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TOTAL INTEGRATED ENERGY SYSTEM (TIES) FEASIBILITY
ANALYSIS FOR THE DOWNTOWN REDEVELOPMENT PROJECT,
PASADENA, CALIFORNIA

April 1977

Work Performed Under Contract No. EY-76-C-03-1151

City of Pasadena
Pasadena, California

Pasadena Redevelopment Agency
Pasadena, California

Levine and McCann
Los Angeles, California

Genge Community Consultants
Los Angeles, California

MASTER

ENERGY RESEARCH AND
DEVELOPMENT ADMINISTRATION

Division of Buildings and Community Systems

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contents

I.	INTRODUCTION	
A.	PURPOSE	I-1
B.	BACKGROUND	I-1
C.	DEFINITION OF SITE AND BUILDING DESIGN DATA	I-5
1.	<i>The Energy Using Community</i>	I-5
2.	<i>Weather Data</i>	I-6
3.	<i>Building Design and Usage</i>	I-6
II.	DEFINITION OF LOADS	
A.	COOLING, HEATING AND NON-HVAC LOADS	II-1
1.	<i>Required Services and Utilities</i>	II-1
2.	<i>Analysis of Space Cooling and Heating Loads</i>	
3.	<i>Energy Analysis Computer Program</i>	II-2
B.	BUILDING PEAK LOADS AND ANNUAL ENERGY CONSUMPTION	II-7
III.	DESCRIPTION OF CONVENTIONAL SYSTEM	
A.	DEFINITION OF CONVENTIONAL SYSTEM	III-1
B.	ENERGY CONSUMPTION	III-2
C.	ANNUAL COSTS OF CONVENTIONAL SYSTEM	III-2
IV.	DESCRIPTION OF CENTRAL COOLING/ HEATING PLANT SYSTEM	
A.	DEFINITION OF CENTRAL PLANT SYSTEM	IV-1
B.	ENERGY CONSUMPTION	IV-2
C.	ANNUAL COSTS OF CENTRAL PLANT SYSTEM	IV-2
V.	EXAMINATION OF TIES SYSTEMS	
A.	METHOD OF APPROACH	V-1
1.	<i>Initial Examination of Energy Systems and Project Constraints</i>	V-1
2.	<i>Energy Cycle Relationships</i>	V-3
3.	<i>Ties Concept Advantages</i>	V-6
B.	TIES SYSTEMS STUDIED	V-10
1.	<i>Systems Studied</i>	V-10
2.	<i>Energy Analysis of Ties Systems</i>	V-20
3.	<i>Other Access Input Parameters</i>	V-21
C.	ENERGY CONSUMPTION OF TIES SYSTEMS STUDIED	V-21
D.	ANNUAL COSTS OF TIES SYSTEMS	V-28
VI.	DISCUSSION AND RECOMMENDATIONS	
A.	COMPARISON OF TIES SYSTEMS WITH THE CONVENTIONAL AND CENTRAL PLANT SYSTEMS	VI-1
1.	<i>Energy Savings</i>	VI-1
2.	<i>Economic Feasibility Comparison</i>	VI-1
3.	<i>Impact on Air Quality</i>	VI-3
B.	COSTS OF GENERATING ELECTRICITY FOR TIES SCHEMES	VI-5
C.	DISCUSSION OF SYSTEMS STUDIED	VI-7
D.	RECOMMENDATIONS	VI-7
VII.	GLOSSARY	

APPENDICES

list of figures

NUMBER	TITLE	PAGE
I-1	CONCEPT DIAGRAMS	I-3
I-2	PASADENA RETAIL CENTER—PARKING LEVELS	I-8
I-3	PASADENA RETAIL CENTER—UPPER AND LOWER LEVELS	I-9
I-4	PASADENA RETAIL CENTER—SECTIONS	I-10
I-5	HOURLY OUTSIDE D.B. TEMPERATURE—FOR COLDEST WEEK	I-11
I-6	HOURLY OUTSIDE D.B. TEMPERATURE—FOR HOTTEST WEEK	I-12
I-7	HOURLY OUTSIDE D.B. TEMPERATURE—FOR MILDEST WEEK	I-13
II-1	BUILDING POWER FLOW—JANUARY	II-9
II-2	BUILDING COOLING FLOW—JANUARY	II-10
II-3	BUILDING HEATING FLOW—JANUARY	II-11
II-4	BUILDING POWER FLOW—AUGUST	II-12
II-5	BUILDING COOLING FLOW—AUGUST	II-13
II-6	BUILDING HEATING FLOW—AUGUST	II-14
II-7	BUILDING POWER FLOW—NOVEMBER	II-15
II-8	BUILDING COOLING FLOW—NOVEMBER	II-16
II-9	BUILDING HEATING FLOW—NOVEMBER	II-17
V-1	ENGINE AND REFRIGERATION CYCLES	V-5
V-2	WORST CASE BUILDING COOLING LOAD—(AUGUST 13)	V-8
V-3	REFRIGERATION MACHINE OPERATION VS. STORAGE TANK SIZE	V-9
V-4	DIESEL ENGINE SYSTEM (WITH ABSORPTION REFRIGERATION)— GROUP 1	V-11
V-5	COMBUSTION TURBINE SYSTEM (WITH STEAM TURBINE CENTRI- FUGAL REFRIGERATION)—GROUP 2	V-14
V-6	BOILER/STEAM TURBINE SYSTEM—GROUP 3	V-16
V-7	COMBUSTION TURBINE SYSTEM (WITH BACKPRESSURE STEAM TURBINE AND ABSORPTION REFRIGERATION)—GROUP 4	V-18
V-8	REFRIGERATION MACHINE AND STORAGE TANK OPERATION	V-22
V-9	SCHEME 1A PLANT POWER OUTPUT — NOVEMBER	V-29
V-10	SCHEME 1A NET GRID OUTPUT — NOVEMBER	V-30
V-11	SCHEME 1A PLANT COOLING OUTPUT — NOVEMBER	V-31
V-12	SCHEME 1A PLANT HEATING OUTPUT — NOVEMBER	V-32
V-13	SCHEME 1B PLANT POWER OUTPUT — NOVEMBER	V-33
V-14	SCHEME 1B NET GRID OUTPUT — NOVEMBER	V-34
V-15	SCHEME 1B PLANT COOLING OUTPUT — NOVEMBER	V-35
V-16	SCHEME 1B PLANT HEATING OUTPUT — NOVEMBER	V-36
V-17	SCHEME 1E PLANT POWER OUTPUT — NOVEMBER	V-37
V-18	SCHEME 1E NET GRID OUTPUT — NOVEMBER	V-38
V-19	SCHEME 1E PLANT COOLING OUTPUT — NOVEMBER	V-39
V-20	SCHEME 1E PLANT HEATING OUTPUT — NOVEMBER	V-40
V-21	SCHEME 2A PLANT POWER OUTPUT — NOVEMBER	V-41
V-22	SCHEME 2A NET GRID OUTPUT — NOVEMBER	V-42
V-23	SCHEME 2A PLANT COOLING OUTPUT — NOVEMBER	V-43
V-24	SCHEME 2A PLANT HEATING OUTPUT — NOVEMBER	V-44
V-25	SCHEME 2D PLANT POWER OUTPUT — NOVEMBER	V-45
V-26	SCHEME 2D NET GRID OUTPUT — NOVEMBER	V-46
V-27	SCHEME 2D PLANT COOLING OUTPUT — NOVEMBER	V-47
V-28	SCHEME 2D PLANT HEATING OUTPUT — NOVEMBER	V-48

list of tables

NUMBER	TITLE	PAGE
II-1a	'H'-LOAD-COOLING AND HEATING LOADS	II-3
II-1b	'H'-LOAD-COOLING AND HEATING LOADS	II-4
II-2	'H'-LOAD-COOLING LOAD	II-5
V-1	GROUP 1-DIESEL ENGINE SYSTEM (WITH ABSORPTION REFRIGERATION)	V-12
V-2	GROUP 2-COMBUSTION TURBINE SYSTEM (WITH STEAM TURBINE DRIVEN CENTRIFUGAL REFRIGERATION)	V-15
V-3	GROUP 3-DESCRIPTION OF BOILER/STEAM TURBINE SYSTEM	V-17
V-4	GROUP 4-COMBUSTION TURBINE SYSTEM (WITH BACKPRESSURE STEAM TURBINE AND ABSORPTION REFRIGERATION)	V-19
V-5	GROUP 1-DIESEL ENGINE SYSTEM-ENERGY CONSUMPTION	V-24
V-6	GROUP 2-GAS TURBINE/CENTRIFUGAL REFRIGERATION SYSTEM -ENERGY CONSUMPTION	V-25
V-7	GROUP 3-STEAM BOILER/STEAM TURBINE SYSTEM-ENERGY CONSUMPTION	V-26
V-8	GROUP 4-GAS TURBINE/ABSORPTION REFRIGERATION SYSTEM -ENERGY CONSUMPTION	V-27
V-9	CAPITAL COSTS	V-50
V-10	ANNUAL OPERATING COSTS	V-51
V-11	ANNUAL REVENUE	V-52
V-12	BONDING FEASIBILITY SUMMARY	V-53
VI-1	COMPARISON OF SYSTEM ENERGY CONSUMPTION	VI-2
VI-2	FEASIBILITY COMPARISON-TIES VS. CONVENTIONAL & CENTRAL COOLING/HEATING PLANT	VI-3
VI-3	ANNUAL EMISSIONS FROM PLANTS	VI-5
VI-4	COST OF GENERATING ELECTRICITY FOR TIES SCHEME	VI-6

**TOTAL INTEGRATED ENERGY SYSTEM
FEASIBILITY ANALYSIS FOR
THE DOWNTOWN REDEVELOPMENT PROJECT
PASADENA, CALIFORNIA**

I. INTRODUCTION

A. PURPOSE

The purpose of this study is to determine the most desirable method of serving the energy needs of a commercial development to be constructed in Pasadena, California.

The factors that determine maximum desirability consist of the following:

1. Maximum economic benefit to the energy user and to the surrounding community.
2. Minimum usage of energy by both the energy user and the surrounding community.
3. Minimum introduction of pollutants into the community.

The methods studied were the Total Integrated Energy System (TIES) concept in several configurations.

B. BACKGROUND

Several alternatives are available as methods of meeting a users total energy needs. The most common, however, is to acquire electric power from a serving utility company and to produce heating and cooling media; either through the use of electric power, or by firing a separate fuel in boilers, or by combinations of the two. Figure I-1a describes this "conventional" approach.

Assuming the utility company power plant is thermal in nature, losses of energy occur within the plant due to radiation from plant equipment, cooling of plant equipment, non-recoverable stack losses, auxiliary power usage, and low potential heat rejection to atmosphere.

Within the user's facility, similar losses occur due to the energy conversion processes that take place. There also exists a transmission loss that occurs between the utility source and the user due to line impedance and transformer losses.

Efforts to reduce these losses resulted in the total energy concept, whereby power production was brought into close proximity with the energy user, usually on the same site. (See Figure I-1b)

Under this concept, much of the waste heat by-product of power generation could be used to produce a heating media, and through one cycle or another, most commonly — absorption, a cooling media could also be produced. No energy conversion is required by the energy user, so those losses are also eliminated.

The Total Energy Concept is valid, however, only during those moments of time when the waste heat by-product of power production (a function of instantaneous power demand) closely coincides with the waste heat needed to equate to the sum of heat required to meet the simultaneous demands to heating media and cooling media. This ideal situation seldom occurs, so that during periods when waste heat production exceeds demand, the heat must be wasted to atmosphere. When waste heat production is lower than the simultaneous demand, auxiliary boilers or similar fuel consuming equipment must be fired to make up for the deficiency.

The TIES concept differs from the Total Energy Concept in the respect that the electric power output of the local power generation plant goes into the utility company distribution grid, rather than to the user. The user is served power from the grid, as with a conventional system, but also receives heating and cooling media produced from power generation by-product heat from the TIES plant. The effect of this concept is that a very large source-sink for electric energy is provided by the utility company grid. This in turn permits the plant to operate in response to instantaneous thermal demand, rather than instantaneous power demand. No auxiliary firing is ever required. No waste of unneeded by-product energy to atmosphere ever occurs. Balance is achieved by either delivering excess power into the grid or by withdrawing power production deficiency from the grid. Near optimum efficiency is achieved during all operating conditions. There is no need whatsoever for the power generating plant to be sized to meet the power demand, since it seldom, if ever, tracks the power demand. Sizing of the electric generation is solely a function of economics and the demand for waste heat.

To proceed with the TIES concept, several conditions must be met:

1. Because TIES delivers its electric power output to a serving utility company grid, it becomes a part of the total utility company system and should, therefore, be directly operated by the utility company. The utility company need not own the plant, however.
2. To avoid instability in the combined systems, the TIES plant should be small compared to the utility company. In point of fact, the TIES maximum capacity should not exceed about 20 percent of the utility company's minimum demand.

1a – CONVENTIONAL ENERGY CONCEPT

1b – TOTAL ENERGY CONCEPT

1c – TIES CONCEPT

3. Because the TIES maximum output is available to the utility on demand to meet emergency or other operating situations (albeit at lower energy efficiency) the utility company should see fit to pay a monthly demand charge to the TIES plant owner for this available demand. The amount of this demand charge would normally be negotiated in the range of cost that the utility company would invest in some other form of peaking plant.
4. The TIES energy output, measured in KWH delivered to the grid should be purchased by the utility company. The negotiation of rate would be based on the cost of equivalent options available to the utility company for purchased power. It should be noted that thermal storage (discussed later) coupled with various heating-cooling equipment size selections can be tailored so that power is produced only during the utility company's period of peak demand, when the value of purchased energy is considerably greater than excess energy produced during periods of off-peak demand.

The Pasadena Department of Water and Power (DWP), a municipally owned utility company, agreed to enter into such an arrangement with the Pasadena Redevelopment Agency (PRA) whereby DWP would operate such a plant and pay a monthly demand charge to PRA in the amount of \$1.00 per KW of installed capacity and purchase electric energy delivered to the grid at the rate of 1.8 cents per KWH.

PRA would construct the plant and receive all revenue from the sale of heating and cooling media to the adjacent energy using community.

Together, the two agencies sought and received funding from the Energy Research and Development Administration (ERDA) to explore the viability of the approach.

In arguing for these funds from ERDA the agencies relied on the apparent advantages of TIES which are obvious:

- Continuous operation at optimum efficiency would consume less fuel.
- Less fuel burned would produce less air pollution.
- Demand capacity installed in TIES plants would offset part of the capital requirement needed to expand available demand by the utility company.

This report indicates the merits of rigorous analysis, for all that is apparent is not necessarily true.

C. DEFINITION OF SITE AND BUILDING DESIGN DATA

1. *The Energy Using Community*

The community under study is a proposed Retail/Office Building development in downtown Pasadena, California. The development consists of a two level retail shopping center, adjoining office buildings and parking facilities, the composition of which is planned as follows:

DESCRIPTION	APPROXIMATE AREA (SQUARE FEET)
Retail Center:	
Major Department Stores	295,000
Tenant Retail Shops	317,000
Common Areas (Enclosed malls, courts, corridors, stairs and exits)	<u>126,000</u>
SUBTOTAL	738,000
Office Buildings (Two in number)	<u>60,000</u>
TOTAL	798,000
Parking Facilities:	
Two underground parking levels located under the shopping center proper	829,000
Adjoining multi-level parking	628,000
TOTAL	1,457,000

Drawings of the proposed Energy Using Community are shown in Figures I-2 through I-4 inclusive.

In addition to the Energy Using Community described above, the program was to consider the future development of nearby office and retail spaces that would total an additional 642,000 square feet.

2. *Weather Data*

The weather conditions prevailing at the development site are those of the typically benign climate of Southern California. Summers are warm and dry with somewhat cool evenings. Winters are mild, with freezing temperatures rarely achieved. Temperatures lower than 50 degrees F during normal business hours are similarly rare. Seasonal variations are minor. Very warm weather can occur during the "winter" season and it is not uncommon to have a greater demand for cooling occurring during this period than during the spring or fall months.

- The hourly weather data for a typical year was obtained from the nearest local National Weather Bureau station in Burbank, California. Outside air (OSA) Dry Bulb temperatures in degrees Fahrenheit are shown in Figures I-5, I-6 and I-7 plotted on an hourly basis for three weeks representing the coldest week (January), the hottest week (August) and a typically mild week (November).

Cooling and heating design conditions recommended by ASHRAE for Pasadena are as follows:

Cooling (.5% values)

Outside dry bulb = 94° F

Outside wet bulb = 70° F

Daily Range = 28° F

Heating (.6% values)

Outside dry bulb = 39° F

3. *Building Design and Usage*

As is typical with projects in the early stage of development, the details of neither design nor usage have been totally defined. There did exist from the developer, however, certain information upon which reasonable engineering judgments could be based:

a. There would be two large stores:

- A two-level store, similar in character to a major J. C. Penney store.
- A three-level store, similar in character to a Broadway Department Store (Broadway being a major Southern California chain).

