

MAJOR BRIEFINGS AND CONSULTATIONS

PSE&G Senior and Middle Management

New Jersey Board of Public Utilities

New Jersey Department of Energy

New Jersey Department of Environmental Protection

New Jersey Department of Labor & Industry-Office of Boiler and Pressure Vessel
Compliance

Bergen County Utilities Authority (Sewage and Municipal Solid Waste authority)

Hackensack Meadowlands Development Commission

Newark Redevelopment and Housing Authority

Summit Plaza (Former "Operation Breakthrough" Total Energy Housing Complex)

Hartz Mountain Industries, Inc. (Land developers in the

and Hackensack Meadowlands)

Bergen County Associates

Various potential sources of venture capital for "third-party" energy projects

Office of the Mayor - Jersey City and Newark

TABLE 5-I

FULLY DEVELOPED SYSTEM
DESCRIPTION OF CASES

Conventional Heating	• Conventional financing
	• Rate of return regulated
District Heating Base	• Conventional financing
	• Rate of return regulated
District Heating Tax-Exempt	• Distribution plant financed with Industrial Development Bonds (IDB) @ 7.5%
	• Straight line depreciation of distribution plant over the ACRS tax life
	• Remaining capital conventionally financed
	• Rate of return regulated
District Heating Lease	• Heater plant leased at an annual payment of 11.3% of capital cost
	• Total investment reduced by heater plant capital investment
	• Remaining capital conventionally financed
District Heating Non-Utility Status	• No gross receipts and franchise tax
	• All plant depreciated over five years for tax purposes

TABLE 5-II

DISTRICT HEATING ANALYSIS
FINANCIAL ASSUMPTIONS

Long Term Cost of Capital (All Cases)

	<u>Ratio</u>	<u>Cost</u>	<u>Weighted Cost</u>
Debt	43%	10.5%	4.5%
Preferred Stock	12	9.5	1.1
Common Stock	<u>45</u>	14.0	<u>6.3</u>
Total	<u>100%</u>		<u>11.9%</u>

District Heating Tax-Exempt Case - Distribution plant financed with 7.5% industrial development bonds.

District Heating Lease Case - Heater plant leased at an annual payment of 11.3% of capital cost.

TABLE 5-111
FULLY DEVELOPED SYSTEM
1984-1993

<u>Case</u>	<u>Average*</u> <u>Price of</u> <u>Heat</u>		<u>Total</u> <u>Construction</u> <u>Expenditures</u>		<u>%</u> <u>Internal</u> <u>Generation</u>	
	<u>\$/mBtu</u>	<u>Rank</u>	<u>\$Million</u>	<u>Rank</u>	<u>%</u>	<u>Rank</u>
Conventional System	27	1	27	1	77	1
Dist. Heating Base	42	4	199	3	43	3
Dist. Heating Tax-Exempt	40	3	199	3	37	5
Dist. Heating Lease	42	4	172	2	42	4
Dist. Heating Non-Utility	36	2	199	3	52	2

*Time average price, unweighted and undiscounted.

TABLE 5-IV
DISTRICT HEATING
1984-1993
PRICE OF HEAT
(\$/mBtu)

<u>Year</u>	<u>(1)</u>	<u>(2)</u>	<u>(3)</u>	<u>(4)</u>	<u>(5)</u>
1984	13.89	106.24	104.76	108.39	92.35
1985	20.44	42.40	40.94	40.45	36.87
1986	22.11	33.99	32.15	33.93	29.17
1987	24.03	31.62	29.43	29.32	26.77
1988	25.70	32.88	30.39	31.61	27.56
1989	27.56	31.54	28.77	30.95	26.13
1990	29.79	32.46	29.44	31.98	26.70
1991	32.19	33.28	30.16	33.01	27.28
1992	34.85	36.36	33.19	36.24	29.77
1993	37.60	41.00	37.77	41.11	33.50

- (1) Conventional Heating System
- (2) District Heating - Base Case
- (3) District Heating - Tax-Exempt
- (4) District Heating - Lease
- (5) District Heating - Non-Utility Status

TABLE 5 -V
DERRY'S CREEK
WITHOUT HUDSON RETROFIT
1984-1993

<u>Case</u>	Average* Price of Heat		Total Construction Expenditures		Internal Generation	
	<u>\$/mBtu</u>	<u>Rank</u>	<u>\$Million</u>	<u>Rank</u>	<u>%</u>	<u>Rank</u>
Conventional System	26	2	6	1	83	1
District Heating	22	1	26	2	72	2

*Time average price, unweighted and undiscounted.

