InterTechnology Corporation
Proposed
Systems Level Plan for Solar Heating and Cooling
Commercial Buildings
National Solar Demonstration Program

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NON-RESIDENTIAL BUILDING DATA

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1. Selection of Building Types

The Systems Level Plan presented in the Technical Report is designed to address the commercial portion of the Federal Solar Heating and Cooling Demonstration Program. The types of buildings adopted for inclusion in the program were based upon those classifications employed in the Dodge Construction Potentials published by the F. W. Dodge Company. There are several reasons and advantages in selecting this classification:

1. Dodge Construction Potentials are the standard reference used by the building community for information on construction rates for these building types. Thus, we believe this classification permits continuity and consistency with the building community -- the sector of economy addressed by this program.
2. Compression of the many building types listed in the Dodge Construction Potentials into five basic classes (offices, retail, schools, hospitals, and "other") were employed in developing national inventories (floor space) and projected inventories reported in the Federal Energy Administration's Project Independence Blueprint Final Task Force Report, Residential and Commercial Energy Use Patterns (1970-1990) dated November 1974, Volume 1. Development of floor space inventories was crucial to program development.

Technically, manufacturing establishments and apartment houses (and related "for-profit" residential establishments) are part of the commercial sector. Manufacturing establishments have been omitted from this study because we found it impossible to characterize their space energy loads and because we were unable to locate any information on floor space inventories (needed to estimate total space energy loads required by this sector). Apartment houses and related were omitted from this study since these buildings are being considered in the HUD Residential Program.

The basic approach taken to establish the final set of building types which would be considered for the program was an evolutionary one. The first step

consisted of determining the "fineness" with which building inventories could be determined. The data presented in the next section illustrates the level of detail attained. The next step consisted of analyzing the general construction and energy usage characteristics of each type so that any similarities could be taken advantage of in order to reduce the number required for consideration. The result of this qualitative analysis is a consolidation of the 25 building types into the 12 general classes illustrated in Figure 1. Dormitories were not considered since the HUD program is considering this group. Terminals and miscellaneous include railroad, bus, and air passenger terminals, all types of freight terminal buildings, hangers, equipment storage buildings, etc. We were unable to characterize either their construction or energy usage patterns in a reasonably consistent way. Since this group comprises less than four percent of the total inventory, this group was not given further consideration.

For each of the building types of Figure 1, typical construction was assumed so that space heating and cooling loads could be calculated. While construction of real buildings varies considerably, the intent of this exercise was to expose the relative differences in energy requirements so that the potential application of each for solar could be evaluated.

2. Floor Space Inventories

Floor space inventories (total floor space) for the various building types were required in order to estimate the space heating and cooling load requirements. These energy requirements were then used as a measure of the impact a given building would have on the program relative to all other building types on a climatic regional basis.

Establishing these inventories proved to be a formidable task since no inventory of existing buildings (by specific type) was available during the course of this work. By far the most complete and helpful reference on this subject was the Federal Energy Administration's Project Independence Blueprint Final Task Force Report, "Residential and Commercial Energy Use Patterns, 1970-1990", Volume 1 dated November 1974. This report presents estimated existing inventories for five broad classes of buildings -- schools, offices, retail, hospitals, and "other" -- for 1970 and estimates net growth in this inventory for 1980 and 1990.

FIGURE 1

CONSOLIDATION OF BUILDING TYPES INTO
12 CHARACTERISTIC CLASSES

1. OFFICES:
 - Federal
 - State and Local
 - Private, including banks
2. SINGLE STORES AND SERVICE STATIONS
3. RESTAURANTS
4. SHOPPING CENTERS
5. EDUCATIONAL:
 - Elementary, junior, and high schools
 - Vocational, colleges
 - Laboratories
6. LIBRARIES AND MUSEUMS
7. HEALTH:
 - Hospitals
 - Clinics
8. MOTELS (≤ 3 stories) AND NURSING HOMES
9. WAREHOUSES
10. CHURCHES, AMUSEMENT, SOCIAL, AND RECREATIONAL
11. HOTELS (> 3 stories)
12. SUPERMARKETS

What makes this report useful is its consistency with the classifications adopted by the F. W. Dodge Company. Since these five broad classes were not specific enough for our purposes, a method was devised, employing the Dodge data, and other sources to break-out the inventories of these five classes into more specific building types.

The general procedure for developing these inventories is illustrated in Figures 2 and 3, and briefly described as follows:

1. Employing Dodge data, relative rates of construction were taken for 1963, 1964, 1968, and 1969 to estimate the fraction of each building type constructed relative to the total construction for these buildings of interest. These rates of construction were made to coincide with the five classes of buildings in the FEA report. They were assumed to apply to all buildings in existence and to all buildings which will be built during the next 15 years.
2. Applying the fractions to the inventories in the FEA report (see Table 1), national inventories for about 25 building types were obtained and are presented in Tables 2 and 3.
3. Employing data in the 1970-74 Statistical Abstracts, from the National Restaurant Association, from the Government Services Administration, from the American Hospital Association, and from the Virginia Office of Education, number of buildings by type and average building sizes were estimated.
4. Regional shifts in rates of construction were assumed to follow series 1E population projections presented in the 1974 Statistical Abstract. (See Table 4). For those climatic regional boundaries which divided states, an estimate of the regional population was made by determining the population of the counties within each region. That is, the fraction of the state's population within each region was estimated by use of county populations. These regional populations are presented in Table 5.
5. The regional fractions of population for 1975 and projected to 1980 and 1990 were then applied to the national building inventory to obtain estimates of regional building inventories.

FIGURE 2

9

FIGURE 3

TABLE 1

U.S. GENERAL NON-RESIDENTIAL BUILDING INVENTORY
10⁶ ft² (Percent of Total)

	<u>1975</u>	<u>1980</u>	<u>1990</u>
Offices	4382 (17)	5681 (17)	9242 (20)
Retail	5647 (21)	7575 (23)	13034 (28)
Schools	5856 (22)	6804 (21)	8619 (19)
Hospitals	1787 (7)	2128 (7)	2847 (6)
Other	8845 (33)	10458 (32)	12406 (27)
Total	26517 (100)	32646 (100)	46148 (100)

Source: Adapted from Federal Energy Administration's Project Independence Report, Residential and Commercial Energy Use Patterns, November, 1974

TABLE 2

1975 NON-RESIDENTIAL BUILDING INVENTORY

(Excluding Industrial)

<u>Group</u> <u>Type</u>	<u>Percent of Group</u>		<u>Percent of Total</u>	
	<u>Floor Space</u>	<u>No. Bldgs.</u>	<u>Floor Space</u>	<u>No. Bldgs.</u>
OFFICE	100.0	100.0		
Federal Owned	6.6	2.5	1.1	0.3
State and Local	21.2	22.4	3.5	3.0
Private Off. and Bank	72.2	75.1	11.9	10.2
RETAIL	100.0	100.0		
Supermarkets	5.5	2.0	1.2	0.9
Restaurants				
Franchised	2.6	3.5	.6	1.6
Non-Franchised	5.3	21.4	1.1	10.1
Service Stations and				
Service Garages	10.9	26.9	2.3	12.8
Shopping Centers	15.0	1.0	3.2	.5
Stores	49.9	44.2	10.6	20.9
Parking Garages and Other				
Commercial	10.8	1.0	2.3	.5
EDUCATIONAL	100.0	100.0		
Schools (1-12 grades)	74.0	72.8	16.3	6.6
Colleges and Vocational	14.0	10.3	3.1	.9
Laboratories (Not manufacturer				
Owned)	7.0	9.5	1.5	.8
Libraries, Museums	5.0	7.4	1.1	.7
HEALTH	100.0	100.0		
Hospitals	60.7	16.7	4.1	0.3
Clinics, Nursing Homes,				
Mental Institutions	39.3	83.3	2.6	1.5
OTHER	100.0	100.0		
Warehouses	36.5	32.5	12.2	9.3
Religious				
Churches	9.0	16.8	3.0	4.7
Sunday School and Other				
Religious	6.0	9.8	2.0	2.8
Amusement, Social, and				
Recreational	12.5	13.2	4.3	3.7
Hotels, Motels				
> 3 stories	6.0	1.7	2.0	.5
≤ 3 stories	7.0	3.9	2.3	1.2
Dormitories, Fraternity Houses,				
Convents, Other	12.0	5.1	4.0	1.4
Passenger and Freight Terminals,				
Equipment Storage, Other Misc.	11.0	17.0	3.7	4.8

TABLE 3.

