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DISTRICT HEATING AND COOLING SYSTEMS FOR COMMUNITIES THROUGH POWER PLANT RETROFIT AND DISTRIBUTION NETWORK, CITY OF PIQUA, OHIO

MASTER

September 18, 1979

Work Performed Under Contract No. EM-78-C-02-4976

City of Piqua
Piqua, Ohio

Georgia Institute of Technology
Atlanta, Georgia

Hanselman Eskew & Associates
Piqua, Ohio

U. S. DEPARTMENT OF ENERGY

Division of Buildings and Community Systems

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EXECUTIVE SUMMARY

1.0 DEMONSTRATION TEAM

The goal of the Piqua, Ohio District Heating and Cooling Demonstration Project is to demonstrate the feasibility and efficiency of using cogenerated thermal energy from the City's Municipal Power Plant to provide residential, commerical and industrial space heating and cooling and satisfy other community energy needs as appropriate.

Specifically, the objectives are to:

(1) analyze and evaluate the technical, economic market and institutional feasibility of supplying cogenerated thermal energy to the City's potential customers;

(2) identify and evaluate alternative power plant and distribution system retrofit schemes;

(3) ultimately design and implement identified, feasible retrofit solutions;

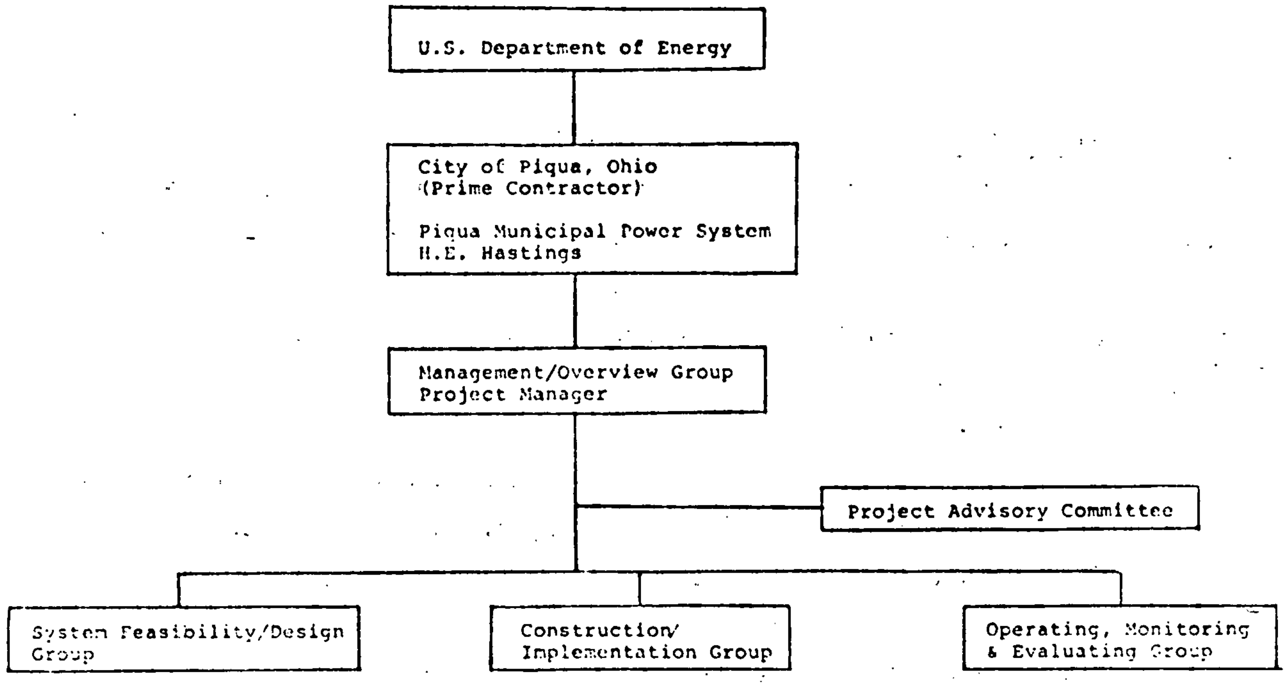
(4) demonstrate the transferability of the system and the approach to other communities throughout the nation; and

(5) efficiently utilize limited energy resources and further limit demand on scarce resources such as natural gas and oil.

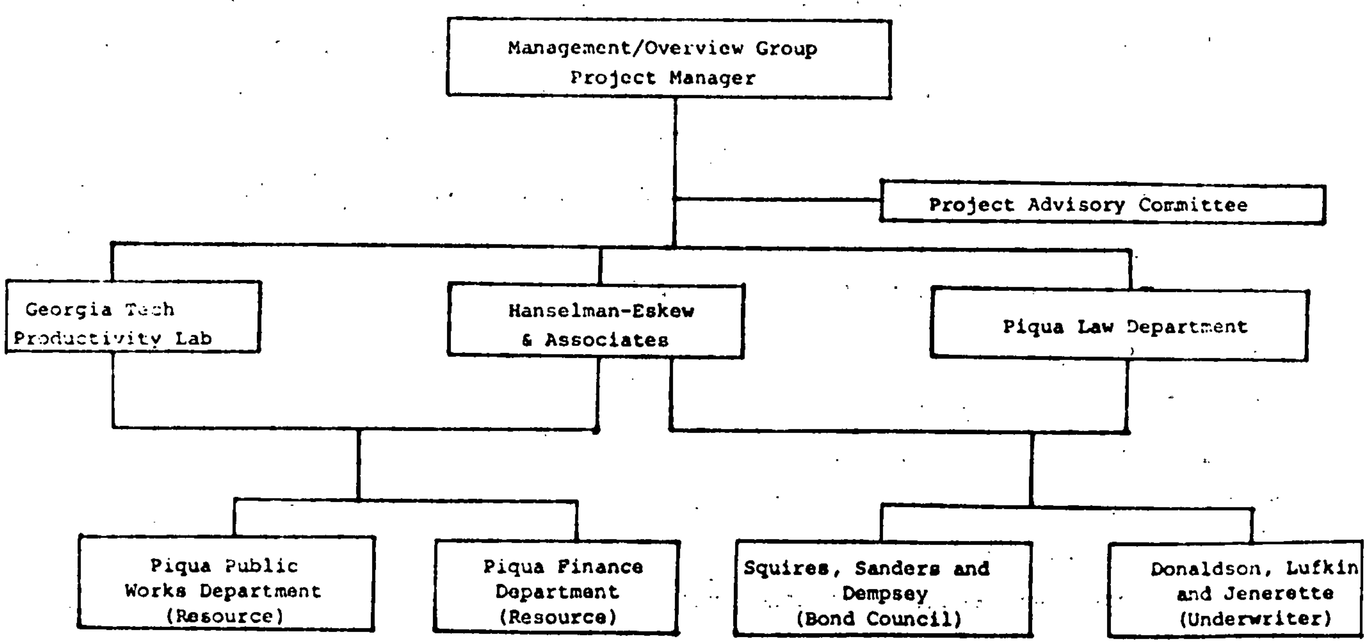
The City of Piqua, Ohio, owns and operates its own Municpal Power System, consequently, its operation is subject to the City Charter and the City's Code of Ordinances. The Municipal Power System is not subject to statutory regulation or control of the State of Ohio. The City and its power system must however answer to the voters. There are approximately 162 municipally owned power systems in the country which currently cogenerate with 77 of these located in the northeast and midwest regions of the United States. Many others could cogenerate.

DEMONSTRATION TEAM STRUCTURE

In order to accomplish the Phase I work program and in order to move forward to completion of all seven phases, the City assembled a highly qualified, experienced team to carry out the technical work. The charts on the following pages graphically present the demonstration team structure.



PHASE I -- PROJECT ORGANIZATION CHART



DEMONSTRATION TEAM MEMBERS

TYPE AND LEVEL OF EFFORT BY TASK/WORK ELEMENTS

TASK/WORK ELEMENTS	LEVEL OF EFFORT GT	HEA	PLD	PCS
Task 1 (Develop Team Work Plan Resource Allocation)				R
1.1 Organize Team	SE	PE		
1.2 Allocate Manpower	SE	PE		
1.3 Identify Interested Parties	SE	PE		
1.4 Propose Structure	SE	PE		
Task 2 (Identify Thermal Energy Source Market)				R
2.2 Project Plant	PE	SE		
2.3 Thermal Density Map	SE	PE		
Task 3 (Energy Market Analysis)				R
3.1 End User Identification	SE	PE		
3.2 Evaluate Service Areas	PE	SE		
3.3 Service, Market Penetration	SE	PE		
Task 4 (Power Plant Retrofit)				R
4.1 Alternate Schemes	PE			
4.2 Operating Modes	PE			
4.3 Assessment of Alternatives	PE			
4.4 Distribution Systems	PE	SE		
4.5 Scarce Fuel Conservation	PE	SE		

PE - Primary Effort
SE - Secondary Effort
R - Resource/Technical Assistance

GT - Georgia Institute of Technology
HEA- Hanselman-Eskew and Associates
PLD- Piqua Law Department
PCS- Piqua City Staff (Including City Manager, City Engineer, Power Plant Director, Finance Director, Secretary)

TASK/WORK ELEMENTS	LEVEL OF EFFORT			
	GT	HEA	PLD	PCS
Task 5 (Institutional Assessment)				R
5.1 Legal Implications	SE	SE	SPE	
5.2 Financial Alternatives	SE	PE	SE	
5.3 State/Local Regulatory Parameters	SE	PE	SE	
5.4 Social/Political Ramifications		PE		
5.5 Environmental Regulations	SE	PE	SE	
Task 6 (Preliminary Economic Analysis)				R
6.1 Power Cost Estimate	PE			
6.2 Annual Operating Cost	PE			
6.3 Revenue Potential	SE	PE	SE	
6.4 Economic Impact	SE	PE		
Task 7 (Proposal for Further Work)				R
7.1 Ranking Criteria	PE	PE		
7.2 Select 3 Alternatives	PE	PE		
7.3 Dem. Team Reevaluation	SE	PE		
7.4 Continued Work Proposal	PE	PE		
Project Administration/ Project Manager		PE		

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The task of designing the appropriate framework for consumer involvement and ultimate commercialization of district heating does not revolve around a specific committee, a single industry or rest solely with the elected decision-makers. Rather, it must be approached from the same basis that all public decisions are made, i.e. the fundamental components of public decision-making. The four components are:

(1) Information and Awareness
(2) Discussion and Debate
(3) Authority and Decision
(4) Monitoring and Feedback

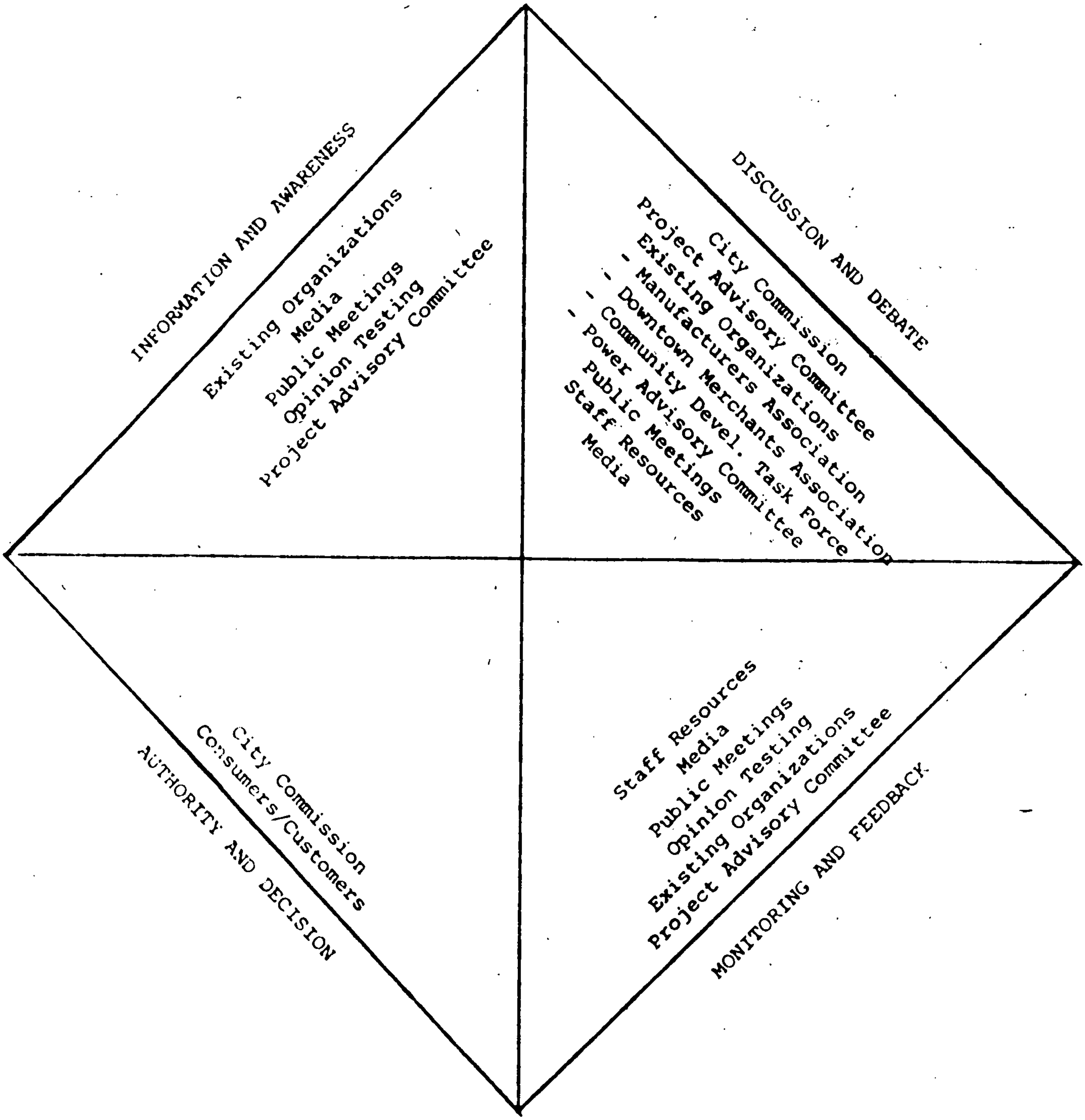
The following illustration, PUBLIC DECISION-MAKING PROCESS, restructures the Process Framework and Specific Involvement Mechanisms used to expand consumer involvement and lead to commercialization of district heating in the Piqua Study Area. The involvement mechanisms are:

(1) Opinion Testing
(2) Media
(3) Project Advisory Committee
(4) Existing Organizations
(5) City Commission
(6) Public Meetings
(7) Staff Resources

These mechanisms are employed during this Phase I process in that they provide the proper forum for consumer/decision-maker interaction, utilize appropriate information dissemination modes, and cast the commercialization of the district heating system within the appropriate context.