- b. There would be a typical mix of tenants in the balance of retail area, as tabulated in APPENDIX B, with desired percentage of area allocation to:
- Food stores
 - Drug stores
 - Junior department stores
 - Restaurants
 - Real estate-travel agencies and other office type functions
 - Jewelry, men's and women's shoes and similar specialty types of stores
- c. Parking garages would be ventilated to meet minimum code requirements and would have mechanical ventilation only for spaces below ground.
- d. It was assumed that the design of the building envelope, lighting and air conditioning systems would meet the minimum requirements of the pending State of California Energy Conservation Standards for New Non-Residential Buildings (Title 24) which is similar in nature to ASHRAE Standard 90-75. The construction details and factors used are tabulated in Appendix A.
- e. Usage was given as follows:
- Weekdays — 10:00 AM to 9:00 PM
 - Saturday — 10:00 AM to 6:00 PM
 - Sundays and Holidays — Closed
 - Christmas Period (December 1 through 24)
 - Weekdays — 10:00 AM to 10:00 PM
 - Saturday — 10:00 AM to 10:00 PM
 - Sunday — 11:00 AM to 7:00 PM
 - 10-20% interior lights on during closed periods for security and display purposes
 - Outside decorative lighting from 7 to 10 PM daily
 - Covered parking lighting from 7 AM to 10 PM

1-8

Figure 1-3 PASADENA RETAIL CENTER - UPPER AND LOWER LEVELS

1-10

HOURLY OUTSIDE D.B. TEMPERATURE - FOR COLDEST WEEK

HOURLY OUTSIDE D.B. TEMPERATURE – FOR HOTTEST WEEK

Figure 1-6
1-12

HOURLY OUTSIDE D.B. TEMPERATURE - FOR MILDEST WEEK

Figure 1-7

II. DEFINITION OF LOADS

A. COOLING, HEATING AND NON-HVAC LOADS

1. *Required Services and Utilities*

The Energy Using Community described and defined in Section I requires the following energy services:

a. Cooling Media

- For space cooling

b. Heating Media

- For space heating
- For domestic hot water

c. Electric Power

- For lighting of interior spaces, garages and landscape areas
- For miscellaneous electrical loads
- For cooking equipment in restaurant areas
- For vertical transportation systems and materials handling systems
- For pumps and fans

2. *Analysis of Space Cooling and Heating Loads*

The maximum cooling and heating loads, for the Energy Using Community, were determined using S&H Information Systems, Inc. H-Load computer analysis program.

The data and procedure used were as follows:

- ##### **a.**
- Design conditions and building construction characteristics were based on data described in Section IC. These building construction characteristics, heating and cooling design criteria and building lighting levels were based upon the pending Energy Conservation Standards for New Nonresidential Buildings, State of California Administrative Code, Title 24.

- b. The building was subdivided into tenant areas and types of usage, such as department stores, shoe stores, restaurants, sales and stock areas, etc., based on information received from the proposed developer of the project. Individual tenant area loads for lighting, miscellaneous power, specialized power, and occupants were determined from developer-furnished records of similar projects and from prior experience of the engineering team. These loads are tabulated in Appendix B.
- c. An assumption was made of the type of heating and ventilating system which would be used in the various areas of the development. Air handling systems were assumed to be of the variable volume type and were input as such. These systems are included under the definition of the Conventional System in Appendix F.
- d. All of this data was input into the H-Load computer analysis program. The program calculated required supply air quantities and maximum cooling and heating loads for each area (room) and each zone. The program summed up all of the calculated data for each zone to calculate the total instantaneous cooling and heating loads.

The total building heating load, on this basis, was 11,619,000 BTU/HR, which, although the instantaneous building load would be lower than this sum of individual zone loads, gives an indication of the magnitude of the full building heating load.

The maximum building cooling load was calculated to be 3,006 tons. This data is shown on the H-Load computer program printout sheets entitled "Full Building Results" and "Building Refrigeration Tonnage Profile," Tables II-1a, II-1b, and II-2 which follow.

3. *Energy Analysis Computer Program*

The community energy usage was analyzed using the Electrical Energy Association's AXCESS computer analysis program (Alternate Choice Comparison for Energy System Selection). The program analyzed the consumption and use of energy for the Energy Using Community, including all of the building areas previously defined and the ancillary landscaping areas and parking structures.

'H' - LOAD
FULL BUILDING RESULTS
=====

COOLING AND HEATING LOADS

ZONE			**CCCLING LOAD**				**SUPPLY AIR**				VENTIL.	**HEATING LOADS - MBH**			
NC.	AREA	NO. OF	PEAK	REFRIG.	AREA		PER	CHANG.	PER		AIR	ROOM	HUMIDI-	VENTI-	ZONE
	SQFT	PEOPLE	MCN	HR	TONNAGE	/TON	CFM	SQFT	/HOUR	PERSON	CFM	TOTAL	FICATION	LATION	TOTAL
111	34470.	870	7	15	140.	245	56758.	1.64	7.0	65	4350.	451.	12.	164.	628.
112	34445.	871	9	16	170.	201	72026.	2.09	8.9	82	4355.	414.	12.	164.	592.
121	35775.	846	7	18	135.	263	55610.	1.55	6.6	65	4230.	183.	12.	159.	355.
122	35640.	933	7	18	67.	529	21517.	0.60	2.5	23	4665.	167.	13.	176.	357.
123	4320.	80	7	18	23.	182	10622.	2.45	10.5	132	400.	31.	1.	15.	47.
211	23540.	528	8	11	118.	198	51734.	2.19	9.4	97	2640.	375.	7.	99.	482.
212	23558.	664	9	11	130.	180	16207.	0.68	2.9	24	3320.	392.	9.	125.	527.
221	25525.	630	7	15	86.	296	33638.	1.31	5.6	53	3150.	74.	9.	119.	202.
222	25525.	602	9	16	89	283	35969.	1.40	6.0	59	3010.	80.	8.	113.	203.
231	23215.	572	7	18	80.	287	32120.	1.38	5.9	56	2860.	171.	8.	108.	287.
232	23212.	613	7	18	83.	276	33172.	1.42	6.1	54	3065.	146.	8.	115.	270.
233	4510.	90	8	18	25.	174	11493.	2.54	10.9	127	450.	46.	1.	17.	64.
341	14370.	425	7	15	62.	228	25033.	1.74	6.8	58	2125.	203.	6.	80.	290.
351	30890.	843	7	15	140.	219	57367.	1.85	7.5	68	4215.	486.	12.	159.	657.
352	39100.	1129	7	15	171.	227	68724.	1.75	7.5	60	5645.	486.	16.	213.	715.
353	6525.	148	7	15	35.	181	15646.	2.39	10.2	105	740.	175.	2.	27.	205.
501	23102.	638	7	18	90.	256	35809.	1.55	5.4	56	3190.	63.	9.	120.	193.
502	20000.	546	7	18	70.	283	27452.	1.37	4.8	50	2730.	51.	7.	103.	162.
503	20000.	486	7	18	65.	304	25893.	1.29	4.5	53	2430.	51.	6.	91.	150.
601	24375.	749	8	16	96.	252	37222.	1.52	5.9	49	3745.	237.	10.	141.	389.

Table II-1a

'H' - LOAD
FULL BUILDING RESULTS
=====

COOLING AND HEATING LOADS

ZONE			**COOLING LOAD**				**SUPPLY AIR**				VENTIL.	**HEATING LOADS - MBH**			
NC.	AREA	NO. CF	PEAK	REFRIG.	APEA		PER	CHANG.	PER		AIR	ROOM	HUMIDI-	VENTI-	ZONE
	SQFT	PEOPLE	MCN	HR	TONNAGE	/TON	CFM	SQFT	/HOUR	PERSON	CFM	TOTAL	FICATION	LATION	TOTAL
701	33750.	920	8	15	126.	267	49253.	1.45	6.2	53	4600.	326.	13.	173.	513.
702	34720.	1333	8	15	215.	161	87264.	2.51	10.7	65	6665.	392.	19.	251.	563.
703	33000.	965	7	18	122.	269	47385.	1.43	5.0	49	4825.	124.	13.	182.	321.
704	36400.	994	7	18	131.	277	51253.	1.40	4.9	51	4970.	94.	14.	187.	296.
801	21100.	70	7	18	36.	555	16864.	0.79	3.1	240	350.	352.	1.	13.	367.
802	23400.	79	9	18	62.	375	29718.	1.27	4.7	376	395.	522.	1.	14.	538.
911	23000.	230	7	15	45.	505	19147.	0.83	3.4	83	1150.	209.	3.	43.	256.
912	23000.	230	9	14	59.	386	26142.	1.13	4.7	113	1150.	291.	3.	43.	338.
921	38900.	170	7	18	40.	957	17725.	0.45	1.5	104	850.	100.	2.	32.	135.
922	19140.	170	7	13	62.	117	78023.	4.07	13.9	458	850.	503.	2.	32.	538.
1001	30000.	473	9	15	16.	256	51620.	1.72	10.3	109	2365.	335.	6.	89.	432.
1002	30000.	473	9	15	116.	256	51620.	1.72	10.3	109	2365.	335.	6.	89.	432.
BUILDING TOTALS															
	818508.	18370			3105.	262	1250040.	1.52	6.2	68	91850.	7882.	264.	3471.	11619.

Table 11-1b

HEAT LOAD SYSTEM
PASADENA RETAIL CENTER
'H' - LOAD
BUILDING REFRIGERATION TONNAGE PROFILE
-----COOLING LOAD-----

MCNTH	HOOR	1	2	3	4	5	6	7	8	9	10	11	12
1	AM	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	PM	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	AM	0.	0.	0.	0.	0.	0.	0.	771.	1173.	1581.	1924.	2052.
	PM	2109.	2159.	2165.	2086.	1970.	1858.	1721.	1616.	1557.	1467.	0.	0.
3	AM	0.	0.	0.	0.	0.	0.	0.	1209.	1602.	1979.	2291.	2418.
	PM	2483.	2545.	2572.	2533.	2458.	2356.	2234.	2126.	2053.	1961.	0.	0.
4	AM	0.	0.	0.	0.	0.	0.	0.	1376.	1755.	2111.	2416.	2543.
	PM	2607.	2670.	2699.	2668.	2610.	2527.	2398.	2285.	2203.	2109.	0.	0.
5	AM	0.	0.	0.	0.	0.	0.	0.	1582.	1942.	2276.	2576.	2699.
	PM	2761.	2824.	2857.	2834.	2796.	2736.	2598.	2474.	2377.	2281.	0.	0.
6	AM	0.	0.	0.	0.	0.	0.	0.	1726.	2079.	2403.	2700.	2820.
	PM	2881.	2944.	2979.	2962.	2931.	2881.	2737.	2607.	2504.	2407.	0.	0.
7	AM	0.	0.	0.	0.	0.	0.	0.	1728.	2088.	2421.	2721.	2843.
	PM	2905.	2968.	3001.	2979.	2942.	2882.	2743.	2618.	2521.	2425.	0.	0.
8	AM	0.	0.	0.	0.	0.	0.	0.	1683.	2062.	2417.	2723.	2851.
	PM	2915.	2977.	3006.	2974.	2918.	2834.	2705.	2592.	2510.	2417.	0.	0.
9	AM	0.	0.	0.	0.	0.	0.	0.	1605.	1998.	2374.	2688.	2815.
	PM	2881.	2941.	2968.	2929.	2854.	2754.	2633.	2526.	2454.	2363.	0.	0.
10	AM	0.	0.	0.	0.	0.	0.	0.	1358.	1749.	2136.	2461.	2585.
	PM	2650.	2710.	2734.	2689.	2598.	2506.	2389.	2289.	2220.	2127.	0.	0.
11	AM	0.	0.	0.	0.	0.	0.	0.	1111.	1496.	1886.	2223.	2349.
	PM	2413.	2471.	2491.	2437.	2334.	2255.	2146.	2057.	1993.	1901.	0.	0.
12	AM	0.	0.	0.	0.	0.	0.	0.	735.	1113.	1523.	1881.	2020.
	PM	2081.	2130.	2133.	2040.	1917.	1825.	1704.	1610.	1557.	1467.	0.	0.

The data and procedure used were as follows:

- a. In Section IIA, a determination of the services required by the community was made. The assignment of these services to a utility for the energy usage analysis is as follows:

Space Cooling	COOLING UTILITY
Space Heating	HEATING UTILITY
Domestic Hot Water	
Lighting	ELECTRICAL UTILITY
Misc. Power (convenience receptacles for portable appliances, etc.)	
Vertical Transportation	
Materials Handling	
Fans & Pumps for HVAC & Plumbing Systems	
Cooking	

- b. Heating and cooling design criteria, building electrical lighting and power levels and building construction characteristics were based on the same data used for the H-Load Analysis, and as tabulated in Appendices A, B and D and for the weather year of 1975 recorded at Burbank, California, a nearby station with weather similar to Pasadena.
- c. The calculations for domestic hot water heating loads were made based on storage-type hot water heaters. Hot water flow rates for the retail areas were based on gallons per day per person. The figures used were taken from a study of comparable spaces made by the Department of Civil Engineering of the University of Maryland, published in the AWWA Journal, May 1975.

Office area and restaurant loads were calculated on the basis of the latest published data by the American Society of Plumbing Engineers.

A tabulation of the estimated domestic hot water loads and usage profiles is included in Appendix C.

- d. Profiles were established for electrical power on an hourly basis for each of the various building areas within the community, and for all the services required to those areas.
- The profiles were based on the hours of operation stated in Section I.
 - The profiles used were obtained from the Electric Energy Association and modified from analysis of computer printouts of hourly electrical meter readings of similar local department stores obtained from the Southern California Edison Co.

- All cooking and water heating was assigned to the electrical service for the Conventional System, and cooking was assumed to be done electrically for the Central Cooling/Heating Plant System. The profiles used in this analysis and the electrical loads and profile maximum percentages used are tabulated in Appendix D.
 - Part-load efficiency curves were developed for all primary cooling and heating equipment, based upon data obtained from equipment manufacturers.
- e. The AXCESS computerized energy analysis program, using the above-mentioned input data, calculated and tabulated instantaneous zone cooling and heating loads, and from these, calculated the required rates of conditioned air circulation and the power requirements and energy consumed by the required air moving equipment (fans).

The AXCESS program then calculated and tabulated the hourly, monthly and yearly values of the electrical energy usage of the building, and the energy used for building space cooling and heating and domestic water heating. It also calculated and tabulated the maximum demand values and time of occurrence for these loads.

These values and quantities were shown in the AXCESS program printouts in the form of simulated "meter" readings. The program printout for the yearly total energy consumption for the building is shown in Appendix E.

B. BUILDING PEAK LOADS AND ANNUAL ENERGY CONSUMPTION

1. The results of the AXCESS energy analysis (computer run of March 4, 1976) shown in Appendix E, is summarized as follows:
 - a. Building Base Power: 22,575,248 KWH with maximum demand of 5,803 KW occurring on December 7 at 3:00 PM.
 - b. Building Cooling: 3,447,875 ton-hours with maximum demand of 2,952 tons occurring on August 13 at 10:00 AM.
 - c. Building Heating: 7,566 million BTU with maximum demand of 10 million BTU occurring on January 2 at 10:00 AM.
 - d. Building Domestic Hot Water: 2,184 million BTU with maximum demand of 800 MBTU occurring uniformly at 2:00 PM on each business day.
2. Plots were made of the hourly building electrical power flow (demand), cooling flow, and heating flow, for the coldest week (January), hottest week (August), and most stable week (November), based upon the load data and AXCESS computer program runs of March 4 and May, 1976.

Figures II-1 through II-9 inclusive, following, illustrate the daily flow and fluctuation of energy usage and occurrence of peak loads.

3. It is important to understand the relative energy use of the facility. Expressing annual usage in equivalent terms of trillions of BTU:

265.5 are consumed to produce electric power

86.2 would be consumed to produce cooling with an absorption cycle

32.4 would be consumed to produce cooling with a compressive cycle

7.6 is consumed for heat

2.2 is consumed for domestic hot water

The user's energy needs were dominated by electric power and by cooling, both of which involve second-law cycles, and are poor candidates for use of low potential waste heat. The sum of first-law energy needed for space heating and water heating which are excellent users of waste, represented only 2 to 3 percent of the total energy consumed.

Figure 11-1

Figure 11-2

Figure 11-3
11-11

Figure 11.4

Figure 11-5

Figure 11-6

11-14

Figure 11-7

Figure 11-8

Figure 11-9

III. DESCRIPTION OF CONVENTIONAL SYSTEM

A. DEFINITION OF CONVENTIONAL SYSTEM

It was agreed that the base used to compare cost, energy use and pollution production of the various options would be that used and produced by the development if it were built by the developer in whatever legal and satisfactory manner he wished.

The hypothetical Conventional System was then assumed to consist of systems and components that followed the typical construction practice that prevails in Southern California for Projects of this nature. These were modified somewhat to conform with the applicable sections of the pending State of California Energy Conservation Standards for New Nonresidential Buildings.

The Conventional Systems, in this report, were based on the following groups of equipment:

1. Department Stores, each (Penney's, Broadway):
 - a. Cooling and Heating Equipment: Centrally located electric drive air-cooled screw-type refrigeration and oil-fired hot water boilers for space and domestic water heating, serving the main areas of the stores.
 - b. Air Moving Equipment: Variable air volume economy cycle air conditioning units with variable volume reheat terminal units.
 - c. Specialty Areas (restaurants, beauty parlor, tailor shop): Self-contained air conditioning units same as for tenant retail shops, below.
2. Tenant Retail Shops, each:
 - a. Cooling and Heating Equipment: Self-contained air-cooled roof mounted package air conditioner, with variable air volume feature and economy cycle.
 - b. Air Distribution: Variable air volume electric reheat terminal. Heating for glassed areas only.
 - c. Domestic Hot Water: Local electric domestic water heater.
3. Mall: Multiple self-contained air-cooled roof mounted package air conditioners, with variable air volume, electric heating and economy cycle features.
4. Office Buildings, each: Same as department stores.

B. ENERGY CONSUMPTION

1. The AXCESS computer program was used to analyze the yearly energy consumption for the Conventional System. This was done in an AXCESS program run of February 28, 1976.
2. This computer run was also used to simultaneously analyze the yearly energy consumption for a Central Cooling/Heating Plant to serve the community, and is discussed in this report in the succeeding Section IV.
3. In order to measure and analyze the energy used for electrical power, cooling, heating and domestic water heating for the Conventional System for the various use areas of the building, various combinations of schemes and primary equipment systems were selected to be analyzed by the AXCESS program. These combinations are described and tabulated in Appendix F.
4. The average system heat rate used in this report, or in other words the heating value of electricity purchased from the utility company, the Pasadena Department of Water and Power, was determined by them to be 11,200 BTU/KWH plus 5% in estimated distribution line losses to the site, resulting in 11,760 BTU/KWH.

