260
5/14/84
LB

7

0055-8
DR-0055-8

DOE/CS/20071-1(Vol.4)
(DE84006861)

Energy

CONSERVATION

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

Final Report for the Period March 1, 1980—January 31, 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

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

This report has been reproduced directly from copy supplied by the originating organization. Although the copy supplied may not in part or whole meet the standards for acceptable reproducible copy, it has been used for reproduction to expedite distribution and availability of the information being reported.

Available from the National Technical Information Service, U. S. Department of Commerce, Springfield, Virginia 22161.

Price: Printed Copy A12
Microfiche A01

Codes are used for pricing all publications. The code is determined by the number of pages in the publication. Information pertaining to the pricing codes can be found in the current issues of the following publications, which are generally available in most libraries: *Energy Research Abstracts (ERA)*; *Government Reports Announcements and Index (GRA and I)*; *Scientific and Technical Abstract Reports (STAR)*; and publication NTIS-PR-360 available from NTIS at the above address.

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

VOLUME IV

REPORT DATE: 31 JANUARY 1984

WORK PERFORMED UNDER CONTRACT
DE-AC022-78CS20071

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:

PSE&G R&D Department: C. R. Guerra, M. L. Zwillenberg

**PSE&G, System Planning Department: M. P. Bhavaraju, T. M. Piascik,
F. Cassidy, J. P. Everett,
K. Krauszer**

**Stone & Webster Engineering Corp.: D. Samela, R. Ulfstam,
G. Kan**

Transflux International, Ltd.: M. G. Kurz

**Stone & Webster Management Consultants, Inc.: G. S. Levitt,
E. Schiaffino**

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

PREFACE

This volume contains the following elements:

- Discussion of cost estimating methodology - Transflux
- Detailed cost estimates of Hudson No. 2 retrofit, intermediate thermal plant (Kearny No. 12) and local heater plants: SWEC (original cost estimate packages provided by SWEC are included.)
- Transmission and Distribution (T&D) Cost Estimate: SWEC with PSE&G Gas T&D Department, and comparative cost estimate by Danpower, Inc.
- Landfill Gas Cost Estimate: PSE&G R&D Department (Mr. J. J. Pardus)
- Staged Development Scenarios: Transflux
- Economic Evaluation: PSE&G System Planning Department (Messrs. J. P. Everett, T. M. Piasek, Dr. M. P. Bhavaraju)
- Fuel Use Impact: PSE&G System Planning Department (as above)
- Air Quality Impact: Trenton State College (Dr. D. Letcher)
- Alternatives to District Heating: PSE&G R&D and System Planning Departments

- **Conclusions and Recommendations: PSE&G R&D Department in consultation with PSE&G District Heating Project Coordination Team**

SECTION 7

COST ESTIMATES

TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
7 COST ESTIMATES	
7.1 Methodology	2
7.2 Hudson Unit No. 2 Full Retrofit – 1,600x10 ⁶ BTU/hr Heat Supply	11
7.3 Limited (Partial) Retrofit, Hudson Unit No. 2, 200x10 ⁶ BTU/hr Heat Supply	22
7.4 Local Heater Plant and Kearny No. 12 Retrofit (Intermediate Plant) Cost Estimates	34
7.5 PSE&G Capital Costs of Conversion Schemes for Various Types of Customer Heating Systems	37
7.5.1 Design criteria	37
7.5.2 Customer conversion modules	37
7.6 PSE&G District Heating Transmission and Distribution Piping Installation Costs	42
7.6.1 Design bases	42
7.6.2 Method of Construction and Installation	42
7.6.2.1 Rural	42
7.6.2.2 Urban	42
7.6.2.3 Suburban	44
7.6.2.4 Right-of-Way	44
7.6.3 Determination of piping costs	44
7.6.3.1 Qualifications to estimate	44
7.6.4 Overall transmission and distribution system piping costs	45
7.6.4.1 Transmission system piping costs	45
7.6.4.2 Distribution system piping costs	47
7.7 Landfill Gas Supply Cost Estimate	52
7.8 Comparative Distribution/Transmission Cost Estimates	59
8 STAGED DEVELOPMENT SCENARIOS	
8.0 Introduction	73

Table of Contents (continued)

<u>Section</u>		<u>Page</u>
	8.0.1 Conventional customer owned system	73
8.1	Scenario I - Berry's Creek District Heating System	75
	8.1.1 Introduction	75
	8.1.2 The development	75
	8.1.3 Proposed D-H system	75
	8.1.3.1 Hudson G.S. based system	82
	8.1.3.2 Landfill gas based system	84
	8.1.4 HTW distribution	86
	8.1.5 Operation and maintenance	87
8.2	Scenario II - Berry's Creek & Harmon Meadows District Heating System	100
	8.2.1 Introduction	100
	8.2.2 The developments	100
	8.2.3 Proposed D-H system	100
	8.2.3.1 Hudson G.S. based system	101
	8.2.3.2 Landfill gas based system	102
	8.2.4 HTW distribution	102
	8.2.5 Operation and maintenance	102
8.3	Scenario III Fully Developed District Heating System (Jersey City, Newark, Meadowlands)	115
	8.3.1 Introduction	115
	8.3.2 The supply areas	115
	8.3.2.1 The Hackensack Meadowlands	115
	8.3.2.2 Jersey City-Hoboken	116
	8.3.2.3 Newark/Harrison	116
	8.3.2.4 Other areas	117
	8.3.3 Summary of D-H load potential	118
	8.3.4 Proposed D-H system	119
	8.3.4.1 Capacity	119
	8.3.4.2 Heat supply sources	120
	8.3.4.3 Spare capacity and firm supply	121
	8.3.4.4 Heater plant installations	122
	8.3.4.5 HTW transmission and distribution	124
	8.3.4.5.1 Transmission	124
	8.3.4.5.2 Distribution	125
	8.3.5 Operating cost	126
	8.3.5.1 Heat loss	126
	8.3.5.2 Pumping cost	126

Table of Contents (continued)

<u>Section</u>		<u>Page</u>
	8.3.5.3 Operating personnel	127
	8.3.5.4 Maintenance and other cost	128
	8.3.5.5 Other cost	128
9	ECONOMIC EVALUATION	
9.1	Introduction	149
9.2	Economic Analysis Methodology	150
9.3	Economic Comparisons	150
	9.3.1 Berry's Creek with a Hudson #2 retrofit	150
	9.3.2 Berry's Creek without Hudson #2 retrofit	152
	9.3.3 Berry's Creek plus Harmon Meadows	152
	9.3.4 Fully developed system	155
9.4	Sensitivity to Variations in Capital Costs of Thermal Supplies	158
9.5	Sensitivity to Variations in Fuel Prices	161
10	IMPACT ON FUEL USE AND ON THE ENVIRONMENT	
10.1	Fuel Utilization	165
10.2	Comparison of Fuel Consumption	166
	10.2.1 Berry's Creek without a Hudson #2 retrofit	166
	10.2.2 Berry's Creek with a Hudson retrofit	169
	10.2.3 Berry's Creek plus Harmon Meadows	169
	10.2.4 Fully developed system	169
10.3	Environmental Impact	176
	10.3.1 Dispersion modeling for District Heating	180
	10.3.1 Introduction	181
	10.3.2 Input data for model	186
	10.3.3 Model predictions	195
	10.3.4 Supplementary report to dispersion modeling for district heating	201
	10.3.4 Introduction	202
	10.3.4.1 Methodology	202

Table of Contents (continued)

<u>Section</u>	<u>Page</u>
10.3.4.2 Discussion of result	203
10.3.4.3 Results of executing the climatological dispersion model (CDM) in order to assess the increments in sulfur dioxide due to district heating	207
10.3.5 Guideline on air quality models	210
11 ALTERNATES TO CONVENTIONAL HEATING SYSTEMS	
11.1 Introduction	216
11.2 Selection of Alternate Heating Systems	216
11.3 Economic Comparison of Solar Thermal and Conventional Heating System	217
12 CONCLUSIONS	222
13 RECOMMENDATIONS	226

FIGURES

Figure No.

7.1 Customer Conversion Flow Diagram	40
7.2 Customer Conversion Unit	41
7.3 Transmission Piping	46
7.4 Typical Distribution Layout - Jersey City	49
7.5 Typical Distribution Layout - Newark	50
7.6 District Heating Piping for a Typical Row of Multi-Family Houses	51
8.0.1 No title	76
8.1.1 Development Plan Stage One 1984	77
8.1.2 Development Plan Stage One 1985	78

Table of Contents (continued)

<u>Figure No.</u>		<u>Page</u>
8.1.3	Development Plan Stage One 1986	79
8.1.4	Development Plan Stage One 1987	80
8.1.5	Development Plan Stage One 1988	81
8.1.6	Berry's Creek District Heating Plant Layout	89
8.1.7	Berry's Creek District Heating Plant Piping Schematics	90
8.1.8	Berry's Creek Center D-H from Hudson G.S.	91
8.1.9	Hudson G.S. No. 2 Unit Partial Retrofit for Berry's Creek D-H (Conceptual)	92
8.1.10	Berry's Creek Center Landfill Gas Based D-H System	93
8.1.11	Fuel Source Distribution in a Landfill Gas Supplied System	94
8.1.12	District Heating System - Berry's Creek Heat Sources and Transmission	95
8.2.1	Harmon Meadows D-H System	103
8.2.2	Berry's Creek Center & Harmon Meadows D-H from Hudson G.S.	104
8.2.3	Heat Supply Distribution w/Hudson #2 Unit Partial Retrofit	105
8.2.4	Berry's Creek Center & Harmon Meadows Landfill Gas Based D-II System	106
8.2.5	Fuel Source Distribution in a Landfill Gas Supplied System	107
8.2.6	1988 District Heating System - Berry's Creek & Harmon Meadows Heat Sources and Transmission	108
8.2.7	1993 District Heating System Berry's Creek & Harmon Meadows Heat Sources and Transmission	109
8.3.1	Regional Plan	129
8.3.2	Hudson G.S. Based District Heating System	130

Table of Contents (continued)

<u>Figure No.</u>		<u>Page</u>
8.3.3	Jersey City/Hoboken D-H Supply Area	131
8.3.4	Newark Area of Potential District Heating	132
8.3.5	Transmission System	133
8.3.6	Transmission Mains Development between Hudson & Kearny G.S.	134
8.3.7	1988 District Heating System Heat Sources and Transmission	135
8.3.8	1993 District Heating System Heat Sources and Transmission Facilities	136
8.3.9	1999 District Heating System Heat Sources and Transmission Facilities	137
8.3.10	2001 District Heating System Heat Sources and Transmission	138
8.3.11	2003 District Heating System Heat Sources and Transmission	139
8.3.12	2006 District Heating System Heat Sources and Transmission	140
8.3.13	Full Development of the District Heating System Heat Sources and Transmissions	141
8.3.14	Full District Heating System Load and Capacity Expansion, 1984-2011	142
10.1	Berry's Creek Fuel Consumption without Landfill Gas	167
10.2	Berry's Creek Fuel Consumption with Landfill Gas	168
10.3	Berry's Creek Fuel Consumption with a Hudson #2 Retrofit	170
10.4	Berry's Creek and Harmon Meadows Fuel Consumption with Natural Gas	171
10.5	Berry's Creek and Harmon Meadows Fuel Consumption with Landfill Gas	172
10.6	Berry's Creek and Harmon Meadows Fuel Consumption with Hudson #2 Retrofit and Landfill Gas	173

Table of Contents (continued)

<u>Figure No.</u>		<u>Page</u>
10.7	Full System Fuel Consumption with Hudson #2 Retrofit and Natural Gas	174
10.8	Full District Heating System Thermal Energy Supplied - By Direct Source 1984-2011	175
10.9	Full District Heating System Thermal Energy Supplied - By Fuel Type (Including Effect on Electric System Operation) 1984-2011	177
10.10	No title	179
10.11	Salient Geography of District Heating	182
10.12	No title	183
10.13	Grid Map	196
10.14	Grid Map	197
10.15	No title	204
10.16	Grid Map	205
10.17	Grid Map	208
10.18	Grid Map	209

TABLES

<u>Table No.</u>		
7-I	Capital Cost Estimates Heat Supply	3
7-II	Capital Cost Estimates - Customer Conversion Unit (1981\$)	5
7-III	District Heating Transmission and Distribution Piping Comparison of Cost Estimates from Various Sources	6
7-IV	Cost Estimates	7
7-V	Cost Estimates	8

Table of Contents (continued)

<u>Table No.</u>		<u>Page</u>
7-VI	Preliminary Cost Estimate - Hudson	20
7-VII	Installed Capital Cost for Prefabricated Piping System (Material & Labor)	43
8.1-I	Berry's Creek Project Implementation Forecast - Stage 1	76
8.1-II	Meadowlands System (Berry's Creek Only) HTW Piping Installation Schedule	96
8.1-III	Meadowlands System (Berry's Creek Only) Installations & Load Run Up Estimate	97
8.1-IV	List of Annual Equipment Installation Requirements	98
8.1-V	Meadowlands System (Berry's Creek Only) Annual Pumping Cost Estimate	99
8.2-I	Industrial/Residential Development @ Rt. 3 & N.J. Tpke East Spur	110
8.2-II	Meadowlands System (Berry's Creek Plus Harmon Meadows) HTW Piping Installation Schedule	111
8.2-III	Meadowlands System (Berry's Creek Plus Harmon Meadows) Installations & Load Run Up Estimate	112
8.2-IV	Hartz Mountain-Harmon Meadows 10 Yr Development Plan of D-H	113
8.2-V	Meadowlands System (Berry's Creek Plus Harmon Meadows) Pumping Cost Schedule \$1000 per Annum	114
8.3-I	Heat Source Installation Schedule	143
8.3-II	Total District Heating System Incremental & Accumulative Load Growth Estimate	144
8.3-III	Piping Installation Schedule	145
8.3-IV	Piping Heat Loss Schedule	146
8.3-V	Pumping Cost Schedule \$1000 per Annum	147

Table of Contents (continued)

<u>Table No.</u>		<u>Page</u>
9-I	Levelized Annual Minimum Revenue Requirements for Berry's Creek with a Partial Hudson #2 Retrofit (1983 \$ x 10 ³)	151
9-II	Levelized Annual Minimum Revenue Requirements for Berry's Creek without a Hudson #2 Retrofit	153
9-III	Levelized Annual Minimum Revenue Requirements for Berry's Creek and Harmon Meadows with Hudson #2 Retrofit (1983 \$ x 10 ³)	154
9-IV	Levelized Annual Minimum Revenue Requirements for Fully Developed District Heating System (1983 \$ x 10 ³)	156
9-V	Range of Capital Costs Used in Sensitivity Analysis (1981 \$ 10 ³)	159
9-VI	Levelized Annual Minimum Revenue Requirement for Fully Developed District Heating System Based on Low Range of Estimates (1983 \$ x 10 ³)	160
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 \$ x 10 ³)	162
10-I	Summary of Fuel Burned by Months for the Three Types of Supplies to the Fully Developed District Heating System - Hudson #2 Out for Maintenance for 8 Weeks between April and May	187
10-II	Summary of Fuel Burned by Months for the Three Types of Supplies to the Fully Developed District Heating System - Hudson #2 Out for Maintenance for 18 Weeks between February and May	188
10-III	Air Quality in New Jersey Compared with Air Quality Standards 1981	198
10-IV	Public Service Electric & Gas Company Total Heating Requirements by Customer Class	206
11-I	Levelized Annual Minimum Revenue Requirements for a Berry's Creek Solar Assisted Energy System Compared to a Conventional Heating System	219

Topics of other volumes of this report:

VOLUME I

Detailed Summary

VOLUME II

1. Introduction
2. Load & Service Area Assessment
3. Institutional Questions
4. Rates
5. Financial Considerations

VOLUME III

6. Technical Considerations

VOLUME V

Appendix A – Attachments to Section 2

VOLUME VI

Appendix B – Attachments to Section 6

VOLUME VII

Appendix C – Attachments to Section 5

7. COST ESTIMATES

7.1 Methodology

The conceptual plan and development schedule for the various district heating scenarios were developed by Transflux International Ltd., an energy and district heating consultant firm, in cooperation with PSE&G and other subcontractors. Transflux developed the conceptual designs and layouts for the local heater plants and the Kearny 12 gas turbine retrofit. The Hudson No. 2 full, staged and limited retrofit conceptual designs were developed by Transflux, Stone and Webster, and PSE&G. The steam turbine Manufacturers (Appendix B), (Westinghouse for Hudson No. 2 and General Electric for Essex No. 1 which was considered earlier and then eliminated) determined that the required steam flow could safely be extracted. Stone and Webster then developed capital cost estimates for the local heater plants, the intermediate plant (Kearny No. 12) and the full, staged and limited retrofits of Hudson No. 2. These cost estimates (except for the limited retrofit) were then reviewed by the PSE&G Engineering Department, which increased them as shown in Table 7-1. The large change in the Hudson retrofit cost reflects differences in engineering design philosophy regarding specifications, contingencies and field overheads.

The cost of natural gas service and landfill gas transport pipeline were estimated by the PSE&G Gas Transmission and Distribution Department which has extensive experience in underground gas line design and construction.

The landfill gas supply cost estimate was prepared by PSE&G R&D Department personnel engaged in the design, construction and commercial operation of similar landfill gas recovery systems presently operating and under development.

The foregoing cost estimates are summarized in Table 7-1. The Hudson Unit No. 2 full retrofit (and staging) is described in Section 7.2, the Hudson limited (partial retrofit in Section 7.3, the local heater plants and Kearny gas turbine retrofit (Intermediate Plant) in Section 7.4. Further backup material on these cost estimates is given in Appendix C.

TABLE 7-1

CAPITAL COST ESTIMATES
HEAT SUPPLY

DESCRIPTION	Cost Estimate (Million \$)	
	Stone & Webster	PSE&G
Local Heater Plants (1981\$) (each)	4.0	4.4
Intermediate Plant (Kearny 12) (1981\$)	8.2	10.0
Full Hudson 2 Retrofit (1981\$) (1.6×10^9 BTU/hr)	43.0	80.0
Partial Hudson Retrofit (200×10^9 BTU/hr)		
Original Estimate (1981\$)	6.2	-
Alternate I (1982\$)	6.6	-
Alternate II (1982\$)	5.9	-
Alternate III (1982\$)	4.9	-
Natural Gas Service (1981\$) (each heater plant)	-	0.06
Landfill Gas Supply (1983\$)	-	7.0
Landfill Gas Pipeline (1981\$) (7000 ft., 7.8×10^6 ft ³ /day)	-	0.7

Conceptual designs for the customer conversion packages (interfaces), which convert the district heating system hot water into the thermal services (e.g. space heating and domestic hot water) needed by the customer, were developed by Transflux and Stone & Webster, and costed by Stone and Webster. These designs and cost estimates are given in Section 7.5 and the cost estimates shown in Table 7-II. Stone and Webster also estimated costs of heat metering, given in Tables 7-IV and 7-V.

District heating transmission and distribution (T&D) costs were estimated as follows: (1) Stone and Webster obtained the material cost of the prefabricated piping by averaging, for each pipe diameter, cost data obtained from eight (8) manufacturers of district heating pipe, (2) The PSE&G Gas T&D department utilized their recent experience in the contracting and installation of underground gas lines to estimate the installation cost, per foot, of each diameter of pipe for four environments: rural, suburban, urban and "right-of-way" (completely virgin territory, with no interfering utilities or paving, e.g. under an electric transmission line). This latter was the lowest cost environment. These costs were adjusted to account for differences in joining and installing gas and (insulated) district heating pipe, (3) The material and installation costs were added, for each diameter of pipe to give a table of total installed cost, per foot, for each pipe diameter (Table 7-VII). Stone and Webster then used this table and the transmission and distribution conceptual plan and routing layout developed with Transflux and PSE&G to cost the district T&D piping system. The T&D layouts and cost estimates are given in Section 7.6 and listed in Table 7-III.

The landfill gas supply system development plan and cost estimate is given in Section 7.7.

Table 7-IV tabulates cost estimates in the form used by the System Planning Department as input to perform the Economic Evaluation (Section 9).

TABLE 7-II

CAPITAL COST ESTIMATES

Customer Conversion Units (1981\$)

Description	Unit Cost (1)*	Sq. mi. in Newark	Sq. mi. in Jersey City
Multi-Family Dwelling (4 units, 136×10^3 BTU/hr, peak)	\$ 3,000	-	-
Multi-Unit Apartment House (100 units, 2×10^4 BTU/hr, peak)	14,000	(1) $\times 80 = 1,120,000$	(1) $\times 65 = 910,000$
Block of Multi-Family Houses (1.2-1.4 $\times 10^4$ BTU/hr, peak)	10,600	(1) $\times 85 = 901,000$	(1) $\times 75 = 795,000$
TOTALS		\$2,021,000	\$1,705,000

*Stone & Webster, reviewed and
accepted by PSE&B Customer & Marketing Dept.

TABLE 7-III

DISTRICT HEATING TRANSMISSION AND DISTRIBUTION PIPING
COMPARISON OF COST ESTIMATES FROM VARIOUS SOURCES
MILLIONS OF \$(1983 EXCEPT AS NOTED)

Source	Transmission	River Crossings	Total	Distribution (1 square mile)		
				Jersey City	Newark	Urban New Development
StonesWebster/(1981) Gas T&D	53.5	7.6	61.2	29.4	30.7	18.0
Danpower (Denmark)	91.4	8.0	99.4	26.0	27.0	17.0
St. Paul Project (Report and information from Hans Nyman, reviewed by M. Kurz)	-	-	-	29 (1) 14 (2)	-	-
Peter Margen (Sweden) Studsvik/FVB)	42.	-	-	* 14. (our pipe lengths) * 6.8 (3)	-	-

*based on Willmar, MN costs.
N.J. would be 5% higher

- (1) St. Paul design had 1.5x the pipe length per square mile and 1.5x the cost, or the same cost per unit length. However, St. Paul had 3x the thermal load density as assumed for Jersey City.
- (2) Mr. Kurz's rough estimate of reduction possible at higher load density.
- (3) Reduced pipe length in accordance with Swedish practice.

TABLE 7-IV

COST ESTIMATES

District Heating Capital Related		Estimated Cost*
		\$
Boilers		
50x10 ⁶ BTU/hr		1,100,000
60x10 ⁶ BTU/hr		1,320,000
Hudson #2 Retrofit		
Partial (Phase I)		6,196,000
Phase II		23,093,000
Phase III		48,711,000
Kearny #12 Retrofit		10,000,000
Natural Gas Service		60,000 per heater plant site
Customer Conversion Costs		
Jersey City		5,950/10 ⁶ BTU/hr
Newark		5,890/10 ⁶ BTU/hr
Berry's Creek & Harmon Meadows		2,700/10 ⁶ BTU/hr
Metering Costs		163/10 ⁶ BTU (1982*)
Transmission Costs		
Pipe Diameter	Type of Construction	
42"	Right-of-Way	450/ft
36"	Right-of-Way	400/ft
36"	Urban	836/ft
36"	Suburban	697/ft
30"	Urban	718/ft
24"	Right-of-Way	287/ft
24"	Urban	594/ft
20"	Right-of-Way	250/ft
20"	Urban	513/ft
16"	Right-of-Way	200/ft
Distribution Costs		
Jersey City Plants 1 & 3		97,959/10 ⁶ BTU/hr
Jersey City Plants 2 & 4		59,950/10 ⁶ BTU/hr
Newark		85,274/10 ⁶ BTU/hr
Berry's Creek		6,000,000 TOTAL
Harmon Meadows		6,000,000 TOTAL

* All costs are in 1981\$ unless otherwise noted.

TABLE 7-V

COST ESTIMATES

<u>District Heating Fuel Related</u>	<u>Estimated Cost*</u>
Production Cost Increase	\$ **
Boiler Fuel	
Natural Gas	\$5.80/10 ⁶ BTU (1984\$)
Landfill Gas	\$1.00/10 ⁶ BTU
<u>Operation & Maintenance Related</u>	
Manpower	Various - depending on job responsibilities
Water & chemicals - annual	58/10 ⁶ BTU/hr peak (1983\$)
Materials - annual	59/10 ⁶ BTU/hr peak (1983\$)
Pumping Energy	Various - depending on system size and replace- ment energy costs.
Landfill	\$1.10/10 ⁶ BTU
<u>Conventional System Capital Related</u>	
Boilers	22,000/10 ⁶ BTU/hr
Natural gas service	6,000/10 ⁶ BTU/hr
<u>Conventional System</u>	
Natural Gas Cost	6.23/10 ⁶ BTU (1984\$)
Manpower Cost	7,546/10 ⁶ BTU/hr peak (1983\$)
<u>Escalation Rates</u>	
Capital related	8% annually
O&M related (excluding fuel)	8% annually
Fuel	Various - based on PSE&G annual estimates of commonly used fuels

- * All costs are in 1981\$ unless otherwise noted.
- ** Calculated annually using PSE&G chronological Production Cost Program 0224K(17).

Labor rates were estimated at PSE&G rates, fuel according to PSE&G Corporate Fuel Price Projections, and escalation according to guidelines used for all other corporate planning. Manpower requirements for the district heating system were estimated by Transflux. Manpower for the conventional (individual boiler) alternative was estimated by typical customer boiler room staffing data obtained from the PSE&G Customer and Marketing Department.

In the course of the current study, visitors from Scandinavia had remarked that the district heating T&D piping cost estimates we had derived were much higher than those in Europe. Recognizing that U.S. construction costs could differ considerably from those in Europe, review of our results was requested from recognized district heating authorities with experience under both European and U.S. conditions. These were

- (1) Mr. Peter Margen, Studsvick FVB. Mr. Margen performed the original study for the St. Paul district heating system.
- (2) Mr. Hans Nyman, President of the St. Paul District Heating Company
- (3) Danpower Inc., a consortium of Danish district heating consultants

They were given a draft of Section 7.6 of this report, giving pipe diameters, routing and lengths, but with the price table and costs deleted, and asked to provide independent estimates. The response from Danpower is given in full in Section 7.8. All the responses are tabulated in Table 7-III which compares (1) Mr. Margen's T&D piping cost estimates, (2) the original Stone & Webster/Gas T&D estimates from our study, (3) a review of a report and data on the St. Paul system provided by Mr. Hans Nyman and reviewed by Mr. M. G. Kurz, and (4) a review by Danpower Inc. who were given the same information from our study that Mr. Margen had received.

The following conclusions may be drawn:

1. Mr. Margens' transmission cost estimate is roughly in agreement with our study, but the Danpower estimate is nearly twice as high
2. The Danpower distribution cost estimates agree well with our own study, and with the St. Paul data. Mr. Margen's estimates are 1/2 to 1/4 of these.

3. When experts disagree so widely, careful site-specific studies, including quotations from construction contractors, seem needed. Dr. Ishai Olikar (Burns & Roe), the manager of an EPRI-funded district heating study, has noted that slight changes in routing can change piping costs by "a factor of two" thus, "street-specific" estimates and detailed information on subsurface conditions and interferences seem essential in future studies.

7.2

HUDSON UNIT NO. 2

FULL RETROFIT

$1,600 \times 10^6$ BTU/HR.

Issue
No.

J.O. No. 13222.01

Page 1 OF 4

Item

Client PSE & G Date 10-5-81 By RAS

Location HUDSON #2 Checked By

Subject DISTRICT HEATING PLANT Revised By

BASIS OF ESTIMATE

THIS ESTIMATE IS FOR A STEAM PLANT TO BE CONSTRUCTED AT AN EXISTING STATION. TURBINES ARE NON CONDENSING TYPE. STEAM SUPPLY WILL BE TAKEN FROM AN EXTRACTION POINT IN THE EXISTING PLANT

THIS ESTIMATE WAS CALCULATED USING 100% SUBCONTRACTS. MATERIAL AND LABOR ARE ESTIMATED ON A PRESENT DAY BASIS (NO ALLOWANCE HAS BEEN MADE FOR ESCALATION)

NO CONSTRUCTION SCHEDULE WAS FURNISHED. THE ESTIMATE REFLECTS A CONTINUOUS CONSTRUCTION PERIOD TO PERFORM ALL REQUIRED WORK.

CRAFT RATES

CRAFT RATES WERE DETERMINED USING 1981 MEAD'S LABOR RATES FOR NEWARK, N.J. DEVELOPMENT CAN BE SEEN IN BACK UP.

TURBINE BLDG

PRELIMINARY DRAWINGS AND ASSUMPTIONS WERE SUPPLIED BY ENGINEERING SHOWING: TYPE AND NUMBER OF PILES; FOUNDATION SIZES AND LAYOUTS; STRUCTURAL STEEL QUANTITIES; INSULATED METAL SIDING; ROOF AND DECK CONSTRUCTION; CONCRETE; PARTITIONS REQUIRED; DOORS, WINDOWS AND LOUVERS REQUIRED.

SEE LIST OF OMISSIONS PAGE 4 OF 4 FOR ITEMS NOT INCLUDED.

DETAILS MAY BE SEEN IN BACK UP.

GRADE

ENGINEERING SUPPLIED THE MATERIAL COST OF A 50/10 TAN 80 FT SPAD GRADE. LABOR FOR INSTALLATION WAS ESTIMATED.

DETAILS MAY BE SEEN IN BACK UP.

Issue
No.

J.O. No. 13222.01

Page 2 of 4

Item

Client PSE & G

Date 10-5-81 By RAS

Location HUDSON #2

Checked By

Subject DISTRICT HEATING TRANT

Revised By

MECHANICAL EQUIPMENT

ENGINEERING SUPPLIED THE MATERIAL COST OF ALL MECHANICAL EQUIPMENT (TURBINE GENERATORS, HEATERS, PUMPS AND STRAINERS). LABOR MANHOURS FOR INSTALLATION WERE ESTIMATED. DETAILS MAY BE SEEN IN BACK UP.

PIPING & VALVES

PIPING LAYOUT DRAWINGS, FLOW DIAGRAMS AND SPECS. WERE SUPPLIED BY ENGINEERING. A PIPING TAKE OFF WAS MADE AND MATERIAL WAS PRICED FROM A MCJUNKIN CATALOGUE USING CURRENT PUBLISHED DISCOUNTS WHEREVER POSSIBLE. THE REMAINDER OF THE PIPE WAS PRICED ON A \$/LB BASIS.

VALVE PRICES WERE SUPPLIED BY ENGINEERING.

LABOR FOR INSTALLATION WAS FROM THE STANDARD MAN HOUR PIPING MANUAL.

DETAILS MAY BE SEEN IN BACK UP.

INSULATION

PIPE INSULATION WAS DETERMINED FROM INFORMATION SUPPLIED BY ENGINEERING. PRICING WAS DONE ON A \$/LF BASIS FROM PREVIOUS QUOTES, ESCALATED TO PRESENT DAY AND REGIONALIZED FOR NEWARK, N.J.

EQUIPMENT INSULATION REQUIREMENTS WERE SUPPLIED BY ENGINEERING AND PRICED IN THE SAME MANNER AS PIPE INSULATION.

DETAILS MAY BE SEEN IN BACK UP.

