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MASTER

SAINT PAUL ENERGY PARK:
THE POTENTIAL FOR DISTRICT HEATING

by

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Energy and Environmental Systems Division

March 1980

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Artist's Conception of An Energy-Conserving Building in Energy Park¹

ABSTRACT

This report summarizes the results of ANL's study of the energy and economic aspects of using district heating in the St. Paul Energy Park. The Energy Park is a 6 million ft² residential, commercial/office, and light industrial complex to be built in the midway area of St. Paul, Minnesota. Space heating and cooling design loads for the park were calculated assuming that the ASHRAE's 90-75 energy-conserving construction standards would be used in constructing the park's buildings. Based in part on this assumption, ANL estimated the costs and energy use characteristics of six possible energy system options for supplying Energy Park's space heating, space cooling, and domestic hot water heating needs. The results indicate that in today's economy, a central heating and cooling plant with natural gas boilers and electrically driven centrifugal chillers with thermal storage has good potential for energy and economic savings and clearly merits further consideration.

1 INTRODUCTION

St. Paul's Energy Park is a 6 million ft² industrial, residential, and commercial development proposed for the midway area of the city. This massive complex is part of a joint venture by the St. Paul Port Authority, private developers, and the City of St. Paul to help improve the city's employment situation, tax base, and business climate.

Early in 1980, representatives of the Department of Energy's (DOE) Region V office and the City of St. Paul approached Argonne to request the Labora-

tory's participation in the preliminary study of a district heating system* for Energy Park.

After discussions with the city, ANL entered the Energy Park study with the objectives and limitations given below:

1. ANL would study the technical and economic feasibility of connecting the Energy Park with the University district heating system. Social, political, legal, and environmental impacts should be considered by local organizations more familiar with the local situation.
2. Argonne's study was limited to evaluating only space heating, space cooling, and domestic hot water heating needs. Electricity generation and electric loads beyond those directly used for the above services were not considered in the analysis.
3. DOE and ANL are interested in discovering what local government can do to promote implementation of district heating. The results of the St. Paul experience could be extended to other communities, such as to those involved in DOE's Comprehensive Community Energy Management Planning (CCEMP) Program, agencies participating in the Farmer's Home Administration (FmHA) and DOE-sponsored Small Town Energy Planning (STEP) Program, or to others interested in local energy management.
4. ANL's study was to determine only the economic feasibility of a limited number of general energy systems. Extensive work by engineering consultants will be required to complete preliminary and final system designs.

---

*An Introduction to District Heating is presented in Appendix 1.

2 THE ENERGY PARK COMPLEX

2.1 LOCATION AND ARCHITECTURE

When the Energy Park is completed in 1986, it will be an energy-conserving community comprising about 2 million ft² of residential buildings and about 4 million ft² of office, commercial, and light industrial space. Table 2.1 provides a more detailed breakdown of space allocation.

Table 2.1. Energy Park Buildings and Construction Phasing¹

Buildings	Area (ft ²)	Year Completed
<u>Phase I</u>		1981
400 Unit Apartments	500,000	
Office/Industry/R&D	435,000	
	535,540	
Total	1,470,540	
<u>Phase II</u>		1982
400 Unit Apartments	500,000	
Office/Industry/R&D	500,000	
	679,605	
Total	1,679,605	
<u>Phase III</u>		
400 Unit Apartments	500,000	1983
400 Unit Apartments	500,000	1984
Office/Industry/R&D	400,000	1985-1986
	797,900	
Total	2,197,900	
Project Total	5,348,045*	1986

* Talks with Kenneth Dzugan of the City of St. Paul indicate that this figure probably will be closer to six million by the time the project is complete.

Figure 2.1 shows the Energy Park's location within St. Paul. As shown in the more detailed site map of Fig. 2.2, important characteristics include the proximity of Energy Park to the University of Minnesota campuses and the virtual absence of existing infrastructure on the site.

The key feature of the Energy Park is its focus on energy conservation. One way the park will conserve energy is by improved building design with improved thermal integrity, earth berming, passive solar architecture, and energy management through peak-load monitoring and control. Although time constraints did not allow the study team an opportunity to examine these concepts in detail, all indications are that they should be encouraged.

Figure 2.1. Energy Park Location¹

Figure 2.2. Energy Park Site Plan¹

2.2 ENERGY LOAD CHARACTERISTICS

The community energy loads for space heating, space cooling, and domestic hot water were estimated on the basis of local climatological data and on data supplied by the City of St. Paul. Hourly load profiles for design winter and summer days and typical days of each season were established according to assumed floor areas, building occupancy patterns, and climatological data. Table 2.2 summarizes the building loads on a per-square-foot basis. These loads were used to size the equipment necessary to supply each building's heating and cooling needs. Table 2.3 shows the building sizes assumed for each structure in the Energy Park and their estimated design load characteristics.

Table 2.2. Estimated Design Loads of Energy Park^a

Service	Residential (Btu/h·ft ²)	Non-Residential (Btu/h·ft ²)
Space Heating	20.0	22.0
Space Cooling	18.0	35.0
Domestic Hot Water Heating	5.0	0.9

^aBased on ASHRAE's 90-75 standards.

Table 2.3. Buildings and Their Design Loads^a

Typical Building Number	Building Type ^b	Area Per Bldg.	Number of Bldgs.	Heating/Cooling ^c				
				DHW Capacity (10 ⁶ Btu/hr)	Space Heating Capacity (10 ⁶ Btu/hr)	Boiler Capacity (10 ⁶ Btu/hr)	Cooling Capacity (10 ⁶ Btu/hr)	Cooling Capacity (Tons)
1	Residential	150,000	4	0.75	3.0	3.75	2.70	225
2	Residential	75,000	16	0.38	1.5	1.88	1.35	113
3	Residential	50,000	4	0.25	1.0	1.25	0.90	75
4	C/O	45,000	1	0.05	0.99	1.04	1.58	132
5	C/O	40,000	1	0.04	0.88	0.92	1.40	117
6	C/O	20,000	2	0.02	0.44	0.46	0.70	58
7	C/O	25,000	1	0.025	0.55	0.58	0.88	73
8	C/O	200,000	1	0.02	4.40	4.60	7.06	588
9	C/O	150,000	2	0.15	3.30	3.45	5.25	438
10	C/O	84,400	1	0.084	1.86	1.99	2.95	246
11	C/O/I ^d	100,000	4	0.10	2.20	2.30	3.50	292
12	C/O/I ^e	500,000	2	0.50	11.00	11.50	17.50	1,458
13	I	50,000	3	0.05	1.10	1.15	1.75	146
14	I	600,000	1	0.60	13.20	13.80	21.00	1,750
15	I	75,000	1	0.075	1.65	1.73	2.63	219
16	I	30,000	2	0.03	0.66	0.69	1.05	88
17	I	328,000	1	0.33	7.22	7.55	11.48	957
18	I	600	1	0.0006	0.013	0.014	0.021	1.95

^aInformation to produce this table was based on conversations with persons in St. Paul. See Appendix 5 for details.

^bC/O is commercial office; I is industrial.

^cDHW - Domestic Hot Water Heating; Boiler Capacity = Sum of DWH plus Space Heating.

^dThe four buildings are 1 C/O and 3 I.

^eThe two buildings are 1 C/O and 1 I.

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3 ALTERNATIVE ENERGY SYSTEMS FOR THE ENERGY PARK

The purpose of this section is to evaluate the economic feasibility of various energy system alternatives for the Energy Park, including district heating systems. Table 3.1 lists the characteristics of the six energy systems evaluated by Argonne. Each system is diagrammed in Figs. 3.1.a-3.1.f and described briefly in Sections 3.1 and 3.2.