This means that electricity purchased from the power company grid is being generated at

$$\frac{3413 \text{ BTU/KWH Output (Equivalent Heat Rate)}}{11,760 \text{ BTU/KWH Input}} = 29\% \text{ Efficiency}$$

5. The total energy consumption of the Conventional System(s), as explained in detail in Appendix F, is summarized below:

ENERGY SOURCE	AMOUNT/HR	CONVERSION FACTOR	TOTAL BTU
Electric Power	31,001,492 KWH	11,760 BTU/KWH	36.5×10^{10}
Fuel Oil	32,250 GAL	139,000 BTU/GAL	0.4×10^{10}
TOTAL USE			36.9×10^{10}

C. ANNUAL COSTS OF CONVENTIONAL SYSTEM

1. Capital Costs

The capital costs of mechanical and electrical equipment for the Conventional System, described above, which would provide cooling, heating and domestic water heating, but not including fans and duct distribution or controls for various use areas of the community, were estimated. These estimates included a 15% general contractor mark-up and 11% annual escalation, and are tabulated in Appendix G.

The total equipment cost as shown was	\$1,615,000
Add for permits and fees	100,000
Add for 5% construction management fee	<u>80,800</u>
TOTAL	\$1,795,800

2. *Annual Operating Cost*

This cost is arrived at from the combination of annual maintenance and energy cost. The cost of fuel is based on \$.345 per gallon. Electrical costs were calculated on the basis of DWP Schedule G-2 plus present fuel adjustment charges (\$.015/KWH). Annual maintenance costs were estimated from manufacturer's data for major overhauls and estimated housekeeping and routine maintenance. Again, fan energy was included as it would be a cost common to all systems.

These figures are tabulated below, and in the comparison with the TIES systems, later on in the report, in Section V:

SCHEME	FUEL/YR (OIL) GAL	ANNUAL FUEL COST \$	ANNUAL* ELEC. COST \$	ANNUAL MAINT. COST \$	ANNUAL OPER. COSTS \$
Conventional System	32,250	11,100	328,600	40,000	379,700

*for power consumed by refrigeration machinery and electric heating equipment only.

3. *Annual Owning Cost*

The annual owning cost was computed on the following base:

- A 20-year capital recovery at 9% interest
- 20-year equipment life for large equipment
- 12-year equipment life for small equipment
- 1% Insurance costs
- 2.5% Property Tax Costs

On this basis, with \$1,795,800 invested in heating and cooling apparatus, the average annual owning cost would be \$361,500 and the total annual owning and operating cost would be \$741,200.

This figure is repeated in the comparison with the TIES systems, later on in the report, in Section V.

IV. DESCRIPTION OF CENTRAL COOLING/HEATING PLANT SYSTEM

A. DEFINITION OF CENTRAL PLANT SYSTEM

The Central Plant System, as used in this report, is defined as a central cooling/heating plant that includes the equipment necessary to provide cooling and heating for the entire Energy Using Community. This would be a "standard" central plant, one that would only provide the above utilities, as opposed to a plant that would also produce electricity as in the case of the TIES System plants discussed in Section V.

It was assumed that the central plant would be located in the lower level of Parking Structure Parcel 'H' adjacent to the retail center.

The Central Plant System, was assumed to include the following equipment:

1. *Cooling Equipment*

Three hermetic electric driven centrifugal compressor water chilling units of 1000 tons refrigeration capacity each, piped in parallel, along with a three-cell induced draft cooling tower and three condenser water pumps will provide 42°F chilled water. One primary chilled water pump for each chiller to circulate water to a primary piping loop in the central plant, and a variable flow pumping system to circulate chilled water from the primary piping loop to distribution mains supplying the tenant and common areas.

2. *Heating Equipment*

Hot water for heating produced by two packaged low pressure scotch marine, oil fired hot water boilers, each with an output of 10,000,000 BTU/HR. (One boiler is standby.) One hot water pump for each boiler to circulate water from the boilers to the distribution mains supplying the tenant and common areas.

3. *Domestic Water*

Domestic hot water produced by two packaged low pressure scotch marine oil fired hot water boilers, each with an output of 400,000 BTU/HR (one boiler is standby). One hot water pump for each domestic hot water boiler to circulate water from the boilers to a storage tank. Distribution mains to supply the tenant and common areas from the tank with a recirculating loop and pump to connect from the end of the distribution main back to the Plant, to maintain 120°F hot water temperature in the main.

B. ENERGY CONSUMPTION

1. The AXCESS computer program was used to analyze the yearly energy consumption for the Central Plant System. This was done in an AXCESS program run of February 28, 1976.
2. This computer run was also used to simultaneously analyze the yearly energy consumption for the Conventional System to serve the community, and is discussed in this report in the preceding Section III.
3. The energy used for electrical power, cooling, heating and domestic water heating for the Central Plant System was measured by the AXCESS program under Scheme D, as described and tabulated in Appendix F.
4. Electricity purchased from the power company grid is generated at 29% efficiency (as described in Section III).
5. The total energy consumption of the Central Plant System detailed in Appendix F is summarized below:

ENERGY SOURCE	AMOUNT/HR	CONVERSION FACTOR	TOTAL BTU
Electric Power	27,828,336 KWH	11,760 BTU/KWH	32.7×10^{10}
Fuel Oil	87,141 GAL	139,000 BTU/GAL	1.2×10^{10}
TOTAL USE			33.9×10^{10}

C. ANNUAL COSTS OF CENTRAL PLANT SYSTEM

1. Capital Costs

The capital costs of mechanical and electrical equipment for the Central Plant System, described above, which would provide cooling, heating and domestic water heating for various use areas of the community, were estimated. These estimates included a 15% general contractor mark-up and 11% annual escalation, and are tabulated in Appendix H.

The plant structure and utilities	\$ 490,000
The total mechanical and electrical equipment cost	1,937,000
Add for permits and fees	100,000
Add for 5% construction management fee	121,400
Add for administration by PRA	<u>122,000</u>
TOTAL	\$2,770,400

2. Annual Operating Cost

This cost is arrived at from the combination of annual maintenance and energy cost. The cost of fuel is based on \$.345 per gallon. Electrical costs were calculated on the basis of DWP Schedule G-2 plus present fuel adjustment charges (\$.015/KWH). Annual maintenance costs were estimated from manufacturer's data for major overhauls and estimated housekeeping and routine maintenance.

These figures are tabulated below, and in the comparison with the TIES systems, later on in the report, in Section V:

SCHEME	FUEL/YR (OIL) GAL	ANNUAL FUEL COST \$	ANNUAL ELEC. COST \$	ANNUAL MAINT. COST \$	ANNUAL OPER. COSTS \$
Central Plant System	87,141	30,100	152,600	53,000	235,700

3. Annual Owning Cost

The annual owning cost of the Central Plant System is calculated on the basis of a 22 year life and 7½% borrowing rate. A 5% contingency reserve and 5% investment income loss was added to the loan for the 12 month construction period. Insurance at 1% is included, but property tax is exempt to PRA.

The total annual owning cost thus computed was \$367,900 and the total annual owning and operating cost is \$603,600.

This figure is repeated in the comparison with the TIES systems, later on in the report, in Section V.

V. EXAMINATION OF TIES SYSTEMS

A. METHOD OF APPROACH

1. *Initial Examination of Energy Systems and Project Constraints*

- a. At the start of this study an attempt was made to consider all possible known sources of fuels, energy and fuel processing and energy conversion sub-systems which could serve the energy needs of a community. This initial investigation then evaluated the practicality of applying these known sub-systems to be used in an energy plant serving the specific community under study located in Pasadena, California.
- b. Since the actual project construction schedule, location and budget of the energy plant imposed certain limitations and constraints, the total list of known sub-systems was then reduced to a smaller group of sub-systems which were considered project viable.

- c. The criteria used in evaluating the viability of sub-systems were:

- (1) Number 1 – Commercial Availability: This means sub-systems and their components which are presently produced commercially and have a proven record of efficient performance under operation in at least several existing installations throughout the world.

In the case of raw fuel or energy sub-systems, commercial availability would mean obtainability, such as from a utility company or mine, to the site of the energy using community under study.

- (2) Number 2 – Environmental Constraints, including:

- (a) Impact on air quality – must be approved by the Southern California Air Pollution Control District.

- (b) Impact on community ambient noise levels.

- (c) Impact on community radiation levels.

- (3) Number 3 – Cost Constraints: The maximum initial cost of the project's energy plant installation was established by PRA and ERDA to be \$15,000,000. The cost of any sub-system considered for the project had to be low enough to fit into this budget figure.

- (4) Number 4 – Project Construction Schedule: All sub-systems and their components had to be obtainable in time to meet the project's design and construction schedule of 18 months to completion and useful service.

- (5) Number 5 – Site Space Constraints: All sub-systems and their components had to be able to fit onto and into the proposed site in downtown Pasadena, California.
- (6) Number 6 – Interrelationship of Sub-Systems: All sub-systems considered had to be viable in relationship to all other project sub-systems simultaneously considered in a total system.
- d. Known Sub-Systems Considered and Evaluated: The following is a list of the known sub-systems considered for evaluation and the criteria, if any, which eliminated them from further consideration:

SUB-SYSTEM	ELIMINATING CRITERIA I.D. NUMBER
RAW FUEL/ENERGY SUB-SYSTEMS	
Coal	2
Oil	None
Natural Gas	1
Solid Waste	2, 3 and 5
Liquid Waste	3, 5 and 6
Solar	1, 3 and 5 (considered in this study for supplementing the low potential heat requirements for domestic hot water)
Nuclear	1, 2, 3, 4, 5 and 6
Tidal	1, 3, 4 and 5
Wind Power	1, 3, 4 and 5
FUEL PROCESSING AND/OR CONVERSION SUB-SYSTEMS	
Coal Gasification	1, 2, 3, 4, 5 and 6
Incineration	2, 3, 4 and 5
Solar Energy Collector	5 (used in limited capacity in this study as explained above)
Anaerobic Digestion	2, 3, 4 and 5
ENERGY CONVERSION SUB-SYSTEMS	
Boiler with Steam Turbine (Rankine Cycle)	None
Diesel Cycle	None

SUB-SYSTEM	ELIMINATING CRITERIA I.D. NUMBER
------------	----------------------------------

Combustion (Gas) Turbine (Brayton Cycle)	None
Organic Rankine Cycle Externally Fired	1
Closed Brayton Cycle	1
Sterling Cycle	1

**THERMAL CONVERSION
SUB-SYSTEMS**

Diesel Engine Heat Recovery	None
Combustion Turbine Heat Recovery	None
Refrigeration Cycle Heat Recovery	None
Compressive Refrigeration	None
Absorption Refrigeration	None
Combined Cycle Steam Turbines	None

**THERMAL STORAGE
SUB-SYSTEMS**

Chilled Water — For Cooling	None
Hot Water — For Heating	None

- e. The remaining sub-systems, those not eliminated by the evaluating criteria, were considered viable for the TIES concept project. These are specifically analyzed in the remainder of this study.

2. *Energy Cycle Relationships*

- a. All engine cycles have four major phases:
- (1) A heat input phase, during which heat enters the cycle at high potential (high temperature and pressure).
 - (2) A work output phase, during which work is performed by the cycle to produce power.

- (3) A heat rejection phase, during which low potential heat must be rejected from the cycle.
 - (4) A work input phase, during which the cycle is reinstated to its higher potential. Also included in this phase is the power requirements of equipment needed to drive cooling towers, air compressors, oil pumps, fuel pumps and other auxiliary power consuming units of the engine.
- b. Heat recovery occurs only in phase (3), described above, and the recovered heat is available only at the potential that is inherent to the cycle during this phase. To benefit from the recovered heat, then, it is necessary to be able to use the heat at that potential level.
 - c. In a few cycles, such as a combustion turbine cycle, heat rejection takes place at a sufficiently high potential that a secondary engine cycle can be operated with reasonable efficiency to produce work (and power) from the waste heat. More commonly, however, the primary engine rejects heat at temperatures only 50 to 150° F above ambient, leaving a thermal potential too small to effectively produce work.
 - d. Normally, the creation of a heating media follows the first law of thermodynamics, that is that the amount of heat to raise the potential energy of the media is equal to the potential energy increase plus the losses that must occur in the heating process. Boilers and similar heating devices can seldom operate at efficiencies exceeding 80%, and in the real world, boiler plants seldom operate above 70% efficiency. All that such heating plants do, is to raise the potential of a media to a given level so that heat transfer can occur and the input heat required will be 125 to 135% of the transferred heat. When the potential available in waste heat is adequate to meet the heat transfer needs, no further heat introduction is needed, and the heat introduced into the process need only be the amount of heat transferred plus transmission losses. This makes heating a very logical candidate for waste heat utilization.
 - e. Cooling, however, is a different process. Cooling is a work cycle of sorts, being more or less an engine cycle in reverse. See Figure V-1.
- Cooling, then, has a work (or power) input phase which implies a need for high potential source for the work input phase. The exception to this rule is the absorption refrigeration cycle which can perform the bulk of work input with fairly low potential heat ($\pm 225^{\circ}$ F). The efficacy of this cycle is low, however, requiring about 20,000 BTU per ton-hour as compared to the compressive refrigeration cycle which demands a high potential energy input, but consumes only about 3,000 BTU per ton-hour of refrigerating effect produced.

Figure V-1
ENGINE AND REFRIGERATION CYCLES

- f. Among the options available to the designer of an energy system is to use high potential waste heat to drive the more energy efficient compressive cycle refrigeration machine or to use this energy to drive a second stage electric generator and live with the low efficiency absorption cycle which only needs low potential energy.
- g. Regardless of the potential of the waste energy, the objective is to put as much energy to beneficial use as possible. To accomplish this end, the Total Energy System designer should seek cycles that most closely produce a ratio of work output (power production) to available heat output (recoverable waste heat at useable potential) which most closely approximates the needs of the energy using facility.
- h. The problem in typical total energy applications is that this ratio is not constant. For example, the amount of recovered energy needed for space heating and cooling both diminish considerably in a moderate climate while demand for electric power barely changes with respect to the weather. Similarly, peak demand for heat generally occurs during the morning warm-up cycle which occurs before the building is occupied, lights turned on, etc., so that needed power generation is very low.
- j. The second major problem with the typical total energy system is that while the energy use of the auxiliary equipment is a small fraction (5 to 7%) of the fuel energy input to the cycle when operating at design capacity, design capacity is seldom achieved. When the cycle is operated at part load, the auxiliary power requirement does not diminish nearly

as much as the load and therefore becomes an increasingly larger energy loss as load goes down. Because major power demand fluctuations can and do occur in many buildings this factor becomes an important part of the hour-by-hour analysis.

3. *TIES Concept Advantages*

The TIES concept can minimize these two outstanding problems by incorporating the following major departures from earlier total energy arrangements:

a. Grid Tie-in

By delivering power to the electric utility company's grid rather than to the load, the need for continuous balance between power and thermal flows is eliminated. This permits the prime movers to be loaded in accordance with thermal rather than power flows, and thus assures that the waste heat produced will be usefully consumed. It is not even necessary to match power generation to demand nor is it necessary to be concerned about the ratio of work to heat output. There remain, however, certain problems.

- (1) Thermal requirements in many applications will frequently drop to very low values with the result that much prime mover operation occurs at well below optimum efficiency.
- (2) Thermal flows can change rapidly, particularly when major energy consuming apparatus is turned off or on. Control and system response problems are introduced by this situation that are not easily solved.
- (3) At times, thermal loads below the turn-down capability of the prime mover can exist, resulting in cyclic operation. This is not only damaging to equipment but efficiency is significantly reduced.

b. Thermal Storage

All the above problems can be reduced or eliminated by introducing thermal storage into the cycle.

- (1) Thermal storage offers the opportunity to eliminate part-load operation, as well as to adjust the operating hours of the plant. Utilizing a linearly stratified tank approach with supply temperature maintained at one end and return at the other, it is possible to utilize the design system temperature differential for storage. For this study, 16° F was assumed for chilled water, resulting in $16 \times 8.33 = 133.3$ BTU of storage per gallon or 90 gallons for each ton-hour stored.

- (2) By allowing the system to run more hours, the components of the system can be made smaller. On the worst cooling day evidenced by the energy analysis (August 13) the building required about 30,700 ton-hours of cooling, peaking at 2,952 tons. A 1,278 ton machine running at full capacity over a 24-hour period would produce the same ton-hours. It would be severely overloaded much of the time, but the deficiency would come out of storage. During periods when the building demand is less than the machine output, or when the building systems are turned off, the stored cooling is replaced. See Figure V-2.
- (3) Electric power generation is not required to match the user's power demand in the TIES concept, but is sized solely to produce the thermal requirements of the system. In the case study, thermal input required for the refrigeration equipment exceeds that required for heat by a considerable margin, so the refrigeration system thermal input was used as the basis for sizing electric power generating equipment and waste heat boilers.
- (4) The result of large storage systems is that the size, and therefore the cost, of all the equipment reduces in direct relation to the size of the refrigeration system, which creates a net first cost benefit.
- (5) Storage can also be used to control power peaks and the method deserves consideration. If the cooperating utility company did not wish to accept power into its distribution grid except during periods of maximum system demand, and identified that period, for example as 12 noon to 8 p.m., a 3,835 ton refrigeration plant would be able to produce the needed daily ton-hours within the 8-hour period — 10,800 ton-hours of storage (972,000 gallons) would be required to serve the load that occurs before or after those hours. While this increases the size and initial cost of all apparatus, the utility may be willing to pay the owner considerably more for power produced only during a fixed period of the day.