ILLUSTRATION

PUBLIC DECISION-MAKING PROCESS



Opinion Testing--was used as input to the Market Analysis, Technical Analysis and Institutional Assessment.

Piqua Daily Call--carried extensive coverage throughout the project. Residential, commercial, industrial and institutional issues were addressed. A copy of Piqua's Energy Future is folded herein.

Television and Radio--coverage followed the project continuously. Two radio programs were presented during Phase I. The Demonstration Team, Channel 13, and the vocational school produced a four part special series on district heating in Piqua. These color programs each ran twice.

Project Advisory Committee--in order to insure that various agencies, institutions and interest groups which directly and/or indirectly relate to the overall success of the project are identified and involved in the Demonstration Project during all phases, a Project Advisory Committee was formed and participating. The specific purposes of the advisory committee are:

(1) to provide representation and access to the Demonstration Project by specific community interest groups/agencies which will ultimately contribute to implementation of the project;
(2) to identify other parties/interest groups which will relate to the success of the project;
(3) to identify additional issues which should be subject to analysis within the context of the broader community;
(4) to review and discuss alternative Demonstration Project recommendations; and
(5) to insure that potential customer needs are addressed.

The Project Advisory Committee (PAC) meets periodically throughout the project period.

The PAC includes representation of the following groups:

- real estate
- commercial banking
- savings and loans
- local area-wide agencies
- Miami County

- Chamber of Commerce
- City Commission
- development/construction
- regional air quality agency
- industry
- merchants
- schools
- hospital

Interest Group Meetings--were held with the Chamber of Commerce, the Downtown Merchants Association, the Piqua Manufacturers Association, and the Community Development Task Force.

DEMONSTRATION TEAM MEETINGS HELD

Project Advisory Committee
Manufacturer's Association
Chamber of Commerce
Downtown Merchant's Association
Citizens Community Development Task Force
Regional Air Pollution Control Agency
Ohio Department of Energy
Public Utilities Commission of Ohio
Dayton Power and Light Company
Miami Conservancy District
Department of Housing and Urban Development
   Columbus Area Office
Piqua City Commission
Bond Council - Squire, Sanders & Dempsey
Underwriters-Donaldson, Lufkin & Jenrette
Piqua City Staff
   - Finance Director
   - Law Director
   - Public Utilities Director
Elliott Turbine Company
Rickwill
Perm-pipe
Johns Manville Company
TACO
ITT--Bell & Gosset
Goulds Pumps
Chicago Bridge & Iron
Babcock & Wilcox
Combustion Engineering

CONCLUSIONS

- THE EXISTING PHASE 1 DEMONSTRATION TEAM WORKED WELL TOGETHER AND WILL BE CARRIED OVER TO PHASE 2 WITH ADDITIONAL SUBCONTRACTOR PERSONNEL ADDED AS IS NECESSARY TO COMPLETE SPECIFIC TASKS.
- A DESIGN/BUILD FIRM WILL BE ADDED TO THE DEMONSTRATION TEAM TO ASSIST IN THE FINAL PLANNING STAGES.
- SUBCONTRACTS WILL BE LET FOR BOILER AND TURBINE TESTING IN PHASE 2.
- THE PROJECT ADVISORY COMMITTEE WILL BE EXPANDED TO INCLUDE LARGER REPRESENTATION FROM THE INITIAL SERVICE AREA.

2.0 CHARACTERIZATION OF DEMONSTRATION COMMUNITY - PIQUA, OHIO

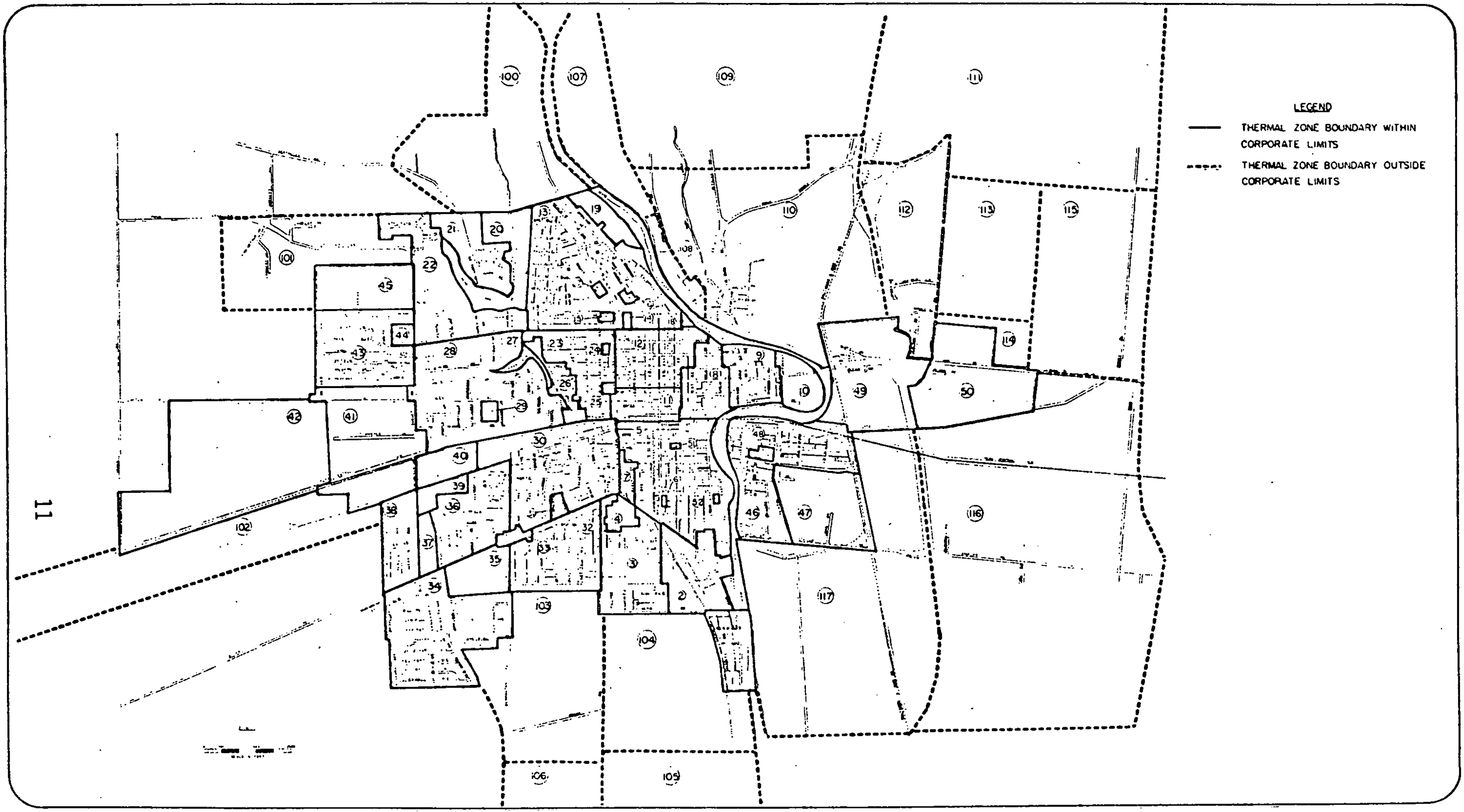
The concept of district heating and cooling through the distribution of thermal energy has been proven effective through many years of utilization in the primary-fuel-resource-poor Scandinavian countries. Those district heating systems have been developed over the period of many years, beginning as early as the 1920's, as the major metropolitan areas in those countries developed. However, in order to adapt district heating technology to cities in the United States, the need for an extensive retrofit approach is obvious.

An attractive source of thermal energy for distribution via the district heating network is cogeneration. Thus, the extensively developed power generation systems in the U.S. can be viewed as a huge and heretofore untapped thermal energy source if the appropriate retrofit approach can be developed. A major technical focus of this study was to analyze Piqua's existing power plant in order to determine the most efficient way to modify it so that it may serve as the thermal energy source, utilizing the cogeneration concept, for the District Energy System.

The City of Piqua is located in the midwestern region of the U.S., in southwestern Ohio and has a population of 23,000. It can be described as an industrial city with over 80 firms located in the City and surrounding area; most of which are engaged in the manufacture of durable goods. Sixty percent of the land uses is residential with institutional/commercial and industrial uses being eight percent and nine percent respectively.

Piqua was selected for this District Heating Study because is offers several advantages: a city owned electric utility with a variety of power units, one of which presently operates on a form of cogeneration cycle; several industrial firms that are now using process steam supplied by the municipal power plant; and an existing, though abandoned, steam distribution system in parts of the downtown area.

A comprehensive thermal density zone map was generated to identify homogeneous areas suitable for district heating and cooling through end-user retrofit. Fifty-two zones in the City of Piqua and eighteen outside the city were identified, reflecting areas of homogeneous building types and energy service requirements (see map following page). County Auditor's



PIQUA MUNICIPAL POWER SYSTEM

CITY OF PIQUA

MIAMI COUNTY OHIO

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

PREPARED FOR DEPARTMENT OF ENERGY CONTRACT NO. EM 78-C-02-[illegible]

TEAM MEMBERS: CITY OF PIQUA, OHIO
GEORGIA INSTITUTE OF TECHNOLOGY ENGINEERING EXPERIMENT STATION
HANSELMAN-ESKEW AND ASSOCIATES

THERMAL ZONES

CITY OF PIQUA & SURROUNDING COMMUNITY

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records were used to obtain square footages of structures in each zone and field surveys were used to obtain a total count of structures by type (use) and size. With the exception of several industrial and institutional cases, the zone is the smallest level at which data is assembled and analysis carried out.

Growth projections were carried out not only within the context of the Dayton SMSA but included State and National trends in industry and population and historical trends in electric consumption. The bulk of the projected growth of the City of Piqua will occur in the northeastern and western areas of the city. All four sectors (residential, commercial, industrial and institutional) of the community will experience growth in these areas and the future expansion phases of the District Heating System are targeted in these same directions to provide heating capability.

Piqua owns and operates its own municipal electric power system. The Municipal Power Plant is located in the southwestern corner of the City, sited along Main Street, approximately one and one-fourth (1 1/4) miles from the central business district, on a site adjacent to residential and industrial sectors of town. A principal advantage of this site to the feasibility study is the close proximity of the thermal energy source to a large potential thermal load in the residential and commercial sections of town.

The six steam generators (boilers) and seven turbine-generator units of the power plant are segregated into essentially two systems within the plant. Steam generator units 1 through 5 (combined capacity 480,000 lbm/hr) along with turbine-generator units 1 through 6 (combined capacity 30,500 kw) comprise what is referred to as the "low-pressure system." Steam generator unit 6 and turbine-generator unit 7 comprise a powerunit segregated from the other units and referred to as the "high-pressure system". All units in the Municipal plant operate on the Rankine thermodynamic cycle, modified with superheat. Normal day-to-day equipment operation on the low-pressure system involves steam generators 4 and 5 and turbine-generators 4, 5, and 6. Operating procedure is to fire the two steam generators (boilers) at approximately the same steam output rates to supply steam to the 400 psig header system. Turbines 4, 5, and 6 intake steam at 400 psig and 750°F from the header for power production.

Turbines 4 and 6 exhaust at a vaccum to condensers utilizing circulating water from the Miami River in a once-through cooling system. Turbine 5 exhausts steam at approximately 150 psig into a steam distribution system ultimately to be distributed to industries in the community with process steam requirements.