Table 3.1. Energy System Alternatives

(a) <u>In-Building Heating</u>	<u>In-Building Cooling</u>
- Gas-Fired Hot Water Boilers	- Electrically Driven Compression Chillers
(b) <u>Central Heating</u>	<u>Central Cooling</u>
- Gas-Fired Hot Water Boilers	- Electrically Driven Centrifugal Chillers
- Hot Water Distribution	- Chilled Water Distribution
(c) <u>District Heating</u>	<u>Central Cooling</u>
- Hot Water Delivered to Energy Park	- Electrically Driven Central Chillers
- Hot Water Distribution	- Chilled Water Distribution
(d) <u>Central Heating</u>	<u>In-Building Cooling</u>
(e) <u>District Heating</u>	<u>In-Building Cooling</u>
(f) <u>In-Building Heating</u>	<u>Central Cooling</u>

3.1 CONVENTIONAL SYSTEM; IN-BUILDING HEATING, IN-BUILDING COOLING (Fig. 3.1.a)

In the Energy Park, Argonne assumed the conventional system would include the following equipment in *each* building:

- gas-fired hot water boilers for space heating,
- electric compression chillers for space cooling, and
- gas-fired domestic hot water heaters.

Because this study was limited to evaluating space heating, cooling, and domestic water heating, any demands not normally supplied by central or district heating systems have been ignored. Thus, this study does not probe non-space-conditioning-related electricity or gas used for cooking.

Figure 3.1.a. Energy System Alternative (a): Conventional In-Building Heating and In-Building Cooling

3.2 CENTRAL AND DISTRICT SYSTEMS

Until now, the term "district heating system" has been used loosely to define any energy system that supplies heating and sometimes cooling to a number of buildings by producing heat in a central plant. Thus far, this definition has been adequate; however, it is now necessary to define terms more narrowly. The terms "central heating" and/or "central cooling" will refer to an energy system with an on-site central plant where a fuel is consumed to produce hot and/or chilled water for distribution to buildings. A fuel in this context includes natural gas, coal, and electricity. The central systems are considered to be independent of the heating system supplying the University of Minnesota. The term "district heating" refers to an energy system for the Energy Park which purchases hot water from an outside source. From this point on in this report, district heating refers only to a heating system connected to the University system.* The district system assumes that the Energy Park has no operable heat-producing equipment of its own.

The selected central or district energy system could encompass one of several designs, with the final choice of system dependent on the design with the best energy and economic performance. Two important features are common to central and district heating systems. First, because the University-linked district heating system is unavailable until 1984, some interim heat supply must be available. Second, after 1984, the University system may be used to supply heat to the Energy Park provided it is economically advantageous to do so. The economics of connecting to the University system are examined more fully in Section 4.3.3. Each of the candidate systems is described in more detail below.

* The University of Minnesota currently is considering linking the district heating systems in its Minneapolis and St. Paul campuses and converting them from oil to coal. The University will have enough capacity to supply the Energy Park with its heating needs after its system has been expanded.

3.2.1 Central Heating, Central Cooling (Fig. 3.1.b)

This system is designed to meet 100% of the Energy Park's space heat, DHW, and space cooling needs by converting fuels in a central plant to hot or chilled water which is then distributed to the buildings through a piping network. Fuels used in the central plant would be natural gas for boilers and electricity to run centrifugal chillers. Thermal storages would be used to improve operating characteristics and to lower costs.

Although this system initially is not connected with the University's heating plant, it can be connected at a later date if proven economically advantageous. Because of the park's planned earlier construction phasing and the unavailability of the University system before 1984, most of the central heating system would have to be built regardless of whether the University system is used.*

Neither in-building nor central absorption chillers were economic options for the Energy Park because of their inefficient use of heat and because no suitable waste heat is produced by the energy systems.

* This assumes that the Energy Park's owners would not want to install interim conventional systems for use between the time of building construction and 1984, when the University system will be available. If the option of installing a temporary conventional system is pursued, the district heating piping would have to be constructed at the time the University system is ready. Not only would the conventional systems have to be replaced, but the streets and some other infrastructure would have to be destroyed and rebuilt to put in the piping system. Clearly this would not be the most efficient way to build the system.

Figure 3.1.b. Energy System Alternative (b): Central Heating, Central Cooling

3.2.2 District Heating, Central Cooling (Fig. 3.1.c)

This system uses the University's hot water system and assumes the water will be available at the time that Energy Park requires heat (e.g., no interim heating system was considered). University-produced hot water would be piped to buildings where heat for space heating and domestic hot water heating would be extracted from heat exchangers.

The central cooling system would be the same as the one used for the Central Heating, Central Cooling system of Section 3.2.1 (Fig. 3.1.b).

Figure 3.1.c. Energy System Alternative (c):
District Heating, Central Cooling

3.2.3 Central Heating, In-Building Cooling (Fig. 3.1.d)

This hybrid system has the gas-fired central heating plant and distribution system mentioned under Section 3.2.1, and the in-building compression cooling equipment of the conventional system. The major difference between this system and the central heating, central cooling system is the substitution of a few large central chillers and accompanying chilled-water distribution and in-building heat exchangers for individual in-building cooling units.

Figure 3.1.d. Energy System Alternative (d):
Central Heating, In-Building Cooling

3.2.4 District Heating, In-Building Cooling (Fig. 3.1.e)

The heating system would be the same as that described in Section 3.2.2, but instead of a central cooling plant, compression cooling units would be installed when the individual buildings are built.

Figure 3.1.e. Energy System Alternative (e):
District Heating, In-Building Cooling

3.2.5 In-Building Heating, Central Cooling (Fig. 3.1.f)

The last option considered was a decentralized heating system with each building operating its own gas-fired boilers. Cooling would be supplied by a central cooling plant using electrically operated centrifugal chillers. A chilled water distribution system would carry water from the plant to the buildings.

Figure 3.1.f. Energy System Alternative (f):
In-Building Heating, Central Cooling

3.3 OTHER SYSTEMS

Other technologies also may be used in the Energy Park, and some may be more economic than the six options listed in Sections 3.1 and 3.2.

The two main alternatives* not studied were In-Building Heat Pump and Central Heat Pump systems. These systems, diagrammed in Figs. 3.2.a and 3.2.b, are based on electrically-driven heat pumps that would provide both heating and cooling. A central system should be explored because of: (1) the higher efficiencies accompanying use of large equipment, (2) the greater opportunity to use peak-load-leveling energy management techniques, (3) the lower average electricity costs from bulk purchases, (4) the economics of scale in operation and maintenance costs, and (5) the opportunity to save energy in the winter by redistributing heat from building cores where heat must be rejected to building perimeters where heat is needed.

Although the heat pump systems would immediately displace natural gas, Argonne did not study them because of time limitations.

Figure 3.2.a. In-Building Heat Pump System

* Active solar and wind systems were not considered because of their unfavorable economic characteristics when compared with Northern States Power's relatively low rates for natural gas and non-residential electricity. However, to meet strict energy-conscious building codes, and for improved life-cycle costs, passive solar designs with tight construction are encouraged.

Figure 3.2.b. Central Heat Pump System

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4 COMPARISON OF ENERGY SYSTEM ALTERNATIVES FOR ENERGY PARK

4.1 GENERAL EVALUATION CRITERIA

The following criteria were used to compare the six energy system options:

- (1) economics,
- (2) energy savings, and
- (3) substitution or conservation of scarce fuels.

The optimal system for the Energy Park should meet all three general criteria. From an economic viewpoint, the best energy system should be able to supply heating, cooling, and domestic hot water at a lower cost than competing technologies. Energy savings relate to the ability of energy systems to use less fuel than conventional systems, i.e., the systems can use fewer Btus to do the same job as the conventional system. Conservation of scarce fuels is important from the national perspective of saving high-quality fuels (especially oil) for use in applications where such fuels are required.

4.2 ENERGY AND SCARCE-FUEL ANALYSIS

Using the COST code*, developed by Mathtech for ANL, the energy requirements of the candidate energy supply systems were calculated and compared to those of the conventional system; the differences are presented in Table 4.1. The conventional system would consume 2.35×10^7 kWh/yr of electricity and would require 3.93×10^{11} Btu/yr of natural gas.