ELECTRICAL

ENGINEERING SUPPLIED THE MATERIAL COST OF THE ELECTRICAL EQUIPMENT REQUIRED AND ONE LINE DIAGRAMS. CABLE, CONDUIT, LIGHTING AND GROUNDING MATERIAL COSTS WERE ESTIMATED ALONG WITH LABOR TO INSTALL ALL ELECTRICAL ITEMS.

Issue
No.

J.O. No. 13222.01

Page 3 OF 4

Item _____

Client PSE & G Date 10-5-81 By RAS

Location HUDSON #2 Checked _____ By _____

Subject DISTRICT HEATING PLANT Revised _____ By _____

ELECTRICAL CONTINUED

SEE LIST OF OMISSIONS PAGE 4 OF 4 FOR ITEMS NOT INCLUDED.

DETAILS MAY BE SEEN IN BACK UP.

CONTROLS

ENGINEERING SUPPLIED A PRICE LIST OF CONTROLS REQUIRED. LABOR FOR INSTALLATION WAS ESTIMATED.

DETAILS MAY BE SEEN IN BACK UP.

WATER TREATMENT SYSTEM

ENGINEERING SUPPLIED A PRICE LIST OF EQUIPMENT REQUIRED. LABOR FOR INSTALLATION WAS ESTIMATED.

SEE LIST OF OMISSIONS PAGE 4 OF 4 FOR ITEMS NOT INCLUDED

DETAILS MAY BE SEEN IN BACK UP.

INDIRECTS

INDIRECT COSTS (HOME OFFICE ENGINEERING AND SUPPORT) WERE ESTIMATED USING HISTORICAL DATA AND CALCULATED AT 14% OF DIRECT CONSTRUCTION COST.

DISTRIBUTABLES

DISTRIBUTABLE COSTS (CONSTRUCTION MANAGEMENT & FIELD INDIRECT COSTS) WERE ESTIMATED USING HISTORICAL DATA AND CALCULATED AT 8% OF DIRECT CONSTRUCTION COST.

CONTINGENCY

A 10% CONTINGENCY WAS ADDED TO COVER UNDEFINED ITEMS, CHANGES IN DESIGN, SITE REWORK, ETC.

Issue
No.

J.O. No. 13222.01

Page 4 of 4

Item

Client PSE & G Date 10-5-81 By RAS

Location HUDSON #2 Checked By

Subject DISTRICT HEATING TRANT Revised By

LIST OF OMISSIONS

- 1 CLEARING, GRUBBING & STRIPPING OF TOPSOIL FROM BUILDING SITE
- 2 DEWATERING IF REQUIRED TO COMPLETE ANY PORTION OF WORK
- 3 OIL CIRCUIT BREAKERS OR OTHER EQUIPMENT WHICH MAY BE REQUIRED IN THE SWITCHYARD
- 4 STREET LIGHTING
- 5 LOSS OF PRODUCTIVITY DUE TO SECURITY REQUIREMENTS AT AN EXISTING TRANT

HUDSON PLANT UNIT 2 PLANT RETROFIT COST ESTIMATE
PUBLIC SERVICE ELECTRIC & GAS COMPANY, N.J.

PRICES OF MAJOR EQUIPMENT

1. Turbine Generator No. 1 (36 MW)	General Electric	\$4,950,000.
Turbine Generator No. 2 (30 MW)	General Electric	\$4,700,000.

Approx. weight of each machine

Generator Stator	152,000 lbs.
Generator Rotor	33,000 lbs.
Turbine Casing	165,000 lbs.
Turbine Rotor	15,000 lbs.

Total	365,000 lbs.
-------	--------------

2. Heaters (Yuba Heat Transfer)

<u>Htr. No.</u>	<u>Weight Each, tons</u>	<u>Price Each</u>
DH1A	90.	\$430,000.
DH1B	90.	\$430,000.
DH2A	82.	\$410,000.
DH2B	82.	\$410,000.
4A	18.	\$120,000.
3A	13.	\$ 85,000.
1A	30.	\$250,000.

3. Pumps and Strainers	<u>Number</u>	<u>Price Each</u>
District Heating Water Pumps & Motors
22,000 GPM & 450 Ft. (Bingham 24x24x25C HSB)
3,000 HP Motor @ 1760 RPM	4	\$151,000.
Heater Drain Pumps & Motors
1,960 GPM & 150 Ft. (Worthington 8LR13)
100 HP Motor @ 1760 RPM (2,500 lbs each)	4	\$ 14,000.
36" District Heating Water Simplex
Strainers, weighing 20,000 lbs each
(Tate Temco 36" FF 300#)	4	\$ 39,000.

4. Bridge Crane (Spantec Systems, Inc.)
50/10 Ton, 80 Ft. Span		\$225,000.
Bridge Weight	87,000 lbs.	
Trolley Weight	31,900 lbs.	
Total	119,000 lbs.	

HUDSON PLANT UNIT 2 PLANT RETROFIT COST ESTIMATE
PUBLIC SERVICE ELECTRIC & GAS COMPANY, N.J.

PRICES OF VALVES

1. 300 lbs. Single Flange Carbon Steel Butterfly Valves
for District Heating Water and Condensate, Price Each

<u>Pipe Size, Inches</u>	<u>Manual Operator</u>	<u>Motor Operator</u>
12	\$ 3,400.	\$ 4,700.
30	\$24,000.	\$27,000.
36	\$29,000.	\$33,000.

2. 150 lbs. Single Flange Carbon Steel Butterfly Valves
for Steam and Heater Drain, Price Each

<u>Pipe Size Inches</u>	<u>Medium* S or W</u>	<u>Manual Operator</u>	<u>Air Operator</u>	<u>Motor Operator</u>	<u>Hydraulic Operator</u>
8	W	\$ 1,350.	\$ 1,900.		
10	W	\$ 2,000.	\$ 2,600.		
12	W	\$ 2,500.	\$ 3,100.		
14	W	\$ 2,700.	\$ 3,500.		
14	S			\$ 9,000.	
16	W	\$ 4,300.	\$ 5,200.		
18	W	\$ 5,100.	\$ 6,000.		
18	S			\$13,500.	
20	W	\$ 7,200.	\$ 8,200.		
24	W	\$ 8,900.	\$10,200.		
30	S			\$23,000.	\$33,000.
36	S			\$35,000.	\$42,000.

3. Non-Return Valves for Extraction Steam Lines, Air Operated

36 Inches, Price Each \$38,000.

4. Gate Valves for Extraction Steam Lines, Motor Operated

36 Inches, Price Each \$45,000.

S - Steam

W - Water

HUDSON PLANT UNIT 2 PLANT RETROFIT COST ESTIMATE
PUBLIC SERVICE ELECTRIC & GAS COMPANY, N.J.

5. Back-pressure Turbine By-passes (SEE FIG. 1)

Eight (8) 24"/30" lines

Eight (8) 24" gate valves, gear operated \$16,500. each

Eight (8) 20" air-operated pressure reducing valves \$16,000. each

Flanges on turbine exhaust & blanking plates

Insulation

Control instrumentations

6. Heater drain water sample and leak detection system \$50,000.

FIG. 1

GTKan, 9-8, 81

TYPE OF BID	_____
-------------	-------

EST./J.O. NO.

13222.01

PAGE

DATE _____

1 of 2

10-5-81

51

RAS

10/5/8

TYPE OF UNIT	UNIT NO.	UNIT NAME	UNIT LOCATION	UNIT STATUS	UNIT COMMENTS
...	...	...	...	...	...

DISTRICT HEATING TRUST - HUDSON #2

CLIENT

HPSE?G

LOCATION

NEWARK

ACCOUNT NO.	DESCRIPTION	QUANTITIES	UNIT COST		MATERIAL	SUBCONTRACT	LABOR	TOTAL	MAN-HOURS
			MATL.	MH/RATE					
	SUMMARY - REVISED								
	WATER TREATMENT PLANT			/	1082000		3111000	1393000	10,990
	MECHANICAL EQUIPMENT			/	12601000		1245000	13846000	46,640
	PIPING			/	3628000		1827000	5455000	61,740
	INSULATION			/	166000		276000	442000	11,640
	VALVES			/	1825000		330000	2155000	11,100
	MISCELLANEOUS MECHANICAL			/	71000		103000	174000	4,280
	ELECTRICAL EQUIPMENT			/	2181000		469000	2650000	17,650
	ELECTRICAL FEEDERS			/	301000		621000	922000	23,350
	LIGHTING			/	142000		249000	391000	9,380
	GROUNDING			/	75000		53000	128000	2,000
	TRANSFORMER PLATFORMS			/	9000		21000	30000	780
	INSTRUMENTS			/	663000		516000	1179000	19,890
	SUBSTRUCTURE - BLDG			/	272000		215000	487000	7,540
	SUBSTRUCTURE - TUNNEL			/	166000		230000	396000	7,690
	SUPERSTRUCTURE			/	1448000		908000	2356000	33,630
	SUB TOTAL →			/	24630000		73690000	31999000	268,300
	INDIRECTS			/				4480000	
	DISTRIBUTABLES & FIELD INDIRECTS			/				2560000	
	SUB TOTAL →			/				39039000	
G.T.	CONTINGENCY			/				3904000	
	TOTAL ESTIMATED COST →			/				42943000	

TABLE 7-VI
PRELIMINARY COST ESTIMATE

HUDSON

	TOTAL COST	\$40 MILLION
FIRST PHASE (1986-7)	<u>10⁶\$</u>	
TURBINE RETROFIT	1.00	
2 HEATERS	1.00	
2 PUMPS	.3	
2 STRAINERS	.8	
1 CRANE	<u>.23</u>	3.33
BUILDING	2.50	2.50
ELECTRIC EQUIP.	.65	
FEEDER	.5	
INSTR.	<u>.3</u>	1.45
PIPING VALVES	2.5	
PRESS. RED. STA.	.5	
MISC.	<u>.5</u>	3.52
		10.80
	CONT.	1.50
	ENG.	<u>1.50</u>
		13.80

SECOND PHASE (1996-7)

1 TURBINE	5.	
13.8 KV SWITCHGEAR	.65	
1 MAIN TRANSF.	.22	
ELECTRIC EQUIPMENT	2.00	
FEEDER	.50	
INSTR.	<u>.20</u>	8.67
PIPING VALVES	2.00	
MISC.	.50	2.50
DRAIN PUMP	.03	11.17
HEATERS	<u>.2</u>	<u>0.23</u>
		11.40
	CONT.	1.70
	ENG.	<u>1.70</u>
		14.80

THIRD PHASE (1998-9)

1 TURBINE	5.	
1 MAIN TRANSF.	.2	
ELEC. EQUIP.	.85	
INSTR.	<u>.1</u>	6.15
PIPING VALVES	.7	
MISC.	<u>1.45</u>	2.15
DRAIN PUMP	.03	
HEATERS	<u>.9</u>	<u>.93</u>
		9.23
	CONT.	1.37
	ENG.	<u>1.40</u>
		12.00

7.3

LIMITED (PARTIAL) RETROFIT

HUDSON UNIT NO. 2

200×10^6 BTU/HR HEAT SUPPLY

ORIGINAL ESTIMATE

SUMMARY & BASIS OF ESTIMATE

TYPE OF BID

EST./J.O. NO.

13222.02

TYPE OF UNIT **DISTRICT HEATING**
LIMITED RETRO FIT SCHEME

PAGE

DATE 5/26/82

CLIENT

PSE #G

LOCATION

HUDSON #2

BY

JK. 4/9/82

SUMMARY

ACCOUNT NO.	DESCRIPTION	QUANTITIES	UNIT COST		MATERIAL	SUBCONTRACT	S/C LABOR	TOTAL	MAN-HOURS
			MATL.	MH/RATE					
				/					
	SUBSTRUCTURE			/	309000		323000	632000	11000
	SUPERSTRUCTURE			/	393000		257000	650000	7860
	MECHANICAL EQUIPMENT			/	1052000		165000	1217000	5070
	PIPING & VALVES			/	515000		503000	1018000	15450
	INSULATION			/	57000		86000	143000	2800
	MISCELLANEOUS MECHANICAL			/	28000		43000	71000	1320
	ELECTRICAL			/	299000		380000	679000	11830
	INSTRUMENTATION			/	73000		135000	208000	4430
	TOTAL DIRECT COST			/	2726000		1892000	4618000	59760
	HEADQUARTERS			/				646000	
	CONSTRUCTION MANAGEMENT & DISTRIBUTABLES			/				369000	
	SUBTOTAL			/				5633000	
B.D.	CONTINGENCY			/				663000	
	TOTAL			/				6196000

Issue
No.

J.O. No. 13222.02

Page 1/3

Item

Client PSE & G

Date Noted MAY 28 1982 J. ARDARY

Location HUDSON #2

Checked By

Subject LIMITED DISTRICT HEATING PLANT Revised By

Basis of Estimate

Overview

This estimate was prepared using the previous (Oct. 1981) Hudson station district heating plant estimate as the basis and modifying it for the reduced scope of the limited facility. All material costs taken from the base estimate were updated for escalation to present day. All subcontract labor rates were brought to present day using Means 1982 craft rates. No allowance for escalation into the future was included as no construction schedule was furnished.

Civil / Structural

The estimates for the building & its foundation were priced using \$/FT² for the foundation and \$/FT³ for the building. These units were taken from the base estimate and escalated. Adjustments were made to the base estimate prior to the calculation for omitting the T.G. pedestals.

Mechanical Equipment

The equipment costs were taken from the base estimate and adjusted for escalation (heaters, pumps & strainers). The water treatment system cost was supplied by engineering for a previous district heating study and adjusted for escalation. All labor was estimated.

Issue
No.J.O. No. 13222.02Page 2/3

Item _____

Client PSE & G Date Noted MAY 28 1982 J. ARDARYLocation HUDSON #2 Checked _____ By _____Subject LIMITED DISTRICT HEATING PLANT Revised _____ By _____Basis of Estimate (contd.)Piping & Valves

Piping layout drawings were furnished by engineering. A complete takeoff made and material was priced using current unit prices and applicable discounts (GUYON). Valve prices were taken from the base estimate and escalated to present day. Piping labor manhours were taken from the piping manhour manual.

Insulation

Insulation prices were obtained from a NY/NJ area contractor (KEASBY Co) and are reflective of current material and labor prices.

Electrical & Instrumentation

Electrical & instrumentation allowances were made using the same relationship to Total Direct Cost as was developed in the base estimate.

Headquarters Office

Engineering & Design & support services were allowed for by calculating 14% of Total Direct Cost.

Construction Mgmt & Distributables

Const. mgmt & distribts were estd. using 8% of Total Direct Cost.

J.O. No. 13222.02Page 3/3Item Noted
By MAY 28 1982 J. ARDARYClient PSE & G

Date

Location HUDSON #2

Checked

By

Subject LIMITED DISTRICT HEATING PLANT

Revised

By

Basis of Estimate (Cont'd.)Contingency

A 10% contingency was added to cover undefined items, design changes, etc.

LIST OF OMISSIONS

- 1- Clearing, grubbing & stripping of topsoil from building site.
- 2- Dewatering
- 3- Demolition or relocation of existing facilities
- 4- Exterior lighting (street)
- 5- Oil breakers or other equipment which may be required in the switchyard.
- 6- Loss of productivity due to security in an existing plant
- 7- Client costs.

BASIS OF LIMITED RETROFIT ESTIMATE

Alternate I

Pumps - the capacities of the three district heating water pumps have been increased from 2300 gpm to 3500 gpm with a resultant increase in driver horsepower from 350 to 500. The pumps' differential head remained at 450 ft. Additional labor manhours have been allowed due to the larger pump size.

Piping - a 12" line diameter has been increased to 20". Revisions were made in accordance with a material take off of the 12" line, including all fittings, flanges and valves. No change has been made to the materials of construction. The estimated cost of the three strainers have been included with the mechanical equipment, as before. The estimate for these strainers has been increased from \$14,000 to \$22,000 because of the larger size.

Insulation - insulation costs have been increased because of the increase in pipe size.

Electrical - this account has been re-evaluated by the electrical department because the original estimate was presumed to be too high. This reinvestigation determined that these costs should be increased over what was previously estimated. The original figures were factored off a prior estimate for Hudson Unit #2. The qualitative difference between these two estimates are that the turbo-generators and some heat exchangers have been deleted from the original estimate to produce the original figure. Although there is, in fact, a large reduction in equipment and other direct costs, the omitted equipment does not require much associated electrical work. In factoring the original estimate, a larger than necessary cut was made in the electrical account. This has now been revised.

Headquarters costs, construction management and distributable costs and contingency were factored from the original estimate on the basis of total direct costs.

Alternate II

This scheme includes all changes made for Alternate I above and a building substitution. The original estimate included a factored amount for a structural steel building with reinforced concrete arches, insulated metal siding, masonry partitions, acoustical ceilings, and resilient tile floor covering. The pile foundations and plumbing, sprinkler and HVAC systems were also included in the estimate. The revised building is smaller (7,500 SF vs 13,700 SF) and is a "BUTLER" type building with a steel frame, insulated siding, lighting, heating, three roll up doors for access to tube bundles, structural slab at grade

supported by piles and a steel frame around the exchangers to support piping.

Headquarters costs, construction management and distributable costs and contingency were factored from the original estimate on the basis of total direct costs.

Assumptions for Alternate #3

1. This alternate (#3) was based on previous alternates (#1, and #2).
2. There is no change from alternate #1 in the following estimated items -- mechanical equipment, piping and valves, insulation, electrical and instrumentation.
3. All required equipment can be located on the elevated floor slab of the existing turbine-generator building. This permits the elimination of the building (and building services) and the pipe tunnel.
4. All equipment could be placed on concrete pads which would be dowelled and concreted into the existing floor, and patched as necessary.
5. It would be necessary to remove a section of a wall to allow entry of new equipment into the existing building. This wall section would have to be replaced.
6. The existing overhead crane could be used to place new equipment at required locations.
7. Headquarters, construction management and distribution costs have been prorated from total direct cost.

ACCOUNT NO.	DESCRIPTION	QUANTITIES	UNIT COST		MATERIAL	SUBCONTRACT	SUBCONT.	TOTAL	SUBCONT.
			MATL.	MM/RATE			LABOR		MAN-HOURS
	SUBSTRUCTURE, FNDNS.			/	309000		323000	632000	11,000
	SUPERSTRUCTURE			/	393000		257000	650000	7,860
	MECHANICAL EQUIPMENT			/	1122000		170000	1292000	5,220
	Piping & Valves			/	696000		561000	1257000	17,250
	INSULATION			/	63000		97000	160000	3,170
	MISCELLANEOUS MECHANICAL			/	28000		43000	711000	1,320
	ELECTRICAL			/	419000		265000	684000	8,230
	INSTRUMENTATION			/	73000		135000	208000	4,440
	TOTAL DIRECT COST			/	3103000		1851000	4954000	58,490
	HEADQUARTERS			/				698000	
	CONSTRUCT. MGMT. & DISTRIB.			/				396000	
	SUBTOTAL			/				6043000	
	CONTINGENCY			/				604000	
02 12	TOTAL			/				6647000	

ACCOUNT NO.	DESCRIPTION	QUANTITIES	UNIT COST		MATERIAL	SUBCONTRACT	SUBCONT.	TOTAL	SUBCONT.
			MATL.	MH/RATE			LABOR		MAN-HOURS
	SUBSTRUCTURE, FNDNS.			/	179000		226000	405000	7,700
	SUPERSTRUCTURE			/	290000		127000	417000	3,900
	MECHANICAL EQUIPMENT			/	1122000		170000	1292000	5,220
	PUMP & VALVES			/	696000		561000	1257000	17,250
	INSULATION			/	63000		97000	160000	3,170
	MISCELLANEOUS MECHANICAL			/	-		-	-	-
	ELECTRICAL			/	419000		265000	684000	8,230
	INSTRUMENTATION			/	73000		135000	208000	4,440
	TOTAL DIRECT COST			/	2842000		1581000	4423000	49,910
	HEADQUARTERS			/				619000	
	CONSTRUCT. MGMT. & DISTRIB.			/				354000	
	SUBTOTAL			/				5396000	
	CONTINGENCY			/				540000	
50 10	TOTAL			/				5936000	

7.4

LOCAL HEATER PLANT

AND

KEARNY NO. 12 RETROFIT (INTERMEDIATE PLANT)

COST ESTIMATES

STONE & WEBSTER ENGINEERING CORPORATION

TYPE OF BID

FST./J.O. NO.

13222.01

TYPE OF UNIT

PAGE

DATE 12/31/8

CLIENT

P.S. Ed G

LOCATION

US

Ja / Jhe^{11.18}

HEATER PLANT SUMMARY

ACCOUNT NO.	DESCRIPTION	QUANTITIES	UNIT COST		MATERIAL	SUBCONTRACT	LABOR	TOTAL	MAN-HOURS
			MATL.	MH/RATE					
	CIVIL / STRUCTURAL			/	2899 ⁰⁰		2636 ⁰⁰	5535 ⁰⁰	9555
	MECHANICAL			/	13712 ⁰⁰		2439 ⁰⁰	14151 ⁰⁰	8981
	PIPING & INSULATION			/	1693 ⁰⁰		1724 ⁰⁰	3417 ⁰⁰	5977
	ELECTRICAL			/	2053 ⁰⁰		1259 ⁰⁰	3312 ⁰⁰	4735
	INSTRUMENTATION			/	1000 ⁰⁰		784 ⁰⁰	11784 ⁰⁰	3025
	TOTAL DIRECT COST			/	21357 ⁰⁰		8842 ⁰⁰	30199 ⁰⁰	32273
	CONSTR. MGMT. & DISTRIBUTABLES			/				2416 ⁰⁰	
	HEADQUARTERS			/				4228 ⁰⁰	
	SUBTOTAL			/				36843 ⁰⁰	
35	CONTINGENCY ~ 10%			/				3687 ⁰⁰	
	TOTAL			/				40530 ⁰⁰	

13222.01

[illegible]

PAGE

DAVE

CP

1/11/82

CLIENT

LOCATION	LAKE CHARLES, MISSISSIPPI
-----------------	---------------------------

13 Y

PSE & G

GAS TURBINE PLANT SUMMARY

ACCOUNT NO.	DESCRIPTION	QUANTITIES	UNIT COST		MATERIAL	SUBCONTRACT	LABOR	TOTAL	MAN-HOURS
			MATL.	MH/RATE					
	CIVIL / STRUCTURAL			/	396000		294000	690000	10.102
	MECHANICAL			/	2800600		754400	3555000	29298
	PIPING & INSULATION			/	631200		342900	974100	12033
	ELECTRICAL			/	371700		227800	599500	8567
	INSTRUMENTATION			/	180800		142000	322800	5478
	TOTAL DIRECT COST			/	4380300		1761100	6141400	65478
	CONSTR. MGMT & - DISTRIBUTABLES			/				491300	
	HEADQUARTERS			/				859800	
	SUBTOTAL			/				7492500	
CC	CONTINGENCY	~ 10%		/				749500	
	TOTAL			/				8242000	

7.5 PSE&G CAPITAL COSTS OF CONVERSION SCHEMES FOR VARIOUS TYPES OF CUSTOMER HEATING SYSTEMS

7.5.1 DESIGN CRITERIA

To determine the economic viability of the conversion schemes which are applicable to the various heating and domestic water systems encountered in the District Heating Study, the following criteria was established:

1. The design supply and return water ranges for the heating systems will be 290°F supply and 170°F return. The supply and return temperatures will vary with the outside air temperature.
2. The domestic water supply temperature will be 140°F leaving the storage heater.
3. Multi-Family Dwelling
 - a) Heating Load: 34,000 BTUH per average family with four families per dwelling, therefore a total load of 136×10^3 BTUH per dwelling.
 - b) Domestic Water Load: 12 persons per dwelling (3 per family) 3 hour peak usage morning and evening, with a 40×10^3 BTUH hot water heating requirement for each peak load.
4. Multi-Unit Apartment House
 - a) Heating Load: 20,000 BTUH per average apartment with 100 families per Apartment House, therefore a total load of 2×10^6 BTUH.
 - b) Domestic Water Load: 2-1/2 persons per average apartment, 3 hour peak usage morning and evening, with a 460×10^3 BTUH hot water heating requirement for each peak load.
5. Block of Multi-Family Houses

The heating loads and domestic hot water loads are approximately 1.2 to 1.4×10^6 BTU an hour or about 2/3 of a multi-unit apartment house load.

7.5.2 CUSTOMER CONVERSION MODULES

1. Hot Water Heating System Module For Multi-Family Dwelling (See Figure 7.1)
 - a) The heating module will provide space and domestic hot water energy requirements for a multi-family dwelling. This module will monitor and maintain all the space heat-

ing and domestic hot water requirements while having the capacity of relieving excessive pressure and shutting down the high temperature supply and return water if a leak is detected within the system.

This module will also provide double wall protection for domestic water.

- b) The heat transfer module for the Multi-Family Dwelling will consist of:

High Temperature Heat Exchanger
Tube-In-Tube Type Heat Exchangers
Cartridge Type Circulators
Zone Valves
Expansion Tank and Air Separator Package Relief Valve
Pressure Switch
Solenoid Valves
Two (2) 65 Gallon Hot Water Storage Tanks

All components will arrive in a module form, completely assembled at the factory. This module is capable of producing 136,000 BTU an hour for space heating. It is also capable of supplying 40,000 BTU an hour for the making of domestic hot water.

The above package as outlined would cost \$2,800.00.

The installation cost for the above module would be \$250.00.

2. Hot Water Heating System Module for Multi-Unit Apartment House
(See Figure 7.2)

- a) The heating module will provide space and domestic hot water energy requirements for a multi-unit apartment house. This module will monitor and maintain all the space heating and domestic hot water requirements while having the capacity of relieving excessive pressure and shutting down the high temperature supply and return water if a leak is detected within the system.

This module will also provide double wall protection for domestic water.

- b) The Heat Exchanger package for Multi-Unit Apartment House will consist of:

Tank Unit with:
Air Removal Package
Pressure Reducing Valve
Multi-Purpose Valves
In-Line Pump
Heat Exchangers
Base Mounted Pump
Two (2) 1,300 Gallon Hot Water Storage Tanks

Tank unit and hot water storage tanks to be supplied and shipped separately, existing system hot water heating pumps and expansion tanks to be utilized.

Heat Exchanger Package is designed for a performance of 2,000,000 BTU an hour for space heating and 460,000 BTU an hour for the making of domestic hot water. The price for the complete unit is \$13,000.00.

The installation cost for the module package above would be \$750.00.

3. Hot Water Heating System Module for Block of Multi-Family Row Houses

The total load for one block of Multi-Family Houses is approximately 1.2 to 1.4×10^6 BTU an hour. Therefore, the module size is basically the same as for the Multi-Unit Apartment Module shown on Figure 7.2, except the total cost is \$10,000.00 with an installation cost of \$600.00.

ITEM	QTY.	DESCRIPTION	MODEL	REMARKS
1	1	HEAT EXCHANGER	10406-8HTT	
2	1	HEAT EXCHANGER	10416-8HTT	
3	1	AIR SCOOP	431	
4	1	PRESS. RED. VALVE	535	
5	1	EXTRUSION TANK	442	
6	1	MP VALVE	360T	
7	1	INLINE PUMP	1632	
8	1	MP VALVE	362F	
9	1	LP PUMP	583006	
10	1	TANK UNITS	10416-TA	

* TANK UNIT SUPPLIED SEPARATELY
 ** L.P. PUMP SUPPLIED SEPARATELY

FLOW DIAGRAM

FIG. 7.1

CUSTOMER CONVERSION	
MULTI-UNIT APARTMENT HOUSE	
DISTRICT HEATING PHASE II	
PUBLIC SERVICE ELECTRIC & GAS CO.	
NEW JERSEY	
BROWN & WOODMAN ENGINEERING CORPORATION	
	FIGURE 7BT

ITEM	QTY.	DESCRIPTION	MODEL	RE-MARKS
1	1	HEAT EXCHANGER	G6410-2L	
2	2	HEAT EXCHANGER	9H1000-25	
3	1	CIRCUIT SETTER	791	
4	1	CIRCUIT SETTER HI TEMP		
5	2	ZONE VALVE	975	
6	1	PUMP	007-F3	
7	2	PUMP BRONZE	006-B	
8	1	AIR REMOVAL PKG	440	
9	1	CABINET

FLOW DIAGRAM

FIG. 7.2

CUSTOMER CONVERSION	
MULTI-FAMILY DWELLING	
DISTRICT HEATING PHASE II	
PUBLIC SERVICE ELECTRIC & GAS CO	
NEW JERSEY	
DESIGN & WORKMAN ENGINEERING CORPORATION	
	FIGURE 7B2

7.6 PSE&G DISTRICT HEATING TRANSMISSION AND DISTRIBUTION PIPING INSTALLATION COSTS

7.6.1 Design Bases

The piping used for the District Heating Transmission and Distribution Systems was considered to be of the factory prefabricated type, standard weight carbon steel inner pipe with either reinforced fiberglass or polyethylene outer jacket. The insulating material is a polyurethane foam suitable for a maximum operating temperature of 290°F. However, in order to obtain the most competitive pricing, the piping was priced as follows:

- 290°F maximum temperature up to 14" inner pipe size.
- 250°F maximum temperature from 16" to 48" inner pipe size.

Six (6) suppliers of pre-fabricated piping systems were contacted and their quotations were all based upon the above criteria. Included in the pricing for the piping is the cost of a complete electric water alarm system which will indicate if and where a break in the piping system has occurred.

7.6.2 Method of Construction and Installation

7.6.2.1 Rural

The estimate was prepared first on the basis of rural application with the following considerations:

- a) Two sections of pipe in 40 foot lengths (shop fabricated from 20 ft. random lengths) will be placed side by side in a trench with all welds made in the trench.
- b) Differential rate established for trench welding. (Also evaluated in sizes 2" and smaller were slip joint pipe.)
- c) No welding for core pipe will be required for slip joint connections. It is assumed that the portion of pipe handling manhours for aligning and tacking are sufficient for making up the joint.
- d) Open cut excavation considered with sloping sides on a 1:1 basis and minimal impact by such things as traffic, lighting access, or restrictions of any kind.

7.6.2.2 Urban

Having completed the "Base" case, i.e. rural application, the extreme case of urban application was considered in the following manner:

TABLE 7-VII

2. INSTALLED CAPITAL COST FOR
PREFABRICATED PIPING SYSTEM
(MATERIAL & LABOR)

Cost in \$/100 L.F. of Trench

Pipe Size (Inches)	Right-of-Way* Welded	Rural		Suburban		Urban	
		Welded	Slip JT.	Welded	Slip JT.	Welded	Slip JT.
1	-	4,600	4,500	9,100	8,700	13,500	12,900
1-1/2	-	4,800	4,700	9,300	8,900	13,700	13,100
2	-	4,900	4,800	9,500	9,100	14,000	13,400
3	-	8,000	-	13,200	-	18,400	-
4	-	8,500	-	14,000	-	19,400	-
6	-	10,900	-	16,800	-	22,700	-
8	-	13,600	-	20,000	-	26,300	-
10	-	17,100	-	24,100	-	31,000	-
12	-	19,600	-	27,100	-	34,600	-
14	-	22,700	-	31,300	-	39,800	-
16	20,000	25,200	-	34,200	-	43,200	-
18	-	26,300	-	40,900	-	45,500	-
20	25,000	31,100	-	41,200	-	51,300	-
24	30,000	36,600	-	48,000	-	59,400	-
30	35,000	45,300	-	58,600	-	71,800	-
36	40,000	53,800	-	69,700	-	85,600	-
42	45,000	60,000	-	78,400	-	96,700	-
48	-	70,200	-	89,300	-	108,300	-

NOTE: 1. The above prices are based upon installing two (2) pipes, per trench. (Supply & Return)

*2. Prices for right-of-way welded pipe were developed using PSE&G Gas T&D Department figures.

a. Quantify and estimate measurable restrictions, e.g.