Normal equipment operation on the high-pressure system, with a design more typical of modern power plant design philosophy with form turbine extractions for staged feedwater heating, is to dynamically balance the operation of the boiler, auxiliaries, and turbine-generator internally on this segregated system.

In order to determine a baseline level of performance for the plant from which comparisons of the various cogeneration cycle efficiencies could be drawn, a heat balance analysis was performed. For the purpose of this preliminary feasibility study it was decided that a rigorous heat balance conforming to the ASME Power Test Codes would not be necessary, but that an approximate analysis based upon existing plant records and manufacturers recommendations for equipment operations would be suitable. It should be noted here that the purpose of this heat balance was to develop an estimate of the level of performance of the overall plant and its individual systems rather than to determine the exact level of performance of the major components such as the steam generators (boilers) or the turbine-generator untis. Utilizing the results of the low-pressure system heat balance, the thermal efficiencies were calculated for turbine-generators 4, 5, and 6 found to be 27.0%, 96.0%, and 27.3%, respectively. By summing the electrical outputs of the three turbine-generators, the rate of electrical energy production of the system was found to be 18,500 KW or 63.1 million Btu/hr. The quantity of heat added to the feedwater by the boilers was found to be 236.8 million Btu/hr. Using these values, the low-pressure system thermal effciency was determined to be 26.7%. Finally, in order to account for a measured boiler combustion efficiency of 80.0%, the above figure was adjusted to give an overall system efficiency of 21.3%. A similar heat balance and calculation was performed on the high-pressure system, yielding a turbine efficiency of 34.97% and an overall system efficiency of 29.72%.

In addition to the aforementioned steam-turbine units, the Municipal System also operates a 20,000 KW combustion turbine to supply peak electrical loads at an approximate efficiency of 21.0%.

The pattern of community electrical energy consumption during the base period 11/1/77 through 10/31/78 was documented by producing from the various available recorded data and billings a set of monthly load duration curves. Due to the fact that the Municipal system's base-load unit, the 20,000 KW unit 7, was out of service during this period, a radical alteration in system operating procedures was in effect. Therefore, in order to predict the operation of the full complement of equipment in meeting the community's energy demand during a typical annual cycle, a scenario for normal operating procedures was constructed, based on power plant operating experience, maintenance requirements, and the seasonal nature of the community energy demand profile, to be utilized in segmenting the monthly load duration curves according to each power unit's operational constraints. The end result of the load dispatch analysis is summarized in the table below which denotes the estimated time on line, power production, and operational statistics of each of the turbine-generator units in service at the plant.

A portion of the community thermal energy demand is also supplied from the Municipal Power Plant in the form of high quality (150 psig) steam. A set of load duration curves for the community steam demand was constructed in a manner similar to the electric energy demand pattern analysis. Total demand for the base period was 202,285,400 lbm; peak demand was 50,000 lbm/hr with a minimum of 3,000 lbm/hr and an average demand of 23,092 lbm/hr throughout the 8760 hour period.

ANNUAL PRODUCTION SUMMARY
BASE PERIOD 11/1/77 - 10/31/78

UNIT	HOL*	KWH GENERATED	CAPACITY FACTOR	OPERATIONAL AVAILABILITY
3	-	-	STANDBY	-
4	1460	7,450,000	67.12%	16.67%
5	4464	2,249,764	50.40%	50.96%
6	3291	20,580,279	62.54%	37.57%
7	8016	124,936,327	77.93%	91.51%
GAS TURBINE	735	1,965,430	13.37%	8.39%

PURCHASED POWER 27,768,000

TOTAL 184,849,800 KWH

The consumption of the significant quantities of primary fuel resources is implicit in the production, or more properly conversion, and distribution of energy for consumption in the community. The on-site consumption of primary fuels was estimated by first converting the unit efficiencies previously calculated to net heat rate form as summarized below, then applying the heat rates to the corresponding estimated production of each unit.

PIQUA MUNICIPAL POER PLANT
POWER UNIT HEAT RATES

UNIT	EFFICIENCY	NET HEAT RATE*
4	21.6%	16,749 $\frac{Btu}{KWH}$
5	76.8%	4,711 $\frac{Btu}{KWH}$
6	21.84%	16,565 $\frac{Btu}{KWH}$
7	27.98%	12,930 $\frac{Btu}{KWH}$
GAS TURBINE	21.0%	16,252 $\frac{Btu}{KWH}$

* NET HEAT RATE IS ADJUSTED TO REFLECT A 6% ELECTRIC POWER REQUIREMENT FOR STATION SERVICE FOR EACH UNIT.

A tabulation of all pertinent data was made for the twelve month period showing that, for the 157,181,800 KWH produced by the Municipal Power Plant under the predicted operations scenario, 2.122×10^{12} Btu's of primary fuel resources were consumed.

Also to be considered is the primary fuel consumption which may be attributed to the community steam demand. Based on the heat balance on the low-pressure system, it was assumed that boilers 4 and 5, indirectly connected to the steam distribution system through the plant's header system, supply steam to the community at their 80% coal combustion efficiency. Primary fuel consumption attributed to steam was then calculated for each of the twelve months in the base period. The results show that the 202,285,400 pounds of steam supplied from the plant during the base period represent a primary fuel consumption of 2.862×10^{11} BTU's.

Obviously, a distinction must be made in the form in which the total Btu's of primary energy were consumed. Steam turbine units 4 through 7 utilize sub-bituminous coal as their primary resource for energy conversion. In addition, boilers 4 and 5, which supply steam to the low-pressure system, also utilize the same coal source in supplying steam to the community distribution system. The gas turbine utilizes No. 2 fuel oil. Purchased power, which could ultimately be broken down to primary resource consumption according to the mix and average heat rate of the supplier utility, was not considered as on-site primary resource consumption for this analysis. The results of the breakdown reveal that, for the twelve month base period, primary fuel consumption was 100,700 tons of sub-bituminous coal and 229,800 gallons of No. 2 fuel oil in meeting full steam demand and approximately 85% of the total electrical demand of the community.

Long range electrical load projections are somewhat uncertain for the Piqua system due to relatively low population growth projections and unstable growth patterns in the last 5 years. Due to a reduced electric energy consumption pattern such as that shown in recent trends during 1977 and 1978, the study team elected to choose a more conservative 3 percent growth rate for the base case of the study.

Projections on steam system growth during the study period, based on the limited availability of steam from the plant and a decreased emphasis on steam sales by the utility management, assume a zero growth rate for the duration of the study.

CONCLUSIONS

- PIQUA IS A SUITABLE DEMONSTRATION COMMUNITY.
  - MUNICIPALLY OWNED POWER SYSTEM/PRIMARY FUEL IS COAL.
  - POWER PLANT AMENABLE TO RETROFITTING FOR DISTRICT HEATING IMPLEMENTATION.
  - RESIDENTS ARE INFORMED, INNOVATIVE AND GEOGRAPHICALLY STABLE.
  - DENSE RESIDENTIAL, COMMERCIAL AND INDUSTRIAL DEVELOPMENT PATTERNS EXIST WHICH ARE CONDUCIVE TO THE EFFECTIVE DISTRIBUTION OF THERMAL ENERGY.
  - GROWTH PROJECTIONS SUPPORT FUTURE DISTRICT HEATING SYSTEM VIABILITY AND EXPANSION.
- DEMAND FOR DISTRICT COOLING INSUFFICIENT FOR INCLUSION IN THERMAL NETWORK.

3.0 ENERGY MARKET ANALYSIS

The problem of predicting consumer behavior within the private market place as it relates to a specific good or service is not new. Every firm throughout the nation which markets goods on a national, regional or local scale faces this exact question. Simply installing a thermal distribution network and observing whether or not consumers actually hook up is obviously an unacceptable approach. Similarly, test marketing is equally out of the question in that the cost involved and producing even the first hook up is substantial. Therefore, an empirical approach to estimating the market is necessary--the application of multivariate analysis to forecast in advance the consumer response to thermal service for space heating and cooling and other energy needs.

Determining the market penetration for District Heating and Cooling involves the identification of the perceptual dimensions of the market and how thermal energy consumption decisions are perceived by various market segments with respect to these dimensions. From this information, insights can be obtained into the nature of penetration and when coupled with segment preference information, it can lead to product strategy development. The first step then was to determine some meaningful variables upon which to measure the characteristics/perceptions of the potential end-user. 390 residents and 272 merchants in the City of Piqua were exposed to public opinion questionnaires designed specifically as inputs to the market analysis. While the two questionnaires were treated as separate markets - each analysis employed the same methodologies and decision criteria--for this reason the following strategy summary will detail the residential market analysis and results. However, summary commercial statistics are presented in the Final Report.

Primarily, the residential questionnaire was designed to inventory present heating/cooling system types and conditions, demographics, and a variety of other attributes - resulting in a total of 104 questions.

Factor analysis, a descriptive statistical technique, was used in the analysis to summarize the large number of questionnaire items into a smaller, more concise body of information, (set of variables) which could subsequently be used as input into the discriminant analysis.

The specific objectives of factor analysis as applied in the district heating market analysis are:

(a) To establish functional relations between variables, factor analysis can be employed to isolate variables which it may not be possible to measure directly, but can be computed from a set of observable and directly measurable, but otherwise unsatisfactory measures.

(b) To produce a more parsimonious description within the study domain. For example, five questions related to permanency were reduced to one variable which measures the same thing.

(c) To test theories about interrelationships between variables. For example--is heating system maintenance related to willingness to invest in energy saving improvements?

(d) To categorize people or businesses into groups i.e. - innovators, status conscious, energy conscious.

(e) Finally, as a preliminary to discriminant analysis, to identify those variables which are most likely to be usefully included in a discriminant classification function.

The factor loadings portray the degree to which the individual items (questions from the public opinion surveys) represent a factor characteristic as a whole. For example--factor one shows very high positive loadings on attributes like number of years living in Piqua, number of years in this house, number of times resident has moved in the last five years, age of resident and length of current employment.

Each factor is then labelled by grouping those questionnaire items which load heavily on it and then interpreting the characteristics which these grouped items define. The table on the following page displays examples of factor variables composed from the residential survey.

EXAMPLE OF FACTOR ITEMS EMPLOYED IN DISCRIMINANT

Characteristic		
Privilegedness	Financial Capability relative to other community members	What is the head of household's annual income? (Q99)
	Perpensity to consume	Which of the following items do you own? (Q56)
Permanency	Locational permanency	How many years have you lived in Piqua? (Q85) How long have you lived in this house? (Q86) How many times have you moved in the last five years? (Q87) What is your age? (Q90) How long have you held this job? (Q96)
Cosmopolitanism	Geographical mobility	If you could live any place in the world you choose, where would you live? (Q61) How often do you travel outside the Piqua area? (Q62) How often do you travel outside the State of Ohio? (Q63) Have you ever had a passport to visit a foreign country? (Q64)
Product Innovativeness	Attitude toward innovative behavior	How do you feel about buying a new product for your home? (Q55)
	Self perception on represented innovator characteristics	In regards to new products on the market, I am: (first-last)

These labelled characteristics are subsequently used as input into discriminant analysis which is applied to determine the extent to which it might be possible to distinguish between "willing, unwilling, and unsure" connectors to the proposed district heating-cooling system. Discriminant analysis is a predictive technique which attempts to classify an observation on one of several a-priori groupings--"willing, unwilling, or unsure", dependent upon the observations individual characterizations. The primary use of discriminant analysis is to make predictions in problems where qualitive information "willingness to connect" is determined by quantitive data "demographic decisions, etc".

The resulting figures, baring unforeseen technical abatement, are employed as initial penetration rates on the zone and study-wide level. (See following page).

A second objective of the market analysis was to arrive at an appropriate methodology by which potential customers with unknown group membership can be identified as to their willingness to connect once the system is in operation. Discriminant analysis can derive such a classification function which permits classification of cases with unknown memberships.