1975 NON-RESIDENTIAL BUILDING INVENTORY

	<u>10⁶ ft²</u>	<u>1000 Bldgs.</u>	<u>Average Size 1000 ft²</u>
OFFICES			
Federal Owned	289	9	30.6
State and Local	929	82	11.4
Private Office and Bank	3164	275	11.5
RETAIL			
Supermarkets	312	25	12.5
Restaurants			
Franchised	148	45	3.3
Non-Franchised	300	273	1.1
Service Stations and			
Service Garages	617	343	1.8
Shopping Centers	847	13	63.2
Stores	2815	563	5.0
Other Commercial (Primarily parking garages)	608	13	47.0
EDUCATIONAL			
Schools	4333	177	24.5
Colleges, Vocational	820	25	33.3
Laboratories	410	23	17.6
Libraries, Museums	293	18	16.7
HEALTH			
Hospitals	1085	8	136
Clinics, Nursing Homes, and Mental Institutions	702	40	17.5
WAREHOUSES	3224	248	13.0
RELIGIOUS			
Churches	796	128	6.2
Sunday School and Other Religious	531	75	7.1
AMUSEMENT, SOCIAL, AND RECREATIONAL	1110	100	11.1
HOTELS, MOTELS			
> 3 stories	531	13	40
≤ 3 stories	619	30	20.5
DORMITORIES, FRATERNITY HOUSES, CONVENTS, AND OTHER	1061	39	27.2
PASSENGER TERMINALS, FREIGHT TERMINALS, EQUIPMENT STORAGE, AND OTHER MISC.	973	130	7.5
TOTAL	26517	2695	9.8

Table 4

Population Projections - Fractionalized by State

State	1975	1980	1990	State	1975	1980	1990
	<u>Fraction</u> %	<u>Fraction</u> %	<u>Fraction</u> %		<u>Fraction</u> %	<u>Fraction</u> %	<u>Fraction</u> %
Alabama	1.64	1.57	1.47	Montana	.33	.32	.30
Alaska	.15	.16	.16	Nebraska	.71	.69	.66
Arizona	.92	.95	1.01	Nevada	.26	.30	.33
Arkansas	.93	.90	.88	New Hampshire	.37	.39	.41
California	10.21	10.7	11.4	New Jersey	3.61	3.66	3.78
Colorado	1.14	1.16	1.21	New Mexico	.49	.48	.46
Connecticut	1.52	1.56	1.63	New York	8.86	8.72	8.56
Delaware	.28	.29	.30	North Carolina	2.46	2.41	2.33
Florida	3.46	3.65	3.84	North Dakota	.28	.28	.24
Georgia	2.29	2.29	2.30	Ohio	5.2	5.1	5.06
Hawaii	.38	.38	.37	Oklahoma	1.25	1.23	1.21
Idaho	.34	.33	.33	Oregon	1.05	1.07	1.10
Illinois	5.45	5.40	5.37	Pennsylvania	5.61	5.36	5.00
Indiana	2.56	2.55	2.54	Rhode Island	.45	.45	.44
Iowa	1.34	1.28	1.20	South Carolina	1.24	1.20	1.14
Kansas	1.06	1.03	0.97	South Dakota	.31	.29	.26
Kentucky	1.56	1.49	1.41	Tennessee	1.90	1.88	1.83
Louisiana	1.78	1.75	1.71	Texas	5.55	5.65	5.73
Maine	.47	.45	.42	Utah	.53	.54	.56
Maryland & D.C.	2.29	2.27	2.25	Vermont	.22	.22	.22
Massachusetts	2.79	2.77	2.74	Virginia	2.31	2.30	2.29
Michigan	4.39	4.42	4.47	Washington	1.7	1.74	1.79
Minnesota	1.87	1.87	1.88	West Virginia	.81	.72	.62
Mississippi	1.04	.99	.91	Wisconsin	2.17	2.17	2.18
Missouri	2.27	2.23	2.19	Wyoming	.15	.15	.14

Source: 1974 Bureau of Census Statistical Abstract

TABLE 5

ESTIMATED FRACTION OF TOTAL U.S. POPULATION IN CLIMATIC REGIONS

Region	% of Total U.S. Population in Region		
	1975	1980	1990
Seattle	1.503	1.534	1.578
Los Angeles	9.900	10.380	11.060
Bismarck	5.318	5.334	5.317
Phoenix	1.880	1.938	2.017
Omaha	4.554	4.487	4.404
Fort Worth	5.045	5.073	5.092
Nashville	8.291	8.104	7.851
Washington, D. C.	13.034	12.743	12.390
Madison	10.187	10.110	10.029
Boston	29.216	28.913	28.681
Charleston	8.550	8.564	8.516
Miami	1.930	2.030	2.130
U.S. Pop., Series 1E, in 1000's	215,056	226,934	250,630

The results of this analysis are shown in Tables 6 , 7 , and 8 .

3. Building Heating and Cooling Loads

a. Introduction

The process and assumptions used to develop the factors and equations presented by Mueller Associates, Inc. will be discussed in the following. As the intent was to provide a method by which the relative energy requirements of a diversity of buildings could be compared, a simple process suited to wide application was sought. Additionally, since the determinants of heating and cooling differ significantly, two methods were developed. The building sizes used, were supplied by ITC and represent the statistically weighted, average size building for each classification. Building design features such as length/width ratios, wall/glass ratios, number of floors, types of construction, ventilation rates, etc. were those listed in the references 1, 2, 3, 4, 6, 8, 9; and, in general, represent approximate averages. Where such information was not available, assumptions based on corporate experience were made. Similarly, heat conductance (U) values for roof, wall, window, and floors, were based on those in Reference 1. This information is listed in Table 9. Wall U values of .1 indicate a well insulated masonry wall. Similarly a U value of .3 generally indicates uninsulated, or poorly insulated masonry. However, U = .3 is also used for insulated metal walls. Uninsulated metal walls have a conductance of U = .42. A U value for roofs of .1 indicates heavy construction, i.e. built up roof on a concrete deck. U = .2 assumes a metal deck. Both are considered as being insulated. These U values were checked for consistency with the recommendations of ASHRAE Standard 90-75. As this provides guidelines for the construction of energy efficient buildings, it was hoped that the lower U values assumed would be consistent with the 90-75 recommendations. It was found that, with the exception of office buildings, the lower U values resulted in heat losses that met or slightly bettered the 90P values. The large glass area characteristic of office buildings is responsible for the fact that this class exceeded 90-75. However, since many office buildings projects still contain such glass areas, and since 90-75 is not mandatory, the assumptions were not changed.