TABLE 5-VI
BERRY'S CREEK
WITHOUT HUDSON RETROFIT
1984-1993
PRICE OF HEAT
(\$/mBtu)

	<u>Conventional</u>	<u>District Heating</u>
1984	10	21
1985	14	22
1986	17	23
1987	21	21
1988	25	20
1989	28	21
1990	28	22
1991	34	23
1992	39	25
1993	43	26

TABLE 9-I

LEVELIZED ANNUAL MINIMUM REVENUE REQUIREMENTS
FOR BERRY'S CREEK WITH A PARTIAL HUDSON #2 RETROFIT
1983 \$X10³

<u>Capital Related</u>	<u>District Heating</u>		<u>Conventional</u>	
	\$	%	\$	%
Boilers	663	5	531	4
Hudson #2 Retrofit	829	6		
Natural Gas Service	8	—	145	1
Customer Heat Exchangers	142	1		
Metering	4	—		
Transmission	763	6		
Distribution	725	6		
<u>Fuel Related</u>				
Increased Electric System Production Costs	4,569	35		
Natural Gas	2,406	19	9,286	75
<u>O&M Costs</u>				
Manpower	657	5	2,485	20
Pumping Energy	405	3		
Materials	250	2		
<u>Gross Receipts and Franchise Taxes</u>	1,485	12	0	0
<u>Total</u>	<u>12,906</u>	<u>100</u>	<u>12,447</u>	<u>100</u>
<u>Savings (Penalties)</u>	(548)			

(1) Based on LVG rate which includes GR&FT

(2) GR&FT is included in fuel price

0166K(7)

TABLE 9-II

LEVELIZED ANNUAL MINIMUM REVENUE REQUIREMENTS
FOR BERRY'S CREEK WITHOUT A HUDSON #2 RETROFIT

<u>Capital Related</u>	District Heating Without Landfill		District Heating With Landfill		Conventional	
	Gas		Gas			
	\$	%	\$	%	\$	%
Boilers	805	8	805	10	531	4
Natural Gas Service	8	-	8	-	145	1
Customer Heat Exchangers	142	1	142	2		
Metering	4	-	4	-		
Distribution	725	7	725	9		
Landfill Collection & Transmission	-	-	1,001	12		
<u>Fuel Related</u>						
Natural Gas	5,630	58	1,351	16	9,286	75(
Landfill Gas Royalties	-		1,001	12		
<u>O&M Costs</u>						
Manpower	657	7	736	9	2,485	20
Pumping Energy	366	4	366	4		
Materials	250	3	250	3		
Additional Costs Associated With Landfill	-		914	11		
<u>Gross Receipts and Franchise Taxes</u>	1,116	12	949	12	0	0(
<u>Total</u>	<u>9,703</u>	<u>100</u>	<u>8,252</u>	<u>100</u>	<u>12,447</u>	<u>100</u>
<u>Savings (Penalties)</u>	2,744		4,195		-	

(1) Based on LUG rate which includes GR&FT

(2) GR&FT is included in fuel price

0166K(14)

TABLE 9-IV
LEVELIZED ANNUAL MINIMUM REVENUE REQUIREMENTS
FOR FULLY DEVELOPED DISTRICT HEATING SYSTEM
(1983 \$X10³)

<u>Capital Related</u>	District Heating Without Landfill		District Heating With Landfill		Conventional	
	Gas		Gas			
	\$	%	\$	%	\$	%
Boilers	5,426	6	5,426	6	3,978	4
Hudson #2 Retrofit	7,569	8	7,569	8		
Kearny Retrofit #12	835	1	835	1		
Natural Gas Service	61	—	61	—	1,622	2
Customer Heat Exchangers	1,590	2	1,590	2		
Metering	42	—	42	—		
Transmission	5,415	6	5,415	6		
Distribution	20,274	21	20,274	22		
Landfill Collection and Transmission			788	1		
<u>Fuel Related</u>						
Increased Electric System Production Costs	15,279	16	12,973	14		
Natural Gas	13,394	14	10,454	11	67,407	75
Landfill Gas Royalties			1,846	2		
<u>O&M Costs</u>						
Manpower	8,245	9	8,245	9	16,932	19
Pumping Energy	2,988	3	2,988	3		
Materials	1,688	2	1,688	2		
Additional Costs Associated With Landfill			1,237	1		
<u>GROSS RECEIPTS AND FRANCHISE TAXES</u>	10,765	12	10,586	12	0	0(2)
<u>TOTAL</u>	93,571	100	92,017	100	89,939	100
<u>SAVINGS (PENALTIES)</u>	(3,632)		(2,078)		—	

(1) Based on LUG Rate which includes GR&FT

(2) GR&FT is included in fuel price

0166K(13)

TABLE 9-VI
LEVELIZED ANNUAL MINIMUM REVENUE REQUIREMENTS
FOR FULLY DEVELOPED DISTRICT HEATING SYSTEM
BASED ON LOW RANGE OF ESTIMATES
(1983 \$X10³)