Scarce-fuel savings are listed in the last column of Table 4.1. As shown, each of the central and district systems is an efficient energy saver when compared with the conventional system. The very high scarce-fuel savings of the district systems are caused by their use of the University's future coal-fired system rather than the conventional and central system's natural gas.

4.3 ECONOMIC ANALYSIS

4.3.1 Selecting Among Systems

Table 4.2 summarizes the estimated capital expenditures and operation/maintenance costs of the candidate systems. Capital costs include the central heating/cooling plant, the transmission and distribution systems, and the in-building systems. In-building system costs include heating, ventilation, and air-conditioning (HVAC), and domestic water heating systems. The in-building

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* Described in Appendix B.

Table 4.1. St. Paul Energy Park - Energy Analysis

Energy Used...		At Buildings		At Central Plant		At Univ. District Heat Plant	At NSP Electric Plants		Total		% Saved Annually Compared to Conventional Heating/Cooling	
No.	Alternatives	Form	Amount (10 ⁶ Btu/Yr)	Form	Amount (10 ⁶ Btu/Yr)	Form (10 ⁶ Btu/Yr)	Form (10 ⁶ Btu/Yr)	Amount (10 ⁶ Btu/Yr)	Energy (10 ⁶ Btu/yr)	Scarce Fuel (10 ⁶ Btu/Yr)	Energy.	Scarce Fuel
Fig. 3.1.a	In-Building Heating In-Building Cooling	Gas Electricity	393,000 80,200 ^a					Nuclear (45%) 120,600 Coal (51%) 136,700 Oil (4%) 10,700	661,000	404,000	-	-
Fig. 3.1.b	Central Heating Central Cooling	Hot Water Chilled Water	208,000 292,000	Gas Electricity	277,000 76,100 ^a			Nuclear 114,300 Coal 129,500 Oil 10,200	531,000	287,000	20	29
Fig. 3.1.c	District Heating Central Cooling	Hot Water Chilled Water	208,000 ^c 292,000	Hot Water Electricity	220,000 ^d 75,400 ^a	Coal 293,000		Nuclear 113,100 Coal 128,200 Oil 10,100	544,000	10,000	18	98
Fig. 3.1.d	Central Heating In-Building Cooling	Hot Water Electricity	208,000 80,200 ^a	Gas Electricity (Pumping Only)	277,000 730 ^a			Nuclear 124,000 Coal 137,600 Oil 108,000	547,000	299,000	17	26
Fig. 3.1.e	District Heating In-Building Cooling	Hot Water Electricity	208,000 ^c 80,200 ^a	Hot Water	220,000 ^d	Coal 293,000		Nuclear 120,600 Coal 136,700 Oil 10,700	561,000	11,000	15	97
Fig. 3.1.f	In-Building Heating Central Cooling	Gas Chilled Water	393,000 292,000	Electricity	75,400 ^a			Nuclear 113,100 Coal 128,200 Oil 10,100	644,000	403,000	3	~ 0

^a Btu equivalent of electricity demanded. To convert to kWh demanded per year, divide by 3413.

^b Recommended system based on current price estimates.

^c Thermal energy purchased from University heating plants and actually delivered to buildings (includes line losses).

^d Thermal energy purchased from University heating plants for distribution in Energy Park.

Table 4.2. St. Paul Energy Park - Economic Analysis (\$ 10⁶)

No.	Alternatives	ID	Variables ^a	Capital Costs				Annual O/M Costs		Assumed District Heat Price (\$/10 ⁶ Btu)	Annual Energy Costs		Total Annual Cost ^e	ID
				Central Plant	Distribution	In-Building ^b	Total ^c	Plant and District System	In-Building		Central Plant ^d	In-Building		
Fig. 3.1.a	In-Building Heating In-Building Cooling	A	None	-	-	5.51	5.51	-	0.24	-	-	1.66	2.73 ^f	A
Fig. 3.1.b	Central Heating Central Cooling	B	Low Dist	3.74	2.40	0.11	6.25	0.15	-	-	1.14	-	2.23	B
		C	Med Dist	3.74	4.00	0.11	7.85	0.15	-	-	1.14	-	2.47	C
		D	Med Dist	3.74	6.30	0.11	10.15	0.15	-	-	1.14	-	2.81	D
		E	Hi Dist	3.74	11.12	0.11	14.97	0.15	-	-	1.14	-	3.54	E
Fig. 3.1.c	District Heating Central Cooling	F	Low Dist, Low Heat Pr	2.98	2.40	0.11	5.49	0.13	-	4	1.27	-	2.22	F
		G	Low Dist, Med Heat Pr	2.98	2.40	0.11	5.49	0.13	-	5	1.49	-	2.44	G
		H	Low Dist, Hi Heat Pr	2.98	2.40	0.11	5.49	0.13	-	6	1.71	-	2.66	H
		I	Med Dist, Low Heat Pr	2.98	4.00	0.11	7.09	0.13	-	4	1.27	-	2.46	I
		J	Med Dist, Med Heat Pr	2.98	4.00	0.11	7.09	0.13	-	5	1.49	-	2.68	J
		K	Med Dist, Hi Heat Pr	2.98	4.00	0.11	7.09	0.13	-	6	1.71	-	2.90	K
		L	Med Dist, Low Heat Pr	2.98	6.30	0.11	9.39	0.13	-	4	1.27	-	2.81	L
		M	Med Dist, Med Heat Pr	2.98	6.30	0.11	9.39	0.13	-	5	1.49	-	3.03	M
		N	Med Dist, Hi Heat Pr	2.98	6.30	0.11	9.39	0.13	-	6	1.71	-	3.25	N
		O	Hi Dist, Low Heat Pr	2.98	11.12	0.11	14.21	0.13	-	4	1.27	-	3.53	O
		P	Hi Dist, Med Heat Pr	2.98	11.12	0.11	14.21	0.13	-	5	1.49	-	3.75	P
		Q	Hi Dist, Hi Heat Pr	2.98	11.12	0.11	14.21	0.13	-	6	1.71	-	3.97	Q
Fig. 3.1.d	Central Heating In-Building Cooling	R	Low Dist	0.75	1.50	3.76	6.02	0.03	0.20	-	0.75	0.61	2.49	R
		S	Med Dist	0.75	2.50	3.76	7.02	0.03	0.20	-	0.75	0.61	2.64	S
		T	Hi Dist	0.75	6.95	3.76	11.47	0.03	0.20	-	0.75	0.61	3.31	T

Table 4.2. St. Paul Energy Park - Economic Analysis (\$ 10⁶) cont'd.

No.	Alternatives	ID	Variables ^a	Capital Costs				Annual O/M Costs		Assumed District Heat Price (\$/10 ⁶ Btu)	Annual Energy Costs		Total Annual Cost ^e	ID
				Central Plant	Distribution	In-Building ^b	Total ^c	Plant and District System	In-Building		Central Plant ^d	In-Building		
Fig. 3.1.e	District Heating	U	Low Dist,	-	1.50	3.76	5.26	0.01	0.20	4	0.88	0.60	2.48	U
	In-Building Cooling	V	Low Heat Pr	-	1.50	3.76	5.26	0.01	0.20	5	1.10	0.60	2.70	V
		W	Med Heat Pr	-	1.50	3.76	5.26	0.01	0.20	5	1.32	0.60	2.92	W
		X	Hi Heat Pr	-	2.50	3.76	6.26	0.01	0.20	5	0.88	0.60	2.63	X
		Y	Med Dist,	-	2.50	3.76	6.26	0.01	0.20	5	1.10	0.60	2.85	Y
		Z	Med Heat Pr	-	2.50	3.76	6.26	0.01	0.20	6	1.32	0.60	3.07	Z
		AA	Hi Dist,	-	6.95	3.76	10.71	0.01	0.20	4	0.88	0.60	3.30	AA
		BB	Hi Heat Pr	-	6.95	3.76	10.71	0.01	0.20	5	1.10	0.60	3.52	BB
		CC	Hi Dist,	-	6.95	3.76	10.71	0.01	0.20	6	1.32	0.60	3.74	CC
Fig. 3.1.f	In-Building Heating	DD	Low Dist	2.98	1.80	1.94	6.72	0.13	0.04	-	0.39	1.06	2.63	DD
	Central Cooling	EE	Med Dist	2.98	3.00	1.94	7.92	0.13	0.04	-	0.39	1.06	2.81	EE
		FF	Hi Dist	2.98	8.34	1.94	13.26	0.13	0.04	-	0.39	1.06	3.61	FF

^a The abbreviations used are: Dist = distribution cost, Mod = moderate, Med = medium, Hi = high; Heat Pr = district heating cost of heat per 10⁶ Btu as stated in the Assumed District Heat Price column.