Figure V-3 describes the refrigeration machine sizes, maximum run hours on the hottest day and minimum storage sizes required for project and typical calculations are included in Appendix J.

c. Other Storage Considerations:

Other factors involving storage are as follows:

- (1) It may be desirable to store only the heating media, depending on its temperature, pressure and specific heat characteristics, in order to reduce the volume requirement, and install a conventional cooling plant that withdraws the heat in relation to load demand.

Figure V-2
WORST CASE BUILDING COOLING LOAD – (AUGUST 13)

Figure V-3
REFRIGERATION MACHINE OPERATION vs. STORAGE TANK SIZE

- (2) If solid or liquid waste is being processed in the plant for recovery of energy the heat thus recovered can be similarly stored for later use as demand may indicate. The integration of waste heat recovery with total energy has been studied under the Multiple Integrated Utility Systems (MIUS) Program being directed by the Department of Housing and Urban Development.

B. TIES SYSTEMS STUDIED

1. *Systems Studied*

The specific arrangements of sub-systems selected for detailed analysis for the TIES systems, are as follows:

a. Diesel Engine System (Scheme Group 1)

To produce heat, the thermal conversion sub-system which is most applicable to heat recovery from prime mover units, is single package heat recovery units, which are a type of heat exchanger, which recover heat at 15 psig steam pressure at 250° F. This is a sufficient temperature for space heating and domestic hot water heating. For refrigeration purposes it is applicable to absorption refrigeration sub-systems only, since 15 psig saturated steam has too low a potential for practical use to drive compressive refrigeration, or for combined cycle power generation. This scheme, or arrangement, is illustrated in Figure V-4, and described and tabulated in Table V 1, and identified as Schemes 1A through 1E. Scheme 1A has no thermal storage. Schemes 1B through 1E have increasing amounts of storage.

b. Combustion Turbine System (Scheme Groups 2 & 4)

Combustion turbines operate on the thermodynamic cycle called the Open Brayton Cycle. Heat produced by thermal conversion sub-system components used to recover heat from combustion turbines, may reach 400 psig, 500° F superheated steam. This signifies the ability to recover high-grade heat, that which has the potential to perform work to drive generators or other high temperature energy convertors, from the combustion turbine.

Since either compressive refrigeration, using steam turbine drive, or absorption refrigeration may be used as the cooling thermal conversion sub-systems, two arrangements are analyzed with this prime mover.

- (1) The first, Scheme Group 2, with steam turbine refrigeration drive, the most efficient arrangement employs a condensing turbine to drive the chillers. When a requirement for heating exists, a back-pressure steam turbine generator produces electric power, serving in effect as a pressure reducing valve for the high grade heat

Figure V-4
 DIESEL ENGINE SYSTEM (WITH ABSORPTION REFRIGERATION)
 GROUP 1 - RUNS 1A, 1B, 1C, 1D, 1E

**GROUP 1 – DIESEL ENGINE SYSTEM
(WITH ABSORPTION REFRIGERATION)**

RUN NO.	INSTALLED CHILLED WATER STORAGE GALLONS (1)	INSTALLED REFRIG-ERATION TONNAGE (2)	INSTALLED ABSORPTION REFRIG-ERATION MACHINES NO. @ TONS (3)	STEAM FLOW REQUIRED PER AB-SORPTION MACHINE LB/HR (4)	WASTE HEAT UTILI-ZATION FACTOR (5)	EQUIVALENT STEAM FLOW REQUIRED FROM HEAT RECOVERY UNIT LB/HR (6)	DIESEL ENGINE HEAT RECOVERY RATE LB/HR PER KW GENERATED (7)	INSTALLED DIESEL ENGINE GENERATOR SETS NO. @ KW (8)	INSTALLED HOT WATER STORAGE GALLONS (9)
1A	0	3,000	4 @ 750	13,500	.90	15,000	4.18	4 @ 3,589	0
1B	370,000	2,190	3 @ 730	13,140	.92	14,283	4.18	3 @ 3,417	53,000
1C	650,000	1,920	3 @ 640	11,520	.93	12,387	4.18	3 @ 2,963	46,000
1D	1,100,000	1,560	3 @ 520	9,360	.94	9,957	4.18	3 @ 2,382	40,000
1E	1,400,000	1,290	3 @ 430	7,740	.95	8,147	4.18	3 @ 1,949	40,000

(4) Based on 18 lb/ton-hour steam flow at full load.

(5) Allowance for more frequent start-up loss for larger units, than for small units which run more continuously.

(6) Equal (4) ÷ (5).

(7) Average values from manufacturers data, interpolated for size range.

(8) Same number of diesel as absorption refrigeration machines installed at (6) ÷ (7).

recovered. The low potential turbine exhaust heat can then be used for building heating or supplemental domestic hot water heating. The resultant combustion turbine system is illustrated in Figure V-5 and described and tabulated in Table V-2, and identified as Schemes 2A through 2D. In this and all succeeding schemes, Sub-Scheme A has minimum thermal storage and Sub-Scheme D has maximum thermal storage.

- (2) The second arrangement, Scheme Group 4, uses a backpressure steam turbine generator combined with absorption refrigeration. This arrangement allows the high potential heat from the prime mover heat recovery device to be directed to power generation. The resultant combustion turbine-combined cycle system is illustrated in Figure V-7, and described and tabulated in Table V-4, and identified as Schemes 4A through 4D.

c. Boiler/Steam Turbine System (Scheme Group 3)

Steam boilers in conjunction with steam turbines operate on the thermodynamic cycle called the Rankine Cycle. This cycle, while it represents a form of total energy system, does not follow the TIES concept of waste heat recovery to meet site thermal needs. It was, however, included in the study of TIES central plants at the request of the Pasadena Department of Water & Power. No waste heat is recovered from the prime mover, which in this case is the combination of a boiler and steam turbine. Rather the system consists of generation of high potential energy in the boiler, work production in a steam turbine with a turbine discharge of low-potential energy. The only application for the discharged low-grade BTU's in the cooling thermal conversion subsystem is in absorption refrigeration.

The resultant boiler/steam turbine system is illustrated in Figure V-6, and described and tabulated in Table V-3, and identified as Schemes 3A through 3D.

Figure V-5
COMBUSTION TURBINE SYSTEM - (WITH STEAM TURBINE DRIVEN
CENTRIFUGAL REFRIGERATION)
GROUP 2 - RUNS 2A, 2B, 2C, 2D

GROUP 2 – COMBUSTION TURBINE SYSTEM
(WITH STEAM TURBINE DRIVEN CENTRIFUGAL REFRIGERATION)

RUN NO.	INSTALLED CHILLED WATER STORAGE GALLONS (1)	INSTALLED REFRIG-ERATION TONNAGE (2)	INSTALLED STEAM TURBINE DRIVE REFRIG-ERATION NO. @ TONS (3)	STEAM RATE LB/TON HOUR (4)	STEAM FLOW REQUIRED PER REFRIG-ERATION MACHINE LB/HR (5)	WASTE HEAT UTILI-ZATION FACTOR (6)	NET EQUIVALENT STEAM FLOW REQUIRED FROM HEAT RECOVERY UNIT LB/HR (7)	COMBUSTION TURBINE HEAT RECOVERY RATE LB/HR PER KW GENERATOR (8)	INSTALLED COMBUSTION TURBINES CAPACITY NO. @ KW (9)	INSTALLED STEAM TURBINE GENERATOR CAPACITY NO. @ KW (10)	INSTALLED HOT WATER STORAGE GALLONS (11)
2A	370,000	2,190	3 @ 730	15.71	11,470	.92	12,467	4.63	3 @ 2,692	1 @ 385	42,000
2B	650,000	1,920	3 @ 640	15.71	10,055	.93	10,812	4.67	3 @ 2,315	1 @ 355	40,000
2C	1,100,000	1,560	3 @ 520	15.71	8,170	.94	8,691	4.75	3 @ 1,830	1 @ 275	33,000
2D	1,400,000	1,290	3 @ 430	15.71	6,755	.95	7,110	4.85	3 @ 1,470	1 @ 227	27,000

(4) At 400 PSIA, 500°F inlet, 4" HG outlet, 51% net turbine efficiency, steam rate = 18.49 LB/KW, .85 KW/Ton equivalent net drive ratio.

(5) Equals (3) X (4).

(6) Allowance for more frequent start-up loss for larger units than for smaller units which run more continuously.

(7) Equals (5) ÷ (6).

(8) Average values from manufacturers data, interpolated for size range.

(9) Same number of combustion turbines as refrigeration machines, at (7) ÷ (8).

(10) At 400 PSIA, 500°F inlet, 20 PSIA outlet, 51% net turbine efficiency (including gear and generator losses), steam rate = 29.74 LB/KW. Using one steam turbine at same steam flow as one refrigeration, equals (5) ÷ 29.74.

Figure V-6
BOILER/STEAM TURBINE SYSTEM
GROUP 3 - RUNS 3A, 3B, 3C, 3D

GROUP 3 — DESCRIPTION OF BOILER/STEAM TURBINE SYSTEM

RUN NO.	INSTALLED CHILLED WATER STORAGE GALLONS (1)	INSTALLED REFRIG-ERATION TONNAGE (2)	INSTALLED ABSORPTION REFRIG-ERATION MACHINES NO. @ TONS (3)	STEAM FLOW REQUIRED PER ABSORPTION MACHINE LB/HR (4)	INSTALLED STEAM TURBINE GENERATOR CAPACITY NO. @ KW (5)	HEAT UTILIZATION FACTOR (6)	INSTALLED BOILERS NO. @ LB/HR (7)	INSTALLED HOT WATER STORAGE GALLONS (8)
3A	370,000	2,190	3 @ 730	14,052	3 @ 419	.92	3 @ 15,275	53,000
3B	650,000	1,920	3 @ 640	12,320	3 @ 368	.93	3 @ 13,247	46,000
3C	1,100,000	1,560	3 @ 520	10,010	3 @ 299	.94	3 @ 10,649	38,000
3D	1,400,000	1,290	3 @ 430	8,278	3 @ 247	.95	3 @ 8,713	31,000

- (4) Based on 19.25 lb/ton-hour steam flow at full load, with wet steam from turbine into absorption machine.
 (5) At 400 PSIA, 500°F inlet, 30 PSIA outlet, 51% net turbine efficiency, steam rate = 33.46 LB/KW, at same steam flow as absorption machine, equals (4) ÷ 33.46.
 (6) Allowance for more frequent start-up loss for larger units than for smaller units which run more continuously.
 (7) Equals (4) ÷ (6).

Table V-3

GROUP 4 – COMBUSTION TURBINE SYSTEM
(WITH BACKPRESSURE STEAM TURBINE AND ABSORPTION REFRIGERATION)

RUN NO.	INSTALLED WATER GALLONS (1)	INSTALLED REFRIG-ERATION TONNAGE (2)	INSTALLED ABSORPTION REFRIG-ERATION MACHINES NO. @ TONS (3)	STEAM FLOW REQUIRED PER ABSORPTION MACHINE LB/HR (4)	INSTALLED STEAM TURBINE GENERATOR CAPACITY NO. @ KW (5)	HEAT UTILI-ZATION FACTOR (6)	NET EQUIVALENT STEAM FLOW PER STEAM TURBINE REQUIRED FROM HEAT RECOVERY UNIT LB/HR (7)	COMBUSTION TURBINE HEAT RECOVERY RATE LB/HR PER KW GENERATED (8)	INSTALLED COMBUSTION TURBINES CAPACITY NO. @ KW (9)	INSTALLED HOT WATER STORAGE GALLONS (10)
4A	370,000	2,190	3 @ 730	14,052	3 @ 419	.92	15,275	4.5	3 @ 3,394	53,000
4B	650,000	1,920	3 @ 640	12,320	3 @ 368	.93	13,247	4.6	3 @ 2,880	46,000
4C	1,100,000	1,560	3 @ 520	10,010	3 @ 299	.94	10,649	4.7	3 @ 2,266	38,000
4D	1,400,000	1,290	3 @ 430	8,278	3 @ 247	.95	8,713	4.8	3 @ 1,815	31,000

(4) Based on 19.25 lb/ton-hour steam flow at full load with wet steam from turbine into absorption machine.

(5) At 400 PSIA, 500°F inlet, 30 PSIA outlet, 51% net turbine efficiency, steam rate = 33.46 LB/KW, at same steam flow as absorption machine, equals (4) ÷ 33.46.

(6) Allowance for more frequent start-up loss for larger units, than for smaller units which run more continuously.

(7) Equals (4) ÷ (6).

(8) Average values from manufacturers data interpolated for size range.

(9) Equals (7) ÷ (8).

2. *Energy Analysis of TIES Systems*

a. General

Prior to inputting the data for the computer simulation, several assumptions were made for this analysis. These are:

- (1) In order to evaluate both initial cost and annual energy consumption impacts of storage for heating and cooling medium, it was decided to run each system or scheme with varying amounts of thermal storage. The chilled water and hot water thermal storage tanks were assumed to be underground concrete tanks, installed beneath the floor of the TIES Plant. The tank walls, bottom and top would be constructed of 12 inch thick reinforced concrete, and the tanks would include concrete baffles to create a serpentine flow path through the tanks. The tank roofs would be insulated.
 - (2) For all schemes with storage, systems are designed so that component units operate at only full load output.
 - (3) The full load waste heat produced by generating equipment matched the full load thermal input demand of each thermal unit.
 - (4) The daily hours of operation input vary from the minimum of 13 hours of user load demand to a maximum of 24 hours.
 - (5) For considerations of reliability, at least three prime movers and refrigeration machines are considered in each scheme. This allows the TIES plant to furnish at least two-thirds the required thermal demand on a peak day and most or all of it during the balance of the year in the event one prime mover or its associated auxiliaries fails.
 - (6) The capacities selected are interpolations of manufacturers' data (see Appendix J). During preliminary design, which follows, the closest actual available commercial size of components were selected. Such moderate size deviations would not have a major impact on the final results.
- b. For each family of cycles analyzed, the AXCESS program was run four times, varying the installed power, refrigeration tonnage, and installed chilled water and hot water storage tank capacities for each run to determine the theoretical optimum plant capacity and fuel consumption.

In addition, one run, the first (Scheme IA) was made with no storage as a basis for comparison.

3. *Other AXCESS Parameters*

a. Refrigeration Machine Operation

Refrigeration Machine start-stop operation was programmed to function with the storage tank in a manner that when warm water in the tank displaced cold water to an extent that the full running output of a machine for one-hour was required, one machine would start. As displacement continued, second and third machines similarly start. (See Figure V-8) The purpose of this control was to avoid short-cycling the equipment. For hot weather, however, an outdoor thermostat, set at 80° F starts two machines when the building systems start to avoid early depletion of the tank. Other, and perhaps more satisfactory control methods can be devised but this control was simple enough to be programmable to the computer.

b. Solar Energy System

The AXCESS program also analyzed the impact and benefits of a solar energy system. The solar energy system was analyzed on the basis of supplementing the domestic hot water energy needs of the project, as this application is most suited to solar collection.

c. Electrical System

Separate hourly summaries of electrical energy generated and energy consumed by both plant auxiliaries and the proposed development were tabulated. These were then arithmetically summed to obtain net electrical energy flow to or from the DWP grid system. The net amount of power consumed is equal to the gross amount of power delivered minus the gross amount returned to the grid.

d. Auxiliaries

Plant auxiliaries for each scheme were input in two groups; those such as the plant ventilation system which are constant, regardless of plant output, and those such as pumps which vary with the required plant output.

C. ENERGY CONSUMPTION OF TIES SYSTEMS STUDIED

1. *AXCESS Energy Analysis*

The previously described input parameters for each of the 17 TIES schemes described, were input to the AXCESS program. A summary of the results

Figure V-8
REFRIGERATION MACHINE AND STORAGE TANK OPERATION

from the AXCESS Computer program (Runs of May 12 through 16, 1976) are tabulated on the following pages. See Tables V-5 through V-8.

An analysis of the results indicated the following:

- a. There is a substantial energy benefit obtained by introducing minimum thermal storage but a negligible energy benefit for increasing the amount of thermal storage to its maximum. (Comparison of Schemes 1A thru 1E.)
- b. As expected, the diesel schemes ranked highest in energy efficiency, the combustion turbine schemes next and the boiler/steam turbine schemes result in only a marginal energy savings over the standard central plant.
- c. None of the schemes analyzed generated the annual electrical energy needs of the proposed development.

2. *Cyclic Flow of Building and Plant Outputs*

To illustrate the cyclic nature and flow of the building and plant thermal and electric outputs and net power flow in response to load and as effected by thermal storage tank sizes, graphs were prepared for weeks during spring, summer and fall operation, for selected schemes (runs).

- a. A representative sample of these graphs for fall operation (November) are listed below and are included following this listing. These include:

Scheme 1A — Diesel Engine System (with absorption refrigeration) — with no thermal storage

Scheme 1B — Diesel Engine System — with 370,000 GAL (minimum) chilled water thermal storage.

Scheme 1E — Diesel Engine System — with 1,400,000 GAL (maximum) chilled water thermal storage.

Scheme 2A — Combustion Turbine System (with steam turbine driven centrifugal refrigeration) — with 370,000 GAL (minimum) chilled water thermal storage.

Scheme 2D — Combustion Turbine System — with 1,400,000 GAL (maximum) chilled water thermal storage.