The methodology for predictive application of this nature involves reducing the number of discriminant functions from three to two (willing, unwilling). Thus, respondents are once again evaluated, however, this time their scores on the independent discriminanting variables are multiplied by the revised discriminant coefficient, resulting in following post-operative penetration rates. The following Tables illustrate the residential and commerical results. (Further detailed in Final Report)

INITIAL RESIDENTIAL DISCRIMINANT ANALYSIS
CLASSIFICATION RESULTS

ACTUAL GROUP		NO. OF CASES	PREDICTED GROUP MEMBERSHIP 1	2	3
GROUP "willing"	1	216	129 59.7%	36 16.7%	51 23.6%
GROUP "unwilling"	2	77	16 20.8%	42 54.5%	19 24.7%
GROUP "unsure"	3	95	26 27.4%	13 13.7%	56 58.9%
UNGROUPED CASES		2	2 100.0%	0 0.0%	0 0.0%
TOTAL		390	173	91	126

POST-OPERATIONAL RESIDENTIAL DISCRIMINANT ANALYSIS
CLASSIFICATION RESULTS

ACTUAL GROUP		NO. OF CASES	PREDICTED GROUP MEMBERSHIP 1	2
GROUP "willing"	1	202	149 73.8%	53 26.2%
GROUP "unwilling"	2	42	14 33.3%	28 66.7%
UNGROUPED CASES		146	74 50.7%	72 49.3%
TOTAL		390	237	153

RESIDENTIAL

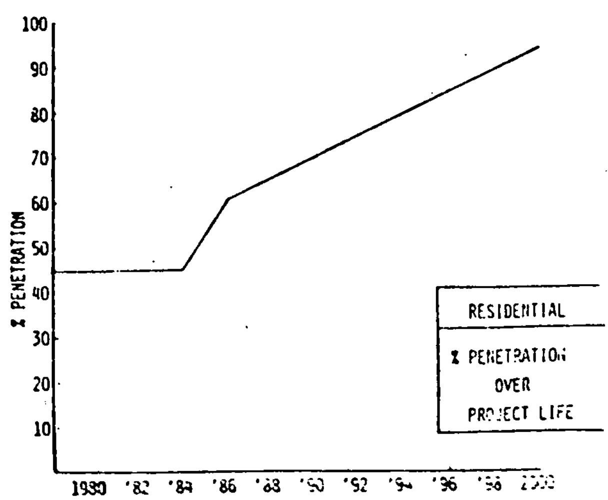
INITIAL PENETRATION BY ZONE

Zone #	Most Willing		Least Willing		Unsure	
3	26.7%		26.7%		46.7%	
5	27.5%		42.5%		30.0%	
8	50.0%		50.0%		0.0%	
9	40.0%		40.0%		20.0%	
11	40.0%		20.0%		40.0%	
12	40.0%		36.0%		24.0%	
13	28.0%		30.0%		42.0%	
21	20.0%		20.0%		60.0%	
22	60.0%		40.0%		0.0%	
23	45.0%		10.0%		45.0%	
26	0.0%		33.3%		66.7%	
28	45.0%		0.0%		55.0%	
30	50.0%		16.7%		33.3%	
32	35.0%		50.0%		40.0%	
33	0.0%		33.3%		66.7%	
34	85.0%		10.0%		5.0%	
36	55.0%		20.0%		25.0%	
38	50.0%		40.0%		10.0%	
39	0.0%		80.0%		20.0%	
43	90.0%		0.0%		10.0%	
46	60.0%		15.0%		25.0%	
49	80.0%		0.0%		20.0%	
50	100.0%		0.0%		0.0%	
101	80.0%		0.0%		20.0%	
103	60.0%		0.0%		40.0%	
109	20.0%		40.0%		40.0%	
110	0.0%		0.0%		100.0%	
111	80.0%		0.0%		20.0%	
112	60.0%		0.0%		40.0%	
116	40.0%		20.0%		40.0%	
TOTAL	44.4%	(173)	23.3%	(91)	32.3%	(126)

RESIDENTIAL

POST-OPERATIONAL PENETRATION BY ZONE

Zone #	Most Willing		Least Willing	
3	53.3%		46.7%	
5	52.5%		47.5%	
8	70.0%		30.0%	
9	50.0%		50.0%	
11	60.0%		40.0%	
12	68.0%		32.0%	
13	46.0%		54.0%	
21	20.0%		80.0%	
22	60.0%		40.0%	
23	75.0%		25.0%	
26	66.7%		33.3%	
28	45.0%		55.0%	
30	60.0%		40.0%	
32	60.0%		40.0%	
33	0.0%		100.0%	
34	80.0%		20.0%	
36	65.0%		35.0%	
38	40.0%		20.0%	
39	80.0%		20.0%	
43	90.0%		10.0%	
46	85.0%		15.0%	
49	40.0%		60.0%	
50	100.0%		0.0%	
101	20.0%		80.0%	
103	80.0%		20.0%	
109	60.0%		40.0%	
110	0.0%		100.0%	
111	100.0%		0.0%	
112	100.0%		0.0%	
116	100.0%		0.0%	
Study Area Wide	60.5	(236)	39.5%	(154)



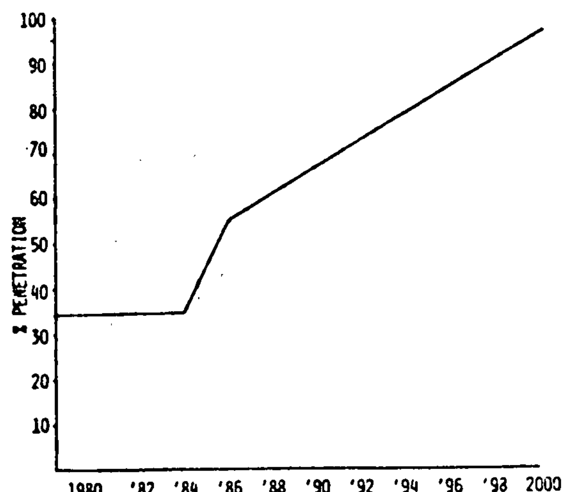
COMMERCIAL

INITIAL PENETRATION BY ZONE

Zone #	Most Willing	Least Willing	Unsure
5	22.9%	33.3%	40.7%
8	36.5%	24.8%	38.7%
11	33.3%	12.5%	54.2%
33	42.9%	24.3%	42.9%
40	18.8%	37.5%	43.8%
41	45.0%	20.0%	35.0%
49	100.0%	0.0%	0.0%
50	20.0%	24.0%	56.0%
110	42.9%	14.3%	42.9%
Study Area Wide	34.2% (93)	23.9% (65)	41.9% (114)

POST-OPERATIONAL PENETRATION BY ZONE

Zone #	Most Willing	Least Willing
5	37.0%	63.0%
8	53.3%	46.7%
11	62.5%	37.5%
33	71.4%	28.6%
40	56.3%	43.8%
41	80.0%	20.0%
49	50.0%	50.0%
50	60.0%	40.0%
110	35.7%	64.3%
Study Area Wide	54.8% (149)	45.2% (123)



COMMERCIAL

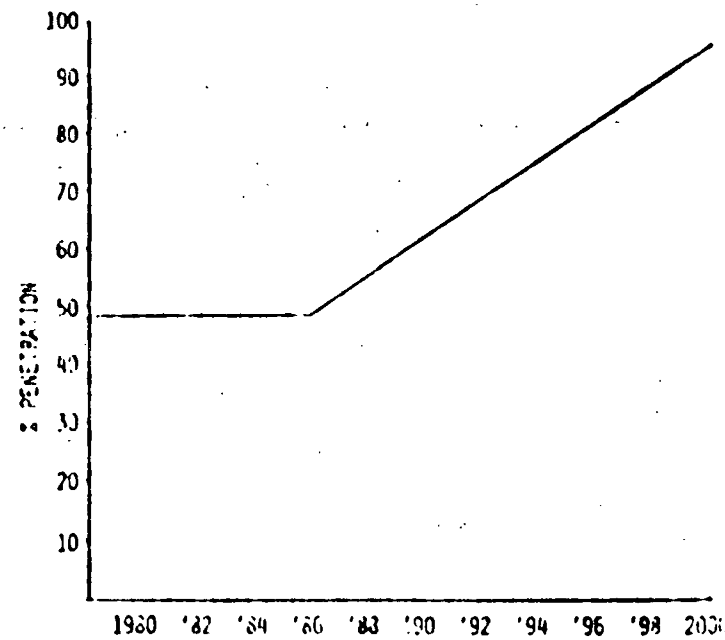
% PENETRATION OVER PROJECT LIFE

The issue of industrial market penetration is influenced by technical and economic facets, which, with the exception of cost per BTU, are not consistent decision criteria across the industrial community. This, coupled with an insufficient number of cases (52) for multivariate application at the zone level, necessitated viewing the industrial market for thermal energy in Piqua as a heterogenious population lacking parsimony in energy loads and service requirements, product mix and business nature.

Each of the 52 industries in the study area were asked to complete a set of questions concerning the social, political, financial and primarily the technical aspect of their operation as it relates to district heating. Current production schedules and processes, (inputs and outputs), energy consumption and costs were also inventoried, providing a complete profile of existing service requirements and costs in all modes of the specific industry's operation. These differentiating characteristics of the industrial portion of the district heating market coupled with the following observations are critical in understanding the industrial market and ultimately obtaining contracts for the delivery of thermal energy:

- with few exceptions, Piqua industries understand that they need and buy BTU's.
- the industrial community regularly participates in long term operational and financial planning.
- Piqua's industries frequently make capital investments and utilize debt capital for expansion of capacity and increases in efficiency.
- industrialists recognize and understand the inevitable sharp increases in energy costs instore during the coming years.

Based upon the industrial survey research and the technical analysis contained in Section 4.0, the penetration rates for district heating within the industrial market are set at 47% for both the initial period and the post-operational period. Industrial processing is accounted for in addition to this space heating load.



INDUSTRIAL--% PENETRATION
OVER PROJECT LIFE

THE INSTITUTIONAL MARKET

The market for thermal energy within the institutional sector is also analyzed and evaluated separately. The institutional sector of the market consists essentially of schools, hospitals, and other public buildings.

All schools and the Piqua Memorial Hospital were inventoried. In addition, a survey research instrument was applied to the public schools through the office of the School Superintendent in order to determine the specific service requirements of each public school building. Relying upon the technical analysis of the building and HVAC system characteristics of the schools and hospitals, a 100% penetration rate is established for this segment of the market. It is apparent from the analysis and especially from discussions with the institutional community that assuming reasonable in-building retrofit changes (nearly all buildings are presently heated with hot water systems), these specific institutional facilities will hook up immediately upon installation of the distribution system near their door.

CONCLUSIONS

- CONSIDERABLY HIGH PENETRATION RATE FOR DISTRICT HEATING DURING START UP PERIOD FOR BOTH RESIDENTIAL AND COMMERCIAL SECTORS.
- 250° HOT WATER SUFFICIENT TO SATISFY INDUSTRIAL NEEDS.
- INSTITUTIONAL SECTOR DISPLAYS 100% PENETRATION WHERE DISTRICT HEATING IS AVAILABLE.
- PRIMARY DECISION CRITERIA ASSESSED AS:
  - FINANCIAL CAPABILITY
  - ECONOMIC ADVANTAGE
  - PERMANENCY OF CONSUMER
  - PRODUCT INNOVATIVENESS
- PHASE 2 MARKETING STRATEGY WILL BE BASED ON TASK 3 RESULTS.
- SUCCESSFUL DEMONSTRATION PERIOD WILL SUBSTANTIALLY INCREASE POST OPERATIONAL PENETRATION RATES.

4.0 ALTERNATE RETROFIT SCHEMES

Examination of the plant and systems layout suggests several opportunities for retrofitting the Municipal Power Plant to serve in a cogeneration cycle as a source of thermal energy to a District Heating System.

The first and most obvious option is to increase the utilization of the high quality steam output by the backpressure turbine (No. 5). This option would involve redirecting the steam output from this turbine through a series of shell and tube heat exchangers for the purposes of generating hot water to distribute throughout the community. It is anticipated that the most effective and most flexible way to achieve this configuration would be not to connect the exhaust piping of this unit directly to the steam supply header for the heat exchanger, but to fabricate a cross-connection between the existing 150 psig steam header (which currently accepts the 150 psig steam exhaust of unit 5) and a steam supply header for the heat exchangers. Thus, with minimal modifications to the low-pressure system, a district heating sub-system could be retrofitted which would utilize steam at the base load capacity of the existing unit 5 to supply 50.152×10^6 Btu/hr to the district heating system at peak demand conditions, in addition to supplying the rated electrical load of 1000 KW.

Options two and three are functionally the same but are accomplished through different approaches. Each option would involve reconfiguring one of the remaining operational units on the low-pressure system. Option two would provide a steam source for the district heating system by modifying the existing condensing turbine No. 6 to exhaust steam at approximately 10 psig. Turbine modifications are of course contingent upon the recommendations of an engineering re-rate study performed by the manufacturer, but indications are that it is a feasible approach. Hot water generation for this option would again be achieved with shell and tube heat exchangers. With the appropriate modification to turbine No. 6 and the installation of district heating system heat exchangers to utilize the low-pressure steam exhaust from the modified unit, Option 2 could provide thermal energy to the system at the rate of 122.99×10^6 Btu/hr at peak load conditions. The rated capacity of unit 6 would be reduced by approximately 42%, down to 5779 kw from 10,000 kw, if the proposed modification were performed. The ratio of thermal energy made available to electric energy sacrificed is 6.8 Btu/Btu, a quite attractive benefit ratio.

Option three would provide a steam source for the district heating system by replacing the existing condensing turbine No. 4 with a new backpressure unit specified explicitly for service in this type application. Steam supply to shell and tube heat exchangers would be approximately 15 psig. This approach has the advantage over the modification approach taken in Option two of avoiding the sacrifice in foregone electricity to make available thermal energy at useable conditions. The new unit, specified for compatibility with the district heating system, can deliver the rated electrical load of 10,000 kw in addition to providing adequate thermal energy.

Thus, the equipment retrofit and heat exchanger system proposed as Option three could deliver thermal energy to the district heating system at a rate of 163,79 x 10^6 Btu/hr in the form of water heated to the required 250°F.