- 1) Shoring
- 2) Straight cutting of excavation
- 3) Cutting and replacing roads
- 4) Hand excavation deemed necessary because of existing services

b. Allowances for non-quantifiable restrictions, e.g.

- 1) Guards and watchman (if required)
- 2) Decking (for access)
- 3) Traffic control
- 4) Barricades and lighting
- 5) Sanitary amenities
- 6) Staging areas
- 7) Lay down and equipment areas
- 8) Permits, licenses and fees
- 9) Impositions by local authorities, utilities, etc.

The above items were estimated on a judgmental basis at a percentage of the total cost.

7.6.2.3 Suburban

Having considered now both of the extremes, i.e. rural and urban, it was recognized that suburban costs would fall somewhere between urban and rural. It was also visualized that in certain suburban areas it would be possible to experience both urban and rural conditions for the installation of pipe.

Therefore, in quantifying the difference between rural and suburban, it was on a judgmental basis considered to be 50% of the difference between the two extremes.

7.6.2.4 Right of Way

The pipe pricing for installation of pipe on a PSE&G or other acceptable right of way was based upon using the same design bases and installation details as used for rural piping with the exception that the open cut excavation and pipe installation assume no impact on traffic, lighting access, etc. In addition, no allowances were made for spoil removal or surface preparation after piping trench is backfilled.

7.6.3 Determination of Piping Costs

7.6.3.1 Qualifications to Estimate

- a) For the purpose of conceptual economic considerations, the estimates for the diameters shown are based on straight runs of pipe with no considerations allowed for or considered for bends, fittings, valves, thrust blocks, etc.
- b) The wage rate established for this effort is considered to be totally contracted, i.e., all contractor's equipment, insurance, site offices, etc., have been considered.
- c) Testing allowances have been included.

7.6.4 Overall Transmission and Distribution System Piping Costs

7.6.4.1 Transmission System Piping Costs

The transmission piping layout shown on Figure 7.3 indicates the overall piping layout for both the Hudson and Kearney Stations. The transmission mains, shown heavy, are actually two (2) lines, supply and return. The common 36" lines and 42" lines between the stations are provided to allow for either plant to supply the total connected district heating system capacity as shown on Figure 7.3.

Four (4) river crossings are indicated on the layout shown on Figure 7.3. All of these crossings will be under the river bottom, except as noted, and will be priced as follows:

	<u>Location</u>	<u>Pipe Size</u>	<u>Length</u>	<u>Installed Cost</u>
1.	Harrison	2-20"	600'	\$ 2,500,000
2.	Essex	2-36"	1000'	2,300,000
3.	Kearney-Hudson	1-42"	1000'	1,400,000
		2-36"	In Existing Tunnel, 650' Horizontal 200' Vertical	400,000
4.	Berry's Creek	2-16"	600'	1,000,000
				<hr/>
				\$ 7,600,000

The piping costs shown below reflect the layout shown on Figure 7.3.

<u>Pipe Size</u>	<u>Length</u>	<u>Pricing Type</u>	<u>Installed Cost</u>
42"	10,800'	Right of Way	\$ 4,860,000
36"	16,900'	Right of Way	6,760,000
36"	2,500'	Urban	2,140,000
36"	7,500'	Suburban	5,227,000
30"	2,500'	Urban	1,795,000
24"	3,000'	Right Of Way	900,000
24"	8,500'	Urban	5,049,000
20"	2,900'	Right of Way	725,000
20"	27,000'	Urban	13,851,000
16"	37,000'	Right of Way	7,400,000
			<hr/>
			\$48,707,000
			4,871,000*
			<hr/>
			\$53,578,000
Cost For Four (4) River Crossings -			7,600,000
Total Transmission System Piping Cost -			<u>\$61,178,000</u>

*Additional 10% for isolation valves, manholes, fittings, etc.

7.6.4.2 Distribution System Piping Costs

a) Typical Piping Layouts

Figures 7.4 and 7.5 show a typical one square mile distribution piping layout from an initial stage Heating Plant. Figure 7.4 is a typical layout in the Jersey City area and Figure 7.5 is a typical layout in the Newark area.

The trunk lines, shown heavy, are 10" and 8" for both Jersey City and Newark. Each line size length is half of the trunk length. All the other lines of the network are 4" and 3" lines which are capable of delivering up to 20×10^6 BTU/hr. The total length of the above lines total somewhat less than 16 miles in each area.

In addition to the above trunk lines, there are approximately 65 connections in Jersey City and 80 connections in Newark to users in multi-unit apartments. These lines are 2" in size and their average length is approximately 150 feet each.

It is also assumed that there will be approximately 35 Multi-Family Housing Groups in Newark and 75 Multi-Family Housing Groups in Jersey City supplied by the distribution system. Each group will be supplied by one heat exchanger. (See figure 7.6 for typical distribution layout.)

It is estimated that there will be about 35 users per heat exchanger group and an average of 330 feet of 2" pipe, 390 feet of 1-1/2" pipe and 450 feet of 1" pipe per heat exchanger group.

b) Piping Costs

1) Jersey City -

The piping costs shown below are based upon one square mile of heating system distribution for a supply heating load of 300×10^6 BTU/hr.

<u>Pipe Size</u>	<u>Length</u>	<u>Installed Cost</u>	<u>Pricing Type</u>
10"	5,900'	\$ 1,829,000	Urban
8"	5,900'	1,552,000	Urban
4"	23,200'	4,501,000	Urban
3"	55,000'	10,120,000	Urban
2"	9,750'	1,365,000	Urban
2"	24,750'	1,782,000	*Suburban/Rural
1-1/2"	29,250'	2,076,750	*Suburban/Rural
1"	33,750'	2,328,750	*Suburban/Rural
		\$25,554,500	
		3,833,200**	
Total Cost For One Square Mile of Distribution Piping -		<u>\$29,387,700</u>	

2) Newark -

The piping costs shown below are based upon one square mile of heating system distribution for a supply heating load of 360×10^6 BTU/Hr.

<u>Pipe Size</u>	<u>Length</u>	<u>Installed Cost</u>	<u>Pricing Type</u>
10"	5,900'	\$ 1,829,000	Urban
8"	5,900'	1,552,000	Urban
4"	23,200'	4,501,000	Urban
3"	55,000'	10,120,000	Urban
2"	12,000'	1,680,000	Urban
2"	28,050'	2,019,600	*Suburban/Rural
1-1/2"	33,150'	2,353,650	*Suburban/Rural
1"	38,250'	2,639,250	*Suburban/Rural
		<u>\$26,694,500</u>	
		<u>4,004,200**</u>	

Total Cost For One Square
Mile of Distribution Piping - \$30,698,700

3) New Developments - Jersey City/Newark

The piping costs shown below are based upon one square mile of heating system distribution for large new developments within the Jersey City/Newark areas supplying a heating load of 300×10^6 BTU/Hr.

<u>Pipe Size</u>	<u>Length</u>	<u>Installed Cost</u>	<u>Pricing Type</u>
10"	5,900'	\$ 1,421,900	Suburban
8"	5,900'	1,180,000	Suburban
4"	23,200'	1,972,000	Rural
3"	55,000'	4,400,000	Rural
2"	9,750'	477,750	Rural
2"	24,750'	1,782,000	*Suburban/Rural
1-1/2"	29,250'	2,076,750	*Suburban/Rural
1"	33,750'	2,328,750	*Suburban/Rural
		<u>\$15,639,150</u>	
		<u>2,345,850**</u>	

Total Cost For One Square
Mile of Distribution Piping - \$17,985,000

*1/2 total length of pipe priced as suburban, 1/2 length priced as rural.

**Additional 15% for isolation valves, manholes, fittings, etc. 48

PRINTS	ISSUE	4							
		3							
		2							
		1	ORIGINAL ISSUE						
APP. CARD	ISSUE	DESCRIPTION							
		STONE & WEBSTER ENGINEERING CORP.							

DISTRICT HEATING PIPING
FOR A TYPICAL ROW OF
MULTI-FAMILY HOUSES

DWG. NO. FIG. 7.6

51

49660.15

DESIGNED BY

DRAWN BY

DSGN CHKD BY

CHKD BY

DSGN ENGR

RESP ENGR

7.7 LANDFILL GAS SUPPLY COST ESTIMATE

Prepared by PSE&G R&D Department personnel engaged in the design, construction and commercial operation of similar landfill gas recovery systems presently operating and under development.

DISTRICT HEATING LANDFILL GAS SUPPLY

Berry's Creek Center

	'83	'84	'85	'86	'87	'88	'89	'90	'91
Total Heating Load (10^6 BTU/hr)	15	70	100	135	150	160	170	180	200
Landfill Gas Load (10^6 BTU/hr)	-	47	67	90	100	107	113	120	133
LF Gas Required (10^6 ft ³ /day) @ 500 BTU/ft ³ & 82% boiler efficiency	-	2.8	3.9	5.2	5.9	6.3	6.6	7.1	7.8

Capital costs are in 1983 dollars and include all gas recovery wells, collection piping, compressors and miscellaneous equipment up to the compressor outlets.

1984

LF Gas Load = 2.8×10^6 ft³/day

Develop: Kingsland and Avon Landfills

	recovery cap. ft ³ /day
Avon	0.9×10^6
Kingsland	2.0×10^6
Total	2.9×10^6

Compressor Capacity $3 \text{ MM ft}^3/\text{day}$

	1983 \$
Gas wells	150,000
Collection piping	1,380,000
Compressors & assoc. equipment (minimal cleanup)	930,000 (capacity of 3×10^6 ft ³ /day)
Misc.	90,000
	<u>\$2,550,000</u>

DISTRICT HEATING LANDFILL GAS SUPPLY

1985

Landfill Gas Load - $3.9 \times 10^6 \text{ ft}^3/\text{day}$

Add gas recovery wells at Kingsland

Develop Kingsland Extension and MSLA site IC

Compressor Capacity = $6 \text{ MM ft}^3/\text{day}$

Landfill capacity:

Avon	$0.9 \times 10^6 \text{ ft}^3/\text{day}$
Kingsland	$2.0 \times 10^6 \text{ "}$
Kingsland Ext.	$0.8 \times 10^6 \text{ "}$
MSLA site IC	$5.2 \times 10^6 \text{ "}$
<hr/>	
Total	$8.9 \times 10^6 \text{ ft}^3/\text{day}$

	<hr/> 1983 \$
Gas Wells	60,000
Collection piping	545,000
Compressor & Assoc.	930,000 (additional 3×10^6 per day capacity)
Misc.	35,000
	<hr/>
	\$1,570,000

1986

Landfill Gas Load - $5.2 \times 10^6 \text{ ft}^3/\text{day}$ $5.2 \times 10^6 \text{ ft}^3/\text{day}$
at gas recovery wells @ MSLA site IC

Compressor Capacity	=	$6 \times 10^6 \text{ ft}^3/\text{day}$
Landfill Capacity	=	$8.9 \times 10^6 \text{ ft}^3/\text{day}$
		<hr/> 1983 \$
Gas Wells		70,000
Collection Piping		645,000
Misc.		40,000
		<hr/>
		\$755,000

DISTRICT HEATING LANDFILL GAS SUPPLY

1987

Landfill Gas Load - $5.9 \times 10^6 \text{ ft}^3/\text{day}$
 Add gas recovery wells @ MSLA site 1C

Compressor Capacity - $6 \times 10^6 \text{ ft}^3/\text{day}$
 Landfill Capacity - $8.9 \times 10^6 \text{ ft}^3/\text{day}$

	<u>1983 \$</u>
Gas Wells	40,000
Collection Piping	345,000
Misc.	25,000
	<u><u>\$410,000</u></u>

1988

Landfill Gas Load - $6.3 \times 10^6 \text{ ft}^3/\text{day}$
 Add gas recovery wells and additional
 compressor @ MSLA site 1C

Compressor Capacity $8 \times 10^6 \text{ ft}^3/\text{day}$
 Landfill Capacity $8.9 \times 10^6 \text{ ft}^3/\text{day}$

	<u>1983 \$</u>
Gas Wells	25,000
Collection Piping	200,000
Compressors & assoc.	620,000 (additional $2 \times 10^6 \text{ ft}^3/\text{day}$ capacity)
Misc.	15,000
	<u><u>\$860,000</u></u>

DISTRICT HEATING LANDFILL GAS SUPPLY

1989

Landfill Gas Load - $6.6 \times 10^6 \text{ft}^3/\text{day}$
Add gas recovery wells @ MSLA site 1C

Compressor Capacity	$8 \times 10^6 \text{ft}^3/\text{day}$
Landfill Capacity	$8.9 \times 10^6 \text{ft}^3/\text{day}$
	<hr/> 1983 \$
Gas Wells	15,000
Collection Piping	150,000
Misc.	10,000
	<hr/> <hr/> \$175,000

1990

Landfill Gas Load - $7.1 \times 10^6 \text{ft}^3/\text{day}$
Add gas recovery wells @ MSLA site 1C

Compressor Capacity	$8 \times 10^6 \text{ft}^3/\text{day}$
Landfill Capacity	$8.9 \times 10^6 \text{ft}^3/\text{day}$
	<hr/> 1983 \$
Gas Wells	30,000
Collection Piping	245,000
Misc.	15,000
	<hr/> <hr/> \$290,000

1991

Landfill Gas Load - $7.8 \times 10^6 \text{ft}^3/\text{day}$
Add gas recovery wells @ MSLA site 1C

Compressor Capacity	$8 \times 10^6 \text{ft}^3/\text{day}$
Landfill Capacity	$8.9 \times 10^6 \text{ft}^3/\text{day}$
	<hr/> 1983 \$
Gas Wells	40,000
Collection Piping	345,000
Misc.	25,000
	<hr/> <hr/> \$410,000

DISTRICT HEATING LANDFILL GAS SUPPLY

Capital Expenditures by Years

	<u>1983 \$</u>
1984	\$2,550,000
1985	1,570,000
1986	755,000
1987	410,000
1988	860,000
1989	175,000
1990	290,000
1991	410,000
	<hr/> <hr/>
Total	\$7,020,000

7.8

COMPARATIVE DISTRIBUTION/TRANSMISSION
COST ESTIMATES

DANPOWER, INC.

August 22, 1983

Dr. Melvin L. Zwillenberg
Principal Staff Engineer - Research
Public Service Electric and Gas Company
Research and Development Department
80 Park Plaza
Newark, New Jersey 07101

Dear Dr. Zwillenberg:

Referring to our very pleasant meeting on August 2, I send you the following additional material received from Mr. Peter Randloev:

- Revised report on prices.
- A paper on transport capacity of DH-pipes. I will later mail you an example of optimization of a distribution network. (See Appendix B).
- Information on heat loads per square mile.
- A paper on "Recent Development of Pre-insulated Pipes in Denmark" made for the 5th International District Heating Conference in Kiev in 1982 (with reference to our discussion on wall thickness of steel pipes). See Appendix B).

Concerning the report on piping installation costs, some smaller changes and corrections due to better price information have been included. The wages have been adjusted, but the effect on the total cost is only of minor importance. In addition to that, a more realistic division between civil works, piping works, and cost of materials is worked out for dimensions $\leq 4"$, but the total cost in dollars per foot is almost the same.

Concerning pipes above ground, Danish experience shows that almost no reduction in prices can be expected in comparison with buried pipes, because special efforts have to be made to avoid damage of the pipes. Also, the supports of the pipes are very expensive.

DANPOWER, INC.

Dr. Melvin L. Zwillenberg
August 22, 1983
Page Two

All the prices are based on installation of two pipes per trench except for the 42" river crossing, where only one pipe is included. The cost is estimated at two-thirds of the cost for two pipes, which is a correction in relation to the earlier price.

As you can see, we have only made minor changes in the unit prices, and we are not able to explain the differences in prices for the transmission system.

However, keep in mind that for a typical project the total cost for transmission is normally much smaller than the cost for distribution.

I hope that this information will help you and look forward to a further discussion with you.

Sincerely,

Peter N. Jensen
General Manager

Enclosure

PJ:tk

cc: Miklos G. Kurz, P.E.
Transflux International Limited

PSE & G

**DISTRICT HEATING
TRANSMISSION AND DISTRIBUTION
PIPING INSTALLATION COSTS**

TABLE OF CONTENTS

Introduction

Basic assumptions

Comments to the temperatures

Table of "Right of Way" prices.

Installed costs

Introduction

Based on the paper:

PSE & G

District Heating

Transmission and Distribution

Piping Installation Costs

Jan. 6, 1983

Prices for DH pipes according to Danish experience have been analysed. The prices are adjusted according to wages in the US.

The basic prices are from ongoing projects, but it must be emphasized that in relation to the PSE & G project they are planning prices.

Many factors can influence on the unit prices, some of the most important being soil conditions, ground water level, traffic regulation and re-establishment of pavements.

Basic assumptions

The basic assumptions include minor adjustments compared to the PSE & G paper.

This does not necessarily mean that the project cannot be carried out as planned, but it is considered more safe to use assumptions on the conservative side in the planning period.

The assumptions are as follows:

- All media pipes are welded.
- Dimensions $\leq 24"$ are made with preinsulated pipes (steel/polyurethane/PEH).
Dimensions $> 24"$ are made with steel-in-steel systems (media pipe of steel, insulation of polyurethane or mineral wool and casing of corrosionprotected steel).
- The prices refer to January 1983.
- The "Right of Way" prices are based on Danish projects which have been constructed or are under construction. Adjustments are made according to wages in the US.

- All prices include two pipes per trench except for the 42" river crossing, where only one pipe is included.
- In Denmark the ratio between wages and other expences can be roughly estimated as:

50% to 50% for civil works and
75% to 25% for piping works.

- The prices include an addition of 15% for design, supervision and administration.
- The unit prices cover a complete set of twin-pipes including:

Changes in other utility services
Valvepits
Site office
Contractor equipment
Electric alarm system
Bends, fittings, valves and expansion facilities.

- Not included in the prices are:

Insurances
Area compensations
Permits, licenses and fees
Impositions by local authorities, utilities etc.
Pumping stations
Heat exchangers.

- The cost of a heat exchanger in a concrete pit is estimated to be about \$ 50.000 for 35 users and are not included in the estimate of overall costs.
- "Suburban" prices are estimated as "Right of Way" prices with an addition of 60%.

- "Urban prices are estimated as "Right of Way" prices with an addition of 110%.

River Crossings

It is very difficult to calculate the cost of a river crossing without knowing the local conditions. Depending on the geotechnical, the flow and the topographical conditions, the cheapest crossing may be free spanning pipes arranged as a suspension bridge, pipes installed on or under an existing bridge or crossings under the river bottom as indicated for this project.

Pipes under the river bottom can be arranged in several ways depending on the river shore conditions, on the soil, flow and depth conditions and on possible restrictions on interference of the traffic on the river.

The prices used for the river crossings are based on the following assumptions:

- 1) The pipes can be dragged in full lengths from one shore to the other.
- 2) The pipes can be washed down under the bottom of the river.
- 3) Only limited arrangements have to be constructed for receiving the pipes on the shores. If the topography makes it necessary to construct shafts, the prices must be increased considerably.

On this basis the prices are estimated to be:

950	\$/ft	for	2-16"	pipes
1300	\$/ft	for	2-20"	pipes
2720	\$/ft	for	2-36"	pipes
1810	\$/ft	for	2-36"	pipes in existing tunnel
2360	\$/ft	for	1-42"	pipe

Comments on the temperatures

For dimensions $\leq 14"$ a maximum temperature of 290°F is indicated and for dimensions $> 14"$ the maximum temperature is 250°F.

First there must be some special reason that the temperature is higher in the distribution system than in the transmission system. Although this is physically possible, it is normal that the design temperature is highest for the transmission lines. For the large pipes - and that is mainly the transmission lines - a variety of competitive piping technologies are possible, which allow temperatures above 250°F, but for the distribution network there are hardly any choice but preinsulated pipes when considering the costs.

For steel-in-steel systems with polyurethane insulation temperatures of 260-270°F are possible because the foam here is not under shearstress, but in the distribution network where bonded pipes with polyurethane and casing of PEH are used, continuous temperatures above 250°F are not considered to be safe.

The operation temperature for the system naturally must be optimized, but it must be observed that reductions in temperature e.g. from 250°F to 210°F will give a reduction in construction prices and a considerable increase in expected lifetime.

"Right of Way" prices in US \$ per feet.

Price basis is Jan. 1983		1"	1 1/2"	2"	3"	4"
Civil works	Wages	16.1	18.2	20.2	23.5	26.2
	Other exp.	6.7	7.6	8.4	9.8	10.9
		22.8	25.8	28.6	33.3	37.1
Piping works	Wages	12.2	13.7	15.4	18.2	20.6
	Other exp.	1.7	1.9	2.1	2.5	2.9
		13.9	15.6	17.5	20.7	23.5
Cost of materials		6.8	8.5	10.4	14.7	20.3
Sum		43.5	49.9	56.5	68.7	80.9
Design, supervision and administration (15%)		6.5	7.5	8.5	10.3	12.1
Total US \$/feet		50.0	57.4	65.0	79.0	93.0

"Right of Way" prices in US \$ per feet

Price basis is Jan. 1983		8"	10"	16"	20"	24"
Civil works	Wages	30.7	31.2	40.8	62.2	75.6
	Other exp.	12.8	13.0	17.0	25.9	31.5
		43.5	44.2	57.8	88.1	107.1
Piping works	Wages	27.4	30.0	49.0	74.6	119.5
	Other exp.	3.8	4.2	6.8	10.4	16.6
		31.2	34.2	55.8	85.0	136.1
Cost of materials		47.0	69.0	108.8	165.8	233.3
Sum		121.7	147.4	222.4	338.9	476.5
Design, supervision and administration (15%)		18.3	22.1	33.4	50.8	71.5
Total US \$/feet		140.0	169.5	255.8	389.7	548.0

"Right of Way" prices in US \$ per feet

Price basis is Jan. 1983		30"	36"	42"		
Civil works	Wages	92.6	122.6	159.6		
	Other exp.	38.6	51.2	66.6		
		131.2	173.8	226.2		
Piping works	Wages	146.4	193.9	252.5		
	Other exp.	20.3	26.9	35.0		
		166.7	220.8	287.5		
Cost of materials		297.5	394.2	512.5		
Sum		595.4	788.8	1026.2		
Design, supervision and administration (15%)		89.3	118.3	153.9		
Total US \$/feet		684.7	907.1	1180.1		

1. Transmission System Piping CostsRiver Crossings:

<u>Location</u>	<u>Pipe Size</u>	<u>Length</u>	<u>Installed Cost</u>
1. Harrison	2-20"	600'	780,000 \$
2. Essex	2-36"	1000'	2,720,000 -
3. Kearney-Hudson	1-42" 2-36"	1000' In Existing Tunnel, 650' Horizontal 200' Vertical	2,360,000 - 1,538,500 -
4. Berry's Creek	2-16"	600'	<u>570,000 -</u>
			7,968,500 \$
			<u>8,000,000 \$</u>

<u>Pipe Size</u>	<u>Length</u>	<u>Pricing Type</u>	<u>Installed Cost</u>
42"	10,800'	Right of Way	12,745,080 \$
36"	16,900'	Right of Way	15,329,990 -
36"	2,500'	Urban	4,762,275 -
36"	7,500'	Suburban	10,885,200 -
30"	2,500'	Urban	3,594,675 -
24"	3,000'	Right of Way	1,644,000 -
24"	8,500'	Urban	9,781,800 -
20"	2,900'	Right of Way	1,130,130 -
20"	27,000'	Urban	22,095,990 -
16"	37,000'	Right of Way	<u>9,464,600 -</u>
			91,433,740 \$
Cost for 4 river crossings:			<u>8,000,000 -</u>
			99,433,740 \$
Total			<u>100,000,000 \$</u>

2. Distribution System Piping Costs1) Jersey City

<u>Pipe Size</u>	<u>Length</u>	<u>Installed Cost</u>	<u>Pricing Type</u>
10"	5,900'	2,100,105 \$	Urban
8"	5,900'	1,734,600 -	Urban
4"	23,200'	4,530,960 -	Urban
3"	55,000'	9,124,500 -	Urban
2"	9,750'	1,330,875 -	Urban
2"	24,750'	2,091,375 -	Suburban/Rural
1-1/2"	29,250'	2,182,635 -	Suburban/Rural
1"	33,750'	2,193,750 -	Suburban/Rural
		<u>25,288,800 \$</u>	
Total Cost For One Square Mile of Distribution Piping		26,000,000 \$	=====

2) Newark

<u>Pipe Size</u>	<u>Length</u>	<u>Installed Cost</u>	<u>Pricing Type</u>
10"	5,900'	2,100,105 \$	Urban
8"	5,900'	1,734,600 -	Urban
4"	23,200'	4,530,960 -	Urban
3"	55,000'	9,124,500 -	Urban
2"	12,000'	1,638,000 -	Urban
2"	28,050'	2,370,225 -	Suburban/Rural
1-1/2"	33,150'	2,473,653 -	Suburban/Rural
1"	38,250'	2,486,250 -	Suburban/Rural
		<u>26,458,293 \$</u>	
Total Cost For One Square Mile of Distribution Piping		27,000,000 \$	=====

3) New Developments - Jersey City/Newark

<u>Pipe Size</u>	<u>Length</u>	<u>Installed Cost</u>	<u>Pricing Type</u>
10"	5,900'	1,600,080 \$	Suburban
8"	5,900'	1,321,600 -	Suburban
4"	23,200'	2,157,600 -	Rural
3"	55,000'	4,345,000 -	Rural
2"	9,750'	633,750 -	Rural
2"	24,750'	2,091,375 -	Suburban/Rural
1-1/2"	29,250'	2,182,635 -	Suburban/Rural
1"	33,750'	2,193,750 -	Suburban/Rural
		<u>16,525,790 \$</u>	
Total Cost For One Square Mile of Distribution Piping		17,000,000 \$	=====

Suburban/Rural: 1/2 total length of pipe priced as suburban, 1/2
length priced as right of way.

SECTION 8
STAGED DEVELOPMENT
SCENARIOS

8. STAGED-DEVELOPMENT SCENARIOS

8.0 INTRODUCTION

Each of the alternates studies in this analysis is of such a large scope of development as to make a one step completion impractical. The use of a staged-development approach spreads the capital costs over a period of time and permits a construction schedule in concert with projected increases in demand for thermal energy, similar to the manner in which conventional heating systems are installed in new buildings. Uncertainties in obtaining all potential customers and gaining wide acceptance of district heating dictate a prudent strategy to first develop high-potential low-risk areas, such as new developments, and to provide a good base for possible future expansion.

The staged-development scenarios adopted for this study should not be considered as "rigid" but merely indicative of the manner in which a real district heating system could be built, if a decision to do so is made. There are sufficient potential sites for district heating implementation with characteristics similar to the ones selected for this study so that the analysis is not overly sensitive to changes in development schedules or construction plans of specific new developments which are outside of the influence of PSE&G.

Figure 8.0.1 shows a generalized method for developing a district heating system. A heater plant consisting of a group of conventional package type boilers could initially be used to supply a localized area, or an "island" supplied by the respective heater plants could be interconnected to improve reliability and minimize the required reserves (Step 2). The retrofit of existing generating units, either steam or gas turbine, to produce additional thermal energy will be undertaken when economics justify it (Step 3). In actual implementation, it may sometimes be desirable to combine Steps 2 and 3, to make maximum use of the low operating cost thermal energy produced by retrofitting a generating unit. The fuel savings must be evaluated with respect to costs of the retrofit and associated transmission piping. In the development of the fully developed system that was evaluated, all three steps could be occurring simultaneously in different locations.

8.0.1 CONVENTIONAL CUSTOMER OWNED SYSTEM

If a district heating system is not implemented, a conventional heating system supplied either by natural gas or oil would most likely be used in

individual buildings. Since the costs of both natural gas and oil are expected to be generally in parity, with natural gas on the lower side over the long run, for simplicity natural gas was chosen to provide a more conservative comparison with district heating. The boilers in the conventional system would, of course, be customer owned.

Normally there would be two reasons for installing a new boilers:

- 1) Supply for a new building
- 2) Replacement of existing older equipment

Some areas have been identified as having a high potential for future new developments. In these cases, it was assumed that all new boilers would be required. In existing areas, factors ranging from 22 to 40% were calculated to account for the boiler age distribution and remaining life. These factors were used for the development of appropriate replacement costs for the purpose of this study. Normally there may or may not be back-up boilers in a conventional system, so that there may be some advantage over a district heating system in boiler capital costs. The conventional system matches the load almost exactly, eliminating the excess capacity inherent with large boilers at centralized sites, but neither is there a factor of coincidence amounting customarily to 8-10% of contracted peaks of a central system.

8.1 SCENARIO I - BERRY CREEK DISTRICT HEATING SYSTEM

8.1.1 INTRODUCTION

A new commercial/residential development is underway along Berry's Creek of the Hackensack Meadowlands. This approximately 700 acre tract is being developed by Bergen County Assocs. having been joined by Rose Assocs. and the Rouse Co. and under the supervision of the Hackensack Meadowlands Development Commission, a state agency. It has been determined that for both technical and political reasons this site is a natural starting point for the introduction of district heating in Northern New Jersey. Its development is scheduled to take place over 10 years and it is estimated to require 200 million BTU per hour for heating on a peak, zero degree day.

8.1.2 THE DEVELOPMENT

It is a mixed development of a shopping center, offices, hotel/motels and residential housing of mid-rise and multi- and single-family housing. It is to be located on a tract south of Route 3 and west of the western spur of the N.J. Turnpike.

It was estimated on the basis of square foot building area and projected use that the total development at its completion will present a peak heating load of 300 million BTU/hr, as shown on Table 8.1-I. This figure was reduced to 200 million BTU/hr for our further studies to account for improved, energy saving construction and for possible changes in plans.

Based on the present plans and schedules, figures 8.1.1 to 8.1.5 show the year-by-year growth of the project and that of the D-H distribution system required. Tables 8.1-II and 8.1-III show the extent of the pipe work and the heater plant requirements to meet the heating needs of the development as they materialize. Table 8.1-IV gives the equipment installation schedule.