- b. The graphs for Scheme 1A, with no storage, illustrate the thermal and electric outputs in direct response to the building loads. The remaining graphs illustrate: that as the amount of cooling thermal storage is increased, the size of the refrigeration machines can be reduced to

**GROUP 1 – DIESEL ENGINES, WASTE HEAT BOILERS, ABSORPTION
REFRIGERATION MACHINES
(ENERGY CONSUMPTION OF TIES SYSTEMS STUDIED)**

RUN NO.	ELECTRICITY USED DRAWN FROM UTILITY CO. KWH/YR (@ 11,760 BTU/KW)		FUEL OIL USED GAL/YR (@ 139,000 BTU/GAL)	SUB-TOTAL BTU $\times 10^{10}$ /YR USED	TOTAL ETL $\times 10^{10}$ /YR USED	<u>KWH/YR PRODUCED</u> KW INSTALLED
1A	5	5,719,466	1,994,204	6.726 27.719	34.445	1,344
1B		5,717,261	1,438,062	6.723 19.989	26.712	1,808
1C		5,881,373	1,423,664	6.916 19.789	26.705	2,063
1D		6,145,535	1,408,257	7.227 19.574	26.801	2,537
1E		6,393,600	1,384,704	7.518 19.247	26.765	3,056

Table V-5

**GROUP 2 – GAS TURBINES, WASTE HEAT BOILERS, CONDENSING STEAM
TURBINES, CENTRIFUGAL REFRIGERATION MACHINES
(ENERGY CONSUMPTION OF TIES SYSTEMS STUDIED)**

RUN NO.	ELECTRICITY USED DRAWN FROM UTILITY CO. KWH/YR (@ 11,760 BTU/KW)	FUEL OIL USED GAL/YR (@ 139,000 BTU/GAL)	SUB-TOTAL BTU × 10¹⁰/YR USED	TOTAL BTU × 10¹⁰/YR USED	<u>KWH/YR PRODUCED</u> KW INSTALLED
2A	7,856,155	1,852,484	9.23 25.74	34.98	2,008
2B	8,168,519	1,816,615	9.60 25.20	34.85	2,288
2C	8,378,540	1,761,836	9.85 24.40	34.34	2,866
2D	8,871,855	1,691,207	10.43 23.50	33.93	3,480

Table V-6

**GROUP 3 — STEAM BOILERS, BACK PRESSURE STEAM TURBINES,
ABSORPTION REFRIGERATION MACHINES
(ENERGY CONSUMPTION OF TIES SYSTEMS STUDIED)**

RUN NO.	ELECTRICITY USED DRAWN FROM UTILITY CO. KWH/YR (@ 11,760 BTU/KW)	FUEL OIL USED GAL/YR (@ 139,000 BTU/GAL)	SUB-TOTAL BTU × 10¹⁰/YR USED	TOTAL BTU × 10¹⁰/YR USED	<u>KWH/YR PRODUCED</u> <u>KW INSTALLED</u>
3A	22,069,572	794,242	25.95 11.04	36.99	1,808
3B	21,995,764	785,585	25.87 10.92	36.79	2,062
3C	22,062,068	776,720	25.94 10.80	36.74	2,537
3D	22,074,067	764,618	25.96 10.63	36.59	3,053

Table V-7

**GROUP 4 – GAS TURBINES, WASTE HEAT BOILERS, BACK PRESSURE STEAM TURBINES,
ABSORPTION REFRIGERATION MACHINES
(ENERGY CONSUMPTION OF TIES SYSTEMS STUDIED)**

RUN NO.	ELECTRICITY USED DRAWN FROM UTILITY CO. KWH/YR (@ 11,760 BTU/KW)	FUEL OIL USED GAL/YR (@ 139,000 BTU/GAL)	SUB-TOTAL BTU × 10¹⁰/YR USED	TOTAL BTU × 10¹⁰/YR USED	<u>KWH/YR PRODUCED</u> <u>KW INSTALLED</u>
4A	3,729,175	2,206,896	4.39 30.68	35.09	1,799
4B	4,217,239	2,136,114	4.96 29.69	34.65	2,059
4C	4,903,434	2,066,778	5.77 28.73	34.50	2,527
4D	5,470,554	1,993,555	6.43 27.71	34.14	3,050

Table V-8

produce the same ton-hours per day; and that simultaneously less waste heat is rejected to the heating thermal storage tanks, requiring smaller tanks with less heating thermal storage; and that simultaneously the plant electrical power output decreases while the net electricity drawn from the power company grid increases.

FIG. NO.	MONTH	SCHEME	TITLE
V-9	Nov.	1A	Plant Power Output
V-10	Nov.	1A	Net Grid Output
V-11	Nov.	1A	Plant Cooling Output
V-12	Nov.	1A	Plant Heating Output
V-13	Nov.	1B	Plant Power Output
V-14	Nov.	1B	Net Grid Output
V-15	Nov.	1B	Plant Cooling Output
V-16	Nov.	1B	Plant Heating Output
V-17	Nov.	1E	Plant Power Output
V-18	Nov.	1E	Net Grid Output
V-19	Nov.	1E	Plant Cooling Output
V-20	Nov.	1E	Plant Heating Output
V-21	Nov.	2A	Plant Power Output
V-22	Nov.	2A	Net Grid Output
V-23	Nov.	2A	Plant Cooling Output
V-24	Nov.	2A	Plant Heating Output
V-25	Nov.	2D	Plant Power Output
V-26	Nov.	2D	Net Grid Output
V-27	Nov.	2D	Plant Cooling Output
V-28	Nov.	2D	Plant Heating Output

D. ANNUAL COSTS OF TIES SYSTEMS

1. *Capital Costs*

The data for capital costs for the TIES plant, for the various schemes, was developed as follows:

- a. The cost of the plant structure was estimated by the cost estimating and scheduling consultants for Pasadena Redevelopment Agency. This would be the cost of the space or portion of structure occupied by the TIES Plant which was assumed to be located in the lower level of Parking Structure, Parcel 'H', adjacent to the retail center. This cost also included the underground thermal storage tanks.
- b. To these costs were added the costs of site utilities to serve the TIES Plant, also obtained from the community cost consultants.
- c. Plus the costs for mechanical and electrical work.

SCHEME 1-A PLANT POWER OUTPUT
NO CHILLED WATER STORAGE

SCHEME 1-A PLANT COOLING OUTPUT
NO CHILLED WATER STORAGE

SCHEME 1-A PLANT HEATING OUTPUT
NO CHILLED WATER STORAGE

SCHEME 1-B PLANT POWER OUTPUT
370000 GALLON CHW STORAGE

SCHEME 1-B NET GRID OUTPUT
370000 GALLON CHW STORAGE

Figure V-14

SCHEME 1-3 PLANT COOLING OUTPUT
370000 GALLON CHW STORAGE

Figure V-15

V-35

SCHEME 1-B PLANT HEATING OUTPUT
370000 GALLON CHW STORAGE

Figure V-16

SCHEME 1-E PLANT POWER OUTPUT
1400000 GALLON CHW STORAGE

SCHEME 1-E NET GRID OUTPUT
1400000 GALLON CHW STORAGE

Figure V-18

SCHEME 1-E PLANT COOLING OUTPUT
1400000 GALLON CHW STORAGE

SCHEME 1-E PLANT HEATING OUTPUT
1400000 GALLON CHW STORAGE

SCHEME 2-A PLANT POWER OUTPUT
370000 GALLON CHW STORAGE

Figure V-21

V-41

SCHEME 2-A NET GRID OUTPUT
370000 GALLON CHW STORAGE

Figure V-22

0001/5N01 5N17000

SCHEME 2-A PLANT COOLING OUTPUT
370000 GALLON CHW STORAGE

Figure V-23

SCHEME 2-A PLANT HEATING OUTPUT
370000 GALLON CHW STORAGE

SCHEME 2-D PLANT POWER OUTPUT
1400000 GALLON CHW STORAGE

Figure V-25

SCHEME 2-D NET GRID OUTPUT
1400000 GALLON CHW STORAGE

00015N01 9N17000

Figure V-27

V47

SCHEME 2-D PLANT COOLING OUTPUT
1400000 GALLON CHW STORAGE

SPACE HEATING-MMBTU/HOUR

NOV 7-NOV 13

SCHEME 2-D PLANT HEATING OUTPUT

1400000 GALLON CHW STORAGE

Figure V-28

- d. Plus the costs of permits, fees, construction management and administration fees.

These capital costs for the TIES schemes and also for the Conventional scheme and the standard Central Plant scheme for comparison, are tabulated in Table V-9.

2. *Annual Operating Cost*

This cost is arrived at from the combination of annual maintenance and energy cost. Electrical costs were calculated on the basis of DWP Schedule G-2 plus present fuel adjustment charges (\$.015/KWH). The cost of fuel is based on \$.345 per gallon. Annual maintenance costs were estimated from manufacturer's data for major overhauls and estimated housekeeping and routine maintenance. It should be noted that the TIES plant is assumed to be unattended. Start-up, shut-down and other operating and maintenance tasks are expected to be done by DWP personnel on a part time basis. Monitoring of essential operating points would be accomplished at DWP Central Control via leased telephone lines.

These annual operating costs for the TIES schemes and also for the Conventional and the standard Central Plant schemes for comparison, are tabulated in Table V-10.

3. *Annual Revenue*

Total annual revenue includes revenues for power produced, cooling and heating. The values for determining demand and energy revenue for electrical generation were assigned by DWP. The values for heating and cooling were based on average prevalent costs charged for these utilities by operators of central plants in the area. These values and amounts are tabulated in Table V-11.

4. *Bonding Costs and Income*

The following additional factors were considered and estimated by the Pasadena Redevelopment Agency's financial consultant for the TIES schemes.

- (1) Insurance Reserve: 5% of construction cost.
- (2) Cost of Bond Issuance: \$125,000 for all schemes.
- (3) Investment Income: 5% during the course of a 12 month construction period.
- (4) Borrowing Rate: 7-1/2% (with 22 year amortization of principal).

5. Summary

Table V-12 indicates the summary of the bonding feasibility analysis. As can be readily seen, none of the TIES schemes can support the annual owning and operating cost from annual revenue.

CAPITAL COSTS (ALL FIGURES IN THOUSANDS OF DOLLARS)

SCHEME NO.	PLANT STRUCTURE & UTILITIES	M & E, MARK-UP & ESCALATION	PERMITS, FEES,* CONST. MGMT., ADMIN.	TOTAL
CONVENTIONAL	—	1,615	180.8	1,795.8
CENTRAL COOL/HTG. PLANT	490.0	1,937	343.4	2,770.4
1A	772.9	10,416	781.4	11,970.3
1B	1,169.9	8,019	681.4	9,870.3
1C	1,280.9	7,355	653.8	9,289.7
1D	1,487.9	6,349	613.8	8,350.7
1E	1,622.9	5,634	584.8	7,841.7
2A	1,169.9	7,269	643.9	9,082.8
2B	1,280.9	6,673	619.7	8,573.6
2C	1,487.9	6,067	599.7	8,164.6
2D	1,622.9	5,472	576.7	7,671.6
3A	1,169.9	4,106	485.8	5,761.7
3B	1,280.9	3,869	479.5	5,629.4
3C	1,487.9	3,571	474.9	5,533.8
3D	1,622.9	3,361	471.2	5,455.1
4A	1,169.9	8,091	685.0	9,945.9
4B	1,280.9	7,371	654.6	9,306.5
4C	1,487.9	6,476	620.2	8,584.1
4D	1,622.9	5,835	594.9	8,052.8

*Based on \$100,000 for permits and fees, plus 5% construction management fees, plus \$122,000 for administration by PRA for TIES schemes and for the Central Cooling/Heating Plant scheme; and based on \$100,000 permits and fees plus 5% construction management fees for the Conventional scheme.

Table V-9

ANNUAL OPERATING COSTS
(ALL FIGURES IN THOUSANDS)

<u>SCHEME NO.</u>	<u>FUEL/YR (OIL) GAL</u>	<u>ANNUAL FUEL COST \$</u>	<u>ANNUAL* ELEC. COST \$</u>	<u>ANNUAL MAINT. COST \$</u>	<u>TOTAL ANNUAL OPER. COSTS \$</u>
CONVENTIONAL	32.3	11.1	328.6	40.0	379.7
CENTRAL COOL/HTG. PLANT	87.1	30.1	152.6	53.0	235.7
1A	1,994	687.9	66.3	111.8	866.0
1B	1,438	496.1	64.5	95.3	655.9
1C	1,424	491.3	63.0	94.0	648.3
1D	1,408	485.8	71.7	92.8	650.3
1E	1,385	477.8	69.7	91.5	639.0
2A	1,852	638.9	57.1	77.6	773.6
2B	1,817	626.9	56.3	75.9	759.1
2C	1,762	607.9	56.9	74.9	739.7
2D	1,691	583.4	59.5	73.4	716.3
3A	794	273.9	67.7	101.8	443.4
3B	786	271.2	64.6	100.1	435.9
3C	777	268.1	65.4	98.6	432.1
3D	765	263.9	63.9	96.6	424.1
4A	2,207	761.4	49.8	107.7	918.9
4B	2,136	736.9	49.7	106.1	892.7
4C	2,067	713.1	53.0	104.5	870.6
4D	1,994	687.9	52.7	101.9	842.5

*Cost of power consumed by plant auxiliaries for TIES and of electrically driven refrigeration compressors for Conventional and Standard Central Cooling/Heating Plant.

Table V-10

ANNUAL REVENUE
(ALL FIGURES IN THOUSANDS)

SCHEME NO.	INSTALLED CAPACITY KW	REV. @ \$12/YR/ KW \$	ANNUAL ELECT. ENERGY PRODUCED KWH	REV. @ 1.8¢/ KWH \$	TOTAL ELEC. REV. \$	ANNUAL TON-HRS PRODUCED	A/C REV. @ \$.15/ TH	ANNUAL HEATING PRODUCED BTU X 10 ³	HEATING REVENUE @ \$.60/M ² BTU \$	TOTAL THERMAL REVENUE \$	TOTAL REVENUE \$
CONV.	—	—	—	—	—	—	—	—	—	—	—
CENTRAL COOL/HTG. PLANT	—	—	—	—	—	3,477	521.6	9,749	83.8	605.4	605.4
1A	14.356	172.3	19,291	347.2	519.5	3,477	521.6	9,749	83.8	605.4	1,124.9
1B	10.251	123.0	18,544	333.8	456.8	3,477	521.6	9,749	83.8	605.4	1,062.2
1C	8.889	106.7	18,336	330.0	436.7	3,477	521.6	9,749	83.8	605.4	1,042.1
1D	7.146	85.8	18,126	326.3	412.1	3,477	521.6	9,749	83.8	605.4	1,017.5
1E	5.847	70.2	17,867	321.6	391.8	3,477	521.6	9,749	83.8	605.4	997.2
2A	8.461	101.5	16,217	291.9	393.4	3,477	521.6	9,749	83.8	605.4	998.8
2B	7.300	87.6	15,892	286.1	373.7	3,477	521.6	9,749	83.8	605.4	979.1
2C	5.765	69.2	15,733	283.2	352.4	3,477	521.6	9,749	83.8	605.4	957.8
2D	4.637	55.6	15,348	276.3	331.9	3,477	521.6	9,749	83.8	605.4	937.3
3A	1.257	15.1	2,273	40.9	56.0	3,477	521.6	9,749	83.8	605.4	661.4
3B	1.104	13.2	2,276	41.0	54.2	3,477	521.6	9,749	83.8	605.4	659.6
3C	.897	10.8	2,275	41.0	51.8	3,477	521.6	9,749	83.8	605.4	657.2
3D	.741	8.9	2,262	40.7	49.6	3,477	521.6	9,749	83.8	605.4	655.0
4A	11.439	137.3	20,580	370.4	507.7	3,477	521.6	9,749	83.8	605.4	1,113.1
4B	9.744	116.9	20,063	361.1	478.0	3,477	521.6	9,749	83.8	605.4	1,083.4
4C	7.695	92.3	19,448	350.1	442.4	3,477	521.6	9,749	83.8	605.4	1,047.8
4D	6.186	74.2	18,870	339.7	413.9	3,477	521.6	9,749	83.8	605.4	1,019.3

Table V-11

BONDING FEASIBILITY SUMMARY
(All Figures in Thousands of Dollars)

<u>SCHEME NO.</u>	<u>BOND CAPITAL</u>	<u>OWNING COST</u>	<u>ANNUAL OWNING & OPERATING COST</u>	<u>ANNUAL REVENUE</u>
CENTRAL COOL/HTG. PLANT	2,770	368	603.6	605.4
TIES PLANT SCHEMES				
1A	12,377	1,106	1,975.53	1,124.9
1B	10,227	917	1,572.70	1,062.2
1C	9,633	864	1,511.81	1,042.1
1D	8,671	777	1,427.63	1,017.5
1E	8,150	731	1,369.62	997.2
2A	9,421	844	1,617.70	998.8
2B	8,899	797	1,556.49	979.1
2C	8,470	759	1,498.66	957.8
2D	7,976	715	1,430.95	937.3
3A	5,928	531	974.59	661.4
3B	5,885	527	963.22	659.6
3C	5,787	519	950.65	657.2
3D	5,706	511	935.43	655.0
4A	10,304	923	1,842.17	1,113.1
4B	9,650	865	1,757.32	1,083.4
4C	8,910	798	1,668.95	1,047.8
4D	8,366	750	1,592.12	1,019.3

Table V-12

VI. DISCUSSION AND RECOMMENDATIONS

A. COMPARISON OF TIES SYSTEMS WITH THE CONVENTIONAL AND CENTRAL PLANT SYSTEMS

The following conclusions resulted from the case study of the TIES plant for Pasadena:

1. *Energy Savings*

- a. The yearly energy consumption of the various TIES schemes is compared in Table VI-1. This indicates that all TIES schemes analyzed will consume less energy annually than the assumed Conventional System method of providing cooling, heating and electric power services to the Energy Using Community.

With utilization of thermal storage, the energy savings are: 28% for the Diesel Engine System; 8% for (both) Combustion Turbine Systems; and less than 1% for the Boiler/Steam Turbine System.