^b In-building costs are the differences between duct work, heat exchangers, fans, blowers, and other normally required building distribution equipment and the items that would change from system to system.

^c The Total equals the Central Plant plus Distribution plus In-Building capital costs.

^d Assumes costs of purchasing thermal energy from the University are found by metering at one point of the Energy Park boundary.

^e All figures in the table reflect these assumptions:

- Natural gas price of \$2.7/10⁶ Btu
- Electrical rates for individual buildings: residential - 4.21c/kWh; commercial - \$4.70/kW demand charge: 1.9c/kWh energy charge.
- Electrical rates for central plant: \$4.60/kW demand charge: 1.6c/kWh energy charge.
- Capital carrying charge rate of 15%
- 1930 dollars
- The life of all systems is assumed to be 20 yr.

^f The conventional system costs, presented in detail in Appendix 4, are based on estimations using the St. Paul Energy Park prospectus and average square foot building costs with respect to building types. The in-building system costs for central and district heating and cooling take into account the mechanical equipment differences between the new system and conventional system. The size of the mechanical room in each building would also be reduced in the switch to a central or district system.

costs include only those items that vary from alternative to alternative. Operation and maintenance (O/M) costs include salaries, service contract costs, replacement parts, and preventative maintenance. Taxes, insurance, and fuel are not included. The energy costs column is split into three parts. The first, the district heating price, shows a range of prices the University may choose to charge for heat sent to the Energy Park. The figure quoted to Argonne was \$5.30/10⁶ Btu*, but the range from \$4 to \$6 per 10⁶ Btu was calculated to study the effects of price changes on annual costs. The central plant and in-building energy costs include only those costs for fuel consumed at the central plant or in-buildings and only for space heating, space cooling, and domestic hot water heating uses. Annual costs in 1980 dollars are the sum of the carrying charge of total capital (15%), total O/M cost, and total energy cost. The annual cost reflects only those costs encountered during the first year of operation.

Alternatives, ID, and Variables (the first three columns of Table 4.2) show that Argonne considered six system options (those diagrammed in Fig. 3.1) and within these six, calculated costs for 32 cost assumptions. The cost variations are in two critical areas, i.e., the capital cost of the central or district systems distribution network and the price the University might charge for heat. These two charges have significant effects on the feasibility of the various systems as reflected in column 7, Annual Cost. Because the annual cost of the central and district systems must be lower than the cost of the conventional, in-building heating and in-building cooling system, not all 31 central or district options are competitive. Only the options whose annual costs are shaded prove to be more economical than the conventional system. Of the alternatives listed in Table 4.2, there appears to be a virtual tie for the most economical system between ID letter B; the central heating, central cooling plant with low distribution cost, and ID letter F; the district heating, central cooling plant with low distribution cost and low district heating price. Because no other system's annual cost is closer than \$210,000 to B and F, the analysis will focus on these two options.

Because a critical assumption for both B and F is their reliance on low distribution system costs, a vital question is: at what point do excessively high distribution system costs make the systems economically unattractive compared to the conventional system?**

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*Based on the steam price shown in Appendix 3.

**The reason the comparison is between B and F vs. A instead of B and F vs. other central and district systems is that all central and district systems depend on the distribution system cost for their feasibility. In other words, distribution system costs that make B and F look attractive will be the same as those used in the other systems. Alternatives 2 and 3 start out to be more attractive than the conventional system and in the final analysis, they will still be most attractive.

Figure 4.1 provides a basis for answering this question. The vertical scale is the ratio of annual costs of system B and F* to the annual costs of the conventional system. Thus, at 1.0, the annual costs are equal; at points greater than 1.0, the conventional system has better economic prospects; and at points less than 1.0, options B and F look better. The horizontal scale measures possible distribution system capital costs. This graph shows that, if the distribution system cost is \$6.3 million, the economic outlook for the conventional system and options B and F are identical. If the distribution system costs more, the Energy Park would be better off with a conventional system. However, if the distribution system costs less than \$6.3 million, the Energy Park should use option B or F. Because Argonne has estimated that the distribution system cost will be significantly under \$6.4 million (probably in the neighborhood of \$4.0 million), either B or F looks very attractive.

Assuming that the distribution system cost will be less than \$6.3 million, the Energy Park cannot construct both B and F. One must be preferred over the other; but which one? A critical assumption lies behind option F's attractiveness, i.e., the low district heating price of \$4/10⁶ Btu. This assumption may not be reasonable since the University's quoted price was \$5.30/10⁶ Btu. How will changes in the University price affect option F's attractiveness? The answer lies partially in Table 4.2, where the effects of keeping all variables constant except district heating prices are seen in the changes in the annual costs between option F and options G and H. The annual costs rise quickly with fairly small increases in the district heating price.

Figure 4.2 shows the effects of rising district heating prices on the breakeven point between the conventional system and option F. This graph shows that, if the district heating price rises from \$4/10⁶ Btu to \$5/10⁶ Btu, the distribution system's capital cost must fall to at least \$4.75 million if the district heating system is barely to compete with the conventional system. Looking back at Table 4.2, at a distribution system cost of \$4.35 million, the attractiveness of option B and F's counterparts, options C and J, can be compared. C and J both have distribution system costs of \$4.0 million, reasonably close to \$4.35 million. Option J uses a district heating price of \$5/10⁶ Btu, somewhat better than the current price of \$5.30/10⁶ Btu, but still close. If the annual costs of C are lower than those of J, the central heating, central cooling plant is preferred to the district heating, central cooling plant in today's economy. The annual cost column in Table 4.2 shows C's annual cost to be \$2.47 million and J's to be \$2.68 million. Thus C is the lesser cost option.** On the basis of this study, Argonne recommends that the research emphasis of the Energy Park be placed on Option B -- central heating, central cooling -- because this option appears to be the most viable energy system from energy conservation and economic viewpoints.

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* Because the costs of B and F are nearly identical, their annual costs appear as a single line on Fig. 4.1.

** In addition, the assumption that the district heating and cooling systems will be available at the time Energy Park's buildings need the heat may be questionable because the University system will not be available until 1984; whereas, the Energy Park is expected to be substantially under way (and possibly complete) by 1983. If a district heating system were used, the interim period would require a central heating and cooling system. These extra costs do not show up in the Table 4.2 figures, and would hurt system economics.

Figure 4.1. Effects of Distribution System Costs on the Economic Attractiveness of Options B and F

Figure 4.2. Effects of District Heat Price on the Breakeven Point for Option F

4.3.2 Details of the Recommended Central Heating, Central Cooling System

This section provides a more detailed cost breakdown of the recommended central heating, central cooling system. Table 4.3 lists equipment costs for the plant.

Table 4.3. Equipment Cost for the Central Heating, Central Cooling System (Installed, 1980\$)

<u>I. Central Heating and Cooling Plant</u>			
<u>Equipment</u>	<u>No. of Units</u>	<u>Unit Size</u>	<u>Cost (\$)</u>
Boilers	4	18,000 MBH	360,000
Thermal Storage	1	2.46 x 10 ⁵ gal	60,500
Hot Water Pumps	4	400 gpm	11,000
Compression Chillers	7	1,500 tons	1,575,000
Cooling Towers	7	1,500 tons	325,000
Thermal Storage	1	1.28 x 10 ⁶ gal	256,000
Chilled Water Pumps	6	2,500 gpm	105,000
Building			400,000
Total			3,092,500
Contingency (15%)			463,900
Design Fee (6%)			185,600
Total			3,742,000
<u>II. Distribution System^a</u>			
	<u>Type</u>		<u>Cost (\$)</u>
	Hot Water Supply and Returns		2,500,000
	Chilled Water Supply and Returns		1,500,000
<u>III. In-Building Systems^b</u>			
			110,000
<u>IV. Total System Capital I + II + III</u>			
			7,857,100

^a Approximate, could vary considerably in final design.