TABLE 6

1975 REGIONAL BUILDING INVENTORY
(million square feet)

BUILDING TYPE	REGION											
	Seattle	Los Angeles	Bismarck	Phoenix	Omaha	Ft. Worth	Nashville	D.C.	Madison	Boston	Charleston	Miami
Offices:												
Federal	4.4	28.6	15.4	5.5	13.2	14.5	24.0	37.7	29.5	84.5	24.7	5.6
State & Local	14.0	91.9	49.4	17.5	42.3	46.6	77.0	121.1	94.6	271.4	79.3	17.9
Private	47.6	313.0	168.3	59.5	144.1	158.7	262.3	412.4	322.4	924.3	270.0	61.0
Retail:												
Supermarkets	4.7	30.7	16.5	5.8	14.2	15.6	25.8	40.5	31.6	90.7	26.5	6.0
Restaurants												
Franchised	2.2	14.5	7.8	2.8	6.7	7.4	12.2	19.1	15.0	42.9	12.5	2.8
Non-franchised	4.5	29.6	15.9	5.6	13.6	15.0	24.8	39.0	30.5	87.4	25.5	5.8
Service Stations	9.2	60.9	32.7	11.6	28.0	30.9	51.0	80.2	62.7	179.8	52.5	11.9
Shopping Centers	12.7	83.8	45.1	15.9	38.6	42.4	70.2	110.4	86.3	247.5	72.3	16.4
Stores	42.4	279.4	150.2	53.1	128.6	141.6	234.1	367.4	287.7	824.9	240.9	54.5
Other commercial	9.2	60.3	32.4	11.5	27.8	30.6	50.6	79.5	62.1	178.2	52.0	11.8
Educational:												
Schools	65.1	428.7	230.5	81.5	197.4	218.6	359.3	564.8	441.5	1266.1	369.8	83.6
Colleges, Vocational, etc.	12.3	81.1	43.6	15.4	37.4	41.1	68.0	106.9	83.5	239.5	70.0	15.8
Laboratories	6.2	40.6	21.8	7.7	18.7	20.6	34.0	53.4	41.8	119.8	35.0	7.9
Libraries, Museums	4.4	29.0	15.6	5.5	13.3	14.7	24.3	38.1	29.8	85.5	25.0	5.7
Health:												
Hospitals	16.3	107.3	57.7	20.4	49.4	54.4	90.0	141.4	110.5	316.9	92.6	20.9
Clinics, Nursing Homes, etc.	10.6	69.5	37.4	13.2	32.0	35.2	58.2	91.5	71.6	205.2	59.9	13.6
Warehouses	48.5	319.4	171.7	60.7	147.0	161.9	267.7	420.8	328.9	943.2	275.5	62.3
Religious:												
Churches	12.0	78.8	42.4	15.0	36.3	39.9	66.0	103.8	81.1	232.6	67.9	15.4
Other religious	8.0	52.5	28.2	10.0	24.2	26.8	44.0	69.2	54.1	155.0	45.3	10.2
Amusement, Social, Recreational	16.6	109.4	58.8	20.8	50.4	55.4	91.7	144.1	112.7	323.0	94.3	21.3
Hotels, Motels:												
>3 Stories	8.0	52.5	28.2	10.0	24.2	26.6	44.0	69.2	54.1	155.1	45.3	10.2
<3 Stories	9.3	61.3	32.9	11.6	28.2	31.0	51.3	80.7	63.1	180.9	52.8	11.9
Dormitories	16.0	105.0	56.5	20.0	48.3	53.2	88.0	138.4	108.1	310.1	90.6	20.5
Terminals and Miscellaneous	14.6	96.3	51.8	18.3	44.3	48.8	80.7	126.8	99.1	284.3	83.0	18.8

TABLE 7

1980 REGIONAL BUILDING INVENTORY
(million square feet)

BUILDING TYPE	REGION											
	Seattle	Los Angeles	Bismarck	Phoenix	Omaha	Ft. Worth	Nashville	D.C.	Madison	Boston	Charleston	Miami
Offices:												
Federal	5.8	38.9	20.0	7.3	16.8	19.0	30.4	47.8	37.9	108.4	32.1	7.6
State & Local	18.5	125.0	64.2	23.3	54.0	61.1	97.6	153.5	121.8	348.2	103.1	24.5
Private	62.9	425.8	218.8	79.5	184.0	208.1	332.4	522.7	414.7	1185.9	351.3	83.3
Retail:												
Supermarkets	6.4	43.3	22.2	8.1	18.7	21.1	33.8	53.1	42.1	120.5	35.7	8.5
Restaurants												
Franchised	3.0	20.4	10.5	3.8	8.8	10.0	16.0	25.1	19.9	57.0	16.9	4.0
Non-franchised	6.2	41.7	21.4	7.8	18.0	20.4	32.5	51.2	40.6	116.1	34.4	8.2
Service Stations	12.7	85.7	44.0	16.0	37.1	41.9	66.9	105.2	83.5	238.7	70.7	16.8
Shopping Center	17.4	117.9	60.6	22.0	51.0	57.6	92.1	144.8	114.9	328.5	97.3	23.1
Stores	58.1	393.1	202.0	73.4	170.0	192.1	306.9	482.6	382.9	1095.1	324.4	76.9
Other Commercial	12.6	84.9	43.6	15.9	36.7	41.5	66.3	104.2	82.7	236.5	70.1	16.6
Educational:												
Schools	77.2	522.6	268.6	97.6	225.9	255.4	408.0	641.6	509.0	1455.8	431.2	102.2
Colleges, Vocational, etc.	14.6	98.9	50.8	18.5	42.7	48.3	77.2	121.4	96.3	275.4	81.6	19.3
Laboratories	7.3	49.4	25.4	9.2	21.4	24.2	38.6	60.7	48.2	137.7	40.8	9.7
Libraries, Museums	5.2	35.3	18.2	6.6	15.3	17.3	27.6	43.4	34.4	98.4	29.1	6.9
Health												
Hospitals	19.8	134.1	68.9	25.0	58.0	65.5	104.7	164.6	130.6	373.5	110.6	26.2
Clinics, Nursing Homes, etc.	12.8	86.8	44.6	16.2	37.5	42.4	67.8	106.6	84.6	241.8	71.6	17.0
Warehouses	58.7	397.2	204.1	74.2	171.7	194.2	310.1	487.7	386.9	1106.5	327.8	77.7
Religious:												
Churches	14.5	98.0	50.3	18.3	42.3	47.9	76.5	120.3	95.4	272.8	80.8	19.2
Other religious	9.7	65.3	33.6	12.2	28.2	31.9	51.0	80.2	63.6	181.9	53.9	12.8
Amusement, Social, Recreational	20.1	136.0	69.9	25.4	58.8	66.5	106.2	167.0	132.5	378.9	112.2	26.6
Hotels, Motels												
> 3 Stories	9.7	65.3	33.6	12.2	28.2	31.9	51.0	80.2	63.6	181.9	53.9	12.8
< 3 Stories	11.3	76.2	39.2	14.2	32.9	37.2	59.5	93.5	74.2	212.2	62.9	14.9
Dormitories and other	19.3	130.6	67.1	24.4	56.5	63.8	102.0	160.3	127.2	363.8	107.8	25.5
Terminals and Miscellaneous	17.7	119.7	61.5	22.4	51.8	58.5	93.5	147.0	116.6	333.5	98.8	23.4

TABLE 8

1990 REGIONAL BUILDING INVENTORY
(million square feet)

BUILDING TYPE	REGION											
	Seattle	Los Angeles	Bismarck	Phoenix	Omaha	Ft. Worth	Nashville	D.C.	Madison	Boston	Charleston	Miami
Offices:												
Federal	9.6	67.5	32.4	12.3	26.9	31.1	47.9	75.6	61.5	175.0	52.0	13.0
State & Local	30.9	216.7	104.2	39.5	86.3	99.8	153.8	242.8	197.5	562.0	166.9	41.7
Private	105.3	738.0	354.8	134.6	293.9	339.8	523.9	826.8	672.5	1913.8	568.2	142.1
Retail:												
Supermarkets	11.3	79.3	38.1	14.5	31.6	36.5	56.3	88.8	72.3	205.6	61.1	15.3
Restaurants												
Franchised	5.4	37.5	18.0	6.8	14.9	17.3	26.6	42.0	34.2	97.2	28.9	7.2
Non-franchised	10.9	76.4	36.7	13.9	30.4	35.2	54.2	85.6	69.6	198.1	58.8	14.7
Service stations	22.4	157.1	75.5	28.7	62.6	72.3	111.5	176.0	143.2	407.5	121.0	30.3
Shopping Centers	30.9	216.2	104.0	39.4	86.1	99.6	153.5	242.2	197.1	560.7	166.5	41.6
Stores	102.8	720.8	346.5	131.5	287.0	331.9	511.7	807.5	656.9	1869.1	555.0	138.8
Other commercial	22.2	155.7	74.9	28.4	62.0	71.7	110.5	174.4	141.9	403.7	119.9	30.0
Educational												
Schools	100.7	705.4	339.1	128.7	280.9	324.8	500.7	790.2	642.9	1829.3	543.2	135.9
Colleges, Vocational, etc.	19.0	133.5	64.2	24.3	53.1	61.4	94.7	149.5	121.6	346.1	102.8	25.7
Laboratories	9.5	66.7	32.1	12.2	26.6	30.7	47.4	74.8	60.8	173.0	51.4	12.9
Libraries, Museums	6.8	47.7	22.9	8.7	19.0	21.9	33.8	53.4	43.4	123.6	36.7	9.2
Health:												
Hospitals	27.3	191.1	91.9	34.9	76.1	88.0	135.7	214.1	174.2	495.7	147.2	36.8
Clinics, Nursing Homes, etc.	17.7	123.8	59.5	22.6	49.3	57.0	87.8	138.6	112.8	320.9	95.3	23.8
Warehouses	71.5	500.8	240.8	91.3	199.4	230.6	355.5	561.0	456.4	1298.7	385.6	96.5
Religious												
Churches	17.6	123.5	59.4	22.5	49.2	56.9	87.7	138.3	112.5	320.2	95.1	23.8
Other religious	11.8	82.3	39.6	15.0	32.8	37.9	58.4	92.2	75.0	213.5	63.4	15.9
Amusement, Social, Recreational	24.5	171.5	82.5	31.3	68.3	79.0	121.8	192.1	156.3	444.8	132.1	33.0
Hotels, Motels												
> 3 Stories	11.8	82.3	39.6	15.0	32.8	37.9	58.4	92.2	75.0	213.5	63.4	15.9
< 3 Stories	13.7	96.0	46.2	17.5	38.3	44.2	68.2	107.6	87.5	249.1	74.0	18.5
Dormitories and other	23.5	164.7	79.2	30.0	65.6	75.8	116.9	184.5	150.1	427.0	126.8	31.7
Terminals and Miscellaneous	21.5	150.9	72.6	27.5	60.1	69.5	107.1	169.1	137.6	391.4	116.2	29.1