Option four would involve specifying, designing, and constructing a new 30 MW cogeneration unit in the empty bay in the south end of the Piqua Plant. This turbine unit would be specified with three uncontrolled extractions for feedwater heating and two automatic, variable extractions provided specifically for the cogeneration of thermal energy for the district heating system. This unit would have the advantage of being able to vary the electrical load on the unit and steam flow to the district heating system heat exchangers semi-independently. Also, portions of the capital expenditure for the construction of such a unit could be allocated to improvement of the electrical plant, an expansion in capacity that would no doubt be required at some point in the study period even if no cogeneration capacity were specified. The accompanying district heating system would be of a similar configuration to those of the foregoing options, employing shell and turbe heat exchangers to utilize the thermal energy from the steam extracted from the turbine. The construction of the totally new 30,000 kw cogeneration unit as proposed for Option four would make available to the district heating system thermal energy at a rate of 236.155 x 10^6 Btu/hr at rated conditions.

In light of the myraid of options available as thermal sources to a potential district heating system installed at the Municipal Power Plant, and considering the high potential within the community for attracting end-users to such a system, a phased approach to system construction encompassing each of the four aforementioned "hardware options" has been developed. It is this phased construction plan which forms the basis for the construction cost estimates for the in-plant modifications. The design and costing of the initial system provides for, in addition to adequate system capacity to immediately utilize the thermal supply capacity of option one, the expansion of the in-plant system to accommodate options four, three, and two, in order, as thermal demand grows. The cost estimates for each consequent system expansion will therefore reflect the incremental cost of bringing the system to full capacity as defined by the limits of the thermal supplies.

Construction cost for the initial phase including the D.H.S. building annex, main trunk piping inside the plant, expansion tank, electrical and equipment costs, is estimated at $966,336.00 for in-plant system construction, of which $902,984.00 is allocated to the district heating system and $63,352.00 is associated with modifying the No. 3 boiler to serve as a peak period steam supply source. For the purposes of the economic analysis, initial system construction is scheduled to start at the beginning of the study period, 1/1/80, and undergo a two year construction/start-up period. Commercial service will commence on January 1, 1983.

Construction for Phase II is scheduled to start in 1984, with the new expansion to commence operation in 1986. This phase involves the addition of the 30 MW cogeneration power unit in conjunction with the district heating system plant expansion. The incremental cost for this in-plant expansion is estimated as $563,177.00 for the district heating system and $29,157,800.00 for the Boiler-Turbine cogeneration cycle power unit. Of the costs associated with the new cogeneration unit, it is suggested that approximately 93% ($27,000,000.00) of the capital expenditure be allocated to the improvement of the electric plant, with the remainder to be allocated to the district heating system as the incremental cost of specifying the cogeneration capacity from the unit.

Construction for Phase III is scheduled for 1991 with operation to commence in 1993. Hardware Option 4 is implemented with the modification of the existing unit 6 to cogeneration capacity. The estimated construction cost for this incremental increase in capacity is $426,794.00, with approximately 78% ($332,816.00) going to D.H.S. construction and the remainder ($93,977.00) going to turbine modifications.

Construction of Phase IV is scheduled for 1994 with operations to commence in 1996. Hardware Option 3 is implemented with the retrofit of a new cogeneration turbine-generator set to replace the existing unit 4. The estimated construction cost of this incremental step in thermal capacity is $4,019,696.00, with approximately 92% ($3,683,626.00) of the capital cost going to replacement of the existing turbine. It was decided that the full cost of turbine retrofit would be borne by the district heating system since only a marginal increase in plant electrical capacity would result.

It should be emphasized that this scheduling is tentative and was assumed on the basis of the engineering and economic judgment of the team members. The schedule and the order in which the hardware options are phased is subject to change as the economic effectiveness of the project can be optimized through variations in the computer simulation.

The initial district heating system to be installed provides for the utilization of the option one system. System layout is as shown in Figure 1.

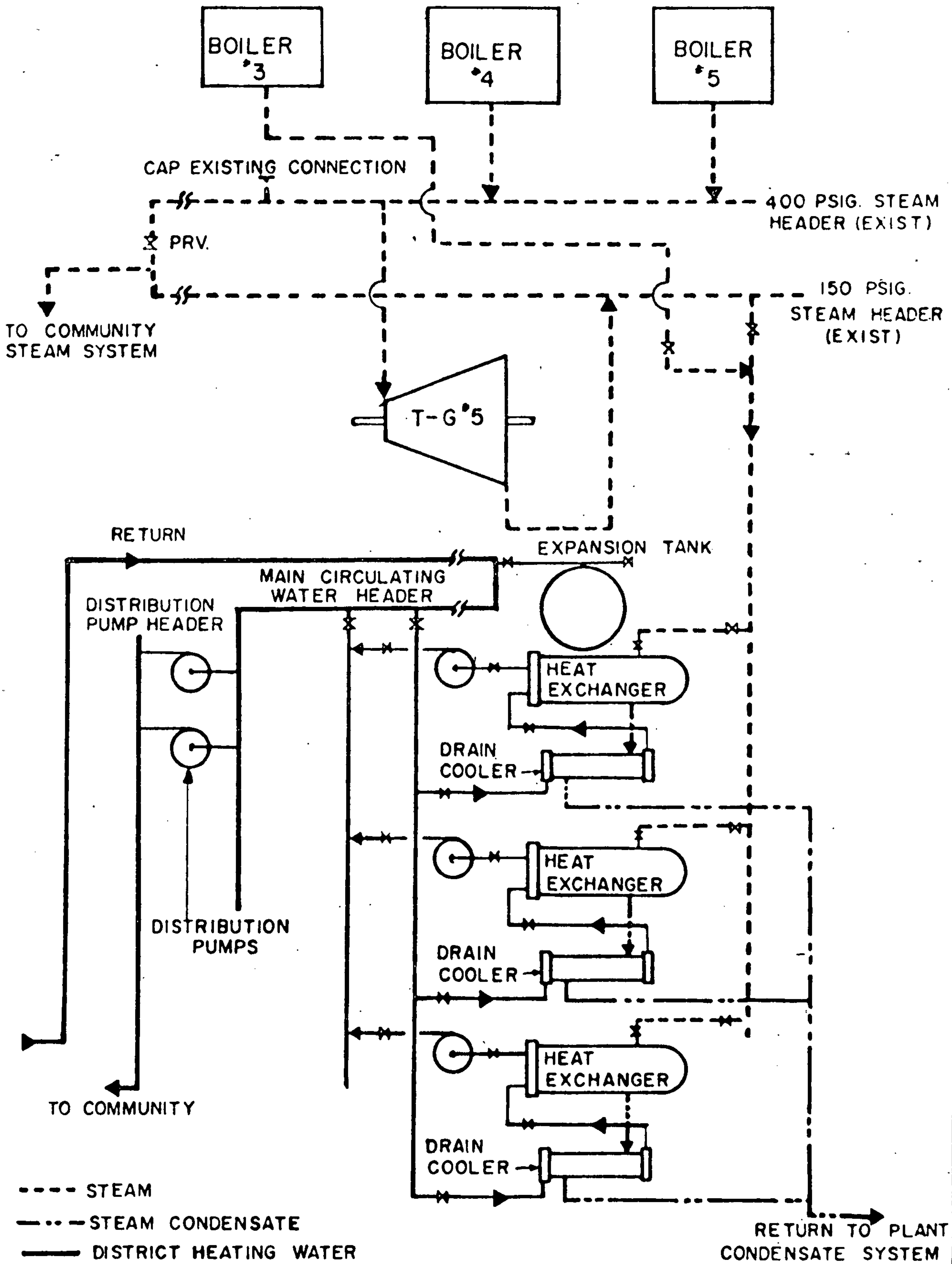

BOILER #3
BOILER #4
BOILER #5
CAP EXISTING CONNECTION
400 PSIG. STEAM HEADER (EXIST)
PRV.
TO COMMUNITY STEAM SYSTEM
150 PSIG. STEAM HEADER (EXIST)
T-G #5
RETURN
EXPANSION TANK
MAIN CIRCULATING WATER HEADER
DISTRIBUTION PUMP HEADER
HEAT EXCHANGER
DRAIN COOLER
HEAT EXCHANGER
DISTRIBUTION PUMPS
DRAIN COOLER
HEAT EXCHANGER
TO COMMUNITY
DRAIN COOLER
STEAM
STEAM CONDENSATE
DISTRICT HEATING WATER
RETURN TO PLANT CONDENSATE SYSTEM

FIG. 1

THERMAL AND ELECTRICAL LOAD-DURATION CURVES

Monthly load-duration curves of steam output and heating load output were derived from the system distribution records as previously described. Temperature dependent space heating loads were estimated using temperature duration data for the Dayton area. These, along with estimated domestic water heating requirements and thermal losses from piping distribution systems, were used to simulate thermal, load duration curves for the thermal components.

ANALYSIS OF POWER PLANT OPERATION

In order to perform the operational analysis on the monthly load data, a computer simulation program which takes all monthly inputs and simulates average daily conditions was developed.

For the purpose of simulating the dynamic response of the power plant to the changing thermal and electrical loads, a reasonable representation of the coincidence of daily thermal and electrical load cycles could be made by using a finite integral load simulation of electrical loads corresponding to thermal loads.

A model was constructed using finite periods of the load duration curves which approximates a typical daily cycle of concurrent thermal and electric loads.

The finite integral estimation procedure resulted in 24 periods per month for the 12 months of each year of the study period. The study period was then extended through load growth projections of the thermal and electrical systems for a period from 1981 to the year 2000.

Once a concurrent thermal and electrical load for each period was estimated, a determination of how the thermal and electrical requirements would be satisfied using the power plant's equipment was simulated.

Several unique considerations were included in the analysis of the Piqua Municipal Power Plant thermal and electrical load dispatch. These considerations included:

1) From an emergency back-up standpoint and to maintain the ability to extract and input power into the power grid it is desirable to maintain an interconnect agreement with the Dayton Power & Light Company.

2. The availability of multiple boiler and turbine sets and several interconnecting steam header situations within the power plant allow peak heating loads to be satisfied with excess available capacity in coal boilers in lieu of going to a direct fired oil peaking system. This may be untrue in large base-load power plants where turbine-generator sets and boilers are independently piped and controlled. The ability to accomplish this peaking by using existing boiler systems substantially reduces the amount of oil needed for oil type peaking boilers in the Piqua plant.

DISTRIBUTION NETWORK SCHEMES

The thermal transmission and distribution system should be capable of conveying the thermal energy produced in the cogeneration plant to the consumers economically and efficiently.

The final choice of a piping system to carry the transport media depended on the space heating and cooling requirements, the service hot water requirements, the transport media (hot water or steam), and on total cost considerations.

In the case of the City of Piqua, a study of the existing heating and cooling loads revealed that the cooling loads are relatively low. From this information it was concluded that separate chilled water lines were not economically feasible. Further, it appeared that the advantages of a three-pipe or four-pipe system that might be considered in new situations cannot be realized in the case of retrofitting an existing community system due to the increased costs of piping.

Therefore, a two-pipe hot water heating system was selected to provide a heating media only. By using separate heat exchangers at each consumer location, the main hot water supply can also provide domestic hot water needs. The hot water system may also serve as an energy source for absorption chillers for air conditioning where attractive.

Piping system configuration is designed to minimize capital investment costs, the thermal losses from the piping network and the energy required for pumping. In addition to these factors, allowance should be made for future increases in heating demand and for the expansion of the network since there will not be 100% penetration of the market in the initial stages of development.

PIPING DISTRIBUTION SYSTEM COST ESTIMATES

The most significant single cost component of the district heating system is the thermal distribution system. This component consists of trunk distribution piping, distribution mains and branches within each zone and run-outs from the distribution mains into the end-user buildings. The significance of the total distribution system cost is emphasized by European experience where distribution costs may range from 50 to 70 percent of total district heating utility capital costs.

In order to estimate total system costs in any given year the total distribution system was estimated in three components: 1) Trunk piping system, 2) Distribution and branch networks within a zone, and 3) Run-out piping from the distribution mains to the end-users. All piping system costs were estimated using a preinsulated direct buried piping system.

DETERMINATION OF INITIAL SERVICE AREA AND ESTIMATION OF SYSTEM GROWTH

For the district heating system to be successful both technically and financially it was anticipated that the initial service area needed to be composed of those zones providing the greatest thermal energy load per unit area. In that manner, thermal energy supplied to end-users could be made more cost effective by low initial investment in a piping distribution system.

It was also anticipated that the higher density zones would prove the system more favorable and that the positive impact of success in those zones would promote other subscribers to district heating in the immediate future. In essence, the initial service zones were chosen so that the system would have the best possible chances of economic success.

Table 4-8 is a summary of the zones chosen for initial inclusion in the service area. The table presents those zones included in the initial service area, their ultimate thermal loads per acre and the initial thermal loads based on the penetration factor determined from the Hanselman-Eskew survey.