^b Difference between the normal in-building distribution equipment and the meters and heat exchangers explicitly required for the central heating, central cooling system.

System operation is fairly straightforward. Figure 4.3 shows a diagram of the system. For heating, natural gas supplied by Northern States Power (NSP) is burned in boilers, with the hot water sent to the distribution system. During off-peak periods, hot water will be stored in concrete, underground, hot-water storage. This water is used during peak periods and allows the Energy Park to use less boiler capacity than would otherwise be necessary. In the buildings, the traditional boilers/furnaces are replaced with heat exchangers that link the distribution system and the inbuilding system. Water from the central plant does not mix with the water that circulates through the building piping. For cooling, NSP electricity is used in centrifugal chillers to produce chilled water. As in the heating system, the water may be sent directly to the buildings or to storage. This water is used during peak periods and allows the Energy Park to use less chiller capacity than would otherwise be necessary. In the buildings, the traditional air conditioning units are replaced with heat exchangers that link the distribution system and the inbuilding system. Water from the central plant does not mix with the water that circulates through the building piping. For cooling, NSP electricity is used in centrifugal chillers to produce chilled water. As in the heating system, the water may be sent directly to the buildings or to storage.

4.3.3 Future Considerations

Installation of a central heating, central cooling plant does not preclude the future use of a district heating, central cooling system. At some point in the future, the Energy Park may find it desirable to hook up to the University system. Hooking up could have several advantages, including cutting the park's use of natural gas and possibly helping the University system's economics. An important question to consider is timing of the conversion: *When will it be economically advantageous for the Energy Park to hook into the University district heating system?*

Figure 4.3. Central Heating, Central Cooling System

Figure 4.4 helps to answer this question. The vertical axis is the annual cost of district heating divided by the annual cost of central heating.* A value of 1.0 indicates the annual costs are equal; a value over 1.0 indicates that district heating is more expensive than central heating and conversion would not be warranted; a value less than 1.0 indicates district heating is less expensive than central heating, and conversion would be attractive. The horizontal scale is the ratio of the price of district heating produced heat (per 10^6 Btu) to the price of natural-gas-produced heat (per 10^6 Btu). Figure 4.4 shows that, if the ratio falls below 1.48, (i.e., district-heating-produced heat costs 1.48 times the cost of natural-gas-produced heat), then conversion to the University district heating system is an economical venture. So, for example, if the district heat price remains at $\$5.30/10^6$ Btu, and the price of natural gas rises from its current level of $\$2.70/10^6$ Btu to over $\$3.58/10^6$ Btu, then conversion should be given serious consideration.

*The central cooling system does not change in the conversion and can be ignored in the analysis.

Figure 4.4. Effects of Changes in Fuel Costs on Desirability of Converting from Central to District Heating

The central heating and cooling plant, if converted, would have the general configuration shown in Fig. 4.5. The old natural-gas-fired central heating boilers and associated equipment would be shut down, sold, or used for standby peaking capacity. Hot water piping from the University would connect into the Energy Park distribution system, and the in-building systems would operate as before conversion. The central cooling equipment, distribution piping, and all in-building equipment would be unchanged.

Figure 4.5. Central Heating, Central Cooling System After District Heating Conversion

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5 CONCLUSION AND RECOMMENDATIONS

Among the alternatives considered here,* a central energy system with hot and chilled water distributed to buildings within the site clearly merits future study. The central system would contain gas-fired package boilers for heating and large electrically-driven centrifugal chillers for cooling. The system would use thermal storage for both heating and cooling. Energy savings for this system compared with a conventional system are estimated to be approximately 20%, with scarce fuel savings of about 30%.

The system would be economically competitive at current gas and electricity prices if the distribution system cost for both hot and chilled water within the park could be held to less than \$7 million. A preliminary estimate for distribution is \$4 million.

The opportunity in the future to link the park to the University of Minnesota district heat system will save significant amounts of scarce natural gas if the University system is coal-fired. However, the economic competitiveness of this option depends on the ratio of the price charged for district heat to the price of natural gas. (Estimates of today's ratio are about 2 to 1 -- \$5.30/10⁶ Btu for district heat vs \$2.70/10⁶ Btu for natural gas.) If this ratio falls to 1.48 or less, then a switchover to district heat may be warranted. Planning for a central system now would allow for this option in the future and the gas boilers then could be converted to peaking and/or standby use. Chilled water would remain an electrically supplied service.

Because the cooling system would be electrically driven and centrally operated, it would also appear to provide an excellent opportunity for peak load management in cooperation with the electric utility.² Thus, discussions should be held with the utility to explore possible load management strategies.

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* Additional study of the heat pump alternative is recommended.

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REFERENCES

1. *Saint Paul Energy Park*. Draft No. 3, Port Authority of St. Paul and St. Paul Department of Planning and Economic Development, St. Paul, Minnesota (October 30, 1979).
2. Calvin Kytte Associates, Inc., *Peak Leveling Through Community Energy Coops*, President's Clearinghouse on Community Energy Efficiency, Washington, D.C. (1980).

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ACKNOWLEDGMENTS

The authors wish to acknowledge the following individuals and organizations who helped in the preparation of this document:

Grateful appreciation to:

Mr. Kenneth Dzigan of the City of St. Paul who spent many hours answering numerous requests for information.

Dr. John Voelker of Argonne, and

Dr. William Price of Princeton who provided timely assistance in running the COST code.

Special thanks to Ms. Diane Duff, and Ms. Jo Ann Lawlor who typed this report; Ms. Barbara Biederman who edited it; and Ms. Linda Samek and Ms. Mary Jo Koelbl who drafted the illustrations.

APPENDIX A. AN INTRODUCTION TO DISTRICT HEATING

A.1 A DESCRIPTION OF DISTRICT HEATING

District heating is defined as the use of one or more centralized sources of heat to heat a group of buildings. Among the services available from a district heating system are space heating, domestic water heating, and sometimes space cooling and industrial process heat.

The three major components that make up a district heating system are shown in Figs. A.1 or A.2. The first component is the set of thermal production plants that takes a primary fuel such as coal, oil, gas, or urban waste and converts it to heat. Although heat can be produced directly for the district heating system using fossil-fueled boilers, this process is expensive. When possible, heat that is being "thrown away" should be put to use. Sources of waste heat include electric generating stations (which normally reject 70% of the heat content of the fuel they consume) and municipal incinerators (which usually burn trash and reject 100% of the heat). The central plant may include facilities for storing thermal energy. This stored hot or chilled water is used to meet peak demands and allows some system components (such as boilers and chillers) to be smaller and less expensive than they would be without storage. The second component is the transmission and distribution system, which conveys energy from the thermal production plants to consumers. Heat is usually piped to consumers in the form of hot water or steam. Chilled water also may be distributed. The final component of the district heating system encompasses the in-building equipment. Typically, a heat exchanger forms the connection between the distribution network of the district heating system and the remainder of the heating and cooling systems in individual buildings.

A.2 ADVANTAGES OF DISTRICT HEATING

Potential advantages of district heating include:

- *Reduced heating costs.* Through the use of currently discarded heat and increased equipment efficiency, district heating systems often can offer thermal energy at lower prices than can conventional heating systems.
- *Increased certainty of fuel supply.* During the past decade, many communities have faced curtailment of home heating oil and natural gas supplies. Communities relying heavily on these fuels might wish to consider construction of a district heating system using waste heat, coal, and/or municipal waste to increase the dependability of fuel supplies.