Building Class	Construction	Length, Ft.	Length: Width Ratio	Width, Ft.	Floor to Floor Height, Ft.	U-Roof, Btu/Hr Sq. Ft.-°F	Roof Area, Sq. Ft.	U-Wall, Btu/Hr Sq. Ft.-°F	Above Ground Area - Wall Construction, Sq. Ft.	Glass/Wall Ratio	Window Area, Sq. Ft.	U-Window, Btu/Hr. Sq. Ft.-°F	U-Basement Walls	Basement Wall Area	U-Floor	Ventilation CFM/Sq. Ft.	Infiltration CFM/Sq. Ft.	
MOTELS & NURSING HOMES	L	320	10:1	32	12	.2	10,250	.3	N	5,376	.3	2,304	1.13	--	--	.1	.12	.01
									E	538	.3	230						
									S	5,376	.3	2,304						
									W	538	.3	230						
									T	11,828	.3	5,068						
	H	320	10:1	32	12	.1	10,250	.1	N	5,376	.3	2,304	.69	--	--	.1	.12	.01
									E	538	.3	230						
									S	5,376	.3	2,304						
									W	538	.3	230						
									T	11,828	.3	5,068						
WARE-HOUSES	L	114	1:1	114	20	.2	13,000	.42	N	2,280	0	--	1.13	--	--	.1	.1	.01
									E	2,280	0	--						
									S	2,166	.05	114						
									W	2,280	0	--						
									T	9,006	.01	114						
	H	114	1:1	114	20	.1	13,000	.1	N	2,280	0	--	1.13	--	--	.1	.1	.01
									E	2,280	0	--						
									S	2,166	.05	114						
									W	2,280	0	--						
									T	9,006	.01	114						

TABLE 9: BUILDING CONSTRUCTION CHARACTERISTICS ASSUMED FOR STUDY

Building Class	Construction	Length, Ft.	Length: Width Ratio	Width, Ft.	Floor to Floor Height, Ft.	U-Roof, Btu/Hr Sq. Ft.-°F	Roof Area, Sq. Ft.	U-Wall, Btu/Hr Sq. Ft.-°F	Above Ground Area - Wall Construction, Sq. Ft.	Glass/Wall Ratio	Window Area, Sq. Ft.	U-Window, Btu/Hr. Sq. Ft.-°F	U-Baseament Walls	Baseament Wall Area	U-Floor	Ventilation CFM/Sq. Ft.	Infiltration CFM/Sq. Ft.	
CHURCHES, SOCIAL & RECREA-TIONAL	L	221	3:1	74	16	.2	16,300	.3	N	3,006	.15	530	1.13	.1	7,080	.1	.4	--
									E	1,006	.15	178						
									S	3,006	.15	530						
									W	1,006	.15	178						
									T	8,024	.15	1,416						
	H	221	3:1	74	16	.1	16,300	.1	N	3,006	.15	530	.69	.1	7,080	.1	.4	--
									E	1,006	.15	178						
									S	3,006	.15	530						
									W	1,006	.15	178						
									T	8,024	.15	1,416						
HOTELS	L	141	2:1	71	12	.2	10,000	.3	N	4,783	.3	2,030	1.13	.1	5,088	.1	.17	.02
									E	2,386	.3	1,022						
									S	4,738	.3	2,030						
									W	2,386	.3	1,022						
									T	14,248	.3	6,104						
	H	141	2:1	71	12	.1	10,000	.1	N	4,738	.3	2,030	.69	.1	5,088	.1	.17	.02
									E	2,386	.3	1,022						
									S	4,738	.3	2,030						
									W	2,386	.3	1,022						
									T	14,248	.3	6,104						

TABLE 9: BUILDING CONSTRUCTION CHARACTERISTICS ASSUMED FOR STUDY (CONT'D)

Building Class	Construction	Length, Ft.	Length: Width Ratio	Width, Ft.	Floor to Floor Height, Ft.	U-Roof, Btu/Hr Sq. Ft.-°F	Roof Area, Sq. Ft.	U-Wall, Btu/Hr Sq. Ft.-°F	Above Ground Area - Wall Construction, Sq. Ft.	Glass/Wall Ratio	Window Area, Sq. Ft.	U-Window, Btu/Hr. Sq. Ft.-°F	U-Baseament Walls	Baseament Wall Area	U-Floor	Ventilation CFM/Sq. Ft.	Infiltration CFM/Sq. Ft.	
SINGLE STORES & SERVICE STATIONS	L	112	3:1	38	16	.2	4,256	.42	N	1,792	0	0	1.13	--	--	.1	.25	.03
									E	608	0	0						
									S	717	.6	1,075						
									W	608	0	0						
	H	112	3:1	38	16	.1	4,256	.1	T	3,725	.29	1,075	.81	.25	.03			
									N	1,792	0	0						
									E	608	0	0						
									S	717	.6	1,075						
LIBRARIES AND MUSEUMS	L	91	1:1	91	16	.2	8,350	.3	W	608	0	0	1.13	.1	4,368	.1	.2	--
									T	9,320	.29	1,075						
									N	2,330	.2	582						
									E	2,330	.2	582						
	H	91	1:1	91	16	.1	8,350	.1	S	2,330	.2	582	.69	.1	4,368	.1	.2	--
									W	2,330	.2	582						
									T	9,320	.2	2,328						
									N	2,330	.2	582						

TABLE 9: BUILDING CONSTRUCTION CHARACTERISTICS ASSUMED FOR STUDY (CONT'D)

Building Class	Construction	Length, Ft.	Length: Width Ratio	Width, Ft.	Floor to Floor Height, Ft.	U-Roof, Btu/Hr Sq. Ft.-°F	Roof Area, Sq. Ft.	U-Wall, Btu/Hr Sq. Ft.-°F	Above Ground Area - Wall Construction, Sq. Ft.	Glass/Wall Ratio	Window Area, Sq. Ft.	U-Window, Btu/Hr. Sq. Ft.-°F	U-Base ment Walls	Basement Wall Area	U-Floor	Ventilation CFM/Sq. Ft.	Infiltration CFM/Sq. Ft.
RES- TAURANTS	L	37.4	1:1	37.4	16	.1	1,400	.1	N 600	0	0	1.13	--	--	.1	1.43	.14
									E 360	.4	240						
									S 360	.4	240						
									W 360	.4	240						
	M	37.4	1:1	37.4	16	.3	1,400	.2	T 1,680	.3	720						
									N 600	0	0						
									E 600	0	0						
									S 300	.5	300						
	H	37.4	1:1	37.4	16	.1	1,400	.1	W 600	0	0						
									T 2,100	.3	300						
									N 600	0	0						
									E 600	0	0						
SHOP- PING CENTERS	L	435	3:1	145	16	.2	63,075	.3	S 300	.5	300	1.13	--	--	.1	1.43	.14
									W 600	0	0						
									T 2,100	.3	300						
									N 6,960	0	0						
	H	435	3:1	145	16	.1	63,075	.3	E 2,088	.1	232	1.13	--	--	.1	.2	.02
									S 6,264	.1	696						
									W 2,088	.1	232						
									T 17,400	.07	1,160						
									N 6,960	0	0	1.13	--	--	.1	.2	.02
									E 2,088	.1	232						
									S 6,264	.1	696						
									W 2,088	.1	232						
									T 17,400	.07	1,160						