TABLE 4-8

ZONE	NO. OF UNITS	ADJUSTED NO. OF UNITS	HEATING PENET FACT	COOLING PENET FACT	TOTAL AREA	TOTAL ADJ AREA	TOTAL HEATING	TOTAL COOLING	ADJUSTED TOTAL HEATING	ADJUSTED TOTAL COOLING
2-P	121	59.0	.400	.400	.109E+07	.525E+06	.122452E+09	.266497E+06	.107771E+08	.120146E+06
8-P	421	232.7	.550	.550	.257E+07	.141E+07	.191271E+09	.390543E+08	.115202E+09	.219198E+08
9-P	286	143.0	.500	.500	.425E+06	.212E+06	.266297E+08	.447051E+07	.133149E+08	.223526E+07
10-P	33	18.7	.400	.400	.410E+06	.197E+06	.452395E+08	.418695E+06	.217150E+08	.198046E+06
12-P	482	327.0	.600	.600	.938E+06	.638E+06	.580730E+08	.969315E+07	.394896E+08	.659134E+07
14-P	18	18.0	1.000	1.000	.707E+05	.707E+05	.619836E+07	.127770E+07	.615436E+07	.127770E+07
15-P	1	1.0	1.000	1.000	.219E+05	.219E+05	.175500E+07	.347600E+06	.175500E+07	.347608E+06
16-P	6	3.3	.550	.550	.671E+05	.369E+05	.565199E+07	.110276E+07	.316971E+07	.656519E+06
17-P	1	1.0	1.000	1.000	.439E+05	.439E+05	.332050E+07	.696050E+06	.332050E+07	.696650E+06
18-P	9	4.3	.400	.400	.174E+06	.833E+05	.195172E+08	.0	.936027E+07	0.
20-P	1	1.0	1.000	1.000	.107E+05	.107E+05	.866467E+06	.170444E+06	.866467E+06	.170444E+06
25-P	1	1.0	1.000	1.000	.142E+06	.142E+06	.101580E+09	.224930E+07	.101580E+08	.224560E+07
52-P	1	1.0	1.000	1.000	.474E+05	.474E+05	.360000E+07	.753000E+06	.360000E+07	.753600E+06

In the initial service area, the significant milestone which must be reached is the installation of the first major trunk distribution piping main from the power plant to a point on the north side of the city adjacent to the Miami River. The terminal point of this line was deemed a pivot point from which the distribution system could be expanded to meet additional loads and respond to the market for thermal energy. This pivot point becomes the key from which future distribution mains and transmission lines are extended. The initial service area is presented in Figure 4-25.

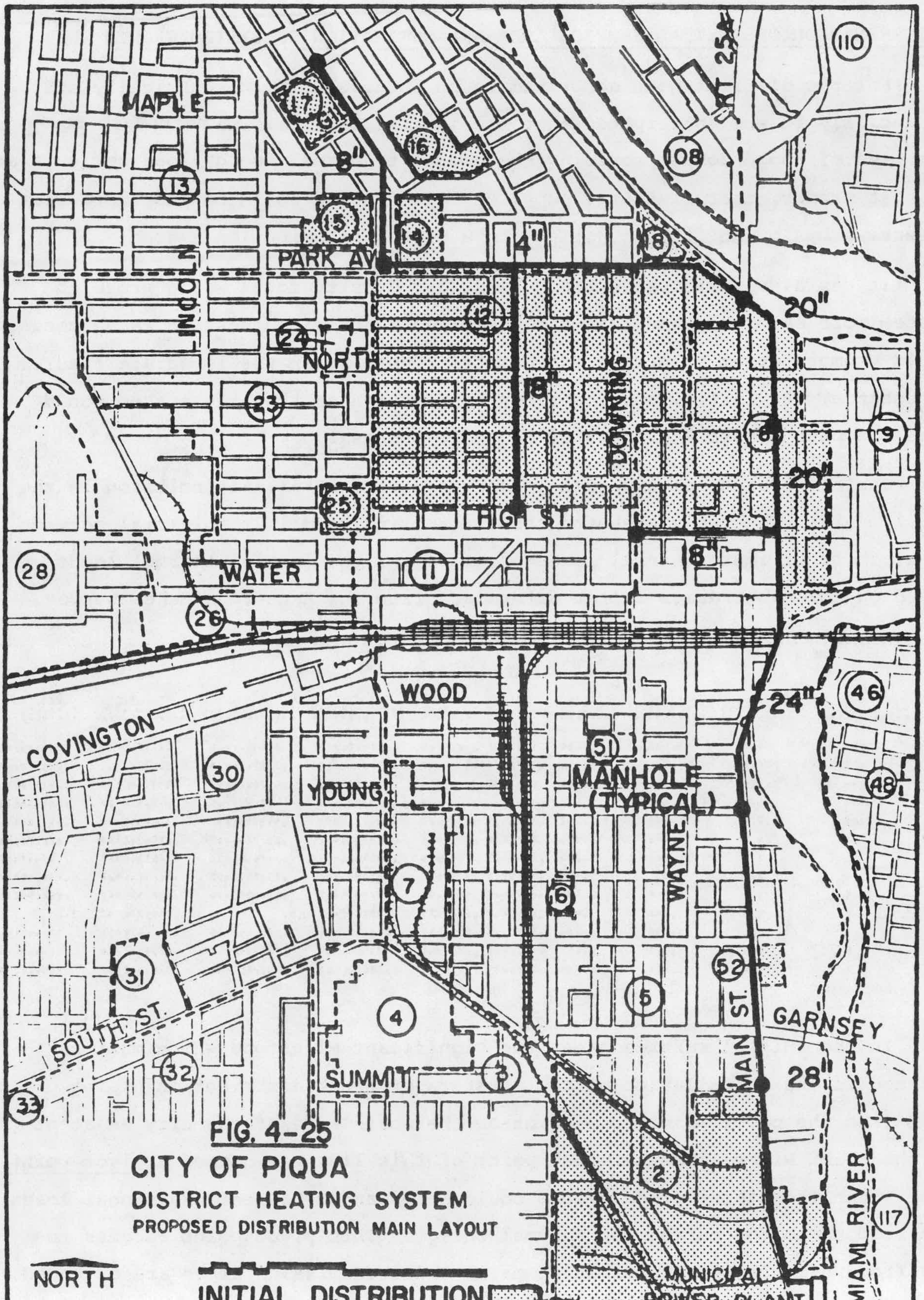


FIG. 4-25
CITY OF PIQUA
DISTRICT HEATING SYSTEM
PROPOSED DISTRIBUTION MAIN LAYOUT

INTERFACE WITH END-USER

In order to interface the district heating system with the typical end-users in the service area a general retrofit and connection criteria was developed.

A criteria for the design and operation of building systems connected to the district heating system is required in order to obtain maximum utility from the district heating system, minimize overall costs, and provide for the safety of building occupants. These criteria are as follows: 1) Energy from the district heating system will be exchanged on the end-users' premises through a water-to-water heat exchanger. 2) Sufficient pressure differential will be provided between the district heating mains to force water through a reasonable series of valves, metering devices, heat exchangers, and associated equipment without the need for additional pumping. 3) The water returned from building systems to the district heating system must be a minimum of $80^{O}F$ cooler than supply water temperature.

SCARCE FUEL CONSERVATION POTENTIAL

The district heating system and power plant retrofit for cogeneration offers Piqua a significant opportunity to alter energy use patterns within the community and to conserve scarce fuels. In Piqua's case, all end-user's within the service area would normally rely on natural gas or electricity for the energy needs which could be supplied by the district heating system.

In order to evaluate scarce fuel conservation potential, the operational analysis data generated by our computerized load simulation of the power plant under the conventional configuration and the cogenerating configuration was used.

The energy consumption for gas fueled appliances in the conventional plan was determined for the heating and cooling requirements projected by the computerized load estimate. An efficiency factor of 65 percent was used for combustion equipment.

A comparison of fuels consumed in the initial year of system operation (1983) and final year (2000) is presented as Table I.

TABLE I

ANNUAL FUEL CONSUMPTION

	CONVENTIONAL SYSTEM (10^9 BTU)	DISTRICT HTG. SYSTEM (10^9 BTU)	NET SAVINGS (10^9 BTU)
1983 (INITIAL)	2,957	2,466	491
2000 (TOTAL SERVICE AREA)	6,861	6,010	851

CONCLUSIONS

- Phased approach to system construction encompassing Options 1 through 4 developed for implementation.
- Two pipe hot water system found to be most feasible for distribution.
- Thermal energy can be delivered by 1983.
- Piqua will maintain tie-in with Dayton Power & Light power grid.
- No affect on utility capacity.

District heating system realizes significant conservation of scarce fuels (natural gas).

- End-user interface with District Heating System developed to obtain maximum efficiency from central system minimum expense to end-user.

5.0 INSTITUTIONAL ASSESSMENT

The City operates under and is governed by its Charter which was first adopted by the voters in 1929, and which has been and may be amended by the voters from time to time. The City is also subject to some general laws of Ohio which are applicable to Chartered Home Rule cities. In addition, the City may exercise all powers of local self-government under Article XVIII, Section 3 of the Ohio Constitution. The Charter provides for a Commission-Manager form of city government.

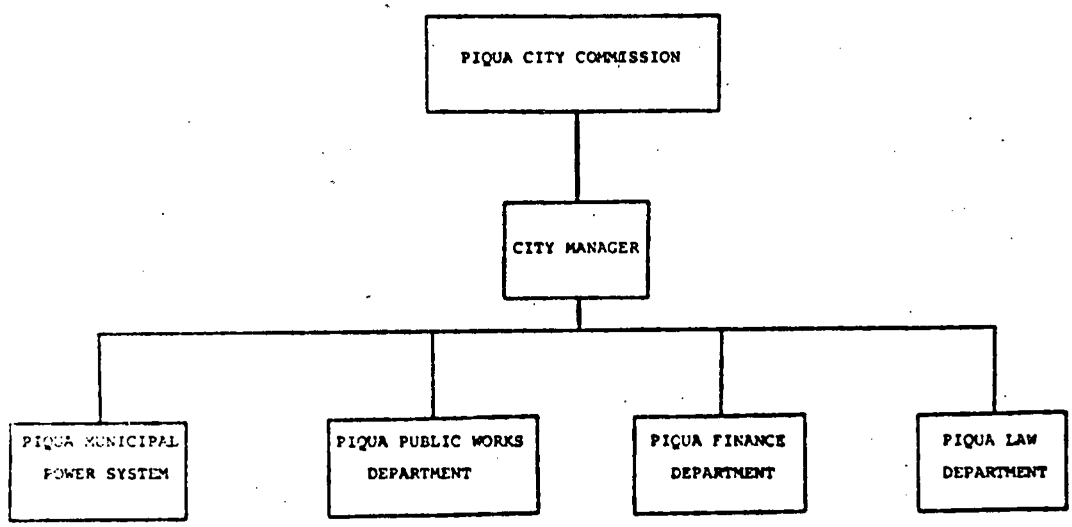
Legislative authority is vested in a five-member Commission, with all of the members elected at large. The members are each nominated from wards, and serve four-year terms. The Commission enacts ordinances and resolutions to provide for, among other subjects, City services, tax levies, appropriations of money, borrowing money and licensing and regulating those engaged in business and trade. The Commission also has the power to fix compensation of City officials and employees. The presiding officer is the Mayor who is elected at large from the members of Commission, for a four-year term; the Mayor serves as head of the City for all ceremonial purposes, and is a participating member of Commission. The Charter establishes certain administrative departments; pursuant to Charter provisions, the Commission may establish divisions thereof or additional departments.

The chief executive and administrative officer of the City is the Manager who is appointed by the Commission to serve at its pleasure. The City Manager may be removed by a vote of a majority of the members of the Commission.

The Manager appoints the directors of the several departments of the City to carry out administrative responsibilities. The major appointed officials are the Directors of Power Systems, Public Works, Finance and Law. The Commission also has the power to appoint members to a number of boards and commissions.

The current elected City officials and major appointed City officials are listed on the following page.

Elected Officials	Name of Incumbent	Beginning Service Date	Expiration Date of Present Term
Members of Commission:			
Mayor	James Henderson	1/1/76	12/31/79
Vice-Mayor	Joseph. C. Goetz	1/1/68	12/31/79
	Charles Tyler	9/7/78	12/31/79
	Cletus Peltier	1/1/74	12/31/81
	Robert Von Aschen	1/1/78	12/31/81
Appointed Officials			
Manager	Frank Patrizio, Jr.	1/15/79	at Commission's pleasure
Director of Power Systems	Houston E. Hastings	9/19/77	at Manager's pleasure
Director of Public Works	Ray N. Miller	3/28/77	at Manager's pleasure
Director of Finance	Robert N. Slagle	6/26/78	at Manager's pleasure
Director of Law	Stephen E. Klein	10/30/78	at Manager's pleasure



CITY OF PIQUA
ORGANIZATIONAL STRUCTURE

LEGAL

The legal assessment of the City of Piqua and its Municipal Power System's ability to proceed with the District Heating and Cooling Project requires reiteration of the basic point--the City of Piqua is a Chartered Home Rule city constituted under the authority of the Ohio Constitution, and as such is not subject to most of the laws which govern private corporations and public, investerowned utility corporations. The nature of the Piqua Municpal Power System influences nearly all legal, ownership, institutional, and financial issues which are subject to the consideration of this District Heating Feasibility Analysis and Evaluation. Specific legal opinions on the following issues are presented in the Final Report:

(1) Public Utilities Commission of Ohio

> "Briefly, then, it is my opinion, and you are so advised, the chapter 4905, R.C. (general powers of the PUCO) does not apply to the Piqua Power Plant . . ."