Fig. A.1 Three Major Components of a District Heating System

Fig. A.2 Schematic Layout of a Simplified District Heating System

- *Improved air quality.* District heating systems offer the potential for improvements in air quality by using: (1) more efficient equipment, (2) better-maintained equipment, and (3) increased application of pollution-control equipment. Experience in Sweden proved that substantial reductions in SO₂ concentrations can occur in cities employing district heating.
- *Reduced land requirements for sanitary landfills.* Through the application of municipal waste incineration with heat recovery, the volume of waste requiring disposal can be greatly reduced. If metals and glass are recovered and fly-ash and clinker are used in road buildings, the volume of wastes requiring disposal can be reduced 99%. Scarcity of land available for landfill operations has been the primary impetus behind the application of heat-recoverable incineration in several European countries.

A.3 DISTRICT HEATING IN THE U.S. AND EUROPE

The history of U.S. district heating can be traced to the late nineteenth century. By 1890, district heating systems were being installed in New York and numerous smaller cities. Most of these systems utilized waste steam from reciprocating steam engines that were used to generate electricity. As turbines replaced reciprocating engines for electric generation and as technological advances decreased electric transmission losses, electric generating plants grew and were relocated away from urban areas. In the process, district heating systems lost their supplies of cheap waste heat and were required to meet substantially higher fuel costs. By the late 1920s, economically-failing systems began to close. Decline continued through World War II; however, since then, the level of district heating in the U.S. has stabilized.

In many European countries, the application of district heating is much more widespread than in the U.S. Principal reasons for this difference include: (1) fewer domestic energy supplies necessitating better fuel utilization, (2) higher fuel prices, (3) scarce land for sanitary landfill operations, (4) fewer governmental and institutional barriers, and (5) frequent government sponsorship for implementation of district heating. In Sweden, Denmark, and other Scandinavian countries, cogeneration* is the rule, rather than the exception, for new electric generating stations. Moreover, both Sweden and Denmark construct urban waste incinerators that supply heat to their district heating systems. Other sources being explored by these countries for their district heating potential include solar energy, industrial waste heat, and nuclear power plants.

---

* Defined as the production of electricity while putting normally wasted heat to productive use.

APPENDIX B. COMPUTER PROGRAM: "COST"*

COST is a computer program package that determines the optimal equipment selection and operating levels for an Integrated Community Energy System (ICES). The system model may include energy conservation devices in a central plant, purchase, and sale of fuel (energy) at time-varying prices, energy storage systems, distribution networks, and end-use-conversion equipment. Given specified demands for services, COST minimizes the annual system cost considering fuel, operation, and investment charges. Because demands are specified by time intervals that collectively represent a full year, both peak and typical requirements can be considered jointly.

The optimization is carried out by mixed-integer linear programming with the integer constraints modeling equipment selection. The constraint equations for each particular case are tailored to the community model under study by an elaborate input processor. Benders' methods is used to decompose the mixed integer LP problems which can be iterated to an approximate solution of specified accuracy. (Benders' algorithm, which iterates between solving an integer program and a linear program, provides both upper and lower bounds on the system cost at each iteration.) The algorithm continues until those bounds become acceptably close to one another.

The chief limitations of COST derive from the linear programming optimization technique: all the constraints, and hence all the models of equipment, costs, etc., must be linear equations. Offsetting this are the primary advantages, which include: the explicit representation of time-varying demand patterns; the establishment and use of optimal operating rules for each device considered; and the ability to select optimal devices from sets of alternatives (comparing the best performance of each selection with all others). Additional advantages are: elimination of intermediate errors of hand calculation once the model components are defined; ability to generate alternative solutions quickly and cheaply, relative to manual methods, after a base system has been set up; and central collection of all data (with important benefits in ensuring consistency). Table B.1 summarizes the COST capability.

COST was developed by Mathtech under contract from the U.S. Department of Energy and Argonne National Laboratory. Users' manuals that further describe COST and its use are available.

The unique advantage of COST is its ability to handle a complex network of factors in solving for an optimal ICES system. This can greatly expedite the investigation of ICES applicability for various sites, and it can easily answer "what if" questions with respect to a wide range of system parameters.

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* Excerpted from *Preliminary Evaluation of Automated ICES Selection Methodology*, COST, Voelker, J., C. Lee, W. Price, and V. Rabl, ASME Century 2 - Computer Technology Conference (1980).

Table B.1. COST Capability Summary

COST Minimizes the sum of the following:

- (1) Annualized capital costs of
  - (a) plant equipment
  - (b) storage facilities
  - (c) devices installed in consuming building
  - (d) transmission network
- (2) Fuel purchases
- (3) Energy sales revenue (a negative cost)
- (4) Operating and maintenance costs
(assumed proportional to equipment operating levels)

COST Determines

Integer
Program
Solution

- (1) Which kind of equipment, selected from a set of alternative kinds, to use in central plant (there may be several such sets, from each of which a selection must be made).

Linear
Program
Solution

- (2) How much capacity of each kind of equipment and storage device to install.
  - (3) For each time period
    - (a) fuel purchases, energy sales
    - (b) equipment operating levels
    - (c) inputs and withdrawals from storage
  - (4) For each zone, how much of each kind of end use device to install (e.g., for Zone #1, 40% of buildings should have electric heat pumps and 60% should have devices to interface with hot water piped in from central plant).
  - (5) Size of transmission lines.
-

APPENDIX C. QUESTIONS AND ANSWERS CONCERNING THE ENERGY PARK PROJECT

Throughout the study, the Argonne team had many questions that required answers. Most requests were made by telephone to Mr. Kenneth Dzigan, the Energy Park NIS Assistant Team Leader. The following Appendix lists the questions posed and answers received. The city was very cooperative in assisting ANL data collection efforts.

U.S. DEPARTMENT OF ENERGY

ARGONNE NATIONAL LABORATORY

9700 SOUTH CASS AVENUE, ARGONNE, ILLINOIS 60439

TELEPHONE 312/972-7473

January 18, 1980

Mr. Kenneth G. Dzugan
Energy Park NIS Assistant Team Leader
St. Paul Department of Planning
and Economic Development
Office of the Mayor
Room 365, City Hall
15 W. Kellogg Street
St. Paul, Minnesota 55102

Dear Mr. Dzugan:

Thanks for your help in answering our questions. Enclosed you'll find the full list of questions and the answers you gave me (as I interpreted them). If I accidentally erred in summarizing your responses, or if you have found information on some of the unanswered questions, don't hesitate to call. Hope to talk with you again.

Sincerely,

Norman F. Kron, Jr.
Energy & Environmental Systems Division

NFK/jl
Enclosures

ST. PAUL DATA REQUESTS
(Ken Dzuga - 612-292-6730)

A. Concerning the University DH System:

1. When will the University be able to supply heat?
2. What temperature will the water (steam) be?
3. What GPM will be available at the time the University experiences its peak load? When is the peak expected to occur?
4. What price per MMBtu will the University probably charge?
5. Why can't the University supply heat before the date given in 1 above? Can E Park funds be spent on facilities built at the St. Paul campus plant?
6. At the close of which "Phase" will the University system be on line?
7. What loads does the University expect from Energy Park?

B. Concerning Current Fuel Costs:

1. How much will electricity and gas cost for this development?
2. Are there off-peak rates?

C. Concerning the Aquifer (none asked due to University Work).

D. Concerning the Buildings:

1. On page 18 of the Prospectus, costs for buildings are shown. What mechanical systems (HVAC) were included in those costs? If these are "typical" or "conventional" systems, what fuel and equipment would be considered typical in St. Paul? To get 2 million ft² residential, we are using 1250 ft²/DU as average. Is this acceptable?
2. What is the current projected square footage per building type per phase?
3. When will the first building require heat?
4. The costs on page 17 include a figure for gas mains. What is the expected use of the gas?
5. What is the phasing and real schedule for this project?