- b. A TIES plant with a Diesel Engine System consumes approximately 21% less energy than a "standard" Central Cooling/Heating Plant. All other TIES plant systems studied consume slightly more energy than a Central Cooling/Heating Plant.
- c. Utilization of storage for heating and cooling media results in reduced energy usage.
- d. Schemes utilizing diesel engine generation and absorption refrigeration proved to be most energy efficient of the cycles studied.
- e. A supplemental solar energy system designed to satisfy the domestic hot water needs, could provide approximately 0.5% annual fuel savings in conjunction with all TIES schemes.

2. *Economic Feasibility Comparison*

a. General

Economic feasibility for a given TIES system in this study is defined as a system which can produce the required utilities at an equal or lower cost than conventional means. The basis for this comparison was determined to be the annual owning and operating cost. Only the most feasible of each of the base TIES schemes are compared to the Conventional and the Central Cooling/Heating Plant (Schemes 1E, 2D, 3D and 4D). In all cases, these are the schemes with maximum thermal storage.

The Annual Owning and Operating Cost of the Central Cooling/Heating Plant is calculated on the same basis as the TIES plant on the assumption that the plant will be financed in an identical manner, experiencing the same fees and other costs estimated for the TIES plants.

COMPARISON OF SYSTEM ENERGY CONSUMPTION

Conventional System = 36.9×10^{10} BTU/YR.

Central Plant System = 33.9×10^{10} BTU/YR.

TIES SCHEME	ENERGY USED BTU $\times 10^{10}$ /YR	% ENERGY SAVED COMPARED TO CONVENTIONAL SYSTEM	% ENERGY SAVED COMPARED TO CENTRAL PLANT SYSTEM*
Diesel Engine System:			
Scheme 1A	34.45	6.6	- 1.6
1B	26.71	27.6	21.2
1E	26.77	27.5	21.0
Combustion Turbine- Centrifugal Refrig. System:			
Scheme 2A	34.98	5.2	- 3.2
2D	33.93	8.0	0.0
Boiler/Steam Turbine System:			
Scheme 3A	36.99	0.01	- 9.1
3D	36.59	.80	- 7.9
Combustion Turbine- Absorption Refrig. System:			
Scheme 4A	35.09	4.9	- 3.5
4D	34.14	7.5	- .70

*Negative values indicate more energy used than a Central Plant System.

Table VI-1

b. Summary

As indicated in Table VI-2, none of the TIES schemes are economically feasible in comparison to the Conventional. However, it is evident that the Central Cooling/Heating Plant is the most feasible scheme of all those evaluated. In fact, when a comparison of the annual owning and operating cost of the Central Cooling/Heating Plant is made against estimated annual revenue, it appears that this scheme could return a slight profit to the investor, and therefore justifies further study to optimize the design and to achieve the desired end results.

FEASIBILITY COMPARISON

TIES VS. CONVENTIONAL & CENTRAL COOLING/HEATING PLANT

(All Figures in Thousands of Dollars)

SCHEME	TOTAL ANNUAL OWNING & OPERATING COST	REVENUE FOR ELECTRIC POWER SOLD TO DWP	NET HEATING-COOLING SYSTEM ANNUAL OWNING & OPERATIONS COST
CONV.	741.2	0	741.2
CENTRAL COOLING/HTG. PLANT	603.6	0	603.6
1E	1370.0	321.6	1048.4
2D	1431.3	276.3	1155.0
3D	935.1	40.7	894.4
4D	1592.5	339.7	1252.8

Table VI-2

3. *Impact on Air Quality*

a. General

The total emissions resulting from the installation of a TIES Plant is the sum of the emissions from the TIES Plant prime movers, plus the emissions from the Utility Co. resulting from the generation of grid power drawn by the TIES Plant to meet electrical loads.

Incremental emission rates for the power drawn from the grid were obtained from the Pasadena Water and Power Dept. as:

5 lb/megawatt-hour of NO_x

4½ lb/megawatt-hour of SO_x

NO_x (nitrogen oxides) emissions determined from EPA data and manufacturers were established at:

.4 lb/ 10^6 BTU or .055 lb/gal for boilers

2.69 lb/ 10^6 BTU or .37 lb/gal for diesels

.5 lb/ 10^6 BTU or .07 lb/gal for turbines

SO_x (sulphur oxides) emissions are determined directly from the sulphur content of the input fuel, since 95% of the sulphur content is discharged as oxides to the atmosphere. For the Pasadena project only low sulphur content fuels were considered:

Boiler and Diesel Schemes: 7.8 lb/gal of fuel oil at 0.35% by weight sulphur yields .0546 lb/gal oxides of sulphur.

Internal Combustion Turbine Schemes: 7.2 lb/gal of fuel oil at 0.2% by weight sulphur yields .0288 lb/gal oxides of sulphur.

Table VI-3 indicates the summary of the NO_x and SO_x emissions for each scheme. No evaluation of particulates was made since the data was unavailable from DWP.

b. Summary

- (1) None of the diesel schemes is acceptable from an air quality standpoint because of the NO_x emissions. The balance of the TIES schemes appear to be acceptable, although somewhat marginally so. The most acceptable scheme is the Central Cooling/Heating Plant.
- (2) Other than the diesel schemes, the TIES schemes appear to be acceptable within the present air quality regulations of Los Angeles County, although the total pollution rate is increased by all TIES schemes.
- (3) A supplemental solar energy system for domestic hot water reduces total pollutants discharged for all TIES schemes by approximately 0.2%.

ANNUAL EMISSIONS FROM PLANTS

SCHEME	KWH FROM GRID	FUEL OIL USED (GAL)	TOTAL NO _x (LBS)	TOTAL SO _x (LBS)
CONV.	31,001,492	32,250	156,781	141,268
CENTRAL COOL/HTG. PLANT	26,216,412	87,141	135,875	122,732
1A	5,719,466	1,994,204	766,453	134,621
1B	5,717,261	1,438,062	560,669	104,264
1C	5,881,373	1,423,664	556,163	104,198
1D	6,145,535	1,408,257	551,783	104,546
1E	6,393,600	1,384,704	544,308	104,376
2A	7,856,155	1,852,484	168,955	88,704
2B	8,168,519	1,816,615	168,006	89,077
2C	8,378,540	1,761,836	165,221	88,444
2D	8,871,855	1,691,207	162,744	88,630
3A	22,069,672	794,242	154,032	142,679
3B	21,995,764	785,585	153,186	141,874
3C	22,062,068	776,720	153,030	141,688
3D	22,074,067	764,818	152,435	141,092
4A	3,729,175	2,206,896	173,129	80,340
4B	4,217,239	2,136,114	170,614	80,498
4C	4,903,434	2,066,778	169,192	81,589
4D	5,470,554	1,993,555	166,902	82,032

Table VI-3

B. COSTS OF GENERATING ELECTRICITY FOR TIES SCHEMES

The costs of generating electricity for various TIES schemes is shown in Table VI-4. This shows that the generating cost varied from 4.3¢/KWH for the Diesel Engine System with maximum thermal storage to 5.1¢/KWH for the best Combustion Turbine System.

The Boiler/Steam Turbine System cost was 14.6¢/KWH with maximum thermal storage.

All of these costs are considerably higher than the price of 1.8¢/KWH, which the utility company DWP would pay for electric energy delivered to the grid.

COSTS OF GENERATING ELECTRICITY FOR TIES SCHEME

SCHEME NO.	KW INSTALLED	KWH/YR PRODUCED KW INSTALLED	KWH/YR PRODUCED (1000's)	TOTAL ANNUAL OWNING & OPERATING COST (\$1000)	COOLING HEATING REVENUE (\$1000)	NET COST FOR POWER (\$1000)	COST/KWH (\$)
1A	14,356	1,134	16,280	1,975.3	505.4	1,369.9	.084
1B	10,251	1,808	18,534	1,572.7	605.4	967.3	.052
1E	5,847	3,056	17,868	1,369.6	605.4	764.2	.043
2A	8,461	2,008	16,990	1,617.7	605.4	1,012.3	.060
2D	4,637	3,480	16,137	1,431.0	605.4	825.6	.051
3A	1,257	1,808	2,273	974.6	605.4	369.2	.162
3D	741	3,053	2,262	935.4	605.4	330.0	.146
4A	11,439	1,799	20,579	1,842.2	605.4	1,236.8	.060
4D	6,186	3,050	18,867	1,592.1	605.4	986.7	.052

Table VI-4

C. DISCUSSION OF SYSTEMS STUDIED

The following conclusions can be drawn from the systems studies:

1. None of the TIES schemes analyzed proved financially feasible. This is in part due to the fact that revenue for power generation was not sufficient to pay for the cost of installing or operating the power generation equipment. In addition, there was insufficient heating usage and, therefore, insufficient heating revenue. This was due to the location and type of project.
2. A standard Central Cooling/Heating Plant is marginally feasible—economically.
3. Minimum capital investment in the TIES schemes is achieved with maximum utilization of storage for heating and cooling media.
4. Thermal storage in conjunction with a TIES plant, can also be used in design of supplemental peaking plants for Electrical Utilities.
5. A supplemental solar system for domestic hot water is not economically feasible primarily due to high initial cost,
6. Applications involving more weekly hours of operation and having more equal summer and winter thermal requirements, would fare better—economically.
7. It is unlikely that the TIES concept will prove economically feasible for communities where cooling is the major thermal demand being served.
8. The concept of producing high pressure steam for a backpressure turbine generator, in order to produce electric power and then reducing to low pressure to meet the cooling requirements, (Scheme Group 4) does not appear to be justifiable from either an energy or cost point-of-view.

D. RECOMMENDATIONS

1. *This study results in the following recommendations:*
 - a. That the Energy Using Community in Pasadena, California purchase electrical power from the local utility company.
 - b. That a further study be made as to the economic feasibility of obtaining cooling and heating media from a Central Cooling/Heating Plant to serve the community's thermal needs.

2. *Recommendations for Further TIES Study*

- a. Generally available computer programs cannot directly accomplish the type of analysis desired, an economical, simple-to-use program geared to optimization and sensitivity analyses of TIES plants should be developed.
- b. Future TIES studies should be funded for industrial, residential, university and health facility communities, located in varied climatological regions, in order to determine the probable national impact of the TIES concept.
- c. Additional load profile data for usage of various utility systems should be determined by actual metering of existing facilities.
- d. Future TIES studies should only include evaluation of systems which are likely to be environmentally acceptable.
- e. This study compares the TIES plant energy use with the *average* heat rate of the utility company. This may or may not be valid, depending on time of day and other factors. TIES power output may at times reduce the utility company's plant efficiency by reducing the loading of an efficient plant. On the other hand, TIES output may eliminate operation of a peaking unit which has a lower than average efficiency. This complex interrelationship requires careful input from the utility company involved.

VII. GLOSSARY

Capacity: The maximum output for which a component, subsystem, or system is rated.

Combined Cycle: The type of plant arrangement in which a combustion turbine drives a generator, and the waste heat from the turbine is recovered in the form of steam which drives a second generator via a steam turbine.

Commercial Article: A manufactured subsystem or component which (1) is commercially available (2) is listed in commercial catalogs showing overall physical and performance characteristics and ratings (3) has been in commercial use and (4) can be covered by warranty or performance bond.

Component: A hardware element.

Demand: The peak requirement imposed upon a utility within a given period of time.

Efficiency: The ratio of the effective or useful output to the corresponding input to the system, subsystem or component.

Energy Conversion Subsystem: The arrangement of components which serve to transform one fundamental form of energy (thermal, electrical, mechanical, chemical) to another.

Energy Distribution Subsystem: The arrangement of components which serves to bring energy from the central plant to a specified location on each site.

Fuel Conversion Subsystem: The arrangement of components which serve to transform an input fuel to another form, i.e. from solid to liquid or gas, without changing its fundamental form (thermal, electrical, mechanical or chemical).

Fuel Processing Subsystem: The arrangement of components which serve as an intermediate step in the transformation of a raw fuel into a fuel more readily usable by energy conversion subsystems.

High-Grade BTU: Thermal energy which has the potential to perform effective mechanical work as well as to provide heat.

Load Profile: A curve showing the demand for a service by the site plotted against time of occurrence.

Low-Grade BTU: Thermal energy which has the potential to provide heating.

Prime Mover: A component which produces shaft output (mechanical) work.

Recovered Heat: That heat which is normally an unused by-product of an energy conversion process, but which is reclaimed in a TIES plant and converted for mechanical or thermal use.

Service: Energy community requirement expressed in its utilization form.

Solid Waste: All unwanted or discarded solid materials of the energy community.

Sub-system: An arrangement of components which serve to perform one of the major functions of a total system.

System: The arrangement of sub-systems which expresses the complete energy inter-relationship.

Thermal Conversion Sub-system: The arrangement of components which serves to recover input heat of one form and by means of heat exchangers, etc., transform the heat into a form more readily usable for satisfying thermal loads of the site.

Utility: Energy product or by-product of an energy plant.

APPENDIX A

FACTORS USED IN LOAD CALCULATIONS

Reference: Pending State of California Energy Conservation Standards for New Non-residential Buildings, (Title 24).

1. CITY OF BURBANK WEATHER (0.5% Design Data)

Winter Design Dry Bulb Temperature: 36° F

Summer Design Dry Bulb Temperature: 94° F

Summer Design Wet Bulb Temperature: 70° F

Annual Degree Days: 1694

Latitude: 34° North

Elevation: 864 feet

2. WALL CONSTRUCTION – RETAIL CENTER AND DEPARTMENT STORES

Assumed Heavy, 60-80 LB/SQ. FT. – 5 hour average

Maximum $U_{ow} = 0.43$ (Figure 4-1, Section T20-1493)

Assumed Fenestration = 16% (unshaded glass)

Required U value of wall = 0.40 BTU/HR Ft² °F

3. WALL CONSTRUCTION – OFFICE BUILDINGS

Assumed Light, 20-30 LB/SQ. FT. – 3 hour average

Maximum $U_{ow} = 0.43$ (Figure 4-1, Section T20-1493)

Assumed Fenestration = 32% Glass, Moderate Shading with open weave drape

Required U value of Net Wall = 0.10 BTU/HR Ft² °F

4. ROOFS

Figure 4-2, Section T20-1493: Required U_{OR} value is 0.10 BTU/HR Ft² °F.

Skylight in retail center is calculated 2.5% of gross roof, with assumed $U_g = 1.1$, therefore, retail center net roof, must have a U value of .074 BTU/HR Ft² °F.

5. FLOORS OVER UNHEATED SPACE

Figure 4-5, Section T20-1493: Maximum $U_f = 0.26$ BTU/HR Ft² °F. (Note, this will require insulation between parking space and rental space.)

APPENDIX B

FACTORS USED TO DEVELOP TENANT AREA ALLOCATIONS AND ELECTRICAL LOADS

1. DEPARTMENT STORES

J.C. Penney — 144,680 Sq. Ft.

Broadway — 149,030 Sq. Ft.

	SELLING AREA (Sales)	SUPPORT AREA (Stock)	SPECIAL AREA
AREA DIVISION			
Merchandising	70%		
Stock Fitting		25%	
Tailor Shop			2%
Restaurant			3%
LIGHT LOADS W/FT ²			
General Lighting	3.6	2.0	2.0
Showcase-Display	2.4		
Vert. Transp.		20 KW	
Steam Boiler			30 KW Tailor Shop
Kitchen — W/FT ² (= 50% Rest. Area)			20 W/FT ²
Kitchen Fans			2 W/FT ²
Tailor Shop Lights			5 W/FT ²
Christmas Lights	0.25		
Occupancy — SF/Person	30	300	20

2. GENERAL RETAIL (SHOPS)

TYPE	TOTAL AREA	RETAIL	SERVICE
Women's Department	64,110	80%	20%
Men's Department	31,900	80%	20%
Jr. Department	41,370	80%	20%
Household	16,420	85%	15%
Shoes	31,900	75%	25%
Seasonal & Misc.	67,900	85%	15%
Jewelry & Gifts	20,210	90%	10%

LIGHTING	RETAIL	SERVICE
General	3.6	2.0
Showcase-Display	2.5	
For Jewelry	3.5	
Christmas Lights	0.25	
Occupancy – SF/Person	30	300

3. FOOD SERVICE (RESTAURANTS)

$$\text{Area} = 10.2\% \times 315,800 \text{ SF} = 31,580 \text{ SF}$$

	SEATING	SERVICE
Area Division	55%	45%
Lighting W/FT ²	1.6	2.8
Misc. Power W/FT ²	0.5	20.0
Kitchen Fans	—	2.0
Occupancy – SF/Person	15	100

4. COMMON AREAS

ENCLOSED MALL

Area = 80,000 Sq. Ft. (Net occupied floor area)

Lighting = 1.5 W/FT²

Occupancy = 1 person/100 Sq. Ft.

STAIRS, EXITS, SERVICE CORRIDORS

Area = 45,700 Sq. Ft.

Lighting = 1.3 W/FT²

Occupancy = 1 person/300 Sq. Ft.

PARKING GARAGES

Lighting = 0.4 W/FT²

Fan Power = 1.2 W/FT²

Occupancy = 1 person/200 Sq. Ft.

LANDSCAPED AREA

Lighting = 0.5 W/FT²

5. OFFICE SPACE AND NON-RETAIL SPACE

$60,000 \text{ SF} + 3.1\% \text{ of } 315,800 \text{ SF} = 9,790 \text{ SF}$

	OCCUPIED	SUPPORT
Area Division	85%	15%
Lighting Load W/FT ²	3.7	1.5
2/3 Task @ 4.8	3.2	1.5
1/3 General @ 1.6	0.5	—
Elevators (2/Office Bldg.)	2 @ 30 HP (Grd..Flr. Only)	
Misc. Power W/FT ² Misc. Small Loads	0.5	0.1
Occupancy — SF/Person	100	300

6. PEAK OCCUPANCY ESTIMATES

Reference: Uniform Building Code

USE	FT ² /OCCUPANT
Retail Space	30
Dining Rooms	15
Store Rooms — exits, etc.	300
Mall Area	100
Office Area	100
Bank Area (Same as Retail)	30
(1st Flr. Office Bldgs.)	