<u>CAPITAL RELATED</u>	District Heating Without Landfill		District Heating With Landfill		Conventional	
	Gas		Gas			
	\$	%	\$	%	\$	%
Boilers	4,933	6	4,933	6	3,978	
Hudson #2 Retrofit	4,068	4	4,068	5	-	
Kearny Retrofit #12	688	1	688	1	-	
Natural Gas Service	61	-	61	-	1,622	
Customer Heat Exchangers	1,590	2	1,590	2	-	
Metering	42	-	42	-	-	
Transmission	5,415	6	5,415	6	-	
Distribution	20,274	23	20,274	23	-	
Landfill Collection and Transmission			788	1	-	
<u>FUEL RELATED</u>						
Increased Electric System Production Costs	15,279	17	12,973	15		
Natural Gas	13,394	15	10,454	12	67,407 (1)	7
Landfill Gas Royalties			1,846	2		
<u>O&M Costs</u>						
Manpower	8,245	9 (2)	8,245	9	16,932 (2)	1
Pumping Energy	2,988	3	2,988	3		
Materials	1,688	2	1,688	2		
Additional Costs Associated With Landfill			1,237	1		
<u>GROSS RECEIPTS AND FRANCHISE TAXES</u>	<u>10,226</u>	12	<u>10,048</u>	12	0 (3)	
<u>TOTAL</u>	<u>88,891</u>	<u>100</u>	<u>87,338</u>	<u>100</u>	<u>89,939</u>	<u>10</u>
<u>SAVINGS (PENALTIES)</u>	1,048		2,601		-	

(1) Based on LUG Rate which includes GR&FT

(2) District heating system requires 105 men when fully developed. Conventional system requires 400 men when fully developed.

(3) GR&FT is included in fuel price.

TABLE 9-VII
 LEVELIZED ANNUAL MINIMUM REVENUE REQUIREMENTS
 FOR FULLY DEVELOPED DISTRICT HEATING SYSTEM
 WITH A 1% REDUCTION IN ALL FUEL PRICE ANNUAL ESCALATION RATES
 (1983 \$X10³)

<u>Capital Related</u>	District Heating Without Landfill		<u>Conventional</u>	
	<u>Gas</u>			
	<u>\$</u>	<u>%</u>	<u>\$</u>	<u>%</u>
Boilers	5,426	6	3,978	5
Hudson #2 Retrofit	7,569	9		
Kearny Retrofit #12	835	1		
Natural Gas Service	61		1,622	2
Customer Heat Exchangers	1,590	2		
Metering	42	-		
Transmission	5,415	6		
Distribution	20,274	23		
<u>Fuel Related</u>				
Increased Electric System Production Costs	12,743	14		
Natural Gas	11,886	13	56,097	71
Landfill Gas Royalties				
<u>O&M Costs</u>				
Manpower	8,245	9	16,932	22
Pumping Energy	2,484	3		
Materials	1,688	2		
Additional Costs Associated With Landfill				
<u>GROSS RECEIPTS AND FRANCHISE TAXES</u>	10,173	12	0	0(2)
<u>TOTAL</u>	<u>88,431</u>	<u>100</u>	<u>78,629</u>	<u>100</u>
<u>SAVINGS (PENALTIES)</u>	(9,802)			

(1) Based on LUG Rate which includes GR&FT
 (2) GR&FT is included in fuel price

0166K(17)

LEVELIZED ANNUAL
MINIMUM REVENUE
REQUIREMENTS (LAMRR)
1983 \$ X 10³

SCENARIO	Base	Savings (penalty) over base			
	Conventional	incl. GR&FT*		w/o GR&FT*	
	\$	\$	%	\$	%
Berry's Creek	12447	2744	22.0	3860	31.0
Berry's Creek w/landfill gas	12447	4195	33.7	5144	41.3
Berry's Creek w/partial Hudson retrofit	12447	(459)	(3.7)	1026	8.2
Berry's Creek & Harmon Meadows					
- w/Hudson #2 retrofit	26060	2259	8.7	4997	19.2
- w/Hudson #2 retrofit & landfill gas	26060	4528	17.4	7005	26.9
Fully developed system	89939	(3632)	(4.0)	7133	7.9
- w/landfill gas	89939	(2078)	(2.3)	8508	9.5

*GR&FT = Gross Receipts and Franchise Tax

TABLE ES-IV

TABLE 13-I

District Heating Barriers to Implementation and Suggestions for Resolution

<u>Barrier</u>	<u>Actions Required</u>
Marginal Economics	(1) Reduce costs, particularly T&D piping installed cost; (2) Negotiate resolution of taxation/regulatory issues with state government; (3) Reduce local heating plant operating costs by use of cogeneration and waste fuels.
Startup losses due to heavy capital loading	(1) Phase DH capital costs more gradually, use transportable heater plants as in Europe; (2) Rate adjustment to offset startup losses and repay later.
High capital costs of T&D piping	(1) Investigate cost reduction via European DH technology and development/adaptation of advanced technologies including cost optimization via subsurface mapping using computer graphics, street-specific cost/routing optimization.
Uncertainties in Economic/Financial conditions and fuel prices	(1) Minimize exposure by starting with small systems; (2) Obtain contingent commitments from customers based on estimated costs (customer supplies his cost projections of alternative supply and agrees to connect if DH is competitive.)
Cost of operating small local heating plants in isolation from central DH system	(1) Use of waste fuels (including landfill gas), coal (using AFBC) (2) Utilization of cogeneration to improve economics.
High total capital costs vs. utility capital constraints due to other construction	(1) Start with small initial system; (2) Seek outside (venture capital) financing (3) Municipality/customer group backing (4) Creative financing leasing, UDAG, Block Grants.