E. Concerning the Previously-Calculated DH System:

1. On page 17 of the Prospectus, costs for "hot water distribution, lines, and boiler" are listed per phase. Can we get these estimates broken down by equipment type? Fuel used?
2. The page 17 costs imply that energy loads were calculated. Can we get the load estimates?
3. What cooling equipment was assumed for the costed district heating system?
4. What cost/MMBtu was calculated for the costed DH system?

5. What are the costs for the interim heating plant and what will happen to the plant when the University system is connected?

F. Concerning Local Regulations:

1. Does St. Paul or the state have a set of required ventilation standards for buildings? If so, what are they for the site? (Min. cfm/ft² or A.C./hr)
2. Are there local regulations concerning the use of underground water? (Not asked)

G. Concerning Economics:

1. What rate of return is wanted? Needed?

H. Concerning the Railroad:

1. Which tracks will stay in and which will be taken out?
2. Will there be any problems obtaining rights-of-way for utility piping? No.

I. Concerning the Study:

1. Why is there a mid-February deadline?
2. What do you want us to do?

FIRST SET OF
ANSWERS FROM KEN DZUGAN OF ST. PAUL
January 17, 1980

- A. 1. The University system can POSSIBLY supply steam in late 1982. Hot water will be available sometime in 1984.
2. KD will check. (KD is Ken Dzugan)
3. KD will check.
4. KD will check.
5. That's when federal funding comes through. KD will check whether Energy Park funds can be spent on campus.
6. See later phasing question.
7. KD will check.
- B. 1,2. KD will check
- C. The University is going to check on aquifer storage in a detailed study. The project is too time constrained for ANL to do an aquifer study.
- D. 1. These figures are "typical construction cost ranges in other Port Authority industrial parks." The standard heating fuel in St. Paul is natural gas for industry and 85% of units are gas apartments. The industrial backup fuel is oil if they are interruptible. There will be 1600 DU in energy park, with the # of bedrooms per unit as specified in Prospectus. Total residential ft² is 2,032,000, one bedroom apts. will have 1000 ft², three bedroom - 1450 ft², and 2 bedroom in between. The complexes will have about 1,693,760 ft² of livable space and some 340,000 ft² of common space. Absorption cooling for all buildings.
2. The current construction phasing is the same as in the Prospectus except the Phase I and II industrial ft² and costs should be reversed. The Midway Stadium site will be built first, then probably the Kopper's Coke site and then West of Snelling (but Kopper's may be delayed until Phase III due to EPA review). See Oct. 29 attachment.
- In 3 years the infrastructure should be completed (1983)
           4 years completes the housing (1984)
           5-6 years for the rest (1985 or 86)
3. The first building should be ready for occupancy in Spring, 1981.
4. The gas mains were costed assuming that some industrial customers may want gas. They run throughout the site beneath the streets.
5. See question 2. The project is on schedule, assume the Prospectus is correct.

- E. 1. KD will try to get cost breakdowns and fuel use, but of the total costs, \$750,000 is for temporary package boilers (fuel unknown) and \$6,750,000 was for hot water distribution. KD was going to double check, but believed the distribution system consisted of 20" main lines, which the designers believed would be the largest ever needed.
2. KD will check.
3. Absorption in all buildings.
4. KD will check.
5. \$750,000, they are considering leasing the equipment instead of purchase thereby eliminating the problem. If leasing is not feasible, the equipment would probably be used as a backup for the University system.
- F. 1. KD will check.
2. Since aquifers were ruled out, I didn't ask.
- G. 1. The Port Authority is nonprofit, therefore ROR is not really relevant. KD will check if the developers will tell him their RORs.
- H. 1. Most of the yard will go, but the two sets of mainline tracks will remain. If heating lines must cross the tracks, there should be little problem getting railroad approval, and there is a major bridge carrying Snelling Avenue over the tracks that could probably be used.
2. No problem.
- I. 1. Due to UDAG proposal due Jan. 31, and modifications or elaborations must be sent in while the review is in process. The 15th is really the last day.
2. The real question they want answered is: Does the proposed hot water district heating system make sense? If not, why and what do you suggest instead? If DH is a good idea, they want a Very Strong endorsement that they can pass to the UDAG people to get infrastructure funding.

ARGONNE
NATIONAL
LABORATORY

INTRA-LABORATORY MEMO

January 18, 1980

TO: St. Paul Team Members

FROM: R. Kron *R. Kron*SUBJECT: Set #2 of Ken Dzugan's Answers to Our Questions of January 17Concerning Questions in Section A on the University DH System:

1. The University will be able to supply hot water in 1984. We can assume no steam will be available before 1984 due to the funding schedule of the state legislature.
2. The supply temperature will be 300°F, with 160°F return.
3. The University buildings' peak will occur in January. The future capacity of the University hot water plant using Western coal will be 653,000 pounds per hour (lbs/hr). The University buildings' peak load will be between 505,000 and 555,000 lbs/hr. Thus, approximately 100,000 to 150,000 lbs/hr will still be available for the Energy Park. The University estimated that the capacity available to Energy Park should be enough to supply services to 4 to 5 million sq ft. of buildings of 1960's vintage. On the basis of this estimation, the University figures they can supply the newer, tighter structures of Energy Park. (The University also estimates that if they had aquifer storage, their peak available to Energy Park would increase to 200,000 to 300,000 lbs/hr.).

The University will also have 360,000 lbs/hr. emergency capacity from their old oil-fired equipment. In addition, the University will be able to supply cooling via an absorption cooling system (check report referenced below for details). The cooling system will apparently be fairly advanced since the supply temperature can drop to 240°F and 12 lb. pressure and still supply cooling.

4. The University's price to recover their total cost is \$3.26 per 1,000 pounds of steam supplied. The price could drop by \$.10/1000 lbs. due to quantity discounts, but no more drop than that may be expected.

Information on the University system should be available from a report Jess Pascual has: Executive Summary to Final Phase II Report, Contract #00-4210-3/1UC-95D.

Concerning Questions in Section F on Local Regulations

1. Yes, the ventilation codes are:

Industrial Buildings: Either 3% of the floorspace must be in operable windows and no additional ventilation is required or 10 CFM per person in outside air must be supplied.

Residential Buildings: 8% of the floor area must be window space, and 4% of the floor space is to be complimented by window space that is operable. No mechanical vents are required, and there is no mechanical alternative to the above rule.

NFK/jl

cc: R. Hrabak
C. Lee
A. Kennedy
H. Davis
J. Pascual
P. Donnelly

ARGONNE
NATIONAL
LABORATORY

INTRA-LABORATORY MEMO

January 18, 1980

TO: St. Paul Team Members
FROM: Rick Kron *R. Kron*
SUBJECT: Set #3 of Ken Dzugan's Answers to our Questions

Relating to Part B: Current Fuel Costs

1. Electric Rates

Residential

There is a \$2.50 to \$4.00/month user fee. On top of this, rates are different by two seasons and quantity used as follows:

Amount Used → Time of Year ↓	First 1000 kWh/Month	Excess over 1,000
October - May	3.82¢/kWh	2.26¢/kWh
June - September	4.21¢/kWh	4.21¢/kWh

There are some adjustments to these figures:

- If you use less than 300 kWh/mo. you get a conservation credit of \$2.50. If you use 300-400 kWh/mo. you get \$1.25.
- Taxes are: 8.7% city fee, which will be phased out in steps by 1985. There is a 4% state sales tax, but residences with electric heat are exempt from the tax in winter.
- All bills have a fuel adjustment clause.

"GENERAL SERVICE RATES" - commercial/industrial customers "small" customers.

Customer user charge is \$3.00/mo., then rate schedule is similar to residential as follows:

Amount Used → Time of Year ↓	First 1000 kWh/Month	Excess over 1,000
October - May	4.04¢/kWh	3.7¢/kWh
June - September	4.42¢/kWh	4.42¢/kWh

-2-

Taxes are 8.7% city fee and 4% state sales tax.

"LARGE" CUSTOMERS, INDUSTRY

Rates are in two parts, a demand charge plus a per kWh cost for actual use.