1/3 of total occupancy is considered employees, except in office space where 3/4 are considered employees.

7. HOT WATER USAGE — PEAK

Lavatories required per Uniform Plumbing Code, Appendix C.

NO. OF PEOPLE	PLUMBING FIXTURES REQUIRED
1-15	1
16-35	2
36-60	3
61-90	4
91-125	5

One additional for each 45 persons over 125.

8. FAN POWER CALCULATIONS

$$\text{Fan HP} = \frac{\text{CFM} \times \text{Total Pressure}}{6356 \times \text{Efficiency}}$$

$$746 \text{ Fan HP} = \text{Fan Watts}$$

Supply Fan CFM x Total Pressure is limited to 0.5/Sq. Ft. by
T20-1506 California Administrative Code.

Fan and Motor Efficiency is estimated to be .60.

$$\begin{aligned} \text{Therefore, Supply Fan W/Sq. Ft.} &= \frac{5.0 \times 746}{6356 \times .60} \\ &= 0.98 \\ &\text{Say } 1.0 \text{ Watt/Sq. Ft.} \end{aligned}$$

$$\text{Return Fan @ 25\% SP, 80\% Air} = 0.20 \text{ W/FT}^2$$

$$\text{Exhaust Fan @ 30\% SP, 15\% Air} = 0.05 \text{ W/FT}^2$$

For VAV fans, discharge damper control is assumed, and hourly used by supply and return fans will vary directly with supply CFM.

APPENDIX C

ESTIMATED DOMESTIC HOT WATER HEATING LOADS

AREA SERVED	RATE GPH	TEMP. RISE (degrees)	MBH
General Retail and Shopping, Non-Retail	320	50-120	200
J.C. Penneys Retail	140	50-120	85
Broadway Retail	140	50-120	85
Office Buildings	125	50-120	80
Shopping Plaza Kit. (2 @ 200 GPH each)	400	50-140	300
Dept. Store Rest. (2 @ 30 GPH each)	60	50-140	50

APPENDIX D

ELECTRICAL LOADS AND LOAD PROFILES

1. ELECTRICAL LOADS

SPACE DESCRIPTION	LOAD DESCRIPTION	CONNECTED LOAD-KW	WATTS PER SQUARE FT.	STD. PERIOD PROFILE MAX. %	SPECIAL PERIOD (CHRISTMAS HOLIDAYS) PROFILE MAX. %
Dept. Stores	Lights — General & Showcase	1467	5.00	77	80
	Vertical Transportation	160	.55	60	60
	Water Heating	65	.22	67	67
	Cooking Equip.	250	.85	35	35
	Tailor Shop Equip.	60	.20	40	40
	Exhaust Fans	23	.08	40	40
	Supply and Return Fans	205	<u>.70</u> 7.60	See Axxess Program	See Axxess Program
Shopping Ctr Stores (Less Restaurants)	Lights — General & Showcase	1621	5.73	90	95
	Water Heating	59	.21	33	33
	Misc. Small Loads	127.3	.45	50	50
	Exhaust Fans	14.2	.05	50	50
	Supply and Return Fans	283	<u>1.00</u> 7.44	See Axxess Program	See Axxess Program
Ctr Restaurants	Lights	67	2.09	95	95
	Water Heating	88	2.75	95	95
	Cooking Equip.	998	31.00	35	35

SPACE DESCRIPTION	LOAD DESCRIPTION	CONNECTED LOAD-KW	WATTS PER SQUARE FT.	STD. PERIOD PROFILE MAX. %	SPECIAL PERIOD (CHRISTMAS HOLIDAYS) PROFILE MAX. %
Ctr Restaurants	Exhaust Fans	29	.90	95	95
	Supply and Return Fans	38.6	<u>1.20</u>	See Access Program	See Access Program
			37.94		
Malls and Corridors	Lights	214	1.44	95	95
	Vertical Transportation	150	1.01	60	60
	Supply and Return Fans	104	<u>.70</u>	See Access Program	See Access Program
			3.15		
Office Buildings	Lights	196	3.27	80	80
	Vertical Transportation	60	1.00	60	60
	Water Heating	22	.37	25	25
	Misc Small Loads	117	1.95	25	25
	Exhaust Fans	3	.05	25	25
	Supply and Return Fans	72	<u>1.20</u>	See Access Program	See Access Program
			7.84		
Landscaping & Uncovered Parking	Lights	99	.50	100	100
Covered Parking	Lights	196	.40	100	100
	Vertical Transportation	455	.93	60	60
	Exhaust Fans	589	1.20	100	100

WEEKDAY _____
WEEKDAY CHRISTMAS - - - - -

SATURDAY _____
SATURDAY CHRISTMAS - - - - -

LIGHTS:
SHOPPING CENTER STORES: PROFILE 2

WEEKDAY —————
WEEKDAY CHRISTMAS - - - - -

SATURDAY —————
SATURDAY CHRISTMAS - - - - -

LIGHTS:
RESTAURANT: PROFILE 3

WEEKDAY _____
WEEKDAY CHRISTMAS -----

SATURDAY _____
SATURDAY CHRISTMAS -----

LIGHTS:
 MALL & CORRIDORS: PROFILE 4
 WEEKDAY _____
 WEEKDAY CHRISTMAS -----

SATURDAY _____
 SATURDAY CHRISTMAS -----

LIGHTS:
OFFICE BLDG.: PROFILE 5

WEEKDAY _____
WEEKDAY CHRISTMAS -----

SATURDAY _____
SATURDAY CHRISTMAS -----

LANDSCAPING & UNCOVERED LIGHTING: PROFILE 6

SUMMER MON.-FRI.
NO SATURDAY

MISC. SMALL LOADS:
SHOPPING CENTER STORES: PROFILE 7

WEEKDAY _____
WEEKDAY CHRISTMAS - - - - -

SATURDAY _____
SATURDAY CHRISTMAS - - - - -

WEEKDAY _____
WEEKDAY CHRISTMAS-----

SATURDAY _____
SATURDAY CHRISTMAS-----

EXHAUST FAN:
DEPT. STORES: PROFILE 9

WEEKDAY _____
WEEKDAY CHRISTMAS - - - - -

SATURDAY _____
SATURDAY CHRISTMAS - - - - -

EXHAUST FANS SHOPPING CENTER STORES: PROFILE 10

WEEKDAY _____
WEEKDAY CHRISTMAS -----

SATURDAY _____
SATURDAY CHRISTMAS -----

EXHAUST FAN
RESTAURANT: PROFILE 11

WEEKDAY _____
WEEKDAY CHRISTMAS -----

SATURDAY _____
SATURDAY CHRISTMAS -----

EXHAUST FANS:
OFFICE BUILDING: PROFILE 12

WEEKDAY _____
WEEKDAY CHRISTMAS -----

SATURDAY _____
SATURDAY CHRISTMAS -----

VERTICAL TRANSPORTATION:
DEPT. STORES & MALLS &
CORRIDORS: PROFILE 13

WEEKDAY

WEEKDAY CHRISTMAS

SATURDAY

SATURDAY CHRISTMAS

VERTICAL TRANSPORTATION:
OFFICE BUILDINGS: PROFILE 1A

WEEKDAY _____
WEEKDAY CHRISTMAS - - - - -

SATURDAY _____
SATURDAY CHRISTMAS - - - - -

COOKING EQUIPMENT:
DEPT. STORES: PROFILE 15

WEEKDAY _____
WEEKDAY CHRISTMAS -----

SATURDAY _____
SATURDAY CHRISTMAS -----

COOKING EQUIPMENT: RESTAURANT: PROFILE 16

WEEKDAY _____
WEEKDAY CHRISTMAS -----

SATURDAY _____
SATURDAY CHRISTMAS -----

DOMESTIC WATER HEATING:
DEPT. STORES: PROFILE 17

WEEKDAY _____
WEEKDAY CHRISTMAS -----

SATURDAY _____
SATURDAY CHRISTMAS -----

DOMESTIC HOT WATER:
SHOPPING CENTER STORES:
PROFILE 18

WEEKDAY

WEEKDAY CHRISTMAS

SATURDAY

SATURDAY CHRISTMAS

DOMESTIC HOT WATER:
RESTAURANTS: PROFILE 19

WEEKDAY _____
WEEKDAY CHRISTMAS -----

SATURDAY _____
SATURDAY CHRISTMAS -----

DOMESTIC HOT WATER OFFICE BUILDING: PROFILE 20

WEEKDAY

WEEKDAY CHRISTMAS

SATURDAY

SATURDAY CHRISTMAS

TAILOR SHOP EQUIPMENT:
DEPT STORES: PROFILE 21

WEEKDAY _____
WEEKDAY CHRISTMAS -----

SATURDAY _____
SATURDAY CHRISTMAS -----

LIGHTS & PARKING EXHAUST FANS:
COVERED PARKING: PROFILE 22

WEEKDAY _____
WEEKDAY CHRISTMAS -----

SATURDAY _____
SATURDAY CHRISTMAS -----

PEOPLE:
 DEPT. & CENTER STORES &
 MALLS: PROFILE 23
 WEEKDAY —————
 WEEKDAY CHRISTMAS - - - - -

SATURDAY —————
 SATURDAY CHRISTMAS - - - - -

PEOPLE:

RESTAURANT: PROFILE 24

WEEK DAY

WEEKDAY CHRISTMAS---

SATURDAY-

SATURDAY CHRISTMAS---

PEOPLE:
OFFICE BUILDINGS: PROFILE 25

WEEKDAY _____
WEEKDAY CHRISTMAS -----

SATURDAY _____
SATURDAY CHRISTMAS -----

CENTRAL PLANT:
 TOTAL DOMESTIC HEATING
 SCH. 4: PROFILE 26
 WEEKDAY
 WEEKDAY CHRISTMAS -----

SATURDAY
 SATURDAY CHRISTMAS -----

WEEKDAY _____
WEEKDAY CHRISTMAS ----

SATURDAY _____
SATURDAY CHRISTMAS-----

PASADENA RETAIL CENTER, PASADENA, CALIF.
TOTAL ENERGY STUDY MARCH 4, 1976

YEARLY TOTAL CONSUMPTION - FOR SCHEME 'F' ONLY (ALL OTHER SCHEMES NOT APPLICABLE TO THIS COMPUTER RUN)

METER	SCHEME A	SCHEME B	SCHEME C	SCHEME D	SCHEME E	SCHEME F
NO. 1/ SERVES MASTER ELECTRIC	MASTER ELECTRIC	MASTER ELECTRIC	MASTER ELECTRIC	MASTER ELECTRIC	MASTER ELECTRIC	MASTER ELECTRIC
USAGE	0.KWH	0.KWH	0.KWH	0.KWH	0.KWH	22575248.KWH
DEMAND	0.KWC	C.KWD	0.KWC	0.KWC	0.KWD	5803.KWD
MONTH	0.	C.	0.	0.	0.	12.
NO. 2 SERVES MASTER OIL	MASTER OIL	MASTER OIL	MASTER OIL	MASTER OIL	MASTER OIL	P1 CEN.PL.COCLG.
USAGE	0.GAL	0.GAL	0.GAL	0.GAL	0.GAL	3477875.TON-HRS
DEMAND	0.GPH	C.GPH	0.GPH	0.GPH	0.GPH	2952.TONS
MONTH	0.	C.	0.	0.	0.	8.
NO. 3 SERVES DEPT.STR.LIGHTS	BASE LDR&VAV FAN	ALL BASE LOADS				P2 CEN.PL.HEATG.
USAGE	0.KWH	C.KWH	0.KWH	0.	0.	7566.MM-BTU
DEMAND	C.KWC	C.KWD	0.KWC	0.	0.	10.MM-BTUH
MONTH	0.	C.	0.	0.	0.	1.
NO. 4 SERVES CENT.STR.LIGHTS	P1 DEPT.STR.HEAT			P3 CEN.PL.DWH		P3 CEN.PL.DWH
USAGE	0.KWH	0.GAL	0.	0.GAL	0.	2183856.MBTU
DEMAND	0.KWC	C.GPH	0.	0.GPH	0.	800.MBTUH
MONTH	0.	C.	0.	0.	0.	1.
NO. 5 SERVES CENT.REST.LIGHTS	P1 AUXILIARIES			P3 AUXILIARIES		
USAGE	0.KWH	0.KWH	0.	0.KWH	0.	0.
DEMAND	0.KWC	C.KWD	0.	0.KWC	0.	0.
MONTH	0.	C.	0.	0.	0.	0.
NO. 6 SERVES MALL&CORR.LIGHTS	P2 CENT.STR.HEAT			P1 CEN.PL.COCLG.	P1 CEN.PL.COOLG.	P1 AUXILIARIES
USAGE	0.KWH	0.KWH	0.	0.KWH	0.TON-HRS	2436623.KWH
DEMAND	0.KWC	C.KWD	0.	0.KWC	0.TONS	700.KWD
MONTH	0.	C.	0.	0.	0.	1.

APPENDIX E YEARLY TOTAL ENERGY CONSUMPTION AND MAXIMUM DEMAND LOADS FOR THE BUILDING

APPENDIX F

YEARLY ENERGY CONSUMPTION FOR CONVENTIONAL SYSTEM AND FOR CENTRAL PLANT SYSTEM

1. LISTING OF COMBINATIONS OF SCHEMES AND PRIMARY EQUIPMENT SYSTEMS ANALYZED

(FROM AXCESS COMPUTER RUNS OF FEBRUARY 28 AND MARCH 4, 1976)

SCHEME NO.	PRIMARY EQUIPMENT SYSTEM NO.	AREA SERVED	SYSTEM USAGE	SYSTEM TYPE
A(1) With economizer cycle terminal units	P-1	Department Stores	Cooling	Conventional
	P-2	Center Stores	Cooling	Conventional
	P-3	Center Restaurants	Cooling	Conventional
	P-4	Common Areas	Cooling	Conventional
	P-5	Office Bldgs.	Cooling	Conventional
	P-6	All Areas	Heating	Central Plant
B(2) With economizer cycle terminal units	P-1	Department	Heating	Conventional
	P-2	Stores	Heating	Conventional
	P-3	Center Stores Restaurants	Heating	Conventional
	P-4	Common Areas	Heating	Conventional
	P-5	Office Bldgs.	Heating	Conventional
	P-6	All Areas	Cooling	Central Plant
C(3) With economizer cycle terminal units	P-1	All Areas	Cooling	Central Plant
	P-2	All Areas	Heating	Central Plant
	P-3	All Areas	Individual (separate) Dom. Water Heating	Conventional
D(4) With economizer cycle terminal units	P-1	All Areas	Cooling	Central Plant
	P-2	All Areas	Heating	Central Plant
	P-3	All Areas	Domestic Water Heating	Central Plant

SCHEME NO.	PRIMARY EQUIPMENT SYSTEM NO.	AREA SERVED	SYSTEM USAGE	SYSTEM TYPE
E(5) With fixed return air cycle terminal units	P-1	All Areas	Cooling Load Only in Ton-Hours	Central— No equipment 100% eff.
	P-2	All Areas	Heating Load Only in million BTU	Central— No equipment 100% eff.
	P-3	All Areas	Central Plant Preheat of Dom. Water Heating	Central Plant
	P-4	All Areas	Local Boost of Domestic Water Heating	Local (Conventional) Booster Water Heaters
F(6) With economy cycle terminal units	P-1	All Areas	Cooling Load Only in Ton-Hours	Central— No equipment 100% eff.
	P-2	All Areas	Heating Load Only in million BTU	Central— No equipment 100% eff.
	P-3	All Areas	Dom. Water— Heating	Central— No equipment 100% eff.

2. YEARLY ENERGY CONSUMPTION FOR CONVENTIONAL SYSTEM
(FROM AXCESS COMPUTER RUN OF FEB. 28, 1976)

(HEATING VALUE OF PURCHASED ELECTRICITY – 11,760 BTU/KWH)
(HEATING VALUE OF NO. 2 OIL = 139,000 BTU/GAL.)

	YEARLY USAGE	YEARLY USAGE	YEARLY DEMAND
FROM SCHEME A(1)			
Master Electric (Meter No. 1) (includes all Conventional. [local] Cooling Systems + Central Htg.) Minus Elec. for Central Htg. Aux. (Meter No. 34)	= 29,557,376 KWH		9320 KWD
	= <u>- 134,880</u>		<u>-35</u>
Net Total Electric Usage for Conventional Cooling Systems	= 29,422,496 KWH		9285 KWD
PLUS: FROM SCHEME B(2)			
Master Oil (Meter No. 2) (includes oil for Conventional Htg. Systems only (for Dept. Stores & Office Bldgs.)	=	32,250 Gal.	
ELECTRIC USAGE FOR CONVENTIONAL HTG. SYSTEMS			
for Dept. Stores Htg. Aux. (Meter No. 5)	= 19,270 KWH		5 KWD
for Center [tenant] Stores Htg. (Meter No. 6)	= 300,472		12
for Restaurant Htg. (Meter No. 8)	= 30,316		129
for Common Area Htg. (Meter No. 9)	= 766,703		591
for Office Bldg. Htg. Aux. (Meter No. 11)	= <u>19,265</u>		<u>5</u>
Net Total Electric Usage for Conventional Heating Systems	= 1,136,026 KWH		742 KWD

	YEARLY USAGE	YEARLY USAGE	YEARLY DEMAND
PLUS: FROM SCHEME C(3)			
ELECTRIC USAGE FOR CONVENTIONAL DWH			
Total Individual [local]			
DWH (Meter No. 13)	= 404,180 KWH		183 KWD
Auxiliaries — for above (Meter No. 14)	= <u>38,790</u>		<u>10</u>
Net total Electric Usage for Conventional DWH Systems	= <u>442,970 KWH</u>		<u>193 KWD</u>
Total for Conventional System	= 31,001,492 KWH	32,250 Gal.	10,220 KWD
31,001,492 KWH × 11,760	= 364,578 M ² BTU/YR.		
32,250 GAL × 139,000	= <u>4,483</u>		
	369,061 M ² BTU/YR.		