8.1.3 PROPOSED D-H SYSTEM

A high temperature water district heating system is to supply the space heating and domestic hot water needs of the entire development. The supply of cooling by this system is subject to negotiations with customers in accordance with the findings of Section 6.7.3. The domestic hot water requirements are estimated to be 7.5% of the space heating peak and it is considered constant year-round. The coincident

TABLE 8.1 -I

HERRY'S CREEK
Project Implementation Forecast

STAGE I

Designation	Project Description	Construction end of	Bldg. area sq. ft.	Est. Heat Load 10 ³ BTU/hr	cumul.
A	office	1984	500000	15000	
B	"	1985	500000	15000	
C	hotel		350 rooms	7000	
D	housing		150 units	3000	
E	conv. hotel		1000 rooms	20000	
M ₁	housing				
	(high & low rise)		307 units	6150	
N ₁	housing				
	(high & low rise)	1985	120 units	2400	68550
F ₁	reg'l. comm.	1987	1300000	32500	
F ₂	offices		400000	12000	
G ₁	transp. center		900	30	
G ₂	"		?		
H	gen. commercial		300000	9000	
J	housing (above H)		150 units	3000	
K	"		300	6000	
L	"	1987	150	3000	
U	fire/police			500	134580
Q ₁	housing				
	(high & low rise)	1988	346	7000	
R ₁	housing		350	7000	148580
S	housing &				
	neighb. canal	1989	207	4200	
T	housing &				
	neighb. canal		200	7500	160280

STAGE II

office	1992	1600000	48000	
housing		3800 units	78000	
commercial		200000	6000	292280

FIG. 8.1.1

BERRY'S CREEK CENTER

EAST RUTHERFORD & RUTHERFORD NEW JERSEY

A Project of Rose Associates/The Rouse Company/BCA-SIA
Planner/Architect: RTKL Associates Inc., Architects & Engineers, Village of Cross Keys, Baltimore, Maryland 21210
Transportation Planner: Benton-Bachman Associates Inc., 820 Davis Street, Evanston, Illinois 60201

D1.9

BERRY'S CREEK CENTER

EAST RUTHERFORD
& RUTHERFORD
NEW JERSEY

A Project of Rose Associates, The Rose Company, BCA-S/A
Planner/Architect: RTKL Associates Inc., Architects & Engineers, Village of Cross Keys, Baltimore, Maryland 21210
Transportation Planner: Barton-Aschman Associates Inc., 820 Davis Street, Evanston, Illinois 60201

D1.9

Date: May 15, 1985

BERRY'S CREEK CENTER

EAST RUTHERFORD & RUTHERFORD NEW JERSEY

A Project of Rose Associates: The Rose Company/BCA-SIA
Planner/Architect: RTKL Associates Inc., Architects & Engineers, Village of Cross Keys, Baltimore, Maryland 21210
Transportation Planner: Barton-Macchman Associates Inc., 820 Davis Street, Evanston, Illinois 60201

D1.9

FIG. 8.1.5

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

peak load of the large number of users is assumed to be 92.5% of the sum of peaks. Therefore in sizing the facilities the domestic hot water load is neglected. It is included however in the energy use (fuel) calculations.

There are two ways one can supply heat to the complex:

- an extraction steam based system originating at the Hudson G.S., or
- a landfill gas fuel based system.

8.1.3.1 Hudson G.S. Based System

This system will be developed in stages, starting with three 50 million BTU/hr capacity units fired by natural gas. This will be complemented by a fourth unit by the time the peak load reaches 100 million BTU/hr. That provides 100% stand-by capacity at this point, which will gradually reduce to 33% (one unit) as the load increases during the following years. The layout and the piping schematics of this plant are shown on Figures 8.1.6 and 8.1.7, except that only four units are required in this scheme. At this point there is sufficient load to justify the construction of a 5-1/2 mile transmission line connecting the site to the Hudson G.S. (see Fig. 8.1.8) and to tap the crossover of No. 2 unit. This tap is shown on Fig. 8.1.9 schematically, and along with two heat exchangers and pumps located in a new building, will provide up to 240 million BTU/hr for district heating. It operates as a bleed with no other but D-H water temperature control, reverse-flow protection and flow limiter. This maximum bleed flow provides 20% more heat than heaterplant which provides 100% back-up. The lost power generation at peak load and full throttle flow accounts for approximately 16MW. This was investigated in some detail by Westinghouse along with other aspects of the scheme and it was discussed in detail in Sect. 6.2.

This development, while it is natural gas fired during its first few years of existence, becomes a nearly 100% coal and waste heat based system after the turbine retrofit and the transmission lines are in place. The 100% figure is unattainable only in consideration for planned and unplanned outages of the No. 2 unit. Only total outages will affect the system; power output reductions will seldom, if at

all. Neither will full heat output be attainable at less than 85% throttle flow.

An intermediate step in installing a gasturbine plant with heat recovery had also been considered and discarded as uneconomical in this case.

8.1.3.2 Landfill Gas Based System

There are several hundred acres of recently completed and still active landfill operations within one to four miles south of the Berry's Creek development. Based on PSE&G's previous on-going operations of gas gathering of this type, it is deemed practical to tap this source of energy for the project. It is estimated that up to 10 million cu. ft. of gas per day at an HHV of 500BTU/cu. ft. can be gained within 2 - 2.5 miles of the site. The productive life of the system is said to be an average of 10 years.

The gaining of this gas involves drilling a large number of wells, a network of pipes connecting them to a compressor station, a simple gas clean-up system and a transmission pipe to the user, that is the heaterplant. The cost of the gas produced per million BTU (10 therms) is \$0.50-1.00 in royalties and \$.05-.10 in operation and maintenance cost plus the cost of the capital recovery. All this adds up to a fuel competitive even with coal on a cost basis, and much cleaner and easier to handle. Its cost compared to other fuels is a fraction.

The heaterplant shown on Figures 8.1.6 and 8.1.7 is different only from that of the previous alternative in that it has a second gas main and the heaters are equipped with burners capable of firing both landfill gas or natural gas. This plant in its final stage will have five units, where the fifth unit serves as stand-by. There is no change in the distribution system or in the schedule of construction. The tie line to Hudson G.S. and the retrofit of Hudson No. 2 may come into existence as an alternative supply of heat after the fields have been depleted. This can possibly extend as far as 15 years. In any case the gas system will be written off in 10 years.

Figure 8.1.10 shows the location of landfills, the compressor and heating plants and the gas transmission line connecting them. The line runs on the

Transco right-of-way most of its length. The estimated production capacity of the landfills is as follows:

Landfill	Recoverable Capacity (ft ³ /day)	Maximum Hourly Supply (ft ³)
Avon	0.9 x 10 ⁶	37,500
Kingsland	2.0 x 10 ⁶	83,500
Kingsland Extension (Bergen)	0.8 x 10 ⁶	33,500
MSLA Site 1C (deKorte Park)	5.2 x 10 ⁶	220,000
MSLA Site 1D (deKorte Park)	1.2 x 10 ⁶	50,000
	10.1 x 10 ⁶	424,500

The proposed development would start with the closest and oldest of these sites, Avon. Since the number of wells and the connection piping is generally proportional to output, it is foreseen that development will be as gradual as the load grows. The compressor station on the other hand will be built at inception, providing ample stand-by capacity at initial start-up, when such is proper to have. Generally the system development will aim at providing sufficient quantities of gas to supply over 90% of the energy needs of the project at all times. In order to achieve that, the maximum rate of gas flow should be sufficient to provide about two-thirds of the peak load. Figure 8.1.11 shows the load frequency curve of a space heating and domestic hot water supply system. It shows that the frequency of loads 66% and over is less than 400 hours annually. The area under the frequency curve is proportional to the energy used during a given time interval. It is easy to see how small that area is from 66% to 100% load and it amounts to less than 3.5% of total annual energy. It is not economical to extend the instantaneous landfill gas supply capabilities at considerable cost to supply this peak. A stand-by natural gas supply line will have to be built in any case and it will be used to supply this energy. Same will be used also to provide fuel for the first year of project development when only one building is planned to be erected. This way the large up-front expenses of compressor plant and transmission line are delayed by one year. The adequacy of the supply system

will be assured by the development of system capabilities a year ahead of predicted loads. This will also have the side effect of reducing the natural gas fuel use even further during most of the development period.

The maximum hourly supply of 424500 cu. ft. of gas, if fully developed, would provide 170 million BTU/hr at 80% fired heater efficiency. This is more than 66% of 200 million BTU/hr by 27.5%. So it will be sufficient to develop not more than 75% of the total potential.

There is no credit given for any other use of the landfill gas system, but for space heating and domestic hot water in our economics calculations. It is to be pointed out however that gas will be generated year-round. Therefore it stands to reason that finding summer uses will further enhance the economics. One logical way of doing that is to put the gas to use for air conditioning. It has been estimated that the project cooling load will grow to 25000T of refrigeration when completed. The gas supply of 7.8×10^6 cu. ft./day is only sufficient to produce not more than half of that requirement using a new, high efficiency ($COP \geq 1$) direct fired absorption cooler. This would involve a landfill gas distribution system at the site and the installation of the proper equipment. Those probably will have to be replaced in 10 years or operated on natural gas at a cost presently unknown.

It was considered using the gas to generate electric power for compression-type air conditioning equipment ($COP \geq 3$). It turns out that beyond the large investment in the gasturbine facility considerable monies would have to be spent on a gas clean-up system. These are not only expensive, but since there is very little actual operating experience, it is also risky. For these reasons this alternative, at least for now, had not been considered any further.

8.1.4 HTW DISTRIBUTION

Independent of the source, heat will be distributed to the users by a two pipe, recirculating hot water system. The nominal supply temperature of $290^{\circ}F$ and the nominal return temperature of $170^{\circ}F$ will only be maintained on the peak heat supply days. At all other

times the temperatures will be lower, proportional to and automatically controlled by ambient temperature.

The distribution network will be constructed by using pre-insulated pipes in protective covers laid directly in the soil. This development will have a zero elevation several feet above present ground level. Consequently most of the piping will be laid above-ground and fill will be placed around and above them afterwards. This will present considerable savings in construction cost, not fully accounted for in our estimates, to stay on the conservative side.

Generally the laying of pipes will follow the progress of the development, however mains will be sized for future loads and pipes will be laid at the site preparation stage, ahead of actual building construction.

The heating of multi-family row houses (town houses) and single-family housing is included in our supply system. These are to be supplied by secondary circuits as described in Sect. 6.5.7.

The developers have no firm plans for the heating/cooling systems should there be no district heating. Lacking these we have assumed that there will be water and air heating systems, oil or gas fired. It has been estimated in an order of magnitude fashion that the boilers and auxiliaries of such systems will cost over 2 million dollars, while the heat exchangers replacing them will be less than \$500000. This is a considerable saving, if PSE&G provides the distribution system.

The fully developed system will require 3333 gpm water circulation in a looped main of 12" and 10" initial diameter pipes. Water flow will be halved during the summer, when the load is less than 10% of peak unless absorption air conditioning systems will present a different demand.

The operation and maintenance of the distribution system requires very little manpower, particularly in its first 10-15 years of existence. Packing of valve stems, exercising of valves and checks for water tightness are the only day-to-day functions.

8.1.5 OPERATION AND MAINTENANCE

It has been assumed that the plant will be attended all the time and therefore five licensed operators

are scheduled. This can be modified later when other plants are in existence since full-time attendance of these fully automated water heater plants is not required. There are four other people assumed to perform routine maintenance and other chores. There will be some manpower in supervisory and clerical functions as well as in billing as part of the central PSE&G organization, not necessarily on full-time duty for this system.

The Hudson retrofit with two heaters and three pumps does not require additional personnel. The few control functions will be automated and the supervisory controls incorporated with the control room of the plant.

The development of pumping cost of the system is shown on Table 8.1-V and is estimated to be \$221000 at its full development and proportional to connected load at any other point. The water make-up and treatment cost is foreseen as \$10000 annually, again in straight ratio to system size.

The gas gathering system operation and maintenance of \$650000 per year should be allocated as one-half for compressor operations while the rest proportional to system size.

The heaterplant will require annual and long-range maintenance. Cost experience for such on generating plant heating boilers will be used for that purpose.

(repeat of Fig. 6.4.1)

FIG. 8.1.8

HUDSON G.S.
NO. 2 UNIT
PARTIAL RETROFIT
FOR BERRY'S CREEK D-H
(CONCEPTUAL)

FIG. 8.1.9

PUBLIC SERVICE ELECTRIC AND GAS CO.
HUDSON GENERATING STATION UNIT 2
HEAT BALANCE DESIGN
MAXIMUM DISTRICT HEATING LOAD
13722 BTU PER HOUR
STONE & WEBSTER ENGINEERING CORP.
10210N HICKORY
01 4 23 11 17 10

LEGEND
A 44 8450
B 102 2640
C 31 1300
D 85 1 04
E 4200
F 1 104
G 12 4330
H 10 3000
I 2 0340
J 4 2500
K 1 7110
L 15 3400
M 2 5100

REV.
0 - 10 00
1 - 0511
2 - 06
3 - 110 00

FIG. 8.1.10

FIG. 8.1.11

FUEL SOURCE DISTRIBUTION IN A
LANDFILL GAS SUPPLIED SYSTEM

SPACE HEATING

DISTRICT HEATING SYSTEM
BERRY'S CREEK
HEAT SOURCES AND TRANSMISSION

LEGEND

42" PIPE	=====
36" PIPE	=====
30" PIPE	=====
24" PIPE	=====
20" PIPE	=====
16" PIPE	=====
RIVER CROSSING	=====

	GENERATING STATION
	HEATER PLANT
	CO GENERATION FACILITY

NOTE: NOT DRAWN TO SCALE

FIG. 8.1.12

TABLE 8.1-II

MEADOWLANDS SYSTEM
(BERRY'S CREEK ONLY)
HTW PIPING INSTALLATION SCHEDULE
IN 1000 FT. OF PAIR OF PIPE

	DIA	1984	1985	1986	1987	1988	1989	1990	1991	TOTAL

ALT. 1 - NO LANDFILL GAS										
BERRY'S CREEK	12"		.6							.6
	10"		3.2	1.0	1.0					5.2
	3"		.6							.6
	4"		2.2	.3	.3	1.0	.4	.3	.3	4.8
	3"		.1							.1
	2"		1.6	.2	.1	1.6	.4	.3	.3	4.5
	1-1/2"		1.2			1.2	.2	.2	.2	3.0
HUDSON G.S. -TRANSMISSION	16"					26.5				26.5

TOTAL - ANNUAL			9.5	1.5	1.4	30.3	1.0	.8	.8	45.3
- ACCUMULATIVE			9.5	11.0	12.4	42.7	43.7	44.5	45.3	

ALT. 2 - LANDFILL GAS

same as above, except no transmission line is required and a gas gathering and supply system has to be constructed.

TABLE 8.1-III

MEADOWLANDS SYSTEM
(DERRY'S CREEK ONLY)
INSTALLATIONS & LOAD RUN-UP
ESTIMATE

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	TOTAL

ALT. 1 - NO LANDFILL GAS											

Berry's Creek											

Heater Plant - 10 ⁶ BTU/hr		150		50							200
Distribution - see Table 8.1-II											
Nat. gas service - 10 ⁶ BTU/hr		250									250
Hudson G.S.											

Turbine retrofit - partial - 10 ⁶ BTU/hr					240						240
Hx's & pumps											
Total - increm.- inst'd. cap.		150		50							200
- accum. - inst'd. cap.		150	150	200	440	440	440	440	440	4400	440 (spare 240)
ALT. 2 - LANDFILL GAS											

Berry's Creek - 10 ⁶ BTU/hr											

Distribution - see Table 8.1-II		150		50			50				250
Gas gathering - 10 ³ cfh			50	300	50		25	25			350
Back-up serv. - nat. gas - BTU/hr		200									200
Total - increm.- inst'd. cap.		150		50			50				250
- accum. - inst'd. cap.		150	150	200	200	200	250	250	250	250	250 (spare 50)
Note: 16"HW transmission line is not required.											
Heat Load											

10 ⁶ BTU/HR											
Berry's Creek - Accumulative peak	15	70	100	135	150	160	170	180	183		
- " heat loss	5	5	9	12	13	14	15	16	17		
- " total	20	75	109	147	163	174	185	196	200

TABLE 8.1 -IV

LIST OF
ANNUAL
EQUIPMENT INSTALLATION
REQUIREMENTSMEADOWLANDS SYSTEM (Berry's Creek only, 200 million BTU/hr. max.)

<u>Yr. of Inst.</u>	<u>Peak Load 10⁶BTU/hr</u>	<u>Equipment to be installed</u>	<u>Location</u>
ALT. 1 - NO LANDFILL GAS			
1983	-	Engineering and programming on equipment	Berry's Creek
1984	15	3 - 50x10 ⁶ BTU/hr gas/oil/land-fill gas fired water heaters, prefabr. 3 - 2500gpm, 20psi total head, approx. 40HP circulating pumps 3 - 2000gpm, 120psi total head, approx. 125HP syst. circ. pumps 1 - stack (as part of adjoining office bldg.) 1 - building, 18000 sq. ft., 25 ft. high 1 - pressurizing system 1 - 100gpm water softening syst. 1 - 240000cfh natural gas trunk-line Distribution piping: none	
1986	100	1 - 50x10 ⁶ BTU/hr fired water heater, as above 1 - 40HP heater circ. pump 1 - 125HP system circ. pumps	Berry's Creek
1987	135	- Hudson No. 2 turbine partial retrofit - - crossover taps	Hudson G.S.
1988	150	2 - heat exchangers - (1 - 130000 lb/hr, 1 - 70000 lb/hr), 235x10 ⁶ BTU/hr 1 - 2000gpm, 100psi total head, approx. 150HP syst. circ. pumps ~4 1/2 mile - 16" dia. aboveground transmission lines	Hudson G.S. Hudson G.S./ Berry's Creek
1992	200	none	
ALT. 2 - LANDFILL GAS			
1983	same as above	- as Alt. 1	Berry's Creek
1984-on		- construction of a 133x10 ⁶ BTU/hr net heat output, 7.8x10 ⁶ cu. ft./day gas gathering and compression system	Avon
		- supply line to heater plant	Avon/Berry's Creek
1985		- as Alt. 1	Berry's Creek
1988		1 - 50x10 ⁶ BTU/hr fired water heater 1 - 20HP heater circ. pump	" "

TABLE 8.1-V**MEADOWLANDS SYSTEM
(BERRY'S CREEK ONLY)
ANNUAL PUMPING COST
ESTIMATE**

	DIA	1984	1985	1986	1987	1988 M\$	1989	1990	1991	1992	TOTAL

ALT. 1 - NO LANDFILL GAS											
BERRY'S CREEK	12"		3.90								3.90
	10"		6.40								6.40
	8"		1.80								1.80
	4"		4.60	.60	.60	2.10					7.90
	3"		.07								.07
	2"		.35	.04	.02	.35	.09	.07	.07		.99
	1-1/2"		.08		.09	.01	.02	.01	.02		.23

TOTAL - ANNUAL			17.20	.64	.71	2.46	.11	.08	.09		21.29
HEATEXCHANGERS											
-FIRED HEATERS		10.00	10.00		5.00						25.00
-POWERPLANT HX'S & TRANSMISSION LINE						47.70	12.00	11.00	10.50	3.60	84.80
-IN-HOUSE (USER) HX'S		6.75	24.75	13.50	15.75	6.75	4.50	4.50	4.50	9.00	90.00

TOTAL - ANNUAL		16.75	51.95	14.14	21.46	56.91	16.61	15.58	15.09	12.60	221.09
- ACCUMULATIVE		16.75	68.70	82.84	104.30	161.21	177.82	193.40	208.49	221.09	

8.2 SCENARIO II - BERRY'S CREEK & HARMON MEADOWS DISTRICT HEATING SYSTEM

8.2.1 INTRODUCTION

Another commercial/residential development is underway in the Hackensack Meadowlands a couple of miles east of Berry's Creek, the Harmon Meadows. This approximately 500 acre tract is being developed by Hartz Mountain Industries Inc. The development plans are approved by the Hackensack Meadowland Development Commission. This development in itself or in conjunction with Berry's Creek can be the starting point for the introduction of district heating in Northern New Jersey. The schedule calls for the construction of several buildings over an 8 year period with an estimated peak heating requirement of at least 200 million BTU/hr.

8.2.2 THE DEVELOPMENTS

The Berry's Creek development has been described in detail in the previous section. It is applicable also when the two areas are considered together.

The Harmon Meadows is an area along Mill Creek and Cromakill Creek straddling the eastern spur of the N.J. Turnpike and located just north of Route 3. It is planned as a mixed development of light industrial buildings, research establishments, residential buildings and a local shopping center, office, hotel, theatre complex. Table 8.2-I shows the building mix and the estimated heating load.

The D-H system layout based on the preliminary development plans of Harmon Meadows is shown on Fig. 8.2.1. It is assumed that the light industrial structures will be constructed first at the northeastern tract, followed by the research park, residential buildings and finally by the office/shopping complex. The heater plant installations and the piping construction following this schedule are shown on Tables 8.2-II, 8.2-III and 8.2-IV.

8.2.3 PROPOSED D-H SYSTEM

The combined system for the two areas does not differ in its initial stage from either of the two developing separately and independently. During this timeframe the individual heater plants supply the heating and DHW needs of each. The conditions for comfort cooling are also the same as stated before.

The alternative sources for the energy are also unchanged, that is

- an extraction steam based system originating at the Hudson G.S.
- a landfill gas fuel supply system.

8.2.3.1 Hudson G.S. Based System

This system is also developed in stages just as a single area would be. A heater plant as described in Sect. 8.1.3.1 is constructed for each of the two areas. The Harmon Meadows plant is proposed to be located south of Route 3 on PSE&G property along a major power distribution point. The layout and growth of this plant will also be identical to the one described previously. Each will be a four-unit plant at its completion. When the combined load of the two plants reaches 200 million BTU/hr peak the construction of the transmission lines as shown on Fig. 8.2.2 becomes necessary along with the partial retrofit of Hudson G.S. No. 2 unit. This retrofit is no different from the one described in the referred previous section, with one exception. The total peak load of this system is double the previous one and so is the water flow required. The circulating pumps will have to be sized for 6600 gpm.

The heater plants with two 50 million BTU/hr standby units in each will still provide 100% back-up in case the No. 2 unit or the transmission line (incl. pumping) are lost.

The utilization of the plant retrofit is greatly improved in comparison with Scheme I. The 200 million BTU/hr heat supply available from the partial retrofit is 50% of the peak in this scheme. The energy supplied by the retrofit can amount to 92.5% of the energy used and to 69% of that potentially available at full utilization during the heating season (Fig. 8.2.3). This is naturally achievable only if there were no unplanned outages during the winter. In addition, it will be supplying all the DHW requirements during all the other times of the year except during the planned outage. Without accounting for the plant outages this means a 49% annual utilization of the potential. This is considerable improvement over the less than 30% utilization expected from Scheme I on the same basis.

With the high percentage of the total energy requirements supplied from the coal fired combined energy source, there is no economic incentive to consider a third--gasturbine heatrecovery--stage. This may become an alternative, when the total system growth is beyond the present expectations and so beyond the capacity of these installations.

8.2.3.2 Landfill Gas Based System

The landfill gas gathering and supply system is described in Sect. 8.1.3.2 along with its potential.

The major additions to that system are the full development of supply to 424500 scfm at peak use and the gas supply main extension along Route 3 to the Harmon Meadows heaterplant (Fig. 8.2.4). This larger system will have a better utilization of capacity since it will be capable of supplying only 42.5% of the peak load at the full development stage. As Fig. 8.2.5 shows, still 87% of the heat will be by landfill gas and only the rest by natural gas. The utilization of the gas gathering system during the entire heating season will average 77%, while in the summer it will decrease to approximately 25%. So the annual utilization rate is approximately 59%.

8.2.4 HTW DISTRIBUTION

The construction and the operating conditions of the distribution system will be identical to that described in Scheme I.

8.2.5 OPERATION AND MAINTENANCE

This system is twice the size of that described in Scheme I and it is practically identical to that one in all relevant detail. The pumping cost was calculated and is shown on Table 8.2-V, and water make-up cost is double that in Scheme I, that is up to \$20000 annually.

The operating manpower requirements however remain unchanged since the small--three mile--distance between plants allows a single crew to operate both.

Neither is there any measurable impact on the cost of operating and maintaining the gas gathering and supply operation. Its growth can be measured mainly in terms of longer annual operation of installed equipment and better utilization of distribution. Compression power cost however will grow in proportion to gas supplied.

HARMON MEADOWS
D-H SYSTEM

FIG. 8.2.1

FIG. 8.2.2

FIG. 8.2.3

HEAT SUPPLY DISTRIBUTION
W/ HUDSON #2 UNIT PARTIAL RETROFIT

SPACE HEATING

FIG. 8.2.4

FIG. 8.2.6

NOTE: NOT DRAWN TO SCALE

FIG. 8.2.7

TABLE 8.2-I

INDUSTRIAL/RESIDENTIAL
DEVELOPMENT
@ RT. 3 & N.J. TPKE EAST SPUR

	land area ac.	bldg. area $10^6 \times$ sq ft	Est. heat/load 10^3 DTU/hr
Island Residential	206	3500 units	105000
Research Park	148	1.2	36000
Light Industrial	137	2.0	20000
Comm. Cent. & Shopping	60	.25	7500
			----- 168500

TABLE 8.2-II

MEADOWLANDS SYSTEM
(BERRY'S CREEK PLUS HARMON MEADOWS)
HTW PIPING INSTALLATION SCHEDULE
IN 1000 FT. OF PAIR OF PIPE
ESTIMATE

	DIA	1984	1985	1986	1987	1988	1989	1990	1991	TOTAL
<hr/>										
ALT. 1 - NO LANDFILL GAS										
BERRY'S CREEK	12"		.6							.6
	10"		3.2	1.0	1.0					5.2
	8"		.6							.6
	4"		2.2	.3	.3	1.0	.4	.3	.3	4.8
	3"		.1							.1
	2"		1.6	.2	.1	1.6	.4	.3	.3	4.5
	1-1/2"		1.2			1.2	.2	.2	.2	3.0
HARMON MEADOWS	10"			2.8	2.3	1.1				6.2
	8"				.7	.7	2.6			4.0
	6"			2.6	2.1	2.0	1.2			7.9
	4"				.6	.7	.7	.7	.8	3.5
	3"						.1			.1
	2"			.8	1.0	1.8	2.0	.2	.8	6.6
	1-1/2"							.2	.1	.3
HUDSON G.S. -TRANSMISSION	20"					3.0				3.0
	16"					23.5			13.5	37.0
<hr/>										
TOTAL - ANNUAL			9.5	7.7	8.1	36.6	7.6	1.9	16.0	87.4
- ACCUMULATIVE			9.5	17.2	25.3	61.9	69.5	71.4	87.4	

ALT. 2 - LANDFILL GAS

same as above, except no transmission line is required and a gas gathering and supply system has to be constructed.

TABLE 8.2-III

MEADOWLANDS SYSTEM
(BERRY'S CREEK PLUS HARMON MEADOWS)
INSTALLATIONS & LOAD RUN-UP
ESTIMATE

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	TOTAL

ALT. 1 - NO LANDFILL GAS											
BERRY'S CREEK											

Heater Plant - 10 ⁶ BTU/hr		150		50							200
Distribution - see Table 8.2-II											
Nat. gas service - 10 ⁶ cfh		250									
HARMON MEADOWS											

Heater Plant - 10 ⁶ BTU/hr				150		50					200
Distribution - see Table 8.2-II											
Nat. gas service - 10 ⁶ cfh				250							
HUDSON G.S.											

Turbine retrofit - 10 ⁶ BTU/hr						240					240
Mx's & pumps											
Transmission - see Table 8.2-II											
TOTAL - Annual inst. cap.		150		200		290					
- Accum. inst. cap.		150	150	350	350	640	640	640	640	640	
- firm capacity*		100	100	250	250	400	400	400	400	400	
ALT. 2 - LANDFILL GAS											
BERRY'S CREEK											

Heater Plant - 10 ⁶ BTU/hr		150		50			50				250
Distribution - see Table 8.2-II											
Nat. gas service - 10 ⁶ cfh		300									
HARMON MEADOWS											

Heater Plant - 10 ⁶ BTU/hr				150		50		50			250
Distribution - see Table 8.2-II											
Nat. gas service - 10 ⁶ cfh				300							
GAS GATHERING - 10 ⁶ cfh			50	30	100	40	40	80	45	40	425
TOTAL - Annual inst. cap.		150		150		50	100	50			
- Accum. inst. cap.		150	150	300	300	350	450	500	500	500	
HEAT LOAD											

Berry's Creek - Accumulative peak		15	70	100	135	150	160	170	180	200	
Harmon Meadows - Accumulative peak				28	60	90	127	170	190	200	
		---	---	---	---	---	---	---	---	---	
		15	70	128	195	240	287	340	370	400	
Distribution loss		5	5	12	16	20	24	30	32	34	

Accumulative total		20	75	140	211	260	311	370	402	434**

TABLE 8.2-IV

HARTZ MOUNTAIN-HARMON MEADOWS
10 YR. DEVELOPMENT PLAN OF D-H
(for Berry's Creek see Table 8.1-IV)

<u>Year 1</u>	Heater plant	3 - 50x10 ⁶ BTU heaters 3 - circ. pumps, 40HP - building - stack 2 - syst. circ. pumps, 175HP - gas line - 250x10 ⁶ BTU/hr (3 buildings in industrial zone)
<u>Year 2</u>		(5 buildings in industrial zone)
<u>Year 3</u>		1 - 50x10 ⁶ BTU/hr heater 1 - circ. pump, 40HP 2 - syst. circ. pumps, 175HP (4 buildings in industrial zone, 2 buildings in research park)
<u>Year 4</u>		(4 buildings in industrial zone, 4 buildings in research park, 200 unit town houses)
<u>Year 5</u>		1 - 50x10 ⁶ BTU/hr heater 1 - circ. pump (4 buildings in research park, 300 unit town houses, 1 office building, low rise residential 800 units)
<u>Year 6</u>		(low rise resid. 800 units, health club, cinema) (high dens. resid. - 1200 units, hotel, retail)
<u>Year 7</u>		(high dens. resid. - 1200 units, local shopping center)

TABLE 8.2-V

MEADOWLANDS SYSTEM
(BERRY'S CREEK PLUS HARMON MEADOWS)
PUMPING COST SCHEDULE
\$1000 PER ANNUM

	DIA	1985	1986	1987	1988	1989	1990	1991	TOTAL
<hr/>									
ALT. 1 - NO LANDFILL GAS									
<hr/>									
BERRY'S CREEK	12"	3.90							3.90
	10"	6.40							6.40
	8"	1.80							1.80
	4"	4.60	.60	.60	2.10	.80	.60	.60	9.90
	3"	.07							.07
	2"	.35	.04	.02	.35	.09	.07	.07	.99
	1-1/2"	.08		.09	.01	.02	.01	.02	.23
HARMON MEADOWS	10"		6.16	5.06	2.42				13.64
	8"			2.10	2.10	7.80			12.00
	6"		3.90	3.15	3.00	1.30		.30	12.15
	4"			1.26	1.47	1.47	1.47	1.26	6.93
	3"					.06			.06
	2"		.18	.22	.40	.44	.05	.18	1.47
	1-1/2"						.01	.01	.02
HUDSON G.S.									
-TRANSMISSION	20"					31.30	25.20	23.66	80.16
	16"					39.00	41.00	38.40	118.40
<hr/>									
TOTAL - INCREMENTAL		17.20	10.88	12.50	11.85	82.78	68.41	64.50	268.12
<hr/>									
HEATEXCHANGERS									
-FIRED HEATERS		10.00	20.00	15.00		5.00			50.00
-POWER PLANT HX'S						25.00			25.00
-IN-HOUSE (USER) HX'S		31.50	26.10	30.15	22.50	18.90	26.10	24.75	180.00
<hr/>									
TOTAL - INCREMENTAL		58.70	56.98	57.65	34.35	131.68	94.51	89.25	523.12
- ACCUMULATIVE		58.70	115.68	173.33	207.68	339.36	433.87	523.12	

8.3 SCENARIO III - FULLY DEVELOPED DISTRICT HEATING SYSTEM (Jersey City, Newark, Meadowlands)

8.3.1 INTRODUCTION

Besides the new developments in the Hackensack Meadowlands discussed in the previous schedules, there are high density commercial/industrial/residential areas within two to five miles distance of the Hudson G.S. These areas are part of Jersey City, Hoboken, Newark and Harrison. Because of the high density construction within the selected areas they are likely targets for an economical D-H network, as shown on Fig. 8.3.1.