TABLE 9: BUILDING CONSTRUCTION CHARACTERISTICS ASSUMED FOR STUDY (CONT'D)

Building Class	Construction	Length, Ft.	Length: Width Ratio	Width, Ft.	Floor to Floor Height, Ft.	U-Roof, Btu/Hr Sq. Ft.-°F	Roof Area, Sq. Ft.	U-Wall, Btu/Hr Sq. Ft.-°F	Above Ground Area - Wall Construction, Sq. Ft.	Glass/Wall Ratio	Window Area, Sq. Ft.	U-Window, Btu/Hr. Sq. Ft.-°F	U-Base ment Walls	Basement Wall Area	U-Floor	Ventilation CFM/Sq. Ft.	Infiltration CFM/Sq. Ft.
MEDICAL INSTITUTIONS	L	200	4:1	50	12	.2	10,000	.3	N 10,200	.15	1,800	1.13	.1	6,000	.1	.4	--
									E 2,550	.15	450						
									S 10,200	.15	1,800						
									W 2,550	.15	450						
									T 25,500	.15	4,500						
	H	200	4:1	50	12	.1	10,000	.1	N 10,200	.15	1,800	.69	.1	6,000	.1	.4	--
									E 2,550	.15	450						
									S 10,200	.15	1,800						
									W 2,550	.15	450						
									T 25,500	.15	4,500						
EDUCATIONAL	L	320	4:1	80	16	.2	25,600	.3	N 4,352	.15	768	1.13	--	--	.1	.2	.02
									E 1,088	.15	192						
									S 4,352	.15	768						
									W 1,088	.15	192						
									T 10,880	.15	1,920						
	H	320	4:1	80	16	.1	25,600	.1	N 4,352	.15	768	.69	--	--	.1	.2	.02
									E 1,088	.15	192						
									S 4,352	.15	768						
									W 1,088	.15	192						
									T 10,880	.15	1,920						

TABLE 9: BUILDING CONSTRUCTION CHARACTERISTICS ASSUMED FOR STUDY (CONT'D)

Building Class	Construction	Length, Ft.	Length: Width Ratio	Width, Ft.	Floor to Floor Height, Ft.	U-Roof, Btu/Hr Sq. Ft.-°F	Roof Area, Sq. Ft.	U-Wall, Btu/Hr Sq. Ft.-°F	Above Ground Area - Wall Construction, Sq. Ft.	Glass/Wall Ratio	Window Area, Sq. Ft.	U-Window, Btu/Hr. Sq. Ft.-°F	U-Base ment Walls	Base ment Wall Area	U-Floor	Ventilation CFM/Sq. Ft.	Infiltration CFM/Sq. Ft.
OFFICE BUILDINGS	L	63 $\frac{1}{4}$	1:1	63 $\frac{1}{4}$	12	.2	4,000	.3	N	1,025	.55	1,252	.1	3,036	.1	.2	--
									E	1,025	.55	1,252					
									S	1,025	.55	1,252					
									W	1,025	.55	1,252					
									T	4,100	.55	5,008					
	H	63 $\frac{1}{4}$	1:1	63 $\frac{1}{4}$	12	.1	4,000	.1	N	1,025	.55	1,252	.1	3,036	.1	.2	--
									E	1,025	.55	1,252					
									S	1,025	.55	1,252					
									W	1,025	.55	1,252					
									T	4,100	.55	5,008					
RETAIL SUPER-MARKETS	L	193 $\frac{1}{2}$	3:1	64 $\frac{1}{2}$	18	.2	12,480	.2	N	1,161	0	--	--	--	.1	.24	--
									E	3,483	0	--					
									S	580	.5	581					
									W	3,483	0	--					
									T	8,707	.06	581					
	H	193 $\frac{1}{2}$	3:1	64 $\frac{1}{2}$	18	.1	12,480	.1	N	1,161	0	--	--	--	.1	.25	--
									E	3,483	0	--					
									S	580	.5	581					
									W	3,483	0	--					
									T	8,707	.06	581					

TABLE 9: BUILDING CONSTRUCTION CHARACTERISTICS ASSUMED FOR STUDY (CONT'D)

The average building sizes as provided by ITC did not include basement areas. Where deemed appropriate, a basement level was considered. Concrete slab floors and concrete block basement walls were considered.

Due to its moderate climate, the Baltimore area was used for design data.

b. Object and Method

The goal was to provide an estimate of the annual energy requirement for space heating and cooling for the twelve classes of buildings by a factor common to each class of buildings. It was theorized that the heating energy requirement could be determined by developing a factor κ_H of units Btu/sq.ft./⁰Day, constant for each class of building. This could be used to determine the heat energy requirement for any building by multiplying κ_H by floor space area (A) and the heating degree-days of the region (D_H) in which the building is located.

Cooling energy estimates provided a slightly more complicated problem. Building cooling loads are comprised of three segments due to: temperature difference (conduction), moisture content, and building internal load. It was determined that an equation summing three factors, one for each of the contributors, could be developed. Twelve such equations resulted, one for each class of buildings. Several assumptions regarding the use pattern of the various classes of buildings were required. Such assumptions were based primarily on corporate experience.

c. Calculation details

For heating, the process began by determining the building heat loads for the various types of construction for each building class at a specified outside air temperature design condition of 15⁰F. This value was obtained from the ASHRAE Fundamentals as suitable for use in the design of a heating system that will be adequate 97-1/2% of the time during the heating season. Indoor design temperature was 72⁰F. Additionally, ground temperatures under slab were assumed to be 50⁰F, ground temperature adjacent to walls at the ground surface (used for slab on grade structures) was assumed to be 32⁰F. The room air change rates used are given in Table 10. These values were derived from ASHRAE recommendations

TABLE 10

Air Charge Rates, CFM

Office Buildings	2,640
Retail Supermarkets	3,000
Medical Institutions	24,000
Educational	5,120
Restaurants	2,200
Shopping Centers	15,900
Single Stores and Service Stations	1,200
Libraries and Museums	6,300
Churches, Social and Recreational	13,000
Hotels	7,650
Motels and Nursing Homes	2,700
Warehouses	1,430

for ventilation requirements and estimates of infiltration rates.

This process yielded a value in units of Btu/hr. It was necessary to extrapolate this number to a value for heating season Btu. The first step here was to convert the design heat loss value to a number representing average heat loss. This was done by the equation:

$$x \frac{\text{Btu}}{\text{Hr}} = \frac{H(t - t_a)}{t_d - t_o}$$

where: H = calculated design condition loss in Btu/Hr
t = average indoor temperature, 70°F assumed
t_a = average outdoor temperature during heating season, 43.7°F for Baltimore area
t_d = indoor design temperature, 72°F
t_o = outdoor design temperature, 15°F

Then x x length of heating season = Y Btu's required to heat structure during heating season. The Baltimore heating season was assumed to be 5040 hours (approximately seven months). Y is then divided by the floor space area of the building and divided again by Degree-days (4656) to determine κ_H.

Thus, the equation to estimate the annual energy requirement to heat a building (E_H) can be stated as:

$$E_H = A ((\kappa_H \times D_H) - F_h h) \quad (1)$$

where F = internal heat gain due to people, lights, etc. in Btu/hr-ft²
h = hours in the heating season

Data used to compute these internal loads is shown in Tables 11 and 12.