(2) Ohio Power Siting Commission

> "Whether or not a Certificate must be ultimately applied for, a Letter of Intent must be submitted. In fact, one of the stated purposes of this Letter of Intent is to qualify jurisdictional questions with respect to replacements of existing facilities with like facilities, substantial additions or other jurisdictional questions."

Pursuant to the Demonstration Team's letter of inquiry, the Ohio Power Siting Commission stated:

> "We understand that the proposed project will not effect generating capacity at all but rather will enable the City to use cooling water discharge from the generation of electricity to provide space heating and domestic hot water to nearby customers. Please be informed, therefore, that inasmuch as this capacity of the City's power plant will not be affected by the proposed conversion to cogeneration, the Ohio Power Siting Commission does not have jurisdiction in this matter. The City may proceed with the proposed project without obtaining OPSC approval."

(3) Boundaries of Certified Electrical Suppliers

"In summation, it is my conclusion and you are so advised that Sections 4933.81 through 4933.90 of the Revised Code are not applicable to the District Heating and Cooling Project for the following reasons:

1. The District Heating and Cooling System does not fit the definition of an "electric supplier";

2. The District Heating and Cooling System does not provide "electric service" as that term is defined;

3. The formulation of boundaries according to "distribution lines" has no practical application to the District Heating and Cooling System; and

4. The application of these statues to municipal utilities would violate Article XVIII of the Ohio Constitution."

(4) The Statutory Mandate to Serve All

"Therefore, it is my opinion, and you are so advised, that neither constitutional nor statutory restrictions exist which would fetter the sound judgement of the City of Piqua by mandating public utility service to all inhabitants without qualification."

(5) The Municipal Power System's Relationship to the Area Gas Suppliers Dayton Power and Light

"In all probability no successful cause of action can be framed under the circumstances which could prevent or hinder competition between the District Heating and Cooling System and other utilities or customers. Clearly, these traditional types of action are inapplicable here because no unfair competition is evident."

Further, the second claim can be dismissed in that:

"Clearly such license to create a competing municipally owned utility within the district of a privately owned but franchised utility demonstrates the conclusion that any existing energy supplier cannot prevent the growth of the proposed District Heating and Cooling System."

(6) Piqua has the Authority to Proceed with the Project

The City of Piqua's ability to proceed is not incombered by any constitutional or statutory restrictions. The Law Director's opinion states:

"Therefore, it is my opinion and you are so advised, that the City of Piqua possesses an authority, free of constitutional or statutory restrictions, to implement the proposed District Heating and Cooling System."

END-USER FINANCING

The primary method of financing the district heating retrofit (in plant work and installation of the distribution system) will be through the issuance of mortgage revenue bonds--self liquidating debt. General Obligation Bonds should be considered as their use relates to:

- the district heating projects broad, longterm impact on general community economic viability
- general investment in the city's future
- easing the initial years front-end burden.

The retrofit of the individual structures will depend upon the ability of the structure owner to assemble the capital required to accomplish the retrofit. Many sources of capital are available, and it is expected that the vast majority of retrofits will be performed relying upon traditional sources of money.

The residential survey indicated that slightly over 45% of the home owners would use cash-on-hand or savings to finance an energy saving improvement of five hundred dollars or more. It is assumed that for actual financing, this estimate should be lowered due to consumers' imperfect knowledge of cost of retrofit and imperfect knowledge of the future market conditions. For these reasons, a conservative estimate would be that approximately 15% will retrofit using cash or savings; the remaining 85% will require financing of one form or another.

Several bankers and loan officers in Piqua were presented with this scenario, and all agreed that financing retrofits would present no problems to their institutions. In fact, they expressed a willingness to participate in lending funds for short-terms ($\pm$ five years) at interest rates around 11%. The bankers stated that loans of this type could generally be processed as signature loans and would not require mortgages to be written as in a home improvement loan. Home improvement loans will also be available.

Although lending institutions have expressed interest in lending money and support the project, it is fully understood that the local lenders will not be able to make loans in support of the full 85% of the retrofits, due to household/business financial conditions. For this reason, other sources of financing have been analyzed as alternatives to end-users. The following indicates sources of capital either available or potentially available to aid in financing end-user systems.

(1) Tax Credits/Incentives

(2) Low Interest Loans for Residential Retrofit (i.e. FHA)

(3) Low Interest Loans for Commercial Retrofit (i.e. Small Business Administration)

(4) Basic or Matching Grants (i.e. CDBG)

CONCLUSIONS

- No legal or institutional barriers to implementation of District Heating System.
  - PUCO has no legal authority over the Piqua Municipal Power System.
  - OPSC has no authority over PMPS.
  - Piqua is not subject to the statutory mandate to serve all.
  - No conflict with PMPS relationship to area gas supplier.

- System financing through issuance of mortgage revenue bonds.

  Lending institutions agree to provide favorable end-user financing assistance.

  Piqua CDBG program can assist low-income retrofit financing.

6.0 ECONOMIC ANALYSIS

The following outline discusses the components considered in determining the amount of financing (and consequently the total revenues and debt service load needed) required to carry the district heating project over the study period. These costs and charges are inputs to the Donaldson, Lufkin & Jenrette Municipal Bond model or are calculated within the model.

CONSTRUCTION COST--considers all elements related to the power plant and distribution system construction-specifically included are:

- materials
- labor
- contingencies
- subcontracts
- overhead
- profit
- engineering & consulting fees
- permits

SITE ACQUISITION--no additional land is required to carry out the Piqua district heating project as currently structured.

FINANCING FEES AND CHARGES--are costs related to the development, preparation, sale and execution of the required debt instruments.

- bond council
  - fees
  - expenses
- financial consultants
  - fees
  - expenses
- underwriter
  - average takedown
  - underwriter's fee
  - expenses and travel
  - management
  - prospections, preparation and printing

- bond rating
- advertising
- bond printing, signatures and fiscal agent
- underwriter's council
- underwriter's financial/feasibility consultant

INTEREST--both interest charges and interest proceeds are considered.

- actual interest rate or bond yield
- capitalized interest
- interest receivable
  (construction and all reserve funds)

FUNDS AND OTHER "ACCOUNTS"--must be included as required by the underwriter, securities ratio/agencies and investors

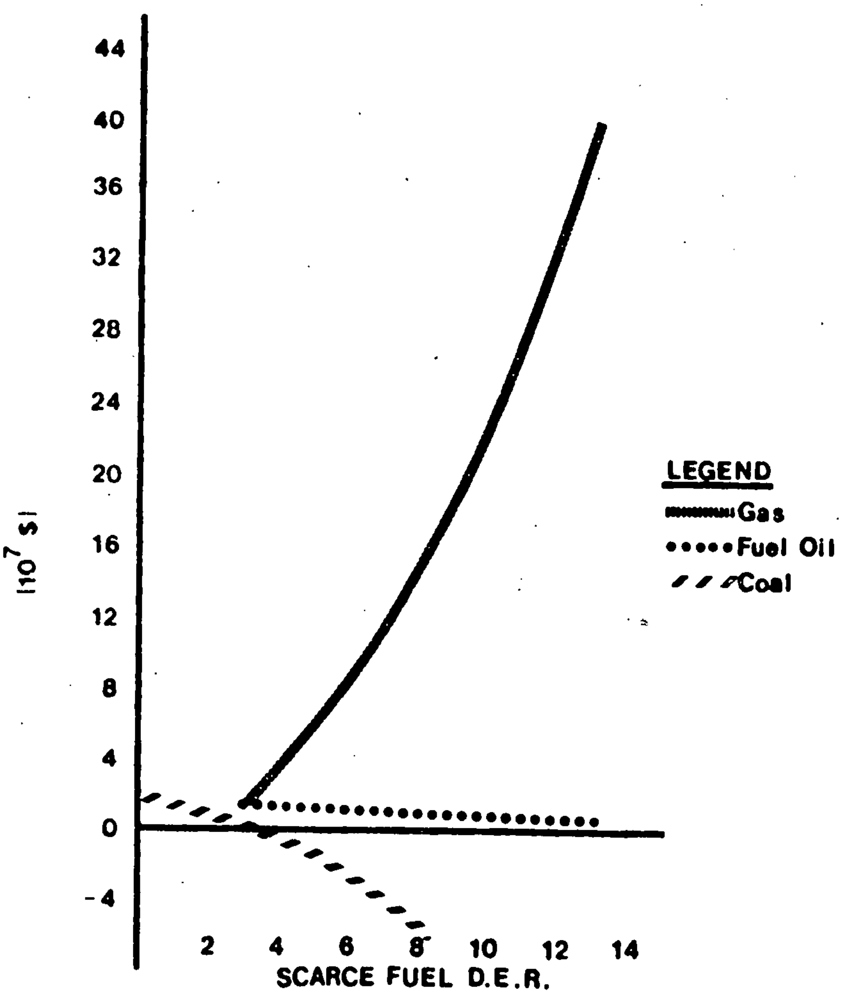
- debt service reserve fund
- coverage ratio

Three alternative financing options were identified for input into the D L & J Model. Option #1 delivers cogenerated thermal energy to customers in January, 1983. A-rated serial bonds with 25 year maturities are assumed-with 4 issuance phases occuring during the project period. The cumulative debt service pay out schedule results in relatively low debt service during the initial or "start up" years and builds, with the highest payments occuring between 1996 and 2008. Although Option #1 offers the advantage of relatively low front-end costs - Phase II costs are deferred to later years where natural gas price increases are expected to be greater.

DISCOUNTED PRESENT VALUE NET BENEFITS

$1000

Inflation 8% Discount 6.75% Escalation: Fuel Oil 3% Coal 0%		Inflation 8% Discount 6.75% Escalation: Natural Gas 3% Coal 0%		Inflation 8% Discount 6.75% Escalation: Fuel Oil 3% Natural Gas 3%	
Escalation of Natural Gas:		Escalation of Fuel Oil:		Escalation of Coal:	
3%	13,928	3%	13,928	0%	13,928
4%	33,733	4%	13,712	1%	8,962
5%	56,405	5%	13,409	2%	3,294
6%	82,354	6%	13,003	3%	-3,176
7%	112,046	7%	12,472	4%	-10,563
8%	146,013	8%	11,793	5%	-18,995
9%	184,858	9%	10,939	6%	-28,622
10%	229,267	10%	9,878	7%	-39,609
11%	280,018	11%	8,575	8%	-52,149
12%	337,994	12%	6,986	9%	-66,458
13%	404,195	13%	5,065	10%	-82,781

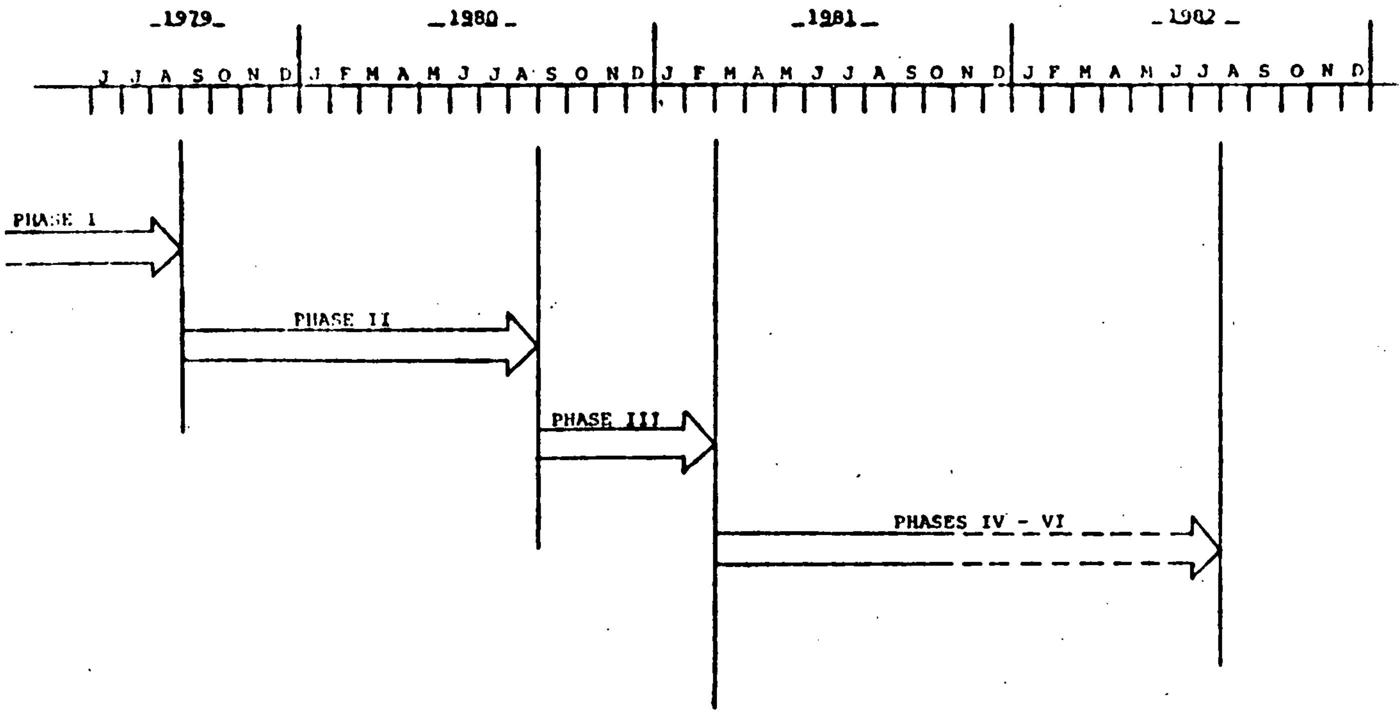


CONCLUSIONS

- NET SAVINGS WITH IMPLEMENTATION OF DISTRICT HEATING
  - RESULTS VERY SENSITIVE TO ESCALATION OF NATURAL GAS AND COAL.
  - INSENSITIVE TO VARIATIONS IN OIL ESCALATION RATES.
- NO ADDITIONAL LAND IS REQUIRED TO CARRY OUT THE PIQUA DISTRICT HEATING PROJECT.
- ULTIMATE FUEL SYSTEM SAVINGS OF 851×10^9 BTU'S ANNUALLY.
- PHASE 2 WILL EXAMINE ALTERNATIVE STAGING OF NET SERVICE AND CASH FLOW.