The basis of this system is the Hudson No. 2 unit. It is a coal-fired, double re-heat 600MW nominal capacity turbogenerator, capable of supplying heat at a very high rate in the cogenerative mode (see Sec. 6.2). A heating system based on it would not only benefit from the inexpensive fuel (coal) used but also from the fact that approximately half the heat supplied can be considered as waste heat.

It is proposed to develop this large, close to four billion BTU/hr peak heat supply system, in small increments. A number of local developments constructed at one time or another will gradually form an increasingly complex and widespread single system. This heat island concept of construction will allow close coordination of expenditures and income growth so as to best support the economic viability of the developing and of the completed system. The system is shown on Fig. 8.3.2.

8.3.2 THE SUPPLY AREAS

8.3.2.1 The Hackensack Meadowlands

The development schedules discussed in sections 8.1 and 8.2 for the new Berry's Creek and Harmon Meadows developments are fully compatible with the larger concept of this scenario. Whether a landfill gas fuel supply will be available for these sites during the first 10-15 years of their existence or not they will in time be connected to Hudson No. 2 unit, as they are compatible with the total concept. After the landfill gas runs out there will be the option of reverting to the Hudson unit the supply of heat by constructing the HTW transmission line. The routing of this line and the partial turbogenerator retrofit needed only for these systems are described previously in Scenario II. In this scenario however landfill gas supply to the Meadowlands is not considered.

8.3.2.2 Jersey City/Hoboken

It is proposed to supply an area as shown on Fig. 8.3.3 located east and southeast of the Hudson G.S. This approximately five sq. mi. area encompasses the most densely built-up sections of both cities. Within its confines are located most of the large office buildings, most of the housing developments including high-rises and a large number of institutions, commercial and industrial establishments. In-progress and proposed new developments as the Montgomery St., the Market St., Pavonia Sta., Glimcher Co. (Henderson St.) and a Port Authority development area are all within this territory. So are such existing complexes as the Journal Square Transport. Center, Summit Plaza, St. Johns apt.'s, the Gregory Park apt.'s and five J.C. Housing Authority apartment complexes. The institutional sector is represented by the City Hall, County Courthouse, Jersey City Medical Center, Pollak, Hague, Pl. Christ, St. Mary's hospitals, Dickinson, Ferris and Lincoln high schools and St. Peters College. There are another 45 schools in the district (see Sec. 2 for details).

A survey of directories yielded information on industrial/commercial establishments. There are 56 such potential users with more than 30000 sq. ft. of building area each or more than 50 people employed indicating sufficient floor space to consider them as significant users of heat. Only the space heating needs were assessed. Process heat requirements and their compatibility with D-H system parameters will have to be determined on a one-by-one survey basis.

The area delineated for heat supply indicates major concentrations of load by hatching and major industrial/commercial users by letters. There are 8800 apartments in large buildings of 50 apartments or more each. About 200000 people live within this area in 60000 houses. Only about 12% of those are single family structures, while over 60% are 2-9 family buildings, most built as row houses. The estimated total load potential in this area exceeds two billion BTU/hr peak, less than 10% of it commercial/industrial. The load density averages around 400 million BTU/hr, sq. mi.

8.3.2.3 Newark/Harrison

The proposed supply area is shown on Fig. 8.3.4. It is on the average five miles WSW of the Hudson G.S. The approximately eight sq. mi. area includes Downtown

with its 40 or so high-rise office and residential buildings and also some of the densest residential/industrial neighborhoods.

The only new development in planning is the extension of the Gateway complex. It is in the middle of the area. The major existing complexes are the Gateway buildings, Western Electric, State of N.J. office building, J. Erwin Federal Bldg., Courthouse, City Hall, Prudential Ins. bldg., several high-rises on Park Plaza and south and north of it on Broad St. The N.J. College of Medicine, N.J. Institute of Technology and Rutgers University, Seton Hall Law School; also the Newark Skills Center, United Hospital of Newark, St. Michaels Medical Center, Penn. Central Station, Essex County Administration bldg., Post Office, Library are there. So are 47 schools, six of them high schools.

The different directories of business and industry yielded 240 identifiable large consumers of heat based on building area and/or number of employees. Again process use of heat has not been evaluated.

The large apartment complexes within the area, mostly high-rises, contain 6000 units. Seventy percent of the over-200000 population lives in small multi-family dwellings, mostly row houses, and only 6% lives in single-family structures.

The estimated total load potential in this area exceeds 3.5 billion BTU/hr peak, one-third being commercial/industrial, while the rest residential. The average load density surpasses 460 million BTU/hr, sq. mi.

8.3.2.4 Other Areas

As Fig. 8.3.1 shows, there are a number of other areas in the southern portion of the Hackensack Meadowlands where future development is planned, first of all, by Hartz Mountain Industries Inc. These yet undeveloped lands are about 1000 acres in size, comparable to the total of the other new developments. So it is reasonable to assume that they will represent a minimum of 500 million BTU/hr peak load potential. The transmission mains to the other areas are laid out to accommodate the easy connection of this potential load, should it materialize before the full system is completed.

Another development plan, this one by the N.Y.-N.J. Port Authority, may call for the creation of an industrial park along Doremus Ave., just south of the Essex G.S. This was not included in our system, since probably a steam system will be needed to provide process heat requirements along with space heating. There are also two potential sources of heat besides Essex or the D-H system. One is the Passaic Valley Sewage Treatment facility at the south end of this street, while the other is the Essex County garbage disposal and heat recovery facility tentatively planned to be located at a site just to the north.

8.3.3 SUMMARY OF D-H LOAD POTENTIAL

The district heating supply area discussed are all within five miles of the Hudson G.S. and the potential peak space heating load requirements within those areas were estimated as follows:

	10 ⁶ BTU/hr -----
Hackensack Meadowlands	
- Berry's Creek & Harmon Meadows	600
- other areas	500
Jersey City/Hoboken	2000
Newark/Harrison	3700
	====
Total	6800

These same buildings will have an estimated average heat requirement of 500 million BTU/hr for domestic hot water preparation. This load is not considered additional to peak load since a factor of coincidence needs to be applied over the peak rates. This factor was taken to equal the domestic hot water load, at 7.3% of peak heating load.

There is an additional load in the form of transmission and distribution losses. It is estimated that the losses coincident with the peak load will be 8.6% of the total send-out. That would be approximately 500 million BTU/hr for the total load potential. Since most of the losses occur at the local distribution level, it can be fairly accurately proportioned with load (see Sec. 6.5).

The supply system developed aims at approximately 50% coverage of the above load potential. This means a system of approximately 3700 million BTU/hr peak send-out and this is what Scenario III is designed for.

As will be shown later approximately 300 million BTU/hr is lost in distribution, leaving actually 3400 million BTU/hr as net billable heat. If some of that capacity is used to supply process heat it will decrease the heat to the space heating and domestic hot water heating customers and increase the use factor of the system to further the economics.

8.3.4 PROPOSED D-H SYSTEM

8.3.4.1. Capacity

The high temperature water D-H system proposed will be supplied by steam extraction from the Hudson No. 2 turbogenerator unit, by waste heat recovered from the Kearny No. 12 combustion turbogenerator unit and by gas-fired hot water heaterplants located at the center of several areas within the supply territory. Each area supplied by one of these plants is typically one square mile. So the total system will have about 11 of these heaterplants, each having an installed heater capacity of 200-240 million BTU/hr (see Sec. 6.4).

The share of each component in the system load and the send-out water temperatures associated with it at peak load condition are as follows:

	10 ⁶ BTU/hr (MW _t)	water temp leaving-°F	% peak load
Heat supplied by fired heaters	1050 (307.5)	296.6	28.37
Heat supplied by gasturb. heat recovery	1050 (307.5)	269.7	28.38
Heat supplied by crossover extrac- tion of Hudson No. 2 unit	1600 (469)	222.8	43.25
Return water temp @ flow of 57000gpm		166.6	
	3700 (1084)	Δt = 130	100

The 6.6°F additional supply temperature and the 3.4°F lower return temperature compensate for the line heat losses. The total of 10°F is 8.33% of the 120°F design temperature differential.

8.3.4.2 Heat Supply Sources

The system is proposed to be constructed in 25 years, starting with what has been described in Scenarios I and II. Following those closely, development will start also in Jersey City by utilizing the Westend Gas Plant boiler facilities and possibly the now privately owned Summit Plaza cogeneration plant facilities. The gas plant has four high pressure, oil fired boilers with a total capacity of 270000 lb/hr. The Summit Plaza facility has 26.8 million BTU/hr oil fired hot water heater capacity and heat recovery on 3 MW diesel generator units with a design output of 9.8 million BTU/hr. Its peak heat load is less than 17 million BTU/hr.

By 1988 it is expected to have sufficient connected load to justify the partial retrofitting of the Hudson No. 2 unit and construct transmission lines to the heaterplants already in service. The extent of that partial retrofit, capable of supplying 240 million BTU/hr, is described in Sec. 6.2 as are the next stages of retrofits. Phase I of the full retrofit is needed by 1992 to increase the share in the peak supply of Hudson No. 2 to 800 million BTU/hr. That is half of its final output of 1600 million BTU/hr to be reached by 2002 (Phase II).

Phase I retrofit may or may not coincide with the installation of a backpressure turbine. A pressure reducing station is installed to supply steam to the heatexchanger controlled by leaving water temperature. The turbine parallels that reducing station and it acts as a spinning reducer generating electric power and therefore improving the overall economy of the system. Its installation can be decided on the basis of economics only. This was done and it will be discussed in Section 9.

What is called retrofit Phase III is the addition of a second backpressure turbine to the Hudson retrofit. This step also adds only to the efficiency of the system, so its timing was also decided on a purely economic basis.

Further plant developments in Jersey City are predicted by 1993, 1997 and finally by the year 2001. Each subsystem is planned to reach full capacity in eight years.

Development of the systems in Newark is foreseen to be starting by 1997 and growing by the addition of

a new system every two years after that, with the last starting in 2005. Each subsystem is planned to reach full capacity also in eight years but start acquiring users at a more rapid rate than in Jersey City. Success in that city and higher load density are the reasons for this assumption.

Table 8.3-I summarizes all of the above. It shows the successive installation of fired heaters, partial and phased full retrofit of Hudson No. 2 unit and that of the Kearny No. 12 combustion turbine unit. It also shows the total peak load run-up as developed and is shown on Table 8.3-II. & on Figures 8.3 to 14.

8.3.4.3 Spare Capacity and Firm Supply

Spare capacity to replace any outage of any one single component of the system will be provided on the following basis:

Heaterplants

- at least one full unit as spare at any time during isolated operation
- at least one full unit as spare at any time during operation of two such plants connected
- 100% stand-by capacity in each plant when system is connected to Hudson (2 units out of 4 installed)

Hudson No. 2 unit

- connection through new pressure reducing station to existing tie line with No. 1 unit ($190 \times 10^6 \text{ BTU/hr}$ or 55 MW_t) or 15% of peak output from this source

Combustion turbine recovery

- 7% stand-by capacity ($75 \times 10^6 \text{ BTU}$ or 22 MW_t) by increased heat recovery on all four pairs of turbine exhaust of the 196 MW_e capacity unit due to lower inlet and leaving water temperatures

This means that on the loss of Hudson No. 2 unit the Hudson No. 1 unit will provide 190 million, the gasturbine heat recovery 75 million and the stand-by heaters ($6 \times 100 + 5 \times 120$) = 1200 million BTU/hr for a total of 1465 million BTU/hr. This compares favorably

with the 1600 million BTU/hr lost by the total default of the Hudson No. 2 unit. The missing 135 million BTU/hr capacity is 3.68% of total system peak and reduces the indoor temperature 2.5°F on a 0°F day. No coincident failure of other equipment is contemplated in accordance with European practice at many similar systems.

Table 8.3-I compares the peak load each year--both total system load and that connected to the Hudson unit--with the firm capacity available. This comparison indicates shortages during the years 1991 through 1996 amounting to 50-100 million BTU/hr. Since the Hudson No. 1 unit to No. 2 unit tie line can supply much more heat than that, there is no need for additional sources. Shortage in firm capacity develops again by 2001, lasts through 2003 and amounts to a maximum of 185 million BTU/hr. It is again within the capability of the tie-line.

There is a possibility to eliminate any shortage in firm capacity during these latter years by switching the installation of the gasturbine retrofit and Phase II of the Hudson retrofit. This produces 800 million BTU/hr more firm capacity in the years 2000 to 2003. Economics of this choice will be the decisive factor, as it will be shown in Section 9.

8.3.4.4 Heaterplant Installations

The details of the heaterplants have been discussed in section 6.4. Typically they are 4-unit plants, since landfill gas supply to any of them is not considered in this scenario. In the Meadowlands and in Jersey City the unit size is 50 million BTU/hr, while in Newark it is 60 million BTU/hr.

At the inception of each plant the following are installed:

- 3 - Heater units

- 3 - Heater circulating pumps

- 3 - System circulating pumps

- Water treatment facility

- Pressurizing and expansion relief equipment

Electric power supply

Building with services

Stack

Natural gas supply

Yard and fence

The second phase typically follows in three years. At that time the additional installations are as follows:

1 - Heater unit

1 - Heater circulating pump

1 - System circulating pump

2 - Starters for pumps

Exceptions to the above could be the Jersey City No. 1 and the Newark No. 1 and No. 5 plants.

The Jersey City No. 1 plant, as described before, is based on existing facilities. Modernization of controls, possible addition of gas burners, installation of pressure reducing/desuperheating station and heatexchangers will be required at the Westend Gas Plant. If the Summit Plaza facility is acquired, a 24" ϕ main will have to be built to connect the two plants. System circulating pumps will be added to each of the facilities. Because of its location it is also foreseen that the plant(s) will be connected to Hudson at the partial retrofit stage (1988) by the extension of the 24" ϕ line.

The Newark No. 1 plant may be housed in an existing PSE&G building on Passaic Place, which also has a more than adequate stack. Newark No. 5 plant (Harrison) may make use of the boilers of the Harrison gas plant if available at that time (2005). None of these opportunities for reducing investment requirements have been made part of the economic calculations.

8.3.4.5 HTW Transmission and Distribution

Independent of source the heat will be distributed to the users by a two pipe, recirculating hot water system. The nominal supply temperature of 290°F (actual 296.6) and the nominal return temperature of 170°F (actual 166.6°F) will only be maintained on the peak heat supply days. At all other times the temperatures will be lower, automatically controlled by ambient temperature. The fully developed system will have a circulation rate of 57000 gpm.

8.3.4.5.1 Transmission

The transmission lines are shown on Fig. 8.3.5 & 6, while their development schedule is detailed on Table 8.3-II. The construction details were discussed in Section 6.5. Most of the lines are routed so as to utilize PSE&G right-of-ways.

The construction schedule reflects the growth of load in each area and the availability of heat sources. Berry's Creek is connected to Hudson when the load reaches 150 million BTU/hr and the partial retrofit at Hudson is completed. Harmon Meadows reaches the same load two years later and gets connected at that time.

As described before, a section of the 24" ϕ transmission main in Jersey City may be constructed early to make use of the Summit Plaza facility. It gets also extended in 1990 to utilize the economies of the partial retrofit to its full advantage.

The second phase of transmission line construction does not start until 1997. That time the successive Jersey City plants will be connected to the central heat supply.

In the years 2000 and 2001, two and then three of the Newark plants are respectively tied together to provide spare capacity for each other.

In 2002 the Newark-Hudson transmission line is constructed, completing the centralization of the system. At this point the pair of 36" ϕ lines leaving the Hudson G.S. feed the Newark users only, as shown on Fig. 8.3.6. When the Kearny gasturbine retrofit has been completed, then a 42" ϕ line will take the total flow from Hudson to Kearny and one of the 36" ϕ lines will become

the main supply line to the Meadowlands/Jersey City area. These developments are shown on Fig. 8.3.7 to 13.

There will be approximately 23 miles of transmission mains (pair of pipe) in the system.

8.3.4.5.2 Distribution

Table 8.3-III also shows the schedule of distribution pipe installations. There will be approximately 185 miles of distribution piping (pair) in the system.

The distribution network will be constructed by using pre-insulated pipes in protective covers laid directly in the soil. Generally the laying of pipes will follow the progress of the development. However mains will be sized for future loads. At new developments, pipes may be laid at the site preparation stage, ahead of actual building construction.

The multi-family row houses (town houses) were included in our supply system. To control the cost of connecting these buildings, it was assumed that a single heat exchanger will be located centrally in a block for a number of housing units (20-40) and the distribution from that point will be on the secondary side (200°F-180°F water) in insulated plastic pipes running through backyards. This aspect could not be cleared with the developers of new complexes since they are not yet at a stage where such details can be adequately addressed, nor was an attempt made to clear it with city governments or groups of landowners.

Most developers have no firm up-front plans for the heating/cooling systems should there be no district heating. Lacking these we have assumed that there will be circulating water baseboard and/or hot air heating systems, oil or gas fired.

The schedule of the secondary piping installations and of the conversion units is not included in the referred tables. Their schedule and cost will be considered on a pro rata basis in the economics calculations.

8.3.5 OPERATING COSTS

The cost of operating the system, that is those beyond the cost of fuel and the cost of replacement power, is

- heat losses
- pumping cost
- operation and maintenance expenses

Fuel and replacement energy costs were calculated by the PSE&G incremental power cost program and the results are shown in Sec. 9 - Economics. The other operating cost items were developed as follows.

8.3.5.1 Heat Loss

Heat Losses, that is the amount of heat lost over the transmission and distribution systems during a year's operation, are shown in Table 8.3-IV for the development in annual increments and accumulated annually. The loss incurred each year is added to the accumulative figure. The data shown here is based on calculations shown in Sec. 6.5. The dollar value of these losses is as calculated by the incremental cost computer program and is also shown in Sec. 9 - Economics.

The average annual heat loss works out to 3.1% of net heat supplied. This can be broken down further to 3.6% average during the six winter months and 2.4% during the summer.

8.3.5.2 Pumping Cost

Pumping Cost is the cost of circulating the hot water through the heaters, the transmission lines, the distribution system, the house connections and the user equipment. The results are shown in Table 8.3-V. The annual increments were calculated in accordance with the development schedules shown on Tables 8.3-II and 8.3-III and also the accumulative cost. The cost of pumping in any year is that given by the accumulative figure for the previous year plus the incremental cost in that year. All the costs are based on the present average replacement cost of power, that is \$69 per MWh. The calculations are based on data developed and shown in Sec. 6.5.

The average cost of pumping for the fully developed system in 1981 dollars is \$.65 per net 10^6 BTU supplied.

8.3.5.3 Operating Personnel

The operation of the fully developed system, consisting of a heating plant at Hudson G.S., a retrofitted gasturbine at Kearny and 11 heater plants scattered over the supply territory will require an organization of 105 people. This estimate is based on the assumption that none of the heater plants will be permanently manned. Roving crews of operators/maintenance men will be kept on constant radio call. On the other hand, the plant at Hudson G.S. will have its round-the-clock attendance. The requirements on that basis are as follows:

Plant operators -

Hudson G.S. facility - 3 shift	12	
11 heating plants, 2 x 3 men crews/shift	24	
crew supervisor (licensed) 1/shift	5	
shift supervisor	5	
load dispatcher	5	51
	--	

Maintenance -

all shifts - 3/shift	12	
day shift (additional)	5	
storekeeper	5	
supervisor	1	23
	--	

Billing -

meter readers	3	
bookkeepers	3	
accountants	3	
comptroller	1	10
	--	

Engineering -

engineers - mech.	3	
- civil	1	
- electrical	1	
draftsmen	3	
gov. liaison, permits	1	
in-house liaison	1	
manager	1	11
	--	

Bal. fwd. 95

Management -		
Pres., treasurer, secretary	3	
chief eng., purch. manager,	2	
clerical	5	10
	--	---
Total personnel		105

Again the cost of this is included in the economic cost calculations using the standard wage rates and overhead experience for the rest of PSE&G's personnel.

8.3.5.4 Maintenance and Other Costs

There is no U.S. experience with this kind of heating system. European experience is applicable only to a limited extent, particularly during the initial 10-20 years of operation of the system, when little deterioration of plant should be experienced.

Using the values shown in the Phase I report and escalated for the three years elapsed, the total system annual maintenance cost is estimated to be \$2000000 for plants, transmission and distribution and \$120000 per year for customer conversion equipment. These are mostly material cost, since labor cost is already included with the personnel costs.

The total \$2120000 annual cost averages \$.25 per million BTU net supplied for the fully developed system.

8.3.5.5 Other Costs

Other Costs - as general overhead, cost of capital during construction, taxes, permits, etc. are all dealt with in the Economics section.

FIG. 8.3.1

DEVELOPMENT TREE

HUDSON G.S. BASED
DISTRICT HEATING
SYSTEM

Fig. 8.3.2

Jersey City/Hoboken
D-H Supply Area

FIG. 8.3.3

FIG. 8.3.4

FIG. 8.3.5

TRANSMISSION MAINS
DEVELOPMENT BETWEEN
HUDSON & KEARNY G.S.

FIG. 8.3.6

FIG. 8.3.7

1993

DISTRICT HEATING SYSTEM
HEAT SOURCES AND TRANSMISSION
FACILITIES CONSTRUCTED BETWEEN
1989 AND 1993 SHOWN DARK

LEGEND

42" PIPE ————
 36" PIPE ————
 30" PIPE ————
 24" PIPE ————
 20" PIPE ————
 16" PIPE ————
 RIVER CROSSING ————

● GENERATING STATION
 □ HEATER PLANT
 □ CO GENERATION FACILITY

NOTE: NOT DRAWN TO SCALE

FIG. 8.3.8

FIG. 8.3.9

FIG. 8.3.10

FIG. 8.3.11

FIG. 8.3.12

FIG. 8.3.13

FULL DISTRICT HEATING SYSTEM
LOAD AND CAPACITY EXPANSION
1984-2011

FIG. 8.3.14

TABLE 8.3-I

**HEAT SOURCE INSTALLATION SCHEDULE
10⁶ BTU/HR**

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006-11
BERRY'S CREEK	150		50																				
HARMON MEADOWS			150			50																	
JERSEY CITY																							
#1			200																				
#2										150			50										
#3														150									
#4																	50						
NEWARK																		150					
#1														180									
#2																180	60						
#3																		180					
#4																							
#5																				180			
HUDSON G.S.																						180	
Partial					240																		
Ph. I									560														
Ph. II																			800				
Ph. III																			none				
KEARNY G.S.																					1100		
Largest unit	150	150	550	550	790	840	840	840	1400	1550	1550	1550	1600	1930	1930	2110	2220	2550	3410	3590	4800	4960	5080
	50	50	150	150	240	240	240	240	800	800	800	800	800	800	800	800	800	800	1600	1600	1600	1600	1600
Cap. after loss of largest unit	100	100	400	400	550	600	600	600	600	750	775	750	800	1130	1130	1310	1420	1750	1810	1990	3200	3360	3480*
System peak load	20	75	160	255	350	457	565	650	715	770	795	840	900	995	1115	1280	1500	1735	1980	2255	2555	2810	3695
Connected to Hudson #2 unit					170	184	565	650	715	755	755	755	755	955	1005	1040	1085	1280	1930	2175	2415	2785	3695

*These figures do not account for the 190x10 BTJ/hr
heat available from the existing Hudson #1 unit to
#2 unit bypass line.

TABLE 8.3-II

TOTAL DISTRICT HEATING SYSTEM
INCREMENTAL & ACCUMULATIVE LOAD GROWTH
ESTIMATE
(Million BTU per hr.)

	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	2000	'01	'02	'03	'04	'05	'06	'07-'11	
BERRY'S CREEK	15	55	30	35	15	10	10	10	20															200	
HARMON MEADOWS			28	32	35	32	43	20	10															200	
JERSEY CITY #1			20	20	40	55	50	45	35	35														300	
JERSEY CITY #2										5	20	40	55	50	45	35	40							300	
JERSEY CITY #3														15	20	40	55	50	45	35	40			300	
JERSEY CITY #4																		15	20	40	55	50	45	75	300
NEWARK #1														25	45	50	65	75	50	30	20			360	
NEWARK #2																25	45	50	65	75	50	30	20	360	
NEWARK #3																		25	45	50	65	75	50	50	360
NEWARK #4																				25	45	50	65	175	360
NEWARK #5																						25	45	290	360
INCREMENTAL GROWTH	15	55	78	87	90	97	103	75	65	50	20	40	55	90	110	150	205	215	225	255	275	230	225	590	
ACCUMULATIVE GROWTH	15	70	148	235	325	422	525	600	665	715	735	775	830	920	1030	1180	1385	1600	1825	2080	2355	2585	2810	3400	3400
ACCUMULATIVE HEAT LOSS	5	5	12	20	25	35	40	50	50	55	60	65	70	75	85	100	115	135	155	175	200	225	245	295	295
TOTAL ACCUMULATIVE GROWTH	20	75	160	255	350	457	565	650	715	770	795	840	900	995	1115	1280	1500	1735	1980	2255	2555	2810	3055	3695	3695

TABLE 8.3-III

PIPING INSTALLATION SCHEDULE
IN 1000 FT. OF PAIR OF PIPE

	DIA	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007-11	TOTAL	
BERRY'S CREEK	12"	.6																							.6	
	10"	3.2	1.0	1.0																					5.2	
	8"	.6																							.6	
	4"	2.2	.3	.3	1.0	.4	.3	.3																	4.8	
	3"	.1																							.1	
	2"	1.6	.2	.1	1.6	.4	.3	.3																	4.5	
	1-1/2"	1.2			1.2	.2	.2	.2																	3.0	
HARMON MEADOWS	10"		2.8	2.3	1.1																				6.2	
	8"			.7	.7	2.6																			4.0	
	6"		2.6	2.1	2.0	1.2																			7.9	
	4"			.6	.7	.7	.7	.6	.2																3.5	
	3"					.1																			.1	
	2"		.8	1.0	1.8	2.0	.2	.8																	6.6	
	1-1/2"					.2	.1																		.3	
JERSEY CITY	10"		1.4		1.3		1.4		1.3	1.4		1.3		2.7		2.7		2.7		2.7		1.4		1.3	21.6	
	8"		1.0		1.1		1.0		1.1	1.0		1.1		2.1		2.1		2.1		2.1		1.0		1.1	16.8	
	4"		6.6	4.8	10.2	15.0	10.8	6.4	4.8	13.0	4.8	10.2	15.0	17.4	11.2	15.0	21.4	17.4	13.0	15.0	21.4	10.8	6.4	11.2	261.8	
	2"		2.1	1.5	3.3	4.8	5.1	3.1	2.3	5.1	1.5	3.3	4.7	7.2	4.6	5.6	7.8	7.2	4.6	5.6	7.8	5.1	3.1	5.4	100.8	
NEWARK	10"													1.4		2.7		4.0		5.4		5.4		8.1	27.0	
	8"													1.0		2.1		3.2		4.2		4.2		6.3	21.0	
	4"													6.9	5.1	17.6	20.9	28.6	27.6	33.7	34.3	33.7	34.3	97.3	340.0	
	2"													2.1	2.7	5.7	8.6	10.8	12.8	14.0	15.5	14.0	15.5	45.8	147.5	
TOTAL		9.5	18.8	14.4	26.0	27.4	20.2	11.8	9.7	20.5	6.3	15.9	19.7	40.8	23.6	53.5	58.7	76.0	58.0	82.7	79.0	75.6	59.3		983.9	
TRANSMISSION	42"																				10.8				10.8	
	36"																								26.9	
	30"																	2.5							2.5	
	24"		3.0				3.0							5.5											11.5	
	20"				2.9								7.5				11.0	3.0		2.5			3.0		29.9	
	16"				23.5		13.5																		37.0	
TOTAL		3.0		26.4		16.5							13.0				11.0	5.5	26.9		2.5	10.8		3.0		118.6

TABLE 8.3-IV

PIPING HEAT LOSS SCHEDULE
10⁶ BTU PER ANNUM

	DIA	1983	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007-11	TOTAL
BERRY'S CREEK	12"	206																							206
	10"	956	298	298																					1550
	8"	149																							149
	4"	420	57	57	191	76	57	57																	915
	3"	17																							17
	2"	204	25	13	204	51	38	38																	573
	1-1/2"	148			148	24	24	25																	365
HARMON MEADOWS	10"		455	686	528																				1849
	8"		173	173	449																				991
	4"		595	480	457	279																			1807
	4"			115	134	134	115	38																	670
	3"					13																			17
	2"		132	128	230	255	25	102																	842
	1-1/2"					24	12																		36
JERSEY CITY	10"		417		388		417		388	417		388		805		805		805		805		417		388	6440
	8"		248		273		248		273	248		273		520		520		520		520		248		273	4164
	4"		1261	917	1950	2867	2065	1223	913	2485	917	1950	2867	3326	2141	2867	4090	3326	2485	2867	4090	2065	1223	2141	50040
	2"		268	191	421	612	651	395	292	651	191	421	600	919	582	715	995	909	587	715	995	651	395	689	12861
NEWARK	10"													417		805		1193		1610		1610		2413	8050
	8"													248		520		793		1041		1041		1561	5204
	4"													1319	975	3364	3995	5457	3276	6442	6556	6442	6556	18599	64991
	2"													268	344	727	1097	1328	1633	1786	1978	1786	1978	5844	18819
TOTAL-INCREMENTAL		2096	4106	3058	4895	4956	5683	1967	7906	3801	1108	3032	3467	7822	4047	10323	10177	14431	9981	15786	13619	14260	10152	31910	180556
TRANSMISSION	42"																				18405				18405
	36"																								33685
	30"																								2158
	24"		1290				596							2685				2158		33685					5071
	20"				1540									3985										1594	18011
TOTAL-INCREMENTAL -ACCUMULATIVE		2096	5896	3058	15737	4556	9623	1967	7909	3801	1108	3032	3467	14492	4047	10323	17085	18153	43666	18176	32024	14260	10152	33504	272532
		2096	7992	11050	26787	31743	41366	43333	45242	49343	50151	53183	56650	71142	75189	85512	102597	120710	164416	182592	214616	228876	239028	272532	

TABLE 8.3-V
**PUMPING COST SCHEDULE
\$1000 PER ANNUM**

	DIA	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007-11	TOTAL
PIPING																									
BERRY'S CREEK	12"	5.90																							3.90
	10"	6.40																							6.40
	8"	1.80																							1.80
	4"	4.60	.60	.60	2.10	.80	.60	.60																	9.90
	3"	.07																							.07
	2"	.35	.04	.02	.35	.09	.07	.07																	.99
	1-1/2"	.08			.09	.01	.02	.01	.02																.23
HARMON MEADOWS	10"		6.16	5.06	2.42																				13.64
	8"			2.10	2.10	7.80																			12.00
	6"		3.90	3.15	3.00	1.80		.30																	12.15
	4"			1.26	1.47	1.47	1.47	1.26																	6.93
	3"					.06																			.06
	2"		.18	.22	.40	.44	.05	.18																	1.47
	1-1/2"					.01	.01																		.02
JERSEY CITY	10"		3.08		2.86	3.08			2.86	3.08		2.86		5.94		5.94		5.94		5.94		3.08		2.86	47.52
	8"		3.00		3.30	3.00			3.30	3.00		3.30		6.30		6.30		6.30		6.30		3.00		3.30	50.40
	4"		13.86	10.08	21.42	31.50	22.68	13.44	10.08	27.30	10.08	21.42	31.50	36.54	23.52	31.50	44.94	36.54	27.30	31.50	44.94	22.68	13.44	23.52	349.78
	2"		.46	.33	.73	1.06	1.12	.68	.51	1.12	.33	.73	1.03	1.58	1.01	1.23	1.72	1.58	1.01	1.23	1.72	1.12	.68	1.19	22.17
NEWARK	10"													3.08		5.94		8.80		11.68		11.68		17.82	59.40
	8"													3.00		6.30		9.60		12.60		12.60		18.90	63.00
	4"													14.49	10.71	36.96	43.89	60.06	57.96	70.77	72.03	70.77	72.03	204.33	714.00
	2"													.46	.59	1.23	1.89	2.37	2.61	3.08	3.41	3.08	3.41	10.80	32.43
	TOTAL-INCREMENTAL		17.20	31.28	22.91	40.16	45.04	32.09	16.56	16.75	34.50	10.41	28.31	32.53	71.39	35.83	95.42	92.44	131.19	89.08	143.30	122.10	128.21	89.56	282.00
42"																					412.00				412.00
36"																			753.20						753.20
30"																									57.50
24"			31.50				10.50							47.25				57.50							89.25
20"						30.45								78.75			136.50	31.50		47.25			31.50		355.95
16"					169.20		97.20																		266.40
TOTAL-INCREMENTAL		17.20	62.78	22.91	239.81	45.04	139.79	16.56	16.75	34.50	10.41	28.31	32.53	197.39	35.83	95.42	228.94	220.19	842.28	190.55	532.10	128.21	89.56	313.50	3542.56
HEATEXCHANGERS																									
-FIRED HEATERS		10.00	15.00	5.00						5.00		5.00		11.00		16.00	12.00	11.00		12.00		12.00		6.00	120.00
-POWER PLANT HX'S					25.00					50.00	35.00								45.00	45.00	10.00	20.00	20.00	10.00	260.00
-HEAT RECOVERY HX'S																					40.00	40.00	40.00	40.00	160.00
-IN-HOUSE (USER) HX'S		31.50	35.10	41.40	40.50	43.65	50.85	29.25	27.00	22.50	11.25	18.00	29.25	54.00	31.75	76.50	94.50	108.00	105.75	121.50	130.50	155.25	99.00	285.75	1462.75
TOTAL-INCREMENTAL		58.70	112.88	69.31	305.31	88.69	190.64	45.81	93.75	97.00	21.66	51.31	61.78	262.39	87.58	187.92	335.44	339.19	993.03	369.05	714.60	355.46	248.56	655.25	5745.31
-ACCUMULATIVE		58.70	171.58	240.89	546.20	634.89	825.53	871.34	965.09	1062.09	1083.75	1135.06	1196.84	1459.23	1546.81	1734.73	2070.17	2409.36	3402.39	3771.44	4486.04	4841.50	5090.06	5745.31	

SECTION 9

ECONOMIC EVALUATION.