TABLE 11

CLIMATIC PARAMETERS FOR CHARACTERISTIC CITIES WITHIN CLIMATIC REGIONS

Region Number	Representative City	Characteristic Location	Heating Degree-Days	Cooling Degree-Days	Hours in Heating Season	Hours in Cooling Season	Average Change in Humidity Ratio*
1	Boston	Boston, Mass.	5634	661	6480	2160	.0037
2	Wash., D.C.	Wash., D. C.	4211	1415	5040	3600	.0024
3	Madison	Madison, Wisc.	7863	460	6480	2160	0
4	Los Angeles	Davis, Calif.	2819	1063	5760	2880	0
5	Charleston	Charleston, S.C.	2033	2078	4320	4320	.0055
6	Bismarck	Bismarck, N.D.	8851	487	7200	1440	.0003
7	Nashville	Oak Ridge, Tenn.	3944	1367	5040	3600	.0035
8	Ft. Worth	Midland, Texas	2621	2250	4320	4320	.0037
9	Omaha	Lincoln, Neb.	6218	1148	5760	2880	.0003
10	Seattle	Seattle, Wash.	5145	200	7200	1440	0
11	Phoenix	Trona, Calif.	2370	2888	4320	4320	0
12	Miami	Miami, Fla.	214	4038	720	7920	.0046

*Relative to indoor design conditions of 78°F dry bulb and 50% relative humidity.

TABLE 12
INTERNAL LOADS APPLIED TO HEATING ONLY

Building Types	Approx. Btu/hr/ft ²	Fraction of Internal Load	Internal Btu/hr/ft ²	OP Hrs. Day Mo.	
I. General Comfort					
A. Office, School	41.4	0.46	19.25	11	284
B. Apartments, Hotel Motel, Hospital	34.9	0.28	9.93	16	481.6
II. Retail Shops					
A. Bank, Barber, Dept. Store, Specialty Shops, etc.	55.4	0.47	26.1	13	308
B. Shopping Centers Supermarkets, etc. Large Stores	49.5	0.53	26.1	13	364
III. High Latent					
A. Auditorium, Church, Etc.	67.2	0.77	51.8	6	78
B. Bar, Restaurant, Theater, Etc.	67.2	0.72	48.4	6.86	207
IV. Factories					
A. Warehouse	32	0.27	8.6	16	378
B. Assembly Areas, Machine Rooms, Etc.	44	0.44	19.45	16	378

The equation developed to describe the annual cooling load requirement is:

$$E_C + A[\underbrace{\kappa_C \times D_C}_I + \underbrace{F_1 \Delta W(1 - 3.54 \times 10^{-5} h)}_{II} + \underbrace{F_2}_{III}] \quad (2)$$

It is noted that this equation sums three terms, one for each component of the cooling load. The numbers and considerations used to develop each number will be described in the following. The first step in determining term I was to calculate the design condition load due to conduction and solar gain in units of Btu/hr. Cooling load calculations are something of an art, as well as a science, in that it is necessary to determine the day of the year and time of day that will cause the maximum solar load on the cooling system. For the Baltimore area, August 21 is used as the maximum day. Calculations for time resulted in peak hours of from 1 p.m. to 4 p.m. Roof area, south glass, and west glass are major recipients of solar gain. Table 13 presents the times used for each class of building. The conditions used were as follows:

	Dry Bulb Temperature	Wet Bulb Temperature	% Relative Humidity
Outdoor	91	78	--
Room	78	--	50

The cooling season was assumed to be 3,720 hours so we now have the capability to determine cooling season Btus. Also, as before, the number represents a design or peak condition. It was necessary then, to convert it to average requirement. This design condition, a function of temperature, corresponds to a cooling season of 4030 cooling degree days. Weather data shows that the Baltimore area cooling season consists of 1415 cooling degree days. The ratio $\frac{1415}{4030} = .35$ was used as the factor to convert design load to average load. The average load was then divided by the floor space area, (A, in square feet), and the cooling degree days, D_C (1415). This determined κ_C of units Btu/sq. ft./°D.

Term II, the latent heat load, i.e., due to the moisture content of the outside air was calculated using information contained in Table 11. The factor F_1 was determined by:

$$F_1 = \frac{4840 \times \text{CFM} \times 3720 \text{ hrs.}}{A}$$

TABLE 13

<u>Building Type</u>	<u>Time of Day (PM)</u>
Office Buildings	3:00
Retail Supermarkets	2:00
Medical Institutions	3:00
Educational	4:00
Restaurants	2:00*
Shopping Centers	4:00
Single Stores and Service Stations	2:00
Libraries and Museums	3:00
Churches, Social, and Recreational	4:00
Hotels	2:00
Motels and Nursing Homes	1:00
Warehouses	4:00

* 3:00 PM for light construction.

and is unique to each class of building. ΔW in this equation represents the average change in the humidity ratio that occurs when transforming air from outside to room conditions. This was calculated by averaging published humidity values during the cooling seasons of the cities identifying the regions. The term $1 - 3.54 \times 10^{-5} h$ (where h is the elevation above sea level, in feet) provides a correction factor for the compressible nature of the atmosphere.

The remaining component of the cooling load, the internal load is expressed in Term III of equation 2. This load is determined by summing the heat producing entities within the building. Such entities include people, cooking appliances, refrigerators, electric lights, electric motors, and miscellaneous laboratory equipment. Assumptions about equipment, population densities, and usage patterns were required for each class of building. Table 14 presents a matrix which matches types and quantities of heat producing equipment with classes of buildings. To calculate F_2 in units of Btus it was necessary to multiply the heat generation rates in Btu/hr. for each entity by the product of the number of hours in the cooling season and the usage factor.

The results of equations one and two, when utilized with the data in Table 14 yield the space heating and cooling loads for 12 building types located in 12 regions. These loads are presented in Table 15 and 16. In developing the parametric studies (see the Technical Report), Table 17, which presents the ratio of heating and cooling loads was also useful.

	PEOPLE		LIGHT AND ELECTRIC		RANGE/ OVEN		COFFEE URN (5 GALLON)		BUNSEN BURNER		MISC. APPLIANCES AND MACHINERY, BTU/HR.		USAGE FACTOR
	QUANTITY	HEAT GAIN, BTU/HR	W/SQ. FT.	BTU/HR.	QUANTITY	HEAT GAIN, BTU/HR	QUANTITY	HEAT GAIN, BTU/HR	QUANTITY	HEAT GAIN, BTU/HR			
Office Buildings	109	49,050	6	244,800									.5
Retail Supermarkets	250	112,500	6	255,000									.5
Medical Institutions	284	262,800	6	1,020,000							60,000		1.0
Educational	285	128,250	3	261,120					30	12,600	12,000		.5
Restaurants	29	15,950	2	9,520	2	22,800	1	9,750					.5
Shopping Centers	1,201	540,450	5	1,072,175									.5
Single Stores and Service Stations	85	38,250	5	72,350									.5
Libraries and Museums	334	150,300	4	340,680									.5
Churches, Social, and Recreational	544	244,800	3	332,520							30,000		.25
Hotels	200	90,000	2	340,000									1.0
Motels and Nursing Homes	350	157,500	2	139,400									1.0
Warehouses	25	11,250	2	88,400									.5

TABLE 14

TABLE 15

Building Seasonal Heating Loads With
Credit For Internally Generated Heat
(1000 Btu/ft²)

Region Number	Representative City	School	Office	Store	Shopping Center	Hospital	Church	Restaurant	Motel	Warehouse	Supermarket	Nursing Home	Social	Library	Hotel
1.	Boston	80	80	153	46	91	101	406	74	57	76	74	101	57	57
2.	Washington, D.C.	64	64	117	42	70	77	306	57	48	64	57	77	46	44
3.	Madison	120	120	220	80	131	144	573	107	91	121	107	144	86	83
4.	Los Angeles	31	31	70	8	41	49	197	33	18	24	33	49	22	23
5.	Charleston	22	22	50	5	29	35	134	23	12	16	23	35	16	17
6.	Bismarck	135	135	247	90	147	162	646	121	103	137	121	162	97	94
7.	Nashville	59	59	109	38	65	72	286	53	44	59	53	72	42	41
8.	Fort Worth	33	33	68	14	40	46	178	32	21	28	32	46	23	24
9.	Omaha	93	93	172	59	102	113	452	84	69	92	84	113	66	65
10.	Seattle	68	68	136	35	81	92	368	65	47	63	65	92	49	20
11.	Phoenix	28	28	60	10	35	41	167	28	18	23	28	41	20	21
12.	Miami	1	1	6	0	3	3	14	2	0	0	2	3	1	1