Demand Charge —▶	< 50 kW	Next 50 kW	Above 100 kW
October - May	\$3.85/kW	\$3.70/kW	\$3.55/kW
June - September	\$4.85/kW	\$4.70/kW	\$4.55/kW

Per kW charges may be reduced 0.15 to 0.25 depending on voltage desired.

Energy Costs	First 100,000 kWh	Next 900,000 kWh	Over 1 million kWh
All Times of Year	1.98¢/kWh	1/80¢/kWh	1/56¢/kWh

There is a full adjustment clause.

GAS RATES

There is a customer user charge of \$2.00/Mo.

Energy Costs	First 50 CCF	Next 450 CCF	All Additional
All Times of Year	26.96¢/CCF	26.54¢/CCF	25.95¢/CCF

TAXES: 8.7% city tax on all uses. 4% state sales tax, except for winter in residences with gas heat.

There is a fuel adjustment clause.

For very large users, interruptible rates are negotiated for each.

See NSP's published rate tables for more information.

RK/jl

cc: R. Hrabak
C. Lee
H. Davis
A. Kennedy
J. Pascual
P. Donnelly

**ARGONNE
NATIONAL
LABORATORY**
INTRA-LABORATORY MEMO

January 22, 1980

TO: St. Paul Team Members
 FROM: R. Kron
 SUBJECT: Set #4 of Ken Dzugan's Answers to Our Questions

On Section E, the Previously Calculated DH System

The study was completed last fall, the figures are 1979 dollars.

Energy loads were calculated using several rules of thumb such as energy use per sq. ft., per employee, per acre, etc. These estimates produced a very wide range of energy loads, with 30 to 125 MW_t for the heating load for the entire park. The DH designers chose a middle value of 70 to 75 MW_t for their estimations.

The estimated line sizes, lengths, costs, and phasing are shown below:

Development Phase			
↓	Pipe Diameter →	16"	Installed Costs
	Pipe Length →	4"	
Phase 1	5200 ft.	2000 ft.	16" = \$375/ft.
Phase 2	6000 ft.	4000 ft.	4" = \$150 ft
Phase 3	1700 ft.	2000 ft.	

The boilers were natural gas fired, with the installation coming in Phases 1 and 2. The engineers estimated an installed capacity of 20 MW, with no breakdown of how many boilers would be installed. The boiler cost was estimated to be \$40/kW, with the boilers being purchased. Absorption cooling with the chillers located in the buildings was assumed.

The total system cost was estimated at \$7.5 million, which may have been a bit high.

No cost per MMBtu was calculated.

Answers to Section G: Economics

1. The ROR is unknown and can't easily be obtained, it is known that Control Data expected a capitalization rate of 11.25% on their rented floor-space six months ago. It is unclear if this rate still holds.

Answer in Section A: University System

5. Mr. Dzugan isn't entirely sure, but he does not believe that Energy Park funds can be spent on equipment in the University's heating plant.

Concerning Utility Rates

1. A "large" electric customer uses over 2500 kWh/month.
2. Electric service can be interruptible for "very large" customers. These special rates are negotiated between the utility and customer. No "very large" customers are expected in Energy Park.

RK/jl

cc: R. Hrabak
C. Lee
A. Kennedy
H. Davis
J. Pascual
P. Donnelly

**ARGONNE
NATIONAL
LABORATORY**
INTRA-LABORATORY MEMO

February 5, 1980

TO: St. Paul Team Members
 FROM: Rick Kron *RK*
 SUBJECT: Set #5 of Ken Dzigan's Answers to Our Questions

1. What is Northern States Power (NSP) company's current fuel mix for their electricity generation?

	<u>1978 Actual</u>	<u>1979 Estimate</u>	<u>1983 Projected</u>
Nuclear	43%	45%	38%
Coal	51	51	51
Hydro, Oil, etc.	6	4	4
Canada Purchases*	0	0	7

* These will be through purchase/exchange agreements where NSP will sell power in the winter and buy in the summer.

2. What is NSP's short-term rate for natural gas that could be used in temporary boilers?

NSP has no separate short-term rate schedule, assume the long-term rates apply. (We have these already!)

3. From where does Energy Park expect to rent boilers? What costs are expected? Has anyone calculated the costs for setting up and dismantling the plant and the future use of the building that would be required?

The whole idea of rented boilers was just a suggestion. No one has looked into it at all.

4. What would be the approximate rental charge per square foot of offices, industrial, and residential space?

Offices - we don't know yet

Industrial - the Control Data building will contain some space for small companies. This will rent for about \$7.40 per sq. ft. per year. This cost is probably higher than that which most tenants will encounter.

Residential - The U.S. Department of Housing and Urban Development recently calculated the following "fair market rent costs" for Minneapolis-St. Paul, effective 4/1/79.

-2-

Housing Type ↓ Average Rent →	Number of Bedrooms				
	Efficiency	1	2	3	4
Detached Living Unit	-	-	\$542	\$588	\$604
Townhouse		396	445	488	533
Walk-up Multi-Family Units	253	311	362	455	477
Low Rise Elevator Apts. 2 to 4 Stories	306	356	444	468	-
High Rise Elevator Apts. Over 5 Stories	338	392	488	-	-

5. How did the district heating consultants calculate their piping costs?

Ask them. The person to talk to is Herb Jaehne (pronounced Jay-nee). His number is (FTS 8-725-4242, then . . .) 612-297-8955. He works for the District Heating Development Company, which is the same group working on the downtown St. Paul system.

RK/jl

cc: R. Hrabak
C. Lee
A. Kennedy
H. Davis
J. Pascual
P. Donnelly

APPENDIX D. CONVENTIONAL SYSTEM COST ESTIMATION

This Appendix provides a cost breakdown for each building in the Energy Park, based on the in-building heating and cooling conventional system. (See Table D.1).

Table D.1. Conventional System Costs

Typical Building Number	Area Per Typical Buildings ^a	Number of Typical Buildings ^b	In-Building Systems			
			Water Heating Equipment Cost 1980 (\$ x 10 ³)	Water Cooling Equipment Cost 1980 (\$ x 10 ³)	Water Heating O&M Cost ^c 1980 (\$ x 10 ³)	Water Cooling O&M Cost ^c 1980 (\$ x 10 ³)
1	150,000	4 R	25	66	1	3.7
2	75,000	16 R	16	32	0.65	3.3
3	50,000	4 R	12	24	0.50	3.2
4	45,000	1 C/O	10	33	0.50	3.3
5	40,000	1 C/O	10	36	0.50	3.3
6	20,000	2 C/O	6	21	0.50	3.2
7	25,000	1 C/O	6	32	0.50	3.2
8	200,000	1 C/O	53	111	2.20	6.4
9	150,000	2 C/O	29	93	1.20	5.3
10	84,400	1 C/O	16	69	0.65	3.7
11	100,000	4 C/O;	19	74	0.80	3.8
		3 I				
12	500,000	2 I/CO	77	224	3.20	12.0
13	328,000	1 I	53	156	2.20	9.1
14	50,000	3 I	12	36	0.50	3.3
15	600,000	1 I	96	275	4.00	13.7
16	75,000	1 I	16	63	0.65	3.7
17	30,000	2 I	7	26	0.50	3.2
18 ^d	600	1 I	3	2	0.50	0.5

^a The costs in this table and the costs in the entire study applies to these particular size buildings. If these buildings are aggregated to be larger structures, the cost estimates will remain reasonably accurate. However, if these buildings are broken into many smaller structures, the costs would substantially increase.

^b R is residential, C/O is commercial and office, and I is industrial.

^c O&M costs include salaries, service contracts, parts, and preventative maintenance. No insurance or property tax expenses are included.

^d The total mechanical room space costs used for the conventional system was $\$3.03 \times 10^6$. In the analysis of central and district alternatives, the costs used were $\$2.19 \times 10^6$ if cooling was still an in-building service, $\$2.17$ if heating was still an in-building service, and $\$1.24 \times 10^6$ if neither service was in-building.