9. ECONOMIC ANALYSIS

9.1 Introduction

An economic evaluation is performed to determine the plan with the lowest overall costs over a period of time. The method of economic evaluation used by PSE&G is based on the Minimum Revenue requirement Methodology which is widely accepted by utilities throughout the United States. A detailed explanation of this method is contained in a book entitled "Profitability and Economic Choice" by Paul H. Jaynes, Iowa State University Press, 1968.

The comparison was made between various district heating scenarios and their conventional alternate utilizing natural gas fueled boilers located at individual buildings and owned by customers. The conventional system is used as a "benchmark" for comparison purposes. In general, it is the magnitude of the difference between district heating and the conventional alternate that indicates the overall economic merit of district heating. An indication of economic merit does not necessarily reflect the profitability or desirability of district heating from the utility point of view. It must be kept in mind that investments made for a district heating system by an electric utility are for a "venture" which should be viewed differently from investments made to assure safe and reliable electric and gas service.

The evaluation is based on an important criterion: All costs associated with district heating should be covered by the revenues from the district heating customers and no such costs should be passed on to existing electric and gas customers.

9.2 Economic Analysis Methodology

Since all costs of a regulated utility must eventually be borne by the rate-payers, costs incurred can therefore be translated into revenue requirements. The revenue requirements include a return on the investment and a return of the investment, or depreciation, for all capital expenses. Based on the anticipated cost of debt for PSE&G, it is possible to define a minimum revenue requirement, that is, the

lowest revenue that must be collected to satisfy investors. The present worth sum of all minimum revenue requirements can be levelized over the study period and stated as a Levelized Annual Minimum Revenue Requirement (LAMRR). If several alternates that are being compared have the same LAMRR among all the alternates, then this alternate is the economically preferred choice. The magnitude of the difference reflects the relative merit of the preferred alternate.

The LAMRR evaluation is merely a tool for making economic comparisons and does not define a firm point at which the preferred alternate can be considered economically and financially viable. Other considerations must also be taken into account such as cash flow, economic uncertainties, project risks and the willingness of the public to accept a new type of service.

9.3 Economic Comparisons

9.3.1 Berry's Creek with a Hudson No. 2 Retrofit

Table 9-I summarizes the LAMRR for Berry's Creek supplied by a partial retrofit of Hudson No. 2 and centralized package boilers for back-up.

The district heating scenario has a LAMRR that is \$459,000, or about 4%, higher than that for a conventional heating system. The 4% difference is within the normal accuracy of estimates of this type, so the two alternates could be considered as economically equivalent. It can, therefore, be concluded that there is no real economic incentive to choose this district heating scenario over a conventional alternate.

The Hudson No. 2 retrofit and associated transmission facilities account for nearly 14%⁽¹⁾ of the LAMRR. However, since the Hudson retrofit is sized to supply

⁽¹⁾Including 13% of revenue requirements for New Jersey Gross Receipts and Franchise Taxes.

TABLE 9-1

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	4,569	35		
System Production				
Costs				
Natural Gas	2,406	19	9,286	75 ⁽¹⁾
<u>O&M Costs</u>				
Manpower	657	5	2,485	20
Pumping Energy	405	3		
Materials	250	2		
<u>Gross Receipts and</u>	1,485	12	0	0 ⁽²⁾
<u>Franchise Taxes</u>				
<u>Total</u>	<u>12,906</u>	<u>100</u>	<u>12,447</u>	<u>100</u>
<u>Savings (Penalties)</u>	(459)			

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

100% of the peak thermal load, there is a significant underutilization of these facilities during off peak periods. In addition, since Hudson No. 2 is the largest single source of thermal supply, an additional 200×10^6 BTU/hr of package boilers capable of supplying the entire peak load is required to meet the reliability criteria. These boilers account for an additional 6% of the LAMRR.

9.3.2 Berry's Creek without Hudson #2 Retrofit

Table 9-II summarizes the LAMRR for the development of the Berry's Creek district heating system supplied solely by centralized package boilers.

The LAMRR for district heating is \$2,744,000, or about 22%, lower than that for the conventional system. The use of landfill gas could reduce the LAMRR to about 34%, or \$4,195,000, less than that for the conventional system.

It appears that this district heating scenario has an economic advantage over a conventional system, even considering some normal uncertainties in the cost estimates.

Without a retrofit of Hudson No. 2 the natural gas cost increases substantially and constitutes the most significant part of the LAMRR. The increased utilization of natural gas is more than offset by capital savings for not providing the Hudson No. 2 retrofit and associated transmission facilities, and elimination of the increase in electric system production costs. It would appear that these additional capital costs might be justified only by a system larger than Berry's Creek alone, to allow for more effective use of the retrofit facilities during periods of low thermal demand. Only one package boiler is required for back-up in this case so that the boiler plant facilities are being utilized to a higher degree than with the Hudson No. 2 retrofit scenario.

9.3.3 Berry's Creek Plus Harmon Meadows

Table 9-III summarizes the LAMRR for the Berry's Creek plus Harmon Meadows district heating scenario with a partial retrofit of Hudson No. 2.

TABLE 9-II.

LEVELIZED ANNUAL MINIMUM REVENUE REQUIREMENTS
FOR BERRY'S CREEK WITHOUT A HUDSON #2 RETROFIT
(1983\$ x 10³)

<u>Capital Related</u>	<u>District Heating Without Landfill</u>		<u>District Heating With Landfill</u>		<u>Conventional</u>	
	<u>Gas</u>		<u>Gas</u>			
	<u>\$</u>	<u>%</u>	<u>\$</u>	<u>%</u>	<u>\$</u>	<u>%</u>
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(1)
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(2)
<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

TABLE 9-III

LEVELIZED ANNUAL MINIMUM REVENUE REQUIREMENTS FOR BERRY'S CREEK AND HARMON MEADOWS WITH HUDSON #2 RETROFIT (1983 \$ x 10 ³)						
Capital Related	District Heating Without Landfill		District Heating With Landfill		Conventional	
	Gas		Gas			
	\$	%	\$	%	\$	%
Bullery	1,283	5	1,283	6	1,912	7
Hudson #2 Retrofit	829	3	829	4		
Natural Gas Service	15	-	15	-	282	1
Customer Heat Exchangers	277	1	277	1		
Metering	7	-	7	-		
Transmission	1,093	5	1,093	5		
Distribution	1,428	6	1,428	7		
Landfill Collection & Transmission	-		1,184	5		
<u>Fuel Related</u>						
Increased Electric System Production Costs	8,767	37	6,008	28		
Natural Gas	5,394	23	2,493	12	19,125	74(1)
Landfill Gas Royalties			1,441	7		
<u>O&M Costs</u>						
Manpower	706	3	706	3	4,741	18
Pumping Energy	792	3	792	4		
Materials	472	2	472	2		
Additional Costs Associated With Landfill	-		1,027	5		
<u>Gross Receipts and Franchise Taxes</u>	2,738	12	2,477	12	0	0(2)
<u>Total</u>	<u>23,801</u>	<u>100</u>	<u>21,532</u>	<u>100</u>	<u>26,060</u>	<u>100</u>
<u>Savings (Penalties)</u>	2,259		4,528			

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

The LAMRR for district heating is \$2,259,000, or about 9%, lower than that for a conventional system, if natural gas alone is used as the fuel for the district heating package boilers. If landfill gas is used as a supplemental fuel supply, the LAMRR savings increase to 4,528,000 or about 17% of the conventional system LAMRR.

Harmon Meadows is similar to Berry's Creek in peak load and load growth. Therefore for Harmon Meadows alone, the economics would be similar to that of Berry's Creek as shown in Table 9-II.

Although there may be some marginal savings in this scenario over the conventional system by constructing the Hudson retrofit, the best economic choice would be independent district heating systems at Berry's Creek and Harmon Meadows without a Hudson No. 2 retrofit. Each of these areas would ultimately require $5-50 \times 10^6$ BTU/hr package boilers. Constructing a hot water transmission line to interconnect the two areas would eliminate only a single boiler normally required for back-up and would not be economically justifiable.

9.3.4 Fully Developed System

Table 9-IV summarizes the LAMRR for the fully developed district heating system comprised of Berry's Creek, Harmon Meadows and additional developments at Newark and Jersey City.

The LAMRR for district heating is \$3,632,000, or about 4%, higher than that for the conventional system. If landfill gas is utilized as a supplemental fuel source for the district heating package boilers, the LAMRR is still \$2,078,000, or about 2%, higher than that for the conventional system.

The 2 or 4% difference in LAMRR between the district heating and conventional systems is within the normal accuracy of the estimates. Therefore, both systems could

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	
	<u>\$</u>	<u>%</u>	<u>\$</u>	<u>%</u>	<u>\$</u>	<u>%</u>
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	16,379	16	13,973	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		
GROSS RECEIPTS AND FRANCHISE TAXES	10,765	12	10,586	12	0	0(1)
<u>TOTAL</u>	<u>93,571</u>	<u>100</u>	<u>92,017</u>	<u>100</u>	<u>89,939</u>	<u>100</u>
<u>SAVINGS (PENALTIES)</u>	<u>(3,632)</u>		<u>(2,078)</u>			

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

be considered as economically equivalent. As in the Berry's Creek scenario with a Hudson No. 2 retrofit, no real economic incentive exists to select district heating over a conventional system, regardless of the use of landfill gas.

Both Newark and most of Jersey City consist of existing urban developments. The costs of transmission and distribution facilities are considerably higher in these areas than those at Berry's Creek or Harmon Meadows. The distribution system alone accounts for 25%⁽¹⁾ of the total LAMRR.

Significant reductions in fuel related costs can be realized through a three-staged retrofit of Hudson No. 2. As a result, fuel related revenue requirements account for only about 30%⁽¹⁾ of the total LAMRR in the full system, instead of nearly 60% as in the case for Berry's Creek plus Harmon Meadows with Hudson No. 2 retrofit.

In the full system the retrofit of Hudson No. 2 ultimately can supply 43% of the combined peak thermal load. The combined thermal capabilities of Hudson No. 2 and Kearny No. 12 can supply nearly 73% of the peak thermal load.

The reduction in fuel cost, however, is not enough to compensate for the capital expenditures required for the hot water transmission and generating unit retrofits. In the post 2011 period it is likely that retirement of both of these generating units will occur. There is considerable uncertainty at this time as to the nature of replacements for these units and whether such replacements would still be located within this geographic area. Although the impact of these retirements will be small on a levelized present worth basis, it should be recognized that these considerations could impact on future system expansion of both the district heating system as well as the electric system.

¹Including 13% of revenue requirements for New Jersey Gross Receipts and Franchise Taxes.

9.4 Sensitivity to Variations in Capital Costs of Thermal Supplies

The capital costs of transmission and distribution for district heating account for most of the capital related LAMRR. These costs were based on material cost estimates provided by vendors and installation cost estimates developed by PSE&G in reference to natural gas pipes. These costs were reviewed by numerous organizations with extensive experience in constructing American and European district heating systems.

There is, however, only limited American experience in retrofitting a large existing generating unit, such as Hudson No. 2, and each generating unit tends to be quite unique. Therefore, a sensitivity analysis was performed primarily to assess the impact of varying these retrofit costs on the study results.

For the sensitivity analysis, the original cost estimate for the Hudson retrofit was reduced by 50%, the Kearny No. 12 retrofit estimate reduced by 20%, and the package boiler estimates by 10%. The sizes of these cost reductions reflect the relative uncertainty of each item.

Table 9-V shows the range of capital costs used for evaluating sensitivity.

As shown in Table 9-VI for the district heating system using the reduced capital costs, the LAMRR for the case without landfill gas is nearly equal to that for the conventional system. Comparing Tables 9-IV and 9-VI, it can be seen that the LAMRR for district heating changes from a previous \$3,632,000 penalty to a \$1,048,000 savings, when the reduced capital costs are used in place of the original estimates. The LAMRR savings in this case for district heating is about 1%. If landfill gas is used, the LAMRR for district heating changes from a \$2,078,000 penalty to a \$2,601,000 savings, or about 3% of the LAMRR of the conventional system.

It can be concluded that uncertainties of the capital cost estimates for thermal supplies may change the magnitude of the savings or penalties but will not drasti-

TABLE 9-V

RANGE OF CAPITAL COSTS USED IN SENSITIVITY ANALYSIS
1981 \$10³

	<u>LOW ESTIMATE</u>	<u>BASE ESTIMATE</u>
Package Boilers 50x10 ⁶ Btu/hr	990 each	1,100 each
Package Boilers 60x10 ⁶ Btu/hr	1,188 each	1,320 each
Total Cost of Boilers	47,520	52,800
Hudson Retrofit		
Stage 1 (Partial)	6,196	6,196
Stage 2	11,494	25,093
Stage 3	22,310	48,711
Total Cost of Hudson Retrofit	40,000	80,000
Kearny #12 Retrofit	8,000	10,000
Total Capacity Costs of Thermal Supplies	95,520	142,800

TABLE 9-VI

LEVELIZED ANNUAL MINIMUM REVENUE REQUIREMENTS
FOR FULLY DEVELOPED DISTRICT HEATING SYSTEM
BASED ON LOW RANGE OF ESTIMATES
(1981 \$X10³)

CAPITAL RELATED	District Heating Without Landfill		District Heating With Landfill		Conventional	
	Gas		Gas			
	\$	%	\$	%	\$	%
Boilers	4,933	6	4,933	6	3,978	4
Hudson #2 Retrofit	4,068	4	4,068	5	-	-
Kearny Retrofit #12	688	1	688	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	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)	75
Landfill Gas Royalties			1,846	2		
<u>O&M Costs</u>						
Manpower	8,245	9(2)	8,245	9	16,932(2)	19
Pumping Energy	2,988	3	2,900	3		
Materials	1,688	2	1,688	2		
Additional Costs Associated With Landfill			1,237	1		
<u>GROSS RECEIPTS AND FRANCHISE TAXES</u>	10,226	12	10,048	12	0(3)	0
<u>TOTAL</u>	<u>88,391</u>	<u>100</u>	<u>87,338</u>	<u>100</u>	<u>89,939</u>	<u>100</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.

cally change the basic economics of district heating system compared to a conventional system.

The sensitivity of the Berry's Creek or the Berry's Creek plus Harmon Meadows scenarios to variations in the capital costs would be even smaller, since both scenarios are supplied primarily by package boilers and only a partial retrofit of Hudson No. 2.

9.5 Sensitivity to Variations in Fuel Prices

While the district heating system is capital intensive, the conventional system is fuel cost intensive. Fuel accounts for 75% of the conventional system LAMRR compared to only 31% for the fully developed district heating system. Recent drops in fuel price estimates for the future are indicative of the uncertainties that exist, and they are generally beyond the influence of a utility. Political effects, OPEC pricing policy, the extent of conservation impact, etc. are only a few of the items that could alter fuel prices.

Since the trend in the past year or two has been toward lower price escalation projections, a sensitivity analysis was performed using a 1% per year reduction in all fuel price projections starting in 1985. In effect, the 1984 fuel prices were held constant, 1985 price projections were reduced by 1%, 1986 price projections by 2%, etc., through the endpoint of 2011.

Secondary effects of lower fuel prices, such as reduced inflation, were not considered although the cost of hot water pumping energy was reduced to account for the lower price of generating electricity that would result from reduced fuel prices.

Table 9-VII shows the LAMRR for the fully developed district heating system compared to the conventional alternate, using the reduced fuel prices.

A comparison of Tables 9-VII and 9-IV indicate the sensitivity of district heating and its conventional alternate to changes in fuel price escalation.

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>	<u>District Heating without Landfill</u>		<u>Conventional</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	16,933	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>70,629</u>	<u>100</u>
<u>SAVINGS (PENALTIES)</u>	(9,802)			

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

When the annual escalation rate for all fuels was reduced by 1%, the LAMRR for district heating dropped to about 95% of its previous value, a relatively modest change. The LAMRR for the conventional system drops to about 87% of its previous value, a more significant change.

With lower fuel escalation rates, the LAMRR penalty for district heating increases from \$3,632,000 to \$9,802,000. This represents an increase in penalty from about 4% to 12% over the conventional system.

The 4% LAMRR penalty, under the basic fuel price assumptions, is relatively small and the full district heating system could be considered as economically equivalent to a conventional heating alternate. If the fuel price escalation rates are reduced, the LAMRR penalty becomes large enough that the full district heating system would definitely be considered as not economically viable.

It can be concluded that the economic comparison of district heating with a conventional alternate is very sensitive to variations in fuel price escalation. Lower fuel cost escalations tend to reduce the viability of district heating while higher fuel prices increase its attractiveness.

SECTION 10
IMPACT ON FUEL
AND ON THE ENVIROMENT

10. IMPACT ON FUEL USE & ON THE ENVIRONMENT

10.1 Fuel Utilization

A major advantage of district heating is the ability to reduce the required amount of fuel to supply the same demand and to substitute low cost fuel such as coal for oil and natural gas. The retrofit of Hudson #2 could supply a significant portion of the thermal demand of a district heating system. The heat supplied by Hudson #2 would come from increased coal consumption at the station, higher overall efficiency and a diversion of energy from electric to thermal production. The reduction in electric generation at Hudson as a result of extracting steam for district heating would require increased output from other generating units, fueled primarily by oil. This increase in oil consumption offsets to a large degree any savings associated with using low cost thermal energy from Hudson #2. Retrofitting Kearny #12 for the recovery of waste heat would have a minimal effect on the electric capability of the unit but could change the number of hours the unit operates. If the unit is required to operate more hours in order to supply thermal energy when it would not operate based on economic dispatch to supply electric demand, there would be some increase in oil consumption at Kearny and some overall operating cost penalties.

PSE&G is a member of the Pennsylvania-New Jersey-Maryland Interconnection (PJM), a power pool covering most of New Jersey, Pennsylvania, Maryland and Delaware, plus the District of Columbia. When conditions permit, the electric output within the pool is normally dispatched based on using the lowest cost generation available without regard to the individual company ownership. The electric energy required to make up for the capacity reduction at Hudson when supplying thermal energy would be the lowest cost energy available over a broad geographic area and not limited to generating units owned by PSE&G. Similarly any generating unit output reductions required to offset increased operation of Kearny #12 to supply thermal load would be the highest cost energy over the same geographic area.

The package boilers are fueled by either natural gas or landfill gas with efficiencies of 83% and 82% respectively for these fuels. These efficiencies compare with a 65% efficiency assumed for individually owned boilers in the conventional system.

The higher efficiency of district heating boilers, due to higher load-factor operation, reduces their fuel consumption as compared to a conventional system.

Although fuel consumption accounts for a major portion of the costs associated with supplying heat, it must be kept in mind that it is the overall economics as well as other considerations and not fuel requirements alone that will determine utility involvement in a district heating system.

10.2 Comparison of Fuel Consumption

10.2.1 Berry's Creek without a Hudson #2 Retrofit

Figure 10.1 shows the total natural gas consumption for Berry's Creek district heating system with neither landfill gas nor a Hudson #2 retrofit, compared to a conventional customer owned heating system. The district heating system uses approximately 21% less fuel than a comparable conventional system. The fuel savings is due to the higher efficiency of the district heating boilers compared to customer owned boilers. Thermal distribution system losses are relatively small for the Berry's Creek district heating system and account for only about 1% of the annual energy supplied.

Figure 10.2 shows fuel consumption by type if landfill gas is utilized as a supplemental district heating fuel source. The decrease in landfill gas beginning in 1995 is due to the limited life of this fuel source. Landfill gas has a limited life whether or not it is used, and unless additional new sources can be developed, natural gas will eventually supply the entire load.

BERRYS CREEK FUEL CONSUMPTION WITHOUT LANDFILL GAS

FIG. 10.1

BERRYS CREEK FUEL CONSUMPTION WITH LANDFILL GAS

FIG. 10.2

10.2.2 Berry's Creek with a Hudson Retrofit

Figure 10.3 shows the thermal supplies for the Berry's Creek scenario including a limited retrofit of Hudson #2. The Hudson #2 retrofit is capable of supplying the entire thermal load at Berry's Creek. The boilers are used only for back-up in the event of the unavailability of Hudson #2 due to either forced or planned outages.

It must be recognized that the thermal energy supplied by Hudson #2 comes, in part, from a reduction in electric capacity that must be made up using other generating units supplied primarily by oil.

10.2.3 Berry's Creek Plus Harmon Meadows

Supplying Berry's Creek and Harmon Meadows with centralized package boilers results in fuel requirements as shown on Figure 10.4. If landfill gas is included as a potential district heating fuel source, the fuel requirements will be those shown in Figure 10.5.

The fuel consumption with a partial retrofit of Hudson #2 to supply the thermal energy is shown in Figure 10.6. Again it should be remembered that the thermal energy supplied by Hudson #2 will require a reduction in electric generation that must be replaced by other units fueled primarily by oil.

10.2.4 Fully Developed System

Figure 10.7 illustrates the various thermal energy sources of the district heating system. The total energy supplied by direct sources in the 1984-2011 period is shown in Figure 10.8. Hudson #2 supplies an impressive 52.7% and Kearny #12 15.9%, giving a total of 68.6% supplied by cogeneration. Considering the fuel required to replace the reduced electric output of Hudson #2, due to district heating, and any fuel use changes associated with operation of Kearny #12, based on district heating demand, the overall fuel consumption by type for district

BERRYS CREEK FUEL CONSUMPTION WITH A HUDSON #2 RETROFIT

FIG. 10.3

BERRYS CREEK AND HARMON MEADOWS FUEL CONSUMPTION WITH NATURAL GAS

FIG. 10.4

BERRYS CREEK AND HARMON MEADOWS FUEL CONSUMPTION WITH LANDFILL GAS

FIG. 10.5

BERRYS CREEK AND HARMON MEADOWS FUEL CONSUMPTION WITH HUDSON #2 RETROFIT AND LANDFILL GAS

FIG. 10.6

FULL SYSTEM FUEL CONSUMPTION WITH HUDSON #2 RETROFIT AND NATURAL GAS

FIG. 10.7

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

JS/Nov. 24, 1982

FIG. 10.8

heating is shown on Figure 10.9. It can be seen that better than 75% of the district heating energy is provided directly or indirectly by oil or natural gas, and less than 25% by coal.

These results are for the site specific study based on the PSE&G and PJM planned systems and may not be interpreted for other utilities.

10.3 Environmental Impact

Potential environmental effects of district heating are (1) air quality impact due to change in the type and quantity of fuel burned and (2) reduction in thermal discharge to waterways. Heating of the ground by heat losses from district heating pipes is minimal for well insulated pipes, and the recovery and utilization of landfill gas for fuel has been found environmentally acceptable in New Jersey (Cinnaminson, N.J. PSE&G/Hoegaenes) and elsewhere.

Although the extraction of 1.6×10^6 lb/hr of steam from Hudson #2 for district heating would reduce thermal discharges to the river by about 1.5×10^9 BTU/hr, this improvement would occur mainly during the winter heating season. However, thermal discharges to waterways are of environmental concern during the summer because of the consequent reduction in dissolved oxygen. Thus the reduction in thermal discharge has minimal environmental significance.

District heating may impact air quality through (1) increase in fuel burned at Hudson #2 and Kearny #12 for district heating; (2) fuel burned at (new) local heater plants of the district heating system and (3) reduction/elimination of fuel which would have been burned by district heating customers in their own boilers.

Because Hudson #2 is at maximum load ("base-loaded") except for a few hours each night, the fuel burned at Hudson increases only slightly due to district heating. The natural gas burned at Kearny #12 and the local heater plants (and the landfill gas burned at the Meadowlands) produce minimal particulate emissions, no SO_2 emissions, but NO_x emissions could be significant.

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

JS/Dec.1, 1982

FIG. 10.9

First, modeling was done for an annual period for particulates, NO_x and SO_2 without taking credit for the displacement of customer fuel use by district heating (Section 10.6.1). The increments in SO_2 and particulates due to district heating were found to be zero. Increments in NO_x ranged from 0–3 micrograms per cubic meter. This is negligible compared to the Federal Ambient Air Quality Standard of 100 micrograms/cubic meter for NO_2 (not NO_x which is only partly NO_2) and a maximum annual average observed level of NO_2 of 78 micrograms per cubic meter. There is no chance that district heating would cause the standard to be exceeded. When "worst-case" NO_x modeling was done for the month of January (very stable meteorological conditions and maximum heating load), but including the effect of customer fuel use reduction (Section 10.6.2), the NO_x increment ranged from +1 to -3 micrograms per cubic meter, with the exception of two points immediately downwind of heater plants (+4 and +5 micrograms per cubic meter). Thus the NO_x impact of district heating is essentially negligible, ranging from minor increases to minor reductions.

Section 10.6.3 shows "worst-case" SO_2 modeling results for January. These range from increases of 0 to 1 micrograms per cubic meter without customer fuel displacement credit to reduction of 0 to 2 micrograms per cubic meter with credit for reduced emissions due to reductions in customer fuel burning (except for one point with a 1 microgram per cubic meter increase). Again the air impact of district heating is negligible. This differs from the situation in Europe (Fig. 10.10) where the heating fuel displaced is high sulfur oil instead of 0.2% No. 2 oil or natural gas with no sulfur.

Sections 10.6.4 and 10.6.5 give a description of the Climatological Dispersion Model used and the month-by-month district heating system fuel use which was input to the model. There are two sets of data given, one (8 week Hudson No. 2 outage) for a normal year and one (18 week outage) reflecting the periodic longer outage (one every 5 years) for steam turbine rebuilding.

In summary, the proposed total system district heating scenario was found to have negligible environmental impact. The smaller scenarios would have even less impact.

wind →

a

The result of district heating, Fig a shows a town with many small boiler installations. This is indicated by a large number of crosses. In Fig b, the ring indicates the location of the district heating station. The ellipsoidal figures represent lines of constant sulphur dioxide content at ground level. A measurement point is indicated by a square.

wind →

b

In a town with decentralised heating, the measurement point will always record a high reading of sulphur dioxide concentrations, regardless of the wind direction.

In a town with centralised heating, the measurement point will record a high concentration only when the wind is blowing in a particular direction. If the wind should veer 5 to 10 degrees, the concentration will fall to zero. The air will be practically free from sulphur dioxide during 90–95 % of the time.

Sulphur dioxide in air, 2 % by weight of sulphur in the fuel oil, °C average temperature during winter season (Uppsala Universitet, Met. Instit. 1974)

10.3.1

DISPERSION MODELING

FOR

DISTRICT HEATING

A Study Performed

for the

P S E & G Research and Development

Corporation

David W. Letcher, Ph.D
Trenton State College
December 3, 1982

10.3.1 Introduction

A. The Scenario of District Heating

From the perspective of dispersion modeling for district heating, there are twenty point sources and forty nine area sources. The point sources are the eight units of Kearny-12, Hudson-2, and eleven boiler plants.

Input data for the point and area sources are presented in section 10.3.2.

The geographic locations of the point sources and the grip map showing the point sources are provided in the following grid map. This map also contains some salient geographic information that allows the reader to see the arrangement of district heating sources in the Newark-Meadowlands-Jersey City area. See Figs. 10.11 & 12.

Boiler plants are shown as triangles; the four pertinent NJDEP air-monitoring stations are circles; the PSE&G building is a small square. The page following the grid map shows a photocopy of the boiler plant arrangement, provided by PSE&G.