TABLE 16

Building Seasonal Cooling Loads With Penalty
For Internal and Moisture Loads
(1000 Btu/ft²)

32	Region Number	Representative City														
			School	Office	Store	Shopping Center	Hospital	Church	Restaurant	Motel	Warehouse	Supermarket	Nursing Home	Social	Library	Hotel
	1.	Boston	38	42	69	49	75	43	181	49	23	56	49	43	42	33
	2.	Washington, D.C.	54	67	111	69	101	47	211	78	36	84	78	47	57	49
	3.	Madison	22	27	44	29	47	14	64	36	13	37	36	14	24	21
	4.	Los Angeles	35	46	76	46	66	23	101	57	24	58	57	23	36	33
	5.	Charleston	79	96	158	100	144	80	350	109	54	120	109	80	84	70
	6.	Bismarck	18	23	38	24	35	13	61	28	12	29	28	13	19	17
	7.	Nashville	57	69	112	73	108	55	240	81	38	88	81	55	61	51
	8.	Fort Worth	75	95	156	94	132	69	308	108	53	116	108	69	78	67
	9.	Omaha	37	47	79	48	69	26	124	60	26	61	60	26	38	35
	10.	Seattle	13	16	25	18	30	8	37	22	8	22	22	8	14	29
	11.	Phoenix	71	98	162	85	112	49	239	111	55	112	111	49	68	64
	12.	Miami	128	165	276	161	226	109	498	191	92	201	191	109	131	115

TABLE 17

Ratio of Building Heating to Cooling Loads

Region Number	Representative City	School	Office	Store	Shopping Center	Hospital	Church	Restaurant	Motel	Warehouse	Supermarket	Nursing Home	Social	Library	Hotel
1.	Boston	2.10	1.90	2.22	0.94	1.20	2.35	2.24	1.51	2.48	1.36	1.51	2.35	1.36	1.73
2.	Washington, D.C.	1.18	0.95	1.05	0.61	0.69	1.64	1.45	0.73	1.33	0.76	0.73	1.64	0.81	0.90
3.	Madison	5.45	4.43	5.00	2.76	2.79	10.29	8.95	2.97	7.00	3.27	2.97	10.29	3.58	3.95
4.	Los Angeles	0.90	0.68	0.92	0.17	0.62	2.13	1.95	0.58	0.75	0.41	0.58	2.13	0.61	0.70
5.	Charleston	0.28	0.23	0.32	0.05	0.20	0.44	0.38	0.21	0.22	0.13	0.21	0.44	0.19	0.24
6.	Bismarck	7.50	5.87	6.50	3.75	4.20	12.50	10.60	4.32	8.58	4.72	4.32	12.50	5.11	5.53
7.	Nashville	1.03	0.85	0.97	0.52	0.60	1.31	1.19	0.65	1.16	0.67	0.65	1.31	0.69	0.80
8.	Fort Worth	0.44	0.34	0.44	0.15	0.30	0.67	0.58	0.30	0.40	0.24	0.30	0.67	0.29	0.36
9.	Omaha	2.50	1.97	2.18	1.23	1.48	4.35	3.65	1.40	2.65	1.51	1.40	4.35	1.74	1.86
10.	Seattle	5.26	4.28	5.44	1.94	2.08	11.50	10.43	2.95	6.27	2.86	2.95	11.50	3.50	0.69
11.	Phoenix	0.40	0.29	0.37	0.12	0.31	0.84	0.70	0.25	0.33	0.21	0.25	0.84	0.29	0.33
12.	Miami	0.01	0.01	0.02	0	0.01	0.03	0.03	0.01	0	0	0.01	0.03	0.01	0.01

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4. Energy Costs for the Commercial Sector

In order to understand and compare the economics of utilizing solar energy among the climatic regions, accurate costs of conventional energy must be employed. The primary sources of our data were the Edison Electric Institute, the American Gas Association, and the Federal Energy Administration. State by state 1974 prices are indicated in Table 18. We were unable to locate state prices for fuel oil. Average prices for several months for FEA regions were obtained, and all states associated with that region were given the regional average. Fortunately, oil prices are fairly uniform around the country so that little error is introduced by doing this.

These state prices were then averaged to yield a climatic regional average. Two factors were included in calculating this average: the fraction of a state's population in a given region and the amount of energy purchased at the indicated price. The energy costs presented in Table 19 are the result of these calculations.

Two things should be noted about these costs: first, no taxes on energy are included; the data is strictly revenue to the utility per Btu delivered to the customer, second, the data electrical energy and gas are averages for all customers; thus the average price paid by any given customer may be higher or lower than this average depending on the amount of energy consumed and the rate structure applicable to that customer.

Table 18

Dollars Per 10⁶ Usable Btu. Paid by the Commercial Sector for Gas, Oil, and Electricity (1974)

<u>State</u>	<u>Gas</u>	<u>Oil</u>	<u>Electricity</u>	<u>State</u>	<u>Gas</u>	<u>Oil</u>	<u>Electricity</u>
Alabama	1.29	3.92	7.07	Montana	1.13	3.58	6.01
Alaska	1.40	N.A.	9.55	Nebraska	1.17	3.54	5.66
Arizona	1.25	3.58	7.33	Nevada	1.52	3.58	6.15
Arkansas	1.04	3.92	7.42	New Hampshire	2.60	4.00	11.46
California	1.27	3.55	8.09	New Jersey	2.41	4.08	12.31
Colorado	1.11	3.58	6.57	New Mexico	1.15	3.58	6.59
Connecticut	3.00	4.00	11.17	New York	2.19	4.08	14.24
Delaware	2.17	3.92	10.87	North Carolina	1.84	3.92	6.70
Florida	1.87	3.92	8.97	North Dakota	1.12	3.54	7.03
Georgia	1.35	3.92	7.85	Ohio	1.43	3.69	8.12
Hawaii	7.16	N.A.	12.08	Oklahoma	.93	3.92	5.89
Idaho	1.81	3.58	4.13	Oregon	2.17	3.55	4.37
Illinois	1.36	3.69	8.85	Pennsylvania	1.75	4.08	9.35
Indiana	1.40	3.69	7.09	Rhode Island	3.04	4.00	11.75
Iowa	1.25	3.54	8.44	South Carolina	1.59	3.92	6.95
Kansas	.87	3.54	6.45	South Dakota	1.20	3.54	8.32
Kentucky	1.27	3.92	4.16	Tennessee	1.36	3.92	5.77
Louisiana	1.04	3.92	7.00	Texas	1.13	3.92	6.07
Maine	3.61	4.00	9.23	Utah	.72	3.58	5.92
Maryland	2.03	3.92	10.52	Vermont	2.65	4.00	9.67
Massachusetts	2.96	4.00	12.10	Virginia	1.84	3.92	8.00
Michigan	1.50	3.69	8.79	Washington	1.67	3.92	3.69
Minnesota	1.64	3.54	8.94	West Virginia	1.20	3.92	7.53
Mississippi	1.19	3.88	7.47	Wisconsin	1.55	3.69	8.44
Missouri	1.12	3.54	8.00	Wyoming	.87	3.58	4.95
				Dist. of Columbia	1.95	3.92	10.52

Assumptions: 65% efficiency for oil heat, 75% efficiency for gas heat, 100% efficiency for electric heat.

Source: American Gas Association, Edison Electric Institute, Federal Energy Administration

TABLE 19

COST OF CONVENTIONAL ENERGY BY FUEL
TYPE BY CLIMATIC REGION
(\$/10⁶ USABLE BTU)
(1974)

<u>Region</u>	<u>Gas</u>	<u>Oil</u>	<u>Electricity</u>
Seattle	1.90	3.74	4.1
Boston	1.74	3.91	11.09
Charleston	1.30	3.92	7.26
Nashville	1.24	3.82	6.87
Ft. Worth	1.05	3.92	6.11
Phoenix	1.25	3.58	7.10
Los Angeles	1.27	3.55	8.09
Washington, D. C.	1.70	3.95	8.88
Madison	1.47	3.80	8.60
Omaha	1.08	3.55	6.70
Miami	1.71	3.92	8.72
Bismarck	1.41	3.58	5.79

Assumptions: 65% efficiency for oil heat, 75% efficiency for gas heat,
100% efficiency for electric heat.