3. YEARLY ENERGY CONSUMPTION FOR CENTRAL PLANT SYSTEM
(FROM AXCESS COMPUTER RUN OF FEB. 28, 1976)

FROM CENTRAL PLANT—SCHEME D(4):

Total Power (Meter #1)	=	27,828,336 KWH
Total Oil	=	87,141 Gal.
27,828,336 × 11,760	=	327,261 M ² BTU/YR
87,141 × 139,000	=	<u>12,113</u>
		339,374 M² BTU/YR

Saves 8% of total energy as compared to
Conventional System
(29,687 M² BTU/YR)

4. COMPARISON OF YEARLY ENERGY CONSUMPTION FOR DOMESTIC WATER HEATING SCHEMES

(FROM AXCESS COMPUTER RUN OF FEB. 28, 1976)

DOMESTIC WATER HEAT – ALL FROM CENTRAL PLANT – SCHEME D(4):

$$\begin{array}{ll} \text{(Meter \#4)} & 19,639 \text{ Gal.} \times 139,000 = 2,730 \text{ M}^2 \text{ BTU/YR} \\ \text{(Meter \#5)} & 116,366 \text{ KWH} \times 11,760 = \underline{1,368} \\ & 4,098 \text{ M}^2 \text{ BTU/YR} \end{array}$$

DOMESTIC WATER – PREHEATED AT PLANT = SCHEME E(5):

$$\begin{array}{ll} \text{(Meter \#10)} & 12,307 \text{ Gal.} \times 139,000 = 1,711 \\ \text{(Meter \#11)} & 58,185 \text{ KWH} \times 11,760 = 684 \\ \text{(Meter \#12)} & 120,076 \text{ KWH} \times 11,760 = 1,412 \\ \text{(Meter \#14)*} & 38,790 \text{ KWH} \times 11,760 = \underline{456} \\ \text{*From Scheme C} & 4,263 \text{ M}^2 \text{ BTU/YR} \quad \text{(4\% more than} \\ & \text{Central Plant} \\ & \text{Scheme above)} \end{array}$$

INDIVIDUAL (LOCAL) DOMESTIC WATER HEAT – SCHEME C(3):

$$\begin{array}{ll} \text{(Meter \#13)} & 404,180 \text{ KWH} \\ \text{(Meter \#14)} & \underline{38,790} \\ & 442,970 \times 11,760 = 5,209 \text{ M}^2 \text{ BTU/YR} \quad \text{(27\% more than} \\ & \text{Central Plant Scheme} \\ & \text{above)} \end{array}$$

APPENDIX G

CAPITAL COSTS OF CONVENTIONAL HEATING, AIR CONDITIONING & DOMESTIC WATER HEATING SYSTEMS

(COSTS INCLUDE EQUIPMENT, LESS AIR HANDLING UNITS, PLUS PIPING INSTALLED, PLUS 15% MARK-UP & 11% ANNUAL ESCALATION)

BUILDING SPACE	AREA SQ. FT.	TONS REFRIGERATION	COSTS OF HEATING & AIR CONDITIONING EQUIPMENT	COSTS OF PLUMBING DWH EQUIPMENT	COSTS OF ELECTRICAL EQUIPMENT	TOTAL COSTS
Two Department Stores	293,740	1146	\$563,600	\$56,190	\$131,625	\$ 751,415
Center (Tenant) Stores	284,012	1096	293,870	18,150	125,890	437,910
Center (Tenant) Restaurants	32,220	227	60,915	12,405	26,065	99,385
Malls	148,540	404	108,250	9,475	46,475	164,225
Two Office Buildings	60,000	232	127,675	7,685	26,705	<u>162,065</u>
TOTAL						\$1,615,000

APPENDIX H

CAPITAL COST ESTIMATE FOR CENTRAL COOLING/HEATING PLANT SYSTEM

MECHANICAL/ELECTRICAL COST

3 — 1000 Ton elec. drive refrig. mach.	\$ 300,000
3000 Ton cooling tower	150,000
2 — Heating Boilers, 300 HP	50,000
2 — Domestic Hot Water Heaters (Boilers)	20,000
Auxiliary equipment	60,000
Piping	330,000
Ventilation & plumbing	50,000
Labor & installation	250,000
Plant electrical	<u>200,000</u>
Sub-Total	1,410,000
Contractor Mark-up & Escalation	<u>527,000</u>
Sub-Total	1,937,000
*Plant Structure including Utilities and Contingency	<u>490,000</u>
TOTAL PLANT COST	\$2,427,000
Distribution From Plant To Site Property Line	<u>40,000</u>
TOTAL	\$2,467,000

* Assumes integrated structure within parking garage, Parcel H.

APPENDIX J

CHILLED WATER AND HOT WATER THERMAL STORAGE CALCULATIONS

1. CHILLED WATER THERMAL STORAGE CALCULATIONS

Meter Readings – Cooling BTU x 10⁴

August 13 – (Maximum Demand Day – from March 4, 1976, AXCESS Calculation Printout)

TIME OF DAY	LOAD: BTU x 10 ⁴
10:00 a.m.	3,543
11:00 a.m.	3,073
12:00 Noon	2,972
1:00 p.m.	2,951
2:00 p.m.	2,945
3:00 p.m.	3,174
4:00 p.m.	3,064
5:00 p.m.	2,965
6:00 p.m.	3,083
7:00 p.m.	2,902
8:00 p.m.	2,773
9:00 p.m.	1,867
10:00 p.m.	<u>1,524</u>

36,816 x 10⁴ Total BTU Needed
= 30,680 Ton-Hours

Capacity Required for 14 Hr. Operation:

30,680/14 = 2,191 Tons
Say 2,190 Tons = 3 Machines @ 730 Tons Ea.

Capacity Required for 16 Hr. Operation:

30,680/16 = 1,917 Tons
Say 1,920 Tons = 3 Machines @ 640 Tons Ea.

Capacity Required for 20 Hr. Operation:

30,680/20 = 1,534 Tons
Say 1,560 Tons = 3 Machines @ 520 Tons Ea.

Capacity Required for 24 Hr. (Continuous) Operation:

30,680/24 = 1,278 Tons
Say 1,290 Tons = 3 Machines @ 430 Tons Ea.

Capacity Required for 13 Hr. (No Storage) Operation:

2952 Tons
Say 2250 Tons = 3 Machines @ 750 Tons Ea.

- *Chilled Water Storage Required – 14 Hr. Operation*

2,191 Tons installed produce $2,629 \times 10^4$ BTU/Hr.

Machine is overloaded entire period from 10:00a.m. through 8:00p.m. (11 hours)

Total BTU withdrawn = $(36,816 - 1,867 - 1,524) \times 10^4 = 33,425 \times 10^4$

BTU inserted = $11 \times 2,629 = 28,919$

BTU storage required = $4,506 \times 10^4$ @ 16° temp. diff. = 338,085 Gals.

Say = 370,000 Gals.

- *Chilled Water Storage Required – 16 Hr. Operation*

1,920 Tons installed produce $2,304 \text{ BTU/Hr.} \times 10^4$

Machine is overloaded: 10:00a.m. to 8:00p.m. (11 hours)

BTU withdrawn = $33,425 \times 10^4$

BTU inserted = $11 \times 2,304 = 25,344 \times 10^4$

BTU storage required = $33,425 - 25,344 = 8,081 \times 10^4$ @ 16° temp. diff. = 606,317 Gals.

Say = 650,000 Gals.

- *Chilled Water Storage Required – 20 Hr. Operation*

1,534 Tons installed produce $1,841 \times 10^4$ BTU/Hr.

Machine is overloaded: 10:00a.m. through 9:00p.m. (12 hours)

BTU withdrawn = $36,916 - 1,524 = 35,292 \times 10^4$

BTU inserted = $12 \times 1,841 = 22,092 \times 10^4$

BTU storage required = $13,200 \times 10^4$ BTU @ 16° temp. diff. = 990,400 Gals.

Say = 1,100,000 Gals.

- *Chilled Water Storage Required – 24 Hr. Operation*

1,278 Tons required produce $1,534 \text{ BTU/Hr.}$

Machine overloaded: 10:00a.m. through 9:00p.m. (12 hours)

BTU withdrawn = $35,292 \times 10^4$

BTU inserted = $12 \times 1,534 = 18,403 \times 10^4$

BTU storage required = $16,889 \times 10^4$ BTU @ 16° temp. diff. = 1,267,000 Gals.

Say = 1,400,000 Gals.

2. HOT WATER THERMAL STORAGE CALCULATIONS

The hot water heating storage tank sizes and capacities were based upon the required number of gallons to hold the waste heat output of one prime mover for a two-hour period, when heated from 140° F to 200° F.

An example for Scheme 1B follows:

Waste heat from one prime mover (diesel engine generator)
= 13,140,000 BTU/Hr.

$$\frac{2 \times 13,140,000 \text{ BTU/Hr.}}{8.33 \times 60^\circ} = 52,580 \text{ Gals. Say} = 53,000 \text{ Gals.}$$

APPENDIX K

SUPPLEMENTAL SYSTEMS

1. SOLAR ENERGY SYSTEM

Solar energy was evaluated to serve the domestic hot water load of the energy community. This load was calculated by the AXCESS program to be 2,184,000 MBTU/YR. The system evaluated would provide 1,115,000 MBTU/YR with approximately 4,000 square feet of collector area, at 130°, with a 5600 gallon storage tank.

The capital cost of the system, including piping and storage was estimated at \$35/ square foot of collector area, or \$140,000.00.

The system evaluated represents an annual fuel savings of approximately 8,000 gallons of oil, representing an annual cost savings of approximately \$2,700.00.

Assuming an annual operating and maintenance cost of 5% of invested capital added to the owning cost, the solar energy system does not represent an economically feasible supplemental system for any of the schemes considered.

The impact of the solar system evaluated on air quality is a reduction of approximately 0.2% in emitted pollutants.

2. SOLID WASTE INCINERATOR WITH HEAT RECOVERY

This system was evaluated on the basis of providing low grade BTU's for space cooling by absorption refrigeration.

Analysis of solid waste loads from the energy community indicated that a 2,000 lb/hr. controlled air incinerator was required. This system provides 104 MBTU/Day at 15 psi, representing approximately 20% of the peak day energy requirement for cooling.

As a trial, Scheme 1E was evaluated for comparative economics. The capital cost of the incinerator, piping, stack and heat exchanger was estimated at \$300,000.00. The reduction in cost from Scheme 1E for the reduction in size of the prime mover and prime mover heat recovery is \$390,000 indicating a capital cost savings of \$90,000.00 for using the incinerator. However, this does not include the cost of equipment to transport the waste from the energy community to the plant. A pneumatic chute delivery system with 3 stations (2 at the retail center, 1 at the office complex) was evaluated. The estimated cost of \$220,000 for this system was determined not economically justified and delivery of the waste was assumed to be done by cart train.

For the particular example chosen, the incinerator system actually increased the amount of fuel consumed by approximately 15%. On an hourly basis, the calculation for this is as follows:

With Incinerator

8 MBTU/HR input from incinerator reduces power generation by 1,914 KWH (at 4.18 lb/KW recovery rate).

Additional 1,914 KWH from grid at 11,760 BTU/KWH =
22,508,000 BTU
plus 1,000,000 BTU input fuel to incinerator
23,508,000 BTU

Without Incinerator

1,914 KWH X 10,600 BTU/KWH = 20,288,000 BTU

A similar calculation for the combustion turbine scheme indicated a negligible impact on fuel consumption with or without the incinerator.

The annual maintenance and operating cost of the incinerator would substantially increase overall plant cost because of the personnel which would have to be assigned to haul the waste, charge the incinerator and remove residual ash. A minimum of \$50,000 was estimated for annual operating and maintenance cost. A net savings in cost for removal of the solid waste to landfill was estimated at \$10,000.00 annually.

An evaluation of the incinerator's impact on air quality indicated that with venturi type scrubbers for removal of particulates, the incinerator would comply with existing air quality standards. SO_x emissions, compared to equivalent BTU of oil burned, could be reduced by one-half. However, since the City of Pasadena is located in an area which experiences particularly bad smog problems, it is difficult to determine whether approval to build or operate an incinerator can be obtained from the Southern California Air Pollution Control District.

Since the addition of an incinerator does not conserve energy, and in fact for some of the TIES schemes actually increases fuel consumption, and since the relatively high operating and maintenance cost precludes economic feasibility, the use of a heat recovery incinerator as a supplemental system is not recommended.

APPENDIX L

STATEMENT OF ARCHITECT-ENGINEER SERVICES

The Architect-Engineer will undertake the following specific tasks under Scope of the Work. The work shall be performed so as to satisfy the requirements of both the Agency and ERDA as set forth in Prime Contract No. EY-76-C-03-1151.

The Architect-Engineer will prepare a feasibility study and report for a total energy plant which will serve an initial development of approximately 825,000 sq. ft. of commercial and office space plus parking structures. After completion of the study, the Architect-Engineer will prepare construction documents for a plant with the chosen system.

I. Load analysis to determine the most feasible and practical system for project including:

A. Load simulation analysis for the following services using computer programming to the maximum feasible extent should be provided.

- 1. heating**
- 2. cooling**
- 3. lighting**
- 4. electrical, other than lighting**
- 5. domestic hot water**
- 6. cooking**
- 7. liquid and solid waste treatment**
- 8. vertical and lateral transportation of goods and people**
- 9. other services**

NOTE: Information on proposed developments such as size, occupancy, location, hours of operation, etc. is to be provided by Project Manager. Time load profiles will be developed on hourly, daily, monthly and seasonal basis for all service and all energy forms necessary to satisfy the services. For services that computer programming are not available for simulation, the load analysis and the time-load characteristics should be determined from known or readily desirable relationships and experienced-based data.

In developing the base data for the study, the Architect-Engineer will investigate all other related studies and activities, including the MIUS program, which may have an application to this study so that maximum available relevant data will be utilized for the development of these tasks.

II. Integrated Systems Alternatives

- A. The data developed under Task I will be the basis of the analysis of the various integrated systems alternative. Develop a matrix interfacing the services requirements as Task I and the following energy converters and energy sources.

ENERGY SOURCES	ENERGY CONVERTERS
oil	steam turbine
gas	diesel engine
coal	combustion turbine
solid waste	combined cycle (combustion turbine-steam turbine)
sewage sludge	externally-fired closed Brayton cycle
solar energy	Lurgi process gasified coal
others	Fluidized bed burning
	Thermal storage
	Others

The operating characteristics of the energy convertors will be compared to the services required for the determination of the optimum combination of supply and demand and the determination of the optimum system. Computer analysis should be used to the maximum feasible extent in this synthesis and the evaluation of the cycle characteristics in conjunction to services to be provided.

- B. Analysis of existing technology available (Resource research). This analysis should be performed parallel to the work for IIA. Analysis should be performed for operating data, equipment availability, cost, reliability, maintenance, and other pertinent data. Various equipment and engineering systems manufacturers should be contacted to determine previous data and other pertinent data necessary for the following analysis configuration.
- C. Analysis configuration of all viable alternatives from above including distribution system of resulting energy forms. A viable alternative is defined as one that will employ technologies that are within the state-of-the-art. However, modest advances of new applications of existing technologies should be the goal for each alternative.
1. Procurement cost and energy analysis of each combination
 2. Inter-combination comparisons and separate predictions based on:
 - a. unit capital cost
 - b. unit total annual owning and operating costs
 - c. energy consumed
 - d. heat recovered

- e. environmental impact
- f. project reliability
- g. flexibility
- h. construction schedule
- i. electrical integration with utility

At the end of this step, the three top contenders should be selected for further evaluation and analysis as follows. Each of the three top contenders should meet the following criteria:

1. The estimated cost of the system to be close to established budget limits.
2. The overall system will maximize conservation of energy and maximize use of replenishable forms of energy such as solar, trash, etc.
3. The system will meet the latest environmental standards.
4. The system will be adaptable to incremental expansion and integration with existing and new facilities and systems.

NOTE: Project Manager to furnish all established budget limits

D. Analysis and feasibility of incremental expansion beyond the first designed area.

1. Delineation of area of energy community of potential customers, feasibility of incremental expansion, etc.

NOTE: Project Manager to assist in determining possible future market considerations for expansion of system including increments and ultimate capacity.

E. Analysis and selection of location of facility taking into consideration energy community, incremental expansion, distribution system, plant size, environmental problems, traffic and parking interaction with existing power distribution, etc.

NOTE: Project Manager to assist in site evaluation process.

F. Comparison of three alternatives with conventional systems in the same elements (C. 2,a,b,c,d,e,f,g,h,i). The conventional system will be energy conserving systems for each building.

NOTE: Project Manager will assist in identification of conventional system.

G. Provide technical assistance to Project Manager in analysis and resolution of problems related to interfacing and integrating the proposed systems with existing and proposed facilities with respect to:

- 1. space layout**
- 2. aesthetics**
- 3. site work**
- 4. underground piping**
- 5. existing utilities**
- 6. electrical system**
- 7. construction phasing**

H. Preliminary test of design methodology of the three viable alternatives to include:

- 1. simplified flow schematic**
- 2. general plant arrangement**
- 3. one-line electrical schematic**

At the end of this phase the Agency and the City will choose one system for further development of a design package as described subsequently.

I. A concise, comprehensive report should be prepared by the Architect-Engineer for publication containing all data and work that was developed during Tasks I and II. This report should be suitable for publication and distribution for the widest dissemination gained in this work and will include the methodology used to determine the optimum system. Submission will be made by the Architect-Engineer of the master original as approved by the Agency plus 20 copies.