Finally, the grid map exhibits the rectangular array of receptor sites. A total of 168 receptor sites were included in the model. Many more receptors could have been included. The number chosen represents a balance between the need for representativeness and the required computer processing time.

For the reader's information the following table presents the coordinates of the four NJDEP air monitoring stations located within the grid.

TABLE I-1.

NJDEP Air Monitoring Station

Station	Coordinates			
	UTM-Units		Grid-Units	
East Orange	567.2	4512.0	3.85	13.85
Newark Lab	569.4	4509.2	6.11	10.94
Bayonne Lab	574.4	4503.5	11.04	5.19
Jersey City	578.8	4509.1	15.36	10.67

GRID MAP

Salient Geography of District Heating

FIG. 10.11

FIG. 10.12

B. The Model

The model employed in this study was the Climatological Dispersion Model (CDM), an EPA-approved model which is part of the UNAMAP series of air pollution computer models.

In this model, long-term quasi-stable air pollutant concentrations at any ground-level receptor can be predicted using average emissions from point and area sources. A joint frequency distribution of wind direction, wind speed, and stability, the so-called Day-Night STAR data, was used as the meteorological input. The period 1960 to 1964 for the Newark Airport-Weather Service Office was chosen for the STAR data. The year 1964 was the last year wherein hourly data on wind speed, direction, and stability were recorded. Thus five years of weather data form the backdrop in this model. Monthly STAR data for Newark were used in this study.

Listed below are the assumptions and considerations made by the CDM:

1. Wind Profile - a power law is used to compute wind speeds above a height of 10 meters.
2. Mixing Height - a climatological mean value of mixing height, obtained from Holzworth (1972) is used as a basis for determining the mixing height for each stability class.
3. Dispersion Functions - an empirical power law used to approximate the Pasquill-Gifford curves for the vertical dispersion function.
4. Plume Rise - The "2/3 law" due to Briggs is used in this study.
5. Emission Rates - Average, continuous emission of any pollutant is assumed. Also, the ratio of average day-time emission to the 24-hour emission rate average is assumed to be 1.0. The ratio of the average nighttime emission rate average to the 24-hour emission rate average is assumed to be 1.0.
6. Decay Rates - The decay half lives for the two pollutants, particulates and nitrogen oxides, are assumed to be infinitely long. In other words, as suggested by the State, a straight dispersion analysis was done.

The model was run on a monthly basis for the following cases:

Case A: Case A represents the scenario where Hudson-2 is out during the months of April and May. Twelve monthly runs were made for the Base Case and then for the District Heating Case. Each of these 24 runs required about 10 hours of computing time on a Burroughs B1955 Small System.

Case B: Case B represents the scenario where Hudson-2 is out during the months of February, March, April, and May. Only February and March fuel uses were different between Case B and A. Hence only four computer runs were necessary (2 base and 2 district heating).

Each computer run is done in the batch mode and produces a line printer output as well as a punched-card deck. The output tabulates the predicted concentrations of each of two different pollutants due to both point and area sources at previously determined points.

10.3.2 Input Data for Model

A. Hudson-2

1. Map coordinates	X = 15, Y = 12.5
2. Stack Height	152 meters
3. Stack Diameter	5.33 meters
4. Gas Exit Velocity	42.31 meters per second
5. Gas Exit Temperature	129°C
6. Fuel	Bituminous Coal; 12979 BTU/lb.
7. Emission Factors:	18 lbs NO _x /Ton coal
.1 lb fly ash/10 ⁶ BTU
8. Fuel Consumption:	District Heating Thermal Source
Dispatch from T.M. Piascik, PSE&G,
July 12, 1982.File/8.1.523.4
Tables 10-I and 10-II

TABLE 10-1

Summary of Fuel Burned by Months for the
Three Types of Supplies to the Fully Developed
District Heating System - Hudson #2 out for Maintenance
For 8 weeks Between April and May
Fuel Burned - 10^9 Btu

Month	Hudson #2			Kearny #12			Boilers Total
	Base Case	Dist. Heat Case	Delta	Base	Dist. Heat Case	Delta	
January	2750	2859	109	134	874	740	632
February	2503	2598	95	76	450	374	340
March	2690	2841	151	34	351	317	197
April	0	0	0	65	823	758	383
May	0	0	0	147	316	169	74
June	2156	2182	26	44	44	0	14
July	2372	2394	22	17	43	26	14
August	2375	2422	47	32	88	56	18
September	2468	2520	52	97	130	33	26
October	2017	2930	113	353	357	4	286
November	2720	2817	97	276	433	157	303
December	2806	2904	98	264	715	451	523
TOTAL	25,657	26,467	810	1,539	4,624	3,085	2,810

TABLE 10-II

Summary of Fuel Burned by Months for the
Three Types of Supplies to the Fully Developed
District Heating System - Hudson #2 out for Maintenance
For 18 weeks Between February and May
Fuel Burned - 10^9 Btu

Month	Hudson #2			Kearny #12			Boilers Total
	Base Case	Dist. Heat Case	Delta	Base	Dist. Heat Case	Delta	
January	2750	2859	109	134	874	740	632
February	0	0	0	76	982	906	1174
March	0	0	0	34	1010	976	681
April	0	0	0	65	823	758	383
May	0	0	0	147	316	169	74
June	2156	2182	26	44	44	0	14
July	2372	2394	22	17	43	26	14
August	2375	2422	47	32	88	56	18
September	2468	2520	52	97	130	33	26
October	2817	2930	113	353	357	4	286
November	2720	2817	97	276	433	157	303
December	2806	2904	98	264	715	451	523
TOTAL	20,464	21,028	564	1,539	5,815	4,276	4,128

B. Kearney - 12 (8 units)

1. Map Coordinate	X = 12.81, Y = 11.57
2. Stack Height	8.5 meters (13.7 meters)*
3. Stack Diameter	4.3 meters (3.4 meters)*
4. Gas Exit Velocity	19.3 meters per second
5. Gas Exit Temperature	477°C (149C)*
6. Fuel	Kerosene; 5.6×10^6 BTU/barrel
7. Emission Factors:	67.8 lbs NO _x /1000 gal 5 lbs particulates /1000 gal
8. Fuel Consumption	same source as Hudson-2

*Figures in parentheses represent the district heating case where a heat recovery unit is present.

C. Boiler Plants - Newark

1. Map Coordinates

	x	y
1.	5.41	12.05
2.	7.14	11.81
3.	8.37	11.93
4.	8.25	10.22
5.	9.83	11.34

2. Stack Heights 15.2 meters (45.7m for plant 2)

3. Stack Diameter 1.5 meters (double-flue)

4. Gas Exit Velocity 8.3 meters per second (partial load)
16.7 meters per second (full load)

5. Gas Exit Temperature 149°C

6. Fuel Natural Gas; 1000 BTU/cubic foot

7. Emission Factors: 230 lbs NO_x/10⁶ cubic feet
15 lbs particulates /10⁶ cubic feet

8. Fuel Consumption same source as Hudson-2

C. Boiler Plants - Meadowlands

1. Map Coordinates	x	y
	1. 13.85	19.11
	2. 17.50	16.04
2. Stack Heights	1. 48.8 meters	
	2. 15.2 meters	
3. Stack Diameter	same as Newark	
4. Gas Exit Velocity	same as Newark	
5. Gas Exit Temperature	same as Newark	
6. Fuel	1. Natural Gas; 1000 BTU/cu.ft.	
	2. Land-fill Gas; 500 BTU/cu.ft.	
7. Emission Factors	same as Newark	
8. Fuel Consumption	same source as Hudson-2	

C. Boiler Plants - Jersey City

1.	Map Coordinates	x	y
		1. 15.17	12.17
		2. 16.20	10.17
		3. 17.72	9.31
		4. 18.34	11.08
2.	Stack Height	15.2 meters	
3.	Stack Diameter	same as Newark	
4.	Gas Exit Velocity	same as Newark	
5.	Gas Exit Temperature	same as Newark	
6.	Fuel	same as Newark	
7.	Emission Factors	same as Newark	
8.	Fuel Consumption	same source as Hudson-2	

D. Area Source Data

Area source emissions for 1981 on a per county basis were obtained from the State of New Jersey, Bureau of Air Pollution Control, Trenton, New Jersey. The grid used in the model consists of 49 basic squares. Any given square may or may not contain more than one county.

Emissions on a per unit area basis were determined for each county. The amount of each county in any given square was estimated by using a planimeter. Thus the contribution of any or all counties to each grid square was calculated.

Therefore, the model assumes 49 area sources each emitting at a constant rate in each of the 12 months.

E. Meteorological Data

Meteorological data required by the climatological Dispersion Model are:

1. Monthly STAR arrays. These are frequencies of wind speed, wind direction, and stability. STAR data are tabulated and purchased from the National Climatic Center in Asheville, North Carolina. Averages for 1960-1964 were used.
2. Mean Nocturnal and Afternoon Mixing Heights. These are tabulated in Holzworth (1972).
3. Mean Monthly air temperature. The nearest U.S. Weather Service Office is Newark Airport. This data was obtained from the monthly "Climatological Data" pamphlets issued by the National Climatic Center.

10.3.3 Model Predictions

A. Sulfur Dioxide

The CDM model was run for an annual period to see if any increments in sulfur dioxide would occur. During this run, each boiler plant was run at full load each month-an improbable but highly conservative estimate of any potential impact.

Each receptor point registered a zero increment for sulfur dioxide.

B. Particulate Matter

Each CDM run allows for two pollutants to be studied. Particulates were studied along with nitrogen oxides using the monthly fuel use data provided for this study.

Both Case A and Case B showed a zero increment at each receptor point during each monthly run.

Since much of the study area is in non-attainment with respect to particulates this result is indeed welcomed.

C. Nitrogen Oxides

There were increments, albeit small, for nitrogen oxides for both Case A and Case B. For Case A, illustrated in the following grid map, Fig.10.13, the increments at the various receptor points ranged between 1 and 2 micrograms per cubic meter. The major area of impact is in the Newark, Meadowlands, Jersey City, Bayonne Area.

Fig.10.14, the next grid map shows the predicted increments in nitrogen oxides for Case B. The increments ranged between 1 and 3 micrograms per cubic meter. Here the major zone of impact lies along a west to east band from Newark to Jersey City

Although there are no PSD increments for nitrogen oxides we can at least say that these predicted increments are indeed small. The National Ambient Air Quality Standard for Nitrogen Dioxide is 100 micrograms per cubic meter on a twelve-month average for both the primary and secondary standards. One notes on the page entitled "Air Quality in New Jersey Compared with Air Quality Standards-1981" which follows the two grid (Table 10-III) maps that the twelve-month average for Bayonne, East Orange and Newark are 56,70, and 68 micrograms per cubic meter respectively. The State assumes too that all nitrogen oxides emitted by sources is directly converted into nitrogen dioxide. Therefore, adding on the predicted increments in nitrogen oxides will not violate the primary or secondary standards.

GRID MAP

Annual Average Increment in NO_x due to District Heating
(micrograms/cubic meter)

CASE A

⊙ = NJDEP Air Monitoring Station

2.5 km
(2 cm)

□ = Public Service Building

△ = District Heating Boiler Plants

FIG. 10.13

GRID MAP

Annual Average Increment in NO_x due to District Heating
(micrograms/cubic meter)

CASE B

○ = NJDEP Air Monitoring Station

◻ = Public Service Building

△ = District Heating Boiler Plants

2.5 km
(2 cm)

FIG. 10.14

TABLE 10-III

AIR QUALITY IN NEW JERSEY COMPARED WITH
AIR QUALITY STANDARDS-1981

NITROGEN DIOXIDE

AIR QUALITY STANDARDS FOR NITROGEN DIOXIDE:

12-MONTH AVERAGE PRIMARY STANDARD: 0.05PPM^A
 12-MONTH AVERAGE SECONDARY STANDARD: 0.05PPM^A

<u>MONITORING SITE</u>	<u>12-MONTH AVERAGE (PPM)</u>
BAYONNE LAB	.028 = 56 $\mu\text{g}/\text{m}^3$
CAMDEN LAB	.027
DUMONT	.027
EAST ORANGE	.033 = 70
ELIZABETH LAB	.039
FLEMINGTON	.016
MCGUIRE A.F.B. ^B	.018
NEW BRUNSWICK ^B	.023
NEWARK LAB	.034 = 68
PHILLIPSBURG ^C	.020
PLAINFIELD	.024

A) NATIONAL AND NEW JERSEY AMBIENT AIR QUALITY STANDARDS

B) DATA NOT AVAILABLE: FEBRUARY

C) DATA NOT AVAILABLE: DECEMBER

AIR QUALITY IN NEW JERSEY COMPARED WITH
AIR QUALITY STANDARDS-1981

NITRIC OXIDE

NO AIR QUALITY STANDARDS HAVE BEEN ESTABLISHED FOR NITRIC OXIDE

<u>MONITORING SITE</u>	<u>12-MONTH AVERAGE (PPM)</u>
BAYONNE LAB	.027
CAMDEN LAB	.025
DUMONT	.032
EAST ORANGE	.045
ELIZABETH LAB	.067
FLEMINGTON	.012
MCGUIRE A.F.B.	.011
NEW BRUNSWICK ^A	---
NEWARK LAB	.042
PLAINFIELD	.033

A) DATA NOT AVAILABLE: FEBRUARY, OCTOBER - DECEMBER

BIBLIOGRAPHY

1. Briggs, G.A., 1969. Plume Rise. AEC Critical Review Series. Oak Ridge, Tenn. Available from NTIS as TID-25075. 81p.
2. Turner, D.B., 1967. Workbook on Atmospheric Dispersion Estimates. National Air Pollution Control Administration, Cincinnati, Ohio, PHS Pub. No. 999-AP-26, 84p.
3. Holzworth, G.C., 1972. Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States. Office of Air Programs, Environmental Protection Agency, RTP, North Carolina. Pub. No. AP-101.
4. Busse, A.D. and Zimmerman, J.R., 1973. User's Guide for the Climatological Dispersion Model. Office of Research and Development, U.S. EPA, EPA-R4-73-024. 131p.
5. EPA, 1977. Compilation of Air Pollutant Emission Factors. U.S. EPA, Office of Air Quality Planning and Standards. R.T.P., North Carolina. Pub. No. AP-42, Part A.

DEC 6 1982
TRENTON STATE
COLLEGE

December 3, 1982

Dr. Mel Zwillenberg
P.S.E. & G. Research Corporation
80 Park Plaza 16A
Newark, New Jersey 07101

Dear Mel,

I am pleased to send you this report on my dispersion modeling for district heating. As you will see, this shows the expected increments in nitrogen oxides due to Case A and Case B on an annual basis. There are zero predicted increments for sulfur dioxide and particulates.

It is important to note that these increments are due only to the addition of district heating sources and do not reflect a reduction of those area sources that would receive the benefit of district heating.

Considering the smallness of the increments, do you think it is worth the effort of about 150 hours of additional computer runs to see what the result would be? As I recall the meeting we had with the state people a couple of years ago, they stated that they could not credit you with area source reductions due to district heating. The exact reason for this eludes me at present but perhaps we could look into this before spending a lot of computer time. What do you think?

I will call you to discuss the matter.

I apologize for delays in getting this to you. My new position here at TSC, which is now a twelve-month administrative position has captured a lot of my research time that I enjoyed as a faculty member.

In any event, I trust this modeling study has successfully shown that your district heating plan is workable with respect to the air quality standards.

Yours truly,

David W. Letcher

DWL:dd

200

10.3.4
SUPPLEMENTARY REPORT
TO
DISPERSION MODELING
FOR
DISTRICT HEATING

DAVID W. LETCHER
TRENTON STATE COLLEGE
MARCH 11, 1983

10.3.4 INTRODUCTION

This supplementary report shows, for the month of January, what the predicted average monthly increment in NO_x would be if the area emissions were reduced in lieu of district heating.

In the original report, dated December 3, 1982, the predicted annual increments in NO_x for cases A and B were presented. But, those graphs did not reflect the concomitant reduction in area sources. Even though the annual increments were very small, it was of interest to see what the result would be for January, the month of greatest district heating fuel use.

10.3.4.1 METHODOLOGY

Based on the district heating map (Fig. 10.15) of customer area, certain of the 49 areas on the grid maps had their area emissions in NO_x reduced. The reduction was calculated in the following manner:

- 1) The percent of fuel use by customers due to gas and number 2,4, and 6 oil was determined from a table of customer survey data. (table 10-IV)
- 2) The number of BTU/sec for each boiler plant in each of the areas (Newark, Berry's Creek, Harmon Meadows, Jersey City) was determined.
- 3) The number of grid squares served by the boiler plants in the areas cited in 2) above was determined.
- 4) The number of BTU/sec per area was established.
- 5) Using the percentages in 1) above and the EPA emission factor from AP-42, the reduction in NO_x emissions was calculated for each area. No losses were assumed. That is, emissions due to District heating sources were subtracted from the particular nearby area sources.
- 6) The Climatological Dispersion Model was run on a computer to determine the expected NO_x concentrations at each grip point.
- 7) The predicted NO_x concentrations determined from the BASE case were subtracted from the results in 6).

- 8) The attached grid map shows, then, the increments in NO_x in micrograms per cubic meter due to district heating for a January scenario (Fig. 10.16).

10.3.4.2 DISCUSSION OF RESULT

The grid map shows that a zero or modest increment of 1 microgram per cubic meter would result. Indeed, many receptor points show a decrease of between 1 and 2 micrograms per cubic meter.

Two receptor points show increments of 5 and 4 micrograms per cubic meter. The first is located near the easternmost boiler plant in the Newark area; the second in the Jersey City area.

However, the grid map shows a favorable result for a typical January period.

FIG. 10.15

GRID MAP

AVERAGE JANUARY INCREMENTS IN NO_x BASED ON A
CONCOMITANT REDUCTION IN CERTAIN AREA SOURCES.

MICROGRAMS/CUBIC METER

2.5 km
(2 cm)

FIG. 10.16

TABLE 10-IV

PUBLIC SERVICE ELECTRIC & GAS COMPANY
TOTAL HEATING REQUIREMENTS BY CUSTOMER CLASS

Customer Class	Gas	No. 2 Oil	No. 4 Oil	No. 6 Oil	Total
	(MMBTU)				
Residential	91,300	883,238	625,152	-	1,599,690
Multiuse	100	6,552	7,680	-	14,332
Commercial	1,342,300	101,065	211,661	906,240	2,561,266
Industrial	<u>4,245,100</u>	<u>1,710,996</u>	<u>947,405</u>	<u>2,200,781</u>	<u>9,104,282</u>
Total	<u>5,678,800</u>	<u>2,701,851</u>	<u>1,791,898</u>	<u>3,107,021</u>	<u>13,279,570</u>

12/14/82

Dear Dave,

These are results of a survey of
281 customers. Table
ratio of total energy from
each fuel to total energy supplied.

$$\left(\text{P.g. } \frac{\text{Gas}}{\text{total}} = \frac{5,678,800 \times 10^6}{13,279,570 \times 10^6}, \text{ etc.} \right)$$

MMBtu = 10^6 Btu
(all annual figures)

Sincerely,
Neil J. Gullone

10.3.4.3 Results of executing the Climatological Dispersion Model (CDM) in order to assess the increments in sulfur dioxide due to district heating.

The CDM was run three times: one to estimate January sulfur dioxide concentrations for the BASE case; another to estimate concentrations for the district heating case without area reductions; the third to estimate concentrations for the district heating case allowing for area reductions in sulfur dioxide emissions. The second case may be needed as an exhibit to the State.

In each run, the half-life decay for sulfur dioxide was set at four hours. This is the EPA recommendation for an urban area.

Results

Fig.10.17 shows the January increments in sulfur dioxide without accounting for any area reductions. At each grid point the increment is either zero or at most one microgram per cubic meter. The increments occur on the eastern and southern regions which encompass Secaucus, Jersey City, Bayonne, and the region of Newark Bay.

Fig.10.18 shows the January increments accounting for area reductions in sulfur dioxide.

The increments are either zero, -1., or -2 micrograms per cubic meter. In general, the favorable negative increments occur in and around each of the three district heating areas of Newark, Secaucus, and Jersey City. Most -2 increments occur in the eastern area of Newark with fewer -2's in Jersey City and one in the Berry's creek area.

One receptor point, about midway between the PSE&G building and Jersey City shows a +1 microgram per cubic meter.

So, in January, the month of highest fuel use for the district heating boiler plants, the monthly increment in sulfur dioxide are minimal and even negative at many receptor sites.

GRID MAP

AVERAGE JANUARY INCREMENTS IN SO₂ WITHOUT ACCOUNTING
FOR ANY AREA SOURCE EMISSION REDUCTIONS.

MICROGRAMS/CUBIC METER

FIG. 10.17

GRID MAP

AVERAGE JANUARY INCREMENTS IN SO₂ BASED ON A CONCOMITANT

REDUCTION IN CERTAIN AREA SOURCES.

MICROGRAMS/CUBIC METER

⊙ = NJDEP Air Monitoring Station

2.5 km

⊠ = Public Service Building

(2 cm)

△ = District Heating Boiler Plants

FIG. 10.18

10.3.5 Guideline on Air Quality Models*

A.3 CLIMATOLOGICAL DISPERSION MODEL (CDM)

References: Busse, A. D. and J. R. Zimmerman. "User's Guide for the Climatological Dispersion Model." Publication No. EPA-RA-73-024 (NTIS PB 227346/AS), Environmental Protection Agency, Research Triangle Park, North Carolina 27711, December 1973.

Brubaker, K. L., P. Brown, and R. R. Cirillo. "Addendum to User's Guide for Climatological Dispersion Model." Publication No. EPA-450/3-77-015, Environmental Protection Agency, Research Triangle Park, North Carolina 27711, May 1977.

Abstract: CDM is a climatological steady-state Gaussian plume model for determining long-term (seasonal or annual) arithmetic average pollutant concentrations at any ground-level receptor in an urban area. An expanded version (CDMQC) includes a statistical model based on Larsen¹ to transform the average concentration data from a limited number of receptors into expected geometric mean and maximum concentration values for several different averaging times.

Equations:

$$x_{\text{point}} = \frac{16}{2\pi} \sum_{n=1}^N \sum_{\ell=1}^6 \sum_{m=1}^6 Q_n \theta_{kn\ell m} S_{\ell m} (\rho_n) / \rho_n$$

$$x_{\text{area}} = \frac{16}{2\pi} \int \left[\sum_{k=1}^{16} q_k(\rho) \sum_{\ell=1}^6 \sum_{m=1}^6 \phi_{k\ell m} S_{\ell m}(\rho) \right] d\rho$$

$$\text{with } q_k(\rho) = \int_{\text{sector } k} Q(\rho, \theta) d\theta$$

$$S_{\ell m}(\rho) = \frac{2}{\sqrt{2\pi} \sigma_z u_{\ell}} \exp \left[-\frac{1}{2} \left(\frac{H}{\sigma_z} \right)^2 \right] \exp \left[-\frac{0.692 \rho}{u_{\ell} T^{1/2}} \right]$$

$$\text{for } \sigma_z \leq 0.8L$$

*EPA-450/2-78-027

$$S_{\ell m}(\rho) = \frac{1}{u_{\ell} L} \exp \left[- \frac{0.692 \rho}{u_{\ell} T_{1/2}} \right] \text{ for } \sigma_z > 0.8L$$

$\sigma_z = a \rho^b$; a, b = functions of stability class (m) and downwind distance (ρ) - three ranges of distance used: 100-500 m, 500-5000 m, and 5000-50,000 m

k_n = wind sector appropriate to the n^{th} point source

Q_n = emission rate of the n^{th} point source (g/s)

ρ_n = distance from the receptor to the n^{th} point source (m)

q_k = emission rate of the area source per unit area and unit time (g/s-m²)

ρ = distance from the receptor to an infinitesimal area source (m)

θ = angle relative to polar coordinates centered on the receptor

ℓ = index identifying the wind speed class

m = index identifying the class of the Pasquill stability category

$\phi(k, \ell, m)$ = joint frequency function

z = height of receptor above ground level (m)

u_{ℓ} = representative wind speed (m/s)

h = effective stack height of source distribution, i.e., the average height of area source emissions in the k^{th} wind direction sector at radial distance ρ from the receptor (m)

L = the afternoon mixing height (m)

$T_{1/2}$ = assumed half life of pollutant hours (s)

a. Source-Receptor Relationship

Arbitrary location for each point source
Arbitrary location for each receptor
Area sources input as multiples of a user-defined unit size
Arbitrary release heights for point and area sources
Actual separation between each source-receptor pair used
Receptors are at ground level
No terrain differences between source/receptor

b. Emission Rate

Point sources: single rate for each source
Area sources: single rate for each source
area integrations are done numerically one 22.5° sector
at a time; sampling at discrete points defined by specific
radial and angular intervals on a polar grid centered on
the receptor
Day/night variations in emissions, same variation assumed
for all sources

c. Chemical Composition

Treats one or two inert pollutants simultaneously

d. Plume Behavior

Only Briggs neutral/unstable formula used for point sources
If stack height plus plume rise is greater than mixing height, ground
level concentrations assumed equal to zero
Alternative to Briggs - input value of plume rise times wind speed for
each point source
No plume rise calculated for area sources
Does not treat fumigation or downwash

e. Horizontal Wind Field

Climatological approach
16 wind directions
6 wind speed classes
Wind speed corrected for release height based on power law variation
exponents from DeMarrais⁵
Constant, uniform (steady-state) wind assumed

f. Vertical Wind Speed

Assumed equal to zero

g. Horizontal Dispersion

Climatological approach
Uniform distribution within each of 16 sectors
Averaging time = 1 month to 1 year or longer

h. Vertical Dispersion

Semi-empirical/Gaussian plume
5 stability classes as defined by Turner²
Day and night cases of neutral stability input separately
Dispersion coefficients taken from Turner⁶
Area sources - stability class is decreased by 1 category from input values (to account for urban effects)
Neutral dispersion coefficients are used for stable classes
No further adjustments made for variations in surface roughness

i. Chemistry/Reaction Mechanism

Exponential decay, user-input half life

j. Physical Removal

Exponential decay, user-input half life
Always applies the same rate constant

k. Background

Input single constant background value for each pollutant

l. Boundary Conditions

Lower boundary (ground): assumes perfect reflection
Upper boundary (mixing height): no effect until dispersion coefficient equals 0.8 of the mixing height, uniform vertical mixing assumed beyond this point

m. Emission and Meteorological Correlation

Wind speed, direction, stability correlated via wind rose
Mixing height is adjusted according to stability class:
Class A - 1.5 times afternoon climatological value
Classes B, C, and D(day) - equal to the afternoon climatological value
Class D(night) - average of morning and afternoon climatological value
Class E - morning climatological value
Emission rates: day-night allowed; all sources vary by same factor
Non-sequential (climatological) limited correlation

n. Validation/Calibration

Calibration option available (CDMQC)
Two validation studies documented in the user's guide
Some unpublished validation experience

o. Output

One month to one-year averaging time simulated (arithmetic mean only)
Arbitrary averaging time by Larsen¹ procedure (typically 1 - 24 hr.)

(CDMQC)

Assumes

- (1) lognormal concentration distribution,
- (2) power law dependence of median and maximum concentrations on averaging time

Arbitrary number and location of receptors

Individual point, area source culpability list for each receptor

(CDMQC)

Point, area concentration rose for each receptor

p. Computer Requirements

Digital computer required

Core requirements are moderate

q. Limitations

Useable for urban areas only

Area source emission densities must not vary rapidly from one area source to the next

SECTION 11

ALTERNATES TO DISTRICT HEATING

(ECONOMIC EVALUATION)

Section 11

Alternates to Conventional Heating Systems

11.1 Introduction

Detailed economic and technical analysis of various district heating scenarios compared to a conventional natural gas heating system was described in the previous sections. Certain district heating scenarios were shown to have a marginal economic advantage. However, there could be alternate methods of supplying heat that would be less expensive than the conventional systems, and could compete with district heating. This section discusses these alternate methods.

11.2 Selection of an Alternate Heating System

With the onset of higher prices for oil and natural gas, numerous methods of reducing our energy consumption or using other alternate energy sources have been proposed. Some of these energy sources, such as landfill gas or refuse-derived fuel, may be practical only for large scale operation, like district heating, but probably will not be suitable for individual building applications. Piping for landfill gas or delivery and handling of refuse or refuse-derived fuel, boiler modifications and pollution controls discourage their use on a small scale.

Renewable energy sources, such as solar thermal, photovoltaic or wind, are much more adaptable to small scale operation and could, from an engineering viewpoint, supplement a conventional heating system.

Due to the high initial capital investment required for these renewable energy systems and based on PSE&G experience gained from testing systems of these types, it was concluded that a detailed technical and economic analysis was unwarranted in this study. Instead, a limited evaluation of one promising technology was made. For this evaluation, a solar thermal system capable of supplying one half of the annual load was judged most promising. Due to excessive land requirements for a large system, the analysis was limited to Berry's Creek.

11.3 Economic Comparison of Solar Thermal and Conventional Heating System

A solar thermal system capable of supplying 50% of the annual load was assumed. Full scale back-up boilers were retained. Due to probable safety requirements and union regulations, no reduction in manpower for conventional boilers was assumed even though the boilers will operate less. An estimate of 112,000 Btu/ft² annual production of

solar thermal energy was used to determine the collector size. To supply 50% of the Berry's Creek annual load, about 48 acres of total collector surface area will be required. Allowing for normal spacing of the collectors, the land requirement is between 82 and 110 acres. For this purpose, the land requirement was estimated at 82 acres. A recent sale of land in the Berry's Creek area was priced at \$70,000 per acre and this cost was used in this comparison. Transmission costs were based on a distance of about one half mile, assuming the collectors would be located adjacent to the Berry's Creek site. The availability of land for solar collectors and the transmission right-of-way, possible costs of distribution and user connections were not considered. A tax credit based on 15% of the capital costs for solar collectors and transmission was assumed.

Table 11.1 summarizes the levelized annual minimum revenue requirements for the solar alternate compared to a conventional system. The LAMRR for the solar alternate is more than three times as large as that of the conventional system. Although a more thorough analysis may change the costs

TABLE 11.1

LEVELIZED ANNUAL MINIMUM REVENUE REQUIREMENTS
FOR A BERRY'S CREEK SOLAR ASSISTED ENERGY SYSTEM
COMPARED TO A CONVENTIONAL HEATING SYSTEM
(1983 \$ X/1000)

	SOLAR ASSISTED THERMAL SUPPLY		CONVENTIONAL	
	\$	%	\$	%
CAPITAL RELATED				
BOILERS	531#	1	531	4
NATURAL GAS SERVICE	145	0	145	1
SOLAR COLLECTORS	20412	49		
TRANSMISSION	1084	3		
LAND REQUIREMENTS	6658	16		
FUEL RELATED				
NATURAL GAS	4643##	11	9286	75
O & M RELATED				
MANPOWER FOR CONV. BOILERS	2485	6	2485	20
SOLAR O&M COSTS	5776	14		
SOLAR TAX CREDITS				
15% OF CAPITAL	(3224)	(8)		
TOTAL	41734	100	12447	100
SAVINGS (PENALTIES)	(29287)			

FULL BOILER BACKUP FOR SOLAR SYSTEM ASSUMED

SOLAR ASSUMED TO SUPPLY 50% OF ANNUAL LOAD

somewhat, the magnitude of the difference is large enough to conclude that there will be little or no impact of solar energy on the viability of district heating.