7.0 Phase II Scope of Work

SCHEDULE OF WORK FOR PHASE II AND FUTURE PHASES



Objective

The objective of this phase of the project is to: (a) establish the Preliminary Feasibility and Conceptual Institutional Arrangements; (b) establish the technical feasibility of the most promising Demonstration Project uncovered in Phase 1; (c) establish the institutional arrangements and framework required to bring this alternative to demonstration; (d) conduct a technical feasibility analysis of the most technologically attractive Demonstration Project identified.

The aforementioned Phase 2 tasks are set forth below and the Contractor shall perform said tasks in accordance with its proposal to DOE to continue to Phase 2 as defined in this project Phase 1 Final Report, except as hereinafter modified.

Task 2 Load and Service Area Assessment

Characterize service area by electric and thermal densities, and develop the thermal and electric diurnal, seasonal, and annual load duration curves for each.

Characterize service area in relation to degree-days heating, average heating season temperature, number of heating days, and design temperature.

Evaluate the City of Piqua's annual load growth relative to growth projections.

Re-evaluate operating projections, service requirements, and cost performance for confirmation or revision over the life of the project.

Reassess potential energy savings and scarce fuel savings (therms and BTU/yr) attributable to Demonstration Program for a typical annual operating cycle.

Develop a full scale district heating marketing program applicable within the service area. The marketing effort shall be targeted toward zones and customers (residential, commercial, industrial) identified in Phase 1. One result of this task is to secure firm, individual customer commitments of sufficient scale to support the anticipated interim construction capital investment.

Secure industrial, commercial, institutional, and residential sign-ups for district heating service on a case by case basis.

Plan for interim district heating service anticipated in latter stage of Phase 2. This shall include the planning and feasibility evaluation necessary to proceed with interim service to those customers using steam to hot water convertors connected to the existing steam distribution system.

Task 3 Technical Assessment

Based on Phase 1 results select optimum retrofit scheme based on expected growth and sensitivity to energy prices.

Characterize operating characteristics cost and the establishment of provisions for future growth.

Select distribution system development pace and power plant capital investment to optimize system feasibility through the matching of debt service loads and thermal and electrical demands.

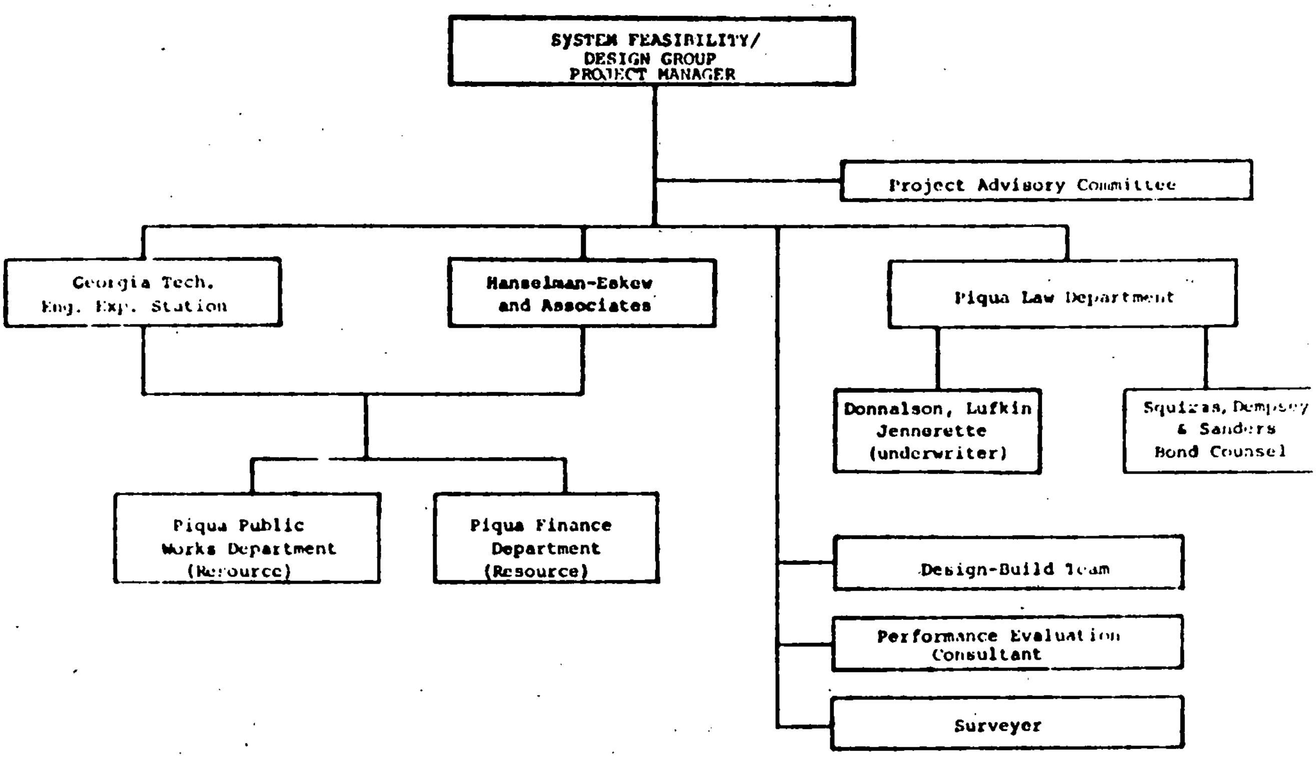
Scope of Work for Phase 2

Task 1 Develop a Detailed Work Management Plan

Develop detailed Work Management Plan to accomplish objectives of Phase 2.

Provide a pert chart, a cost for each task, a milestone chart, a manpower resource requirement plan, a definition of the corporate and program organizational structure, and allocation of responsibility for performance of required tasks.

PHASE II -- PROJECT ORGANIZATION CHART



Determine distribution system line sizes and insulation requirements. Provide outline specification for distribution piping and insulation. Estimate distribution heat losses ($BTU/ft.^2$ and total).

Survey proposed routing of main distribution lines for initial installation along center line of the pipe system. Determine right of ways, and locate underground utilities, identify interferences and property lines. Prepare a topographical map of initial distribution system route.

For determining capital cost, update the distribution system zone level costs from actual distribution system routing proposals and line size determination in the initial service area.

On the basis of the above update information on soil conditions as related to corrosion, drainage, and acceptability to buried pipe.

Verify assumptions made with respect to boiler and turbine performance in Phase 1 through boiler performance and turbine rating studies to determine effects of retrofit. Establish modes of operation and establish control scheme of cogeneration plant with interfacing of existing plant control scheme.

Conduct and document an investigation of domestic and foreign products in order to assure potential customers and installers of the availability and cost of district heating equipment.

Develop end-user outline specifications for use by domestic manufacturers to estimate cost of producing district heating equipment. Assemble a work book on piping materials, heat exchangers, water heaters, controls and meters.

Provide comprehensive heat and material balance along with flowsheet for retrofitted plant.

Provide summarized tabulation of salient features of plant description and operating parameters.

Task 4 Economic Assessment

Finalize thermal and electric rate structure. Quantify and qualify the detailed operating and debt-service costs within context of formulating thermal and electric rate structure for customers within the Piqua community. Rate structure shall include cost impacts for end-user retrofit.

Survey representative buildings in initial service areas to determine the extent of retrofit required including the costs and barriers of retrofit. Compare representative utility bills for these buildings relative to projected thermal energy cost by district heating.

Prepare a comprehensive summary of fuel and electricity price projections applicable to the district heating area based on the best information available from reliable sources. Place particular emphasis on the price of scarce fuel (natural gas and oil where applicable). Select probable price projection ranges acceptable to the decision makers who will be responsible for the decision to proceed with construction.

Based on the selected price projection ranges, analyze the economics of the District Heating System using a methodology familiar to the decision makers. Also, provide two proforma income statements and balance sheets in normal accounting format for each alternative considered. These should reflect the most attractive and least attractive economics within the probable price projection ranges for fuel and electricity. Support all assumptions with appropriate data and include sufficient documentation of computer programs employed to permit a numerical check of results.

Task 5 Institutional Assessment

Identify any additional legal questions and possible resolution not addressed in Phase 1. These questions shall focus upon the preparation of necessary/required opinions and instruments in support of such activities as the design-build RFP/contract, customer hook-up forms, Bond Prospectus, ancillary easements, right of way agreements, and operation of district heating.

Determine by in-house study the possible impact on gas rates for remaining users in Piqua as a consequence of displacing gas and depriving the local gas distributor of customers as a result of implementing district heating. Determine impact on local gas distributor in regard to lost revenue.

Analyze environmental impact of converting the primary heating fuel of Piqua from natural gas to coal. Assess and quantify the microclimatic effects, long term degradation of environmental air quality, and impact of current air pollution abatement plans on the project. Identify any corrective actions required to meet forseeable pollution standards and include in the plans for system implementation.

Analyze and evaluate both the technical and economic issues related to the installation of air quality control equipment. Prepare preliminary plans based upon the analysis.

Develop a local code which will provide standards for end-user connections to the district heating system. Develop technical specifications, identify permit procedures, and prepare outline procedures for district heating installation inspection.

Task 6 Staffing Requirements

Develop scope of work for a Design/Build team member participation in all phases of Phase 2.

Solicit proposal for Design/Build Team. The Design/Build Team shall participate with the project team in developing construction time schedules, construction cost estimates, preliminary schematic plans and be prepared to proceed with future phases of the project.

Identify, qualify, and characterize the manpower skills and knowledge required for the continued developmental (market) operation and maintenance of the district heating system. In addition to ability to assess and evaluate site specific customer retrofits, economic justifications, and the commitment of appropriate equipment, the staff shall be capable of developing applicable operating procedures, policies for a uniform accounting system, meter readings, and collections.

Task 7 Finance Arrangement

Appropriate work product from both Phase 1 and 2 shall be reorganized and assembled within an Engineering/Financial Feasibility Analysis for utilization by both the City's bond counsel and underwriters for inclusion in the Bond Prospectus.

Task 8 Inspection of Operational District Heating System-

As part of the technology survey, three members of the Project Team shall inspect several operating district heating plants in certain Scandanavian countries selected on the basis of similarity to the Piqua demonstration plant. The purpose of the inspection is to obtain information to augment the current state-of-the-art in the United States since technology transfer of operational procedures including problems associated with community scale cogeneration district heating plants has not been fully disseminated.

Foreign manufacturers of district heating equipment shall be contacted and their manufacturing capability assessed. The end-product of this Task shall be the garnering of critical, first-hand knowledge of district heating systems' design and operating practices; thereby optimizing the buildability and ultimate viability of the Piqua District Heating System.

Task 9 Proposal for Implementation

Based upon the work accomplished in Phase 2, prepare a detailed implementation plan for the remainder of the demonstration program. At a minimum, the multiphase program should include:

Description of the Demonstration Project including the preferred retrofit scheme and thermal distribution network.

Demonstration Master Schedule

Detailed Task Schedule for subsequent phases with PERT Charts for each subsequent phase.

PHASE II COST PROPOSAL

	Est. Cost ($)
Georgia Institute of Technology	95,345
Hanselman-Eskew and Associates	276,000
Design/Build Firm to be selected	29,000
KWH/Thermal Rate Analysis; Emission Control Analysis	41,875
Power Plant Performance Tests	55,000
Contingencies	73,125
Total Estimated Cost	570,345
Less City of Piqua Cost Sharing (28.4%)	162,345
Total	408,000

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