0224K(52)

SECTION 12

CONCLUSIONS

12. CONCLUSIONS

- (1) Small localized district heating systems in new developments, each with a peak demand in the order of $200 \times 10^6 \text{ BTU/hr}$ 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).^{*} 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 ($200 \times 10^6 \text{ BTU/hr}$ 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-I).
- (3) A combination of district heating supplies from package boilers and limited retrofit of Hudson No. 2 into one system ($400 \times 10^6 \text{ BTU/hr}$ load) results in averaging their performance providing 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.

^{*} References correspond to main body of report.

- (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 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 Table ES-IV which summarize the (levelized) economic analysis of all scenarios, with and without GR&FT.

13. RECOMMENDATIONS

The major conclusion of this study was that small district heating systems in conjunction with new developments can be profitable, 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 the 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 their 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.

TABLE 13-1

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.

TABLE OF CONTENTS

(Index of all the volumes of this Report)

Page

VOLUME I

DETAILED SUMMARY

Introduction	1
Load and Service Area Assessment	7
Technical Considerations	15
Peaking and Back-up Plants (Initial Development Phase of a Staged System)	16
Intermediate Stage Plants(s) (Gasturbine)	24
Hudson Generating Station Retrofit	28
Transmission and Distribution	41
Landfill Gas Production	61
System Operations	65
User Connections	76
Staged-Development Scenarios	85
Fully Developed District Heating System (Jersey City, Newark, Meadowlands)	115
Cost Estimates	146
Financial Considerations	157
Economic Evaluation	168
Rates	182
Impact on Fuel Use & on the Environment	184

Table of Contents (continued)

	<u>Page</u>
Institutional Questions	198
Conclusions	206
Recommendations	208

VOLUME II

1	INTRODUCTION	2
2	LOAD & SERVICE AREA ASSESSMENT	
2.1	Summary	13
2.2	Characterization of the Service Area	16
2.2.1	Data sources	16
2.2.2	Representation of data	17
2.2.3	Summary data - Newark/Harrison	18
2.2.4	Summary data - Jersey City/Hoboken	19
2.2.5	Summary data - Meadowlands	20
2.3	Special Developments	21
2.3.1	Port Authority plans	21
2.3.2	Montgomery St. redevelopment - Jersey City	23
2.3.3	Summit Plaza - Jersey City	23
2.3.4	Lefrak/Glimcher - Jersey City	23
2.3.5	Newark Redevelopment and Housing Authority	24
2.3.6	Jersey City Housing Authority	24
2.3.7	Schools and Hospitals	24
2.4	Survey of Potential District Heating Customers	27
2.4.1	Questionnaire design	27
2.4.2	Administration of the questionnaire	30
2.4.3	Data analysis	30
2.5	Fuel Use Survey	48
3	INSTITUTIONAL QUESTIONS	
3.1	Regulatory Questions	53

Table of Contents (continued)

	<u>Page</u>
3.2 Environmental Questions	56
3.3 Rights-of-Way	58
3.4 Ownership of Customer Conversion Units	59
3.5 Utility Constraints	59
3.5.1 Replacement power/fuel	59
3.5.2 Impact on the gas system	60
3.5.3 Limited life of retrofitted central plant	60
3.5.4 Capital constraints	61
3.6 Local Heater Plant Operating Costs	61
3.7 Economic/Financial/Regulatory Uncertainties	62
3.8 Summary	62
4 RATES	
Discussion	65
Hypothetical Draft Tariff for Thermal Service	73
5 FINANCIAL CONSIDERATIONS	
5.0 Introduction	114
5.1 Method of Analysis	114
5.2 Scenarios Studied	114
5.3 Results and Conclusions	115
5.4 Results and Conclusions - Berry's Creek	115
5.5 Summary	119
5.6 Sources of Outside Funding for District Heating	123
Attachments A through E - Proforma Income Statements and Balance Sheets	124

Table of Contents (continued)

Attachment F - "Alternative Ownership Arrangements for Proposed District Heating System"	144
---	-----

FIGURES

Figure No.

1.1	No title	3
1.2	Staged Development and Dispatch Concept	5
1.3	Total District Heating System Concept, Heat Sources and Transmission	6
2.1	Regional Plan	14
2.2	No title	22
2.3	Housing Authority (Newark) Project Locations	26
3.1	District Heating Meadowlands Site #1 Estimated Revenues	55
3.2	District Heating System Controls and Interface with Electrical System	57
4.1	Comparison of Total District Heating System with Conventional Heating	70
4.2	Comparison of Total District Heating System with Conventional Heating	71
4.3	District Heating Meadowlands Site #1 Estimated Revenues	72

TABLES

Table No.

1-I	Prime Contractor Demonstration Team	9
2-I	Number of Dwelling Units, Site Areas, Densities and Dates of Initial Occupancy; by Housing Project NRHA - May 28, 1981	25
2-II	District Heating Potential Survey - Heating/Cooling/Fuel Use Data	49

Table of Contents (continued)

2-III	District Heating Potential Survey - Heating/Cooling/Fuel Use Summary	51
2-IV	PSE&G Energy Market Survey - 1981 Annual Fuel Use	50
3-I	District Heating Barriers to Implementation and Suggestions for Resolution	63
4-I	Allocation of District Heating Cost	67
4-II	District Heating 1984-1993 - Cost of Heat	68
4-III	Financial Analysis	69
5-I	Fully Developed System Description of Cases	116
5-II	District Heating Analysis Financial Assumptions	117
5-III	Fully Developed System 1984-1993	118
5-IV	District Heating 1984-1993 Price of Heat	120
5-V	Berry's Creek without Hudson Retrofit 1984-1993	121
5-VI	Berry's Creek without Hudson Retrofit 1984-1993 Price of Heat	122

VOLUME III

6 TECHNICAL CONSIDERATIONS

6.0	Introduction	2
6.1	The concept of the Staged Development of District Heating	7
6.1.1	General econo-technical reasons for staged development	7
6.1.2.1	The initial stage	10
6.1.2.2	The intermediate stage	11
6.1.2.3	The final stage	13
6.1.2.3.1	Hudson GS	13
6.1.2.3.2	Essex GS	16
6.1.3	Operation of the staged D-H system	16
		17

Table of Contents (continued)

6.1.3.1	Initial stage operation - fired heaters only	16
6.1.3.2	Intermediate stage operation - fired heaters and combustion turbine heat recovery	17
6.1.3.3	Final stage - Hudson #2 unit retrofit	18
6.1.3.4	Operation of the distribution system	19
6.1.4	Hudson #2 unit characteristics	21
6.1.5	Reliability criteria	21
6.2	Station Retrofit	27
6.2.1	Summary	27
6.2.1.1	Introduction	27
6.2.1.2	Conclusions and recommendations	28
6.2.1.3	General retrofit scheme	30
6.2.2	Plant description	32
6.2.2.1	Hudson Unit 2	32
6.2.2.2	Essex Unit 1	33
6.2.3	Hudson Unit 2 plant retrofit	36
6.2.3.1	Conceptual design	36
6.2.3.2	Operation	43
6.2.3.3	Electrical system	48
6.2.3.4	Control system	54
6.2.3.5	Water heating plant arrangement	61
6.2.4	Essex Unit 1 plant retrofit	65
6.2.4.1	Conceptual design	65
6.2.4.2	Electrical system	69
6.2.4.3	Control system	72
6.2.4.4	Water heating plant arrangement	73
6.2.5	Water treatment	77
6.2.5.1	Introduction	77
6.2.5.2	Make-up water flow rate	77
6.2.5.3	Make-up water quality requirements	78
6.2.5.4	Alternative treatment methods	80
6.2.5.5	Recommended treatment system	84
6.2.5.6	Wastewater treatment	86
6.2.5.7	Maintenance of water quality	87
6.2.6	Cost estimate	90
6.2.6.1	Summary	90
6.2.6.2	Direct cost	90
6.2.6.3	Other costs	92
6.2.6.4	Special considerations for Essex plant	92

Table of Contents (continued)

	<u>Page</u>
6.3 Intermediate Stage Plant(s) (Casturbine)	96
6.3.1 Purpose of plants	96
6.3.2 Unit selection	96
6.3.3 Plant layout	98
6.3.4 Plant piping schematics	100
6.3.5 Operation and controls	102
6.3.6 Plant construction	102
6.4 Peaking and Back-up Plants (Initial Development Phase of a Staged System)	104
6.4.1 Purpose of "heater plants"	104
6.4.2 Number and size of plants	104
6.4.3 Piping schematics	105
6.4.4 Plant layout	107
6.4.5 Operation and controls	109
6.4.6 Plant construction	111
6.4.7 Operating power requirements	111
6.5 Transmission and Distribution	112
6.5.1 General	112
6.5.2 Basis of economics calculations	112
6.5.3 Pumping cost	113
6.5.4 Piping cost	114
6.5.5 Heat loss	116
6.5.6 Pipe size selection and operating cost	120
6.5.7 Distribution piping	120
6.5.8 Transmission piping	128
6.5.9 System pressures & water circulation	131
6.5.10 System volume	133
6.6 User Connections	134
6.6.1 Hot water and hot air heating system connections	134
6.6.2 L.P. steam heating system connections	138
6.7 Alternatives to District Heating	145
6.7.1 Introduction	145
6.7.2 Individual heatpumps for heating and cooling	145
6.7.2.1 System selection and cost	145
6.7.2.2 Operating cost of individual heatpumps	148

Table of Contents (continued)

	<u>Page</u>
6.7.3 Air conditioning by a district heating system	149
6.7.3.1 Conventional cooling	149
6.7.3.1.1 Duration	149
6.7.3.1.2 Specific load and cost	149
6.7.3.1.3 Investment	149
6.7.3.2 Cooling from a district heating system	151
6.7.3.2.1 Three stage district heating	151
6.7.3.2.2 System layout and operation	151
6.7.4 Waste heat and/or solid waste recovery	156
6.7.4.1 Introduction	156
6.7.4.2 Acceptance criteria of an NDHS	156
6.7.4.3 Connection of outside heat sources	157
6.7.4.4 Series connected NDHS on the supply side	158
6.7.4.5 Parallel connected NDHS	160
6.7.4.6 Series connected NDHS on the return side	161
6.7.4.7 Incorporation in system studied	161
6.7.5 Small cogeneration and/or solid fuel burning plants	162
6.7.6 Solar alternative(s) to district heating	168
6.7.7 Nuclear district heating system supply to Camden residential areas from Salem Nuclear Generating Station	176
6.7.7.1 Introduction	176
6.7.7.2 Results and conclusions	176
6.7.7.3 Discussion	178
6.8 Landfill Gas Production	190
6.8.1 Background	190
6.8.2 Methane generation	191
6.8.3 Methane migration	193
6.8.4 Landfill gas extraction and utilization	193
6.8.5 Landfill gas production	196
6.9 System Operations	199
6.9.1 Heater plants alone	199
6.9.2 Heater plants plus partial retrofit of Hudson #2 Unit	200
6.9.3 Heater plants and combustion turbine plant	202
6.9.4 Heater plants and Hudson No. 2 Unit Phase II & III retrofit	203
6.9.5 Heater plants, combustion turbine plant plus Hudson No. 2 retrofit	205

Table of Contents (continued)

FIGURES

<u>Figure No.</u>		<u>Page</u>
6.1.1	Staged Development of District Heating System	8
6.1.2	Elementary Control of Heating Turbines	15
6.1.3	No title	20
6.1.4	Plant Load Durations of a Three Stage HTW District Heating System as a Function of Outdoor Temp. Frequencies	22
6.1.5	Power Plant D-H Load & D-H Water Temperatures v. Their Annual Duration	23
6.1.6	Hudson #2 Electric Generation vs. Fuel Input for Three Stages of Retrofit and Maximum Thermal Production	24
6.1.7	Hudson #2 Electric Capability vs. Thermal Production for Three Stages of Retrofit	25
6.2.1	Hudson Generating Station Unit 2 Heat Balance at Max. Throttle Flow & Maximum District Heating Load	37
6.2.2	Flow Diagram - Hudson Unit 2 - Plant Retrofit Extraction, Steam & Normal Drain	38
6.2.3	Flow Diagram Hudson Unit 2 Plant Retrofit District Heating Water, Condensate & Emergency Drains	39
6.2.4	Hudson Generating Station Unit 2 - Heat Balance at Maximum Throttle Flow - No District Heating	34,45
6.2.5	One Line Diagram - Hudson Unit 2 - Plant Retrofit	49
6.2.6	Equipment Arrangement District Heating Water Heating Plant Hudson Plant	62
6.2.7	Conceptual Piping Arrangement District Heating Water Heating Plant Hudson Plant	63
6.2.8	Conceptual Piping Arrangement - Existing Building & Tunnel District Heating Water Heating Plant Hudson Plant	64
		237

Table of Contents (continued)

	<u>Page</u>
6.2.9 Flow Diagram Essex Unit 1 - Plant Retrofit Extraction Steam & Normal Drain	66
6.2.10 Flow Diagram Essex Unit 1 - Plant Retrofit District Heating Water and Condensate	67
6.2.11 One Line Diagram Essex Generating Station	70
6.2.12 Equipment Arrangement District Heating Water Heating Plant Essex Plant	75
6.2.13 Conceptual Piping Arrangement District Heating Water Heating Plant Essex Plant	76
6.2.14 Boiler Output vs. Generation	47
6.3.1 3 Stage District Heating Development - Supply Areas & Plant Locations	97
6.3.2 Kearny #12 Combustion Turbine Retrofit Layout	99
6.3.3 Kearny #12 Combustion Turbine Heatrecovery - Flow Sheet	101
6.4.1 District Heating Plant Piping Schematics	106
6.4.2 District Heating Plant Layout	108
6.5.1 Annual Pumping Cost	115
6.5.2 Installed Piping Costs and Comparison with Other Estimates	117
6.5.3 Specific Heat Loss of Buried Prefab. Pipe	121
6.5.4 Annual Cost of 100 Ft of Piping and Economical Pipe Size Determination	122
6.5.5 Typical 1 Sq. Mi. Distribution in Jersey City	123
6.5.6 No title	124
6.5.7 Typical 1 Sq. Mi. Distribution in Newark	125
6.5.8 Typical Block of Multi-Family Row Houses - D-H Piping	127

Table of Contents (continued)

	<u>Page</u>
6.5.9 Typical Aboveground Pipe Supports	129
6.5.10 Crossing Over Obstructions	130
6.5.11 System Pressure Diagram	132
6.6.1 Customer Conversion Unit Schematics - Hot Air Heating	135
6.6.2 Customer Conversion Unit Schematics - Warm Water Heating (A)	136
6.6.3 Customer Conversion Unit Schematics - Warm Water Heating (B)	137
6.6.4 Customer Conversion Unit Schematics - Steam Heating (D-H ● Const. Temp.)	139
6.6.5 Customer Conversion Unit Schematics - Steam Heating w/Heatpump	142
6.7.1 Schematic System Operation for Absorption Cooling	152
6.7.2 Typical Air Conditioning Load Distribution	154
6.7.3 Alternative Methods of Connecting Waste Heat Recovery Plants to an HTW District Heating System	159
6.7.4 Heating Plant Options	163
6.7.5 Heating Plant Options	164
6.8.1 Gas Composition and Evolution in a Typical Landfill	192
6.8.2 Typical Test Well	194
6.8.3 No title	197

TABLES

Table No.

6.2-I	Makeup Water Flow Rates	78
6.2-II	Raw Water Characteristics	78

Table of Contents (continued)

	<u>Page</u>
6.2-III Makeup Water Quality Requirements	80
6.2-IV Cost Estimate of Hudson Unit 2 Plant Retrofit	94
6.2-V Cost Estimate of Essex Unit 1 Plant Retrofit	95
6.6-I Heat Balance of Heat Pump Assisted L.P. Steam User Connection	143
6.7-I No title	146
6.7-II Cooling Cost with Conventional Equipment per Sq. Ft. of Office or Commercial Space	150
6.7-III Assumptions	165
6.7-IV Small Cogeneration and/or Solid Fuel Burning Plants Evaluation	166
6.7-V Cost per million BTU Solar Alternatives	169
6.7-VI Heating and Hot Water Loads of Types of Housing	170
6.7-VII Annual Energy Production Figures, Solar Alternatives	172
6.7-VIII Size and Cost of Solar System Alternatives	173
6.7-IX Turbine Inlet Steam Conditions, Nuclear vs. Fossil	179
6.7-X District Heating Extraction Steam Conditions, Nuclear vs. Fossil	181
6.9-I Summary of Fuel Burned by Months for the Three Types of Supplies to the Fully Developed District Heating System - Hudson #2 Out for Maintenance for 8 Weeks between April & May	207
6.9-II Summary of Fuel Burned by Months for the Three Types of Supplies to the Fully Developed District Heating System - Hudson #2 Out for Maintenance for 18 Weeks between February & May	208

Table of Contents (continued)

VOLUME IV

	<u>Page</u>
7 COST ESTIMATES	
7.1 Methodology	2
7.2 Hudson Unit No. 2 Full Retrofit - $1,600 \times 10^6$ BTU/hr Heat Supply	11
7.3 Limited (Partial) Retrofit, Hudson Unit No. 2, 200×10^6 BTU/hr Heat Supply	22
7.4 Local Heater Plant and Kearny No. 12 Retrofit (Intermediate Plant) Cost Estimates	34
7.5 PSE&G Capital Costs of Conversion Schemes for Various Types of Customer Heating Systems	37
7.5.1 Design criteria	37
7.5.2 Customer conversion modules	37
7.6 PSE&G District Heating Transmission and Distribution Piping Installation Costs	42
7.6.1 Design bases	42
7.6.2 Method of Construction and Installation	42
7.6.2.1 Rural	42
7.6.2.2 Urban	42
7.6.2.3 Suburban	44
7.6.2.4 Right-of-Way	44
7.6.3 Determination of piping costs	44
7.6.3.1 Qualifications to estimate	44
7.6.4 Overall transmission and distribution system piping costs	45
7.6.4.1 Transmission system piping costs	45
7.6.4.2 Distribution system piping costs	47
7.7 Landfill Gas Supply Cost Estimate	52
7.8 Comparative Distribution/Transmission Cost Estimates	59
8 STAGED DEVELOPMENT SCENARIOS	
8.0 Introduction	73

Table of Contents (continued)

	<u>Page</u>
8.01 Conventional customer owned system	73
8.1 Scenario I - Berry's Creek District Heating System	75
8.1.1 Introduction	75
8.1.2 The development	75
8.1.3 Proposed D-H system	75
8.1.3.1 Hudson G.S. based system	82
8.1.3.2 Landfill gas based system	84
8.1.4 HTW distribution	86
8.1.5 Operation and maintenance	87
8.2 Scenario II - Berry's Creek & Harmon Meadows District Heating System	100
8.2.1 Introduction	100
8.2.2 The developments	100
8.2.3 Proposed D-H system	100
8.2.3.1 Hudson G.S. based system	101
8.2.3.2 Landfill gas based system	102
8.2.4 HTW distribution	102
8.2.5 Operation and maintenance	102
8.3 Scenario III Fully Developed District Heating System (Jersey City, Newark, Meadowlands)	115
8.3.1 Introduction	115
8.3.2 The supply areas	115
8.3.2.1 The Hackensack Meadowlands	115
8.3.2.2 Jersey City-Hoboken	116
8.3.2.3 Newark/Harrison	116
8.3.2.4 Other areas	117
8.3.3 Summary of D-H load potential	118
8.3.4 Proposed D-H system	119
8.3.4.1 Capacity	119
8.3.4.2 Heat supply sources	120
8.3.4.3 Spare capacity and firm supply	121
8.3.4.4 Heater plant installations	122
8.3.4.5 HTW transmission and distribution	124
8.3.4.5.1 Transmission	124
8.3.4.5.2 Distribution	125
8.3.5 Operating cost	126
8.3.5.1 Heat loss	126

Table of Contents (continued)

	<u>Page</u>
8.3.5.2 Pumping cost	126
8.3.5.3 Operating personnel	127
8.3.5.4 Maintenance and other cost	128
8.3.5.5 Other cost	128
 9 ECONOMIC EVALUATION	
9.1 Introduction	149
9.2 Economic Analysis Methodology	150
9.3 Economic Comparisons	150
9.3.1 Berry's Creek with a Hudson #2 retrofit	150
9.3.2 Berry's Creek without Hudson #2 retrofit	152
9.3.3 Berry's Creek plus Harmon Meadows	152
9.3.4 Fully developed system	155
9.4 Sensitivity to Variations in Capital Costs of Thermal Supplies	158
9.5 Sensitivity to Variations in Fuel Prices	161
 10 IMPACT ON FUEL USE AND ON THE ENVIRONMENT	
10.1 Fuel Utilization	165
10.2 Comparison of Fuel Consumption	166
10.2.1 Berry's Creek without a Hudson #2 retrofit	166
10.2.2 Berry's Creek with a Hudson retrofit	169
10.2.3 Berry's Creek plus Harmon Meadows	169
10.2.4 Fully developed system	169
10.3 Environmental Impact	176
10.3.1 Dispersion modeling for District Heating	180
10.3.1 Introduction	181
10.3.2 Input data for model	186
10.3.3 Model predictions	195
10.3.4 Supplementary report to dispersion modeling for district heating	201
10.3.4 Introduction	202
10.3.4.1 Methodology	202

Table of Contents (continued)

	<u>Page</u>
10.3.4.2 Discussion of result	203
10.3.4.3 Results of executing the climatological dispersion model (CDM) in order to assess the increments in sulfur dioxide due to district heating	207
10.3.5 Guideline on air quality models	210
 11 ALTERNATES TO CONVENTIONAL HEATING SYSTEMS	
11.1 Introduction	216
11.2 Selection of Alternate Heating Systems	216
11.3 Economic Comparison of Solar Thermal and Conventional Heating System	217
 12 CONCLUSIONS	222
 13 RECOMMENDATIONS	226

FIGURES

Figure No.

7.1 Customer Conversion Flow Diagram	40
7.2 Customer Conversion Unit	41
7.3 Transmission Piping	46
7.4 Typical Distribution Layout - Jersey City	49
7.5 Typical Distribution Layout - Newark	50
7.6 District Heating Piping for a Typical Row of Multi-Family Houses	51
 8.0.1 No title	76
8.1.1 Development Plan Stage One 1984	77
8.1.2 Development Plan Stage One 1985	78
8.1.3 Development Plan Stage One 1986	79

Table of Contents (continued)

	<u>Page</u>
8.1.4 Development Plan Stage One 1987	80
8.1.5 Development Plan Stage One 1988	81
8.1.6 Berry's Creek District Heating Plant Layout	89
8.1.7 Berry's Creek District Heating Plant Piping Schematics	90
8.1.8 Berry's Creek Center D-H from Hudson G.S.	91
8.1.9 Hudson G.S. No. 2 Unit Partial Retrofit for Berry's Creek D-H (Conceptual)	92
8.1.10 Berry's Creek Center Landfill Gas Based D-H System	93
8.1.11 Fuel Source Distribution in a Landfill Gas Supplied System	94
8.1.12 District Heating System - Berry's Creek Heat Sources and Transmission	95
8.2.1 Harmon Meadows D-H System	103
8.2.2 Berry's Creek Center & Harmon Meadows D-H from Hudson G.S.	104
8.2.3 Heat Supply Distribution w/Hudson #2 Unit Partial Retrofit	105
8.2.4 Berry's Creek Center & Harmon Meadows Landfill Gas Based D-H System	106
8.2.5 Fuel Source Distribution in a Landfill Gas Supplied System	107
8.2.6 1988 District Heating System - Berry's Creek & Harmon Meadows Heat Sources and Transmission	108
8.2.7 1993 District Heating System Berry's Creek & Harmon Meadows Heat Sources and Transmission	109
8.3.1 Regional Plan	129
8.3.2 Hudson G.S. Based District Heating System	130
8.3.3 Jersey City/Hoboken D-H Supply Area	131

Table of Contents (continued)

	<u>Page</u>
8.3.4 Newark Area of Potential District Heating	132
8.3.5 Transmission System	133
8.3.6 Transmission Mains Development between Hudson & Kearny G.S.	134
8.3.7 1988 District Heating System Heat Sources and Transmission	135
8.3.8 1993 District Heating System Heat Sources and Transmission Facilities	136
8.3.9 1999 District Heating System Heat Sources and Transmission Facilities	137
8.3.10 2001 District Heating System Heat Sources and Transmission	138
8.3.11 2003 District Heating System Heat Sources and Transmission	139
8.3.12 2006 District Heating System Heat Sources and Transmission	140
8.3.13 Full Development of the District Heating System Heat Sources and Transmissions	141
8.3.14 Full District Heating System Load and Capacity Expansion, 1984-2011	142
10.1 Berry's Creek Fuel Consumption without Landfill Gas	167
10.2 Berry's Creek Fuel Consumption with Landfill Gas	168
10.3 Berry's Creek Fuel Consumption with a Hudson #2 Retrofit	170
10.4 Berry's Creek and Harmon Meadows Fuel Consumption with Natural Gas	171
10.5 Berry's Creek and Harmon Meadows Fuel Consumption with Landfill Gas	172
10.6 Berry's Creek and Harmon Meadows Fuel Consumption with Hudson #2 Retrofit and Landfill Gas	173
10.7 Full System Fuel Consumption with Hudson #2 Retrofit and Natural Gas	174

Table of Contents (continued)

	<u>Page</u>
10.8 Full District Heating System Thermal Energy Supplied - By Direct Source 1984-2011	175
10.9 Full District Heating System Thermal Energy Supplied - By Fuel Type (Including Effect on Electric System Operation) 1984-2011	177
10.10 No title	179
10.11 Salient Geography of District Heating	182
10.12 No title	183
10.13 Grid Map	196
10.14 Grid Map	197
10.15 No title	204
10.16 Grid Map	205
10.17 Grid Map	208
10.18 Grid Map	209

TABLES

Table No.

7-I	Capital Cost Estimates Heat Supply	3
7-II	Capital Cost Estimates - Customer Conversion Unit (1981\$)	5
7-III	District Heating Transmission and Distribution Piping Comparison of Cost Estimates from Various Sources	6
7-IV	Cost Estimates	7
7-V	Cost Estimates	8
7-VI	Preliminary Cost Estimate - Hudson	20
		247

Table of Contents (continued)

	<u>Page</u>
7-VII Installed Capital Cost for Prefabricated Piping System (Material & Labor)	43
8.1-I Berry's Creek Project Implementation Forecast - Stage 1	76
8.1-II Meadowlands System (Berry's Creek Only) HTW Piping Installation Schedule	96
8.1-III Meadowlands System (Berry's Creek Only) Installations & Load Run Up Estimate	97
8.1-IV List of Annual Equipment Installation Requirements	98
8.1-V Meadowlands System (Berry's Creek Only) Annual Pumping Cost Estimate	99
8.2-I Industrial/Residential Development @ Rt. 3 & N.J. Tpke East Spur	110
8.2-II Meadowlands System (Berry's Creek Plus Harmon Meadows) HTW Piping Installation Schedule	111
8.2-III Meadowlands System (Berry's Creek Plus Harmon Meadows) Installations & Load Run Up Estimate	112
8.2-IV Hartz Mountain-Harmon Meadows 10 Yr Development Plan of D-H	113
8.2-V Meadowlands System (Berry's Creek Plus Harmon Meadows) Pumping Cost Schedule \$1000 per Annum	114
8.3-I Heat Source Installation Schedule	143
8.3-II Total District Heating System Incremental & Accumulative Load Growth Estimate	144
8.3-III Piping Installation Schedule	145
8.3-IV Piping Heat Loss Schedule	146
8.3-V Pumping Cost Schedule \$1000 per Annum	147

Table of Contents (continued)

		<u>Page</u>
9-I	Levelized Annual Minimum Revenue Requirements for Berry's Creek with a Partial Hudson #2 Retrofit (1983 \$ x 10 ³)	151
9-II	Levelized Annual Minimum Revenue Requirements for Berry's Creek without a Hudson #2 Retrofit	153
9-III	Levelized Annual Minimum Revenue Requirements for Berry's Creek and Harmon Meadows with Hudson #2 Retrofit (1983 \$ x 10 ³)	154
9-IV	Levelized Annual Minimum Revenue Requirements for Fully Developed District Heating System (1983 \$ x 10 ³)	156
9-V	Range of Capital Costs Used in Sensitivity Analysis (1981 \$ 10 ³)	159
9-VI	Levelized Annual Minimum Revenue Requirement for Fully Developed District Heating System Based on Low Range of Estimates (1983 \$ x 10 ³)	160
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 \$ x 10 ³)	162
10-I	Summary of Fuel Burned by Months for the Three Types of Supplies to the Fully Developed District Heating System - Hudson #2 Out for Maintenance for 8 Weeks between April and May	187
10-II	Summary of Fuel Burned by Months for the Three Types of Supplies to the Fully Developed District Heating System - Hudson #2 Out for Maintenance for 18 Weeks between February and May	188
10-III	Air Quality in New Jersey Compared with Air Quality Standards 1981	198
10-IV	Public Service Electric & Gas Company Total Heating Requirements by Customer Class	206
11-I	Levelized Annual Minimum Revenue Requirements for a Berry's Creek Solar Assisted Energy System Compared to a Conventional Heating System	219

Table of Contents (continued)

	<u>Page</u>
13-I District Heating Barriers to Implementation and Suggestions for Resolution	228

VOLUME V

APPENDIX A (Attachments to Section 2)

	<u>No. of Pages</u>
Newark/Harrison as Potential District Heating Area	115
Jersey City/Hoboken as Potential District Heating Area	53
Hackensack Meadowlands as Potential District Heating Area	22
Special Developments	4

VOLUME VI

APPENDIX B (Attachments to Section 6)

	<u>No. of Pages</u>
"Retrofitting Utility Power Plants for Cogeneration and District Heating," G.T. Kan, Stone & Webster Engineering Corporation & G.J. Silvestri, Jr., Westinghouse Electric Corporation	15
"Discussion of Specific Tax Laws and Regulations Affecting Certain Organizational Options"	46
"Extraction System Requirements," General Electric	72
"Steam Turbine Studies on Hudson 1 and Hudson 2, PSE&G, for District Heating Applications," prepared by G.J. Silvestri, Jr. and J.R. Polacheck, Westinghouse Electric Corp. Steam Turbine Generator Division	70

Table of Contents (continued)

VOLUME VII

APPENDIX C (Attachments to Section 5)

	<u>No. of Pages</u>
Heater Plant and Gas Turbine Plant Cost Estimates	
1. Heater Plant Summary and Basis of Estimate	
2. Gas Turbine Plant Summary and Basis of Estimate	9
Heater Plant and Gas Turbine Plant Cost Estimates	
1. Back Up Information for Heater Plant Cost Estimate	
2. Back Up Information for Gas Turbine Plant Cost Estimate	32
Original Estimate - Summary & Basis of Estimate (limited retrofit)	52
Revised Limited Retrofit Cost Estimate	4
"Yesterday's trash may be today's fuel," Sunday Star Ledger, June 27, 1983	1
Analysis of Relevant Tax Laws	23