Source: American Gas Association, Edison Electric Institute, Federal
Energy Administration.

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APPENDIX C
DEVELOPMENT OF SOLAR PERFORMANCE DATA

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APPENDIX C
DEVELOPMENT OF SOLAR PERFORMANCE DATA

I. Several preliminary studies have been performed to find collector area required to meet a certain fraction of total load by the solar heat collection system. The studies can be divided into the following broad categories:

A. The analysis for the cost of heating and cooling with solar energy for selected United States cities.

B. Performance of water type collectors for space heating in twelve climatic regions of the United States.

C. Performance of air type collectors for space heating in twelve climatic regions of the United States.

D. Performance of water type collectors for space heating and cooling in twelve climatic regions of the United States.

II. Several assumptions were made in the analysis. The assumptions that are common are as follows:

A. Effective absorptance-transmittance product ($\overline{\alpha\tau}$) of the collector at zero angle of incidence is 0.75. The dependence of $\overline{\alpha\tau}$ on angle of incidence has been taken into account.

B. Following are the expressions for upward heat loss for the liquid and air type collectors respectively:

$$Q_{\text{Loss}} = 0.1067 \times \text{Flux absorbed} + 0.5997 \times (T_{\text{inlet}} - T_{\text{ambient}}) - 12.9$$

$$Q_{\text{Loss}} = 0.1729 \times \text{Flux absorbed} + 0.55 \times (T_{\text{inlet}} - T_{\text{ambient}}) - 11.7$$

C. The edge losses and the back losses are zero. These losses can be easily incorporated into the heat loss expressions because, for a given design, they

are approximately proportional to the difference between inlet and ambient temperatures. For our purposes, however, we have assumed that the collector is efficiently designed so that edge and back losses are negligible.

D. Wind speed is 10 mph or wind convection loss coefficient of 4 Btu/hr/ft²/°F.

E. For water type systems, for space heating and cooling, the useful heat collection was calculated under the assumption that the tank temperature remains at 120 and 200°F respectively. For air-type systems, it was assumed that the air temperature at the collector inlet is 85°F. This is possible for air type systems because of large stratification achievable in pebble-bed storage.

F. If used, the reflectivity of reflector is 0.7 and reflector angle = $0.5 \times (90 - \text{Latitude} + 23.5)$ degrees.

G. Coefficient of performance of absorption air-conditioner is 0.6.

H. Heating load is proportional to the floor area and the heating degree days.

I. The cooling load is a sum of two components. One component is proportional to the cooling degree days and floor area and the other component is a constant representing the internal loads like lighting, people, etc.

J. All the performance calculations were done for each month using average daily horizontal radiation for the month at the earth's surface at the location of interest. This data was taken from Appendix Table 1-1 (page 11) published in Low Temperature Engineering Applications of Solar Energy by AHSRAE. The instantaneous distribution of daily radiation on the horizontal surface was assumed to be a cosine function from sunrise to sunset. The total instantaneous radiation on the horizontal surface was divided into the beam and diffuse components using a correlation which depends upon $\bar{K}_T$ (fraction of extra-terrestrial solar radiation that reaches the local ground level). Angle of incidence of the beam radiation on to the tilted collector is obtained and proper corrections applied to obtain flux on the tilted collector plane. The calculations are

repeated every half-hour. If a reflector is used as part of the system, the angle of incidence of the reflected radiation on to the collector is also calculated to find the absorptance-transmittance product for the reflected radiation. Since, whole of the reflected beam may not be intercepted by the collector, proper corrections are applied to account for this effect. These corrections are a function of reflector-collector geometry and position of the sun.

K. All the heat collected during any month is either fully utilized or the excess is not carried on to the next month.

III. The analysis for the cost of heating and cooling with solar energy for selected United States cities:

An analysis was performed for 69 cities using average monthly weather data. A collector area (of water type) was obtained to supply an average of 70 percent of the combined annual heating and cooling load. A separate collector area was obtained to supply 80 percent of the domestic hot water demand. The thermal loads were assumed to be as follows:

A. Heat load during winter = 18,000 Btu per degree day.

B. Cooling load during summer = 34,000 Btu per cooling degree day.

C. Hot water demand = 100 gallons per day at 140°F with the initial temperature of water at 65°F. This translates to a heat requirement of 62,250 Btu/day.

The collector tilt angle was assumed to be the local latitude angle and the reflector angle - $56.65 - \text{latitude} \times 0.5$. This reflector angle is optimum for summer time. No attempt was made to find the optimum.

Cost per million Btu of usable and deliverable heat was calculated for two different collector system costs of \$15.00 and \$7.50 per square foot. It was assumed that annual charges for owning and operating the solar heat collection system will be 15 percent of the initial system price. The results of the analyses are presented in the following Table I and Figures 1 and 2.

TABLE I
Cost of Heating and Cooling with Solar Energy

City	Total heat input for heating and cooling, million Btu/year	Total heating load, million Btu/year	Total heat input required for cooling, million Btu/year	% of heating with solar	% of cooling with solar	Collector area for 70% of heating and cooling load, ft ²	Collector area for 80% of hot water, ft ²	Total collector area, A _T ft ²	Solar heat supplied for heating and cooling 10 ⁶ Btu/yr, Q _{HC}	Q _T , total solar heat delivered including hot water, Million Btu/year	Cost/10 ⁶ Btu = 2.25 x A _T /Q _T	Cost/10 ⁶ Btu = 1.125 x A _T /Q _T
1. Albuquerque, New Mexico	151.8	77.3	74.6	76.7	62.4	357	44	401	105.8	125.1	7.21	3.60
2. Apalachicola, Florida	175.4	24.5	150.9	100.0	64.8	689	52	741	122.2	140.4	11.88	5.94
3. Astoria, Oregon	96.0	95.3	0.7	69.3	100.0	756	130	886	66.8	84.9	23.49	11.74
4. Atlanta, Georgia	145.8	55.7	90.0	83.1	61.2	552	64	616	101.4	119.7	11.58	5.79
5. Bismarck, North Dakota	190.0	162.8	27.6	64.5	100.0	912	71	983	132.5	150.7	14.68	7.34
6. Blue Hill, Massachusetts	139.9	114.0	25.9	62.6	100.0	908	101	1009	97.3	115.4	19.67	9.83
7. Boise, Idaho	145.5	105.0	40.5	57.9	100.0	542	76	618	101.3	119.5	11.64	5.82
8. Boston, Massachusetts	138.6	101.2	37.5	58.3	100.0	871	113	984	96.5	114.6	19.32	9.66
9. Brownsville, Texas	231.2	11.7	219.5	100.0	67.9	840	56	896	160.8	179.3	11.24	5.62
10. Caribou, Maine	180.6	173.4	7.3	68.3	100.0	1366	103	1469	125.7	143.8	22.99	11.50
11. Charleston, S. Carolina	156.4	38.6	117.8	100.0	59.7	622	59	681	108.9	127.1	12.06	6.03
12. Cleveland, Ohio	145.5	110.8	34.7	60.1	100.0	1136	121	1257	101.3	119.4	23.69	10.84
13. Columbia, Missouri	163.3	91.4	71.9	60.5	81.4	601	74	675	113.8	132.0	11.50	5.75
14. Columbus, Ohio	148.5	102.6	45.8	56.0	100.0	1042	129	1171	103.3	121.4	21.70	10.85
15. Davis, California	111.0	50.7	60.2	63.6	75.1	333	67	400	77.5	95.9	9.38	4.69
16. Dodge City, Kansas	166.0	86.0	80.0	72.0	67.5	447	51	498	115.9	134.3	8.34	4.17
17. Lansing, Michigan	154.6	124.3	30.3	62.2	100.0	1501	137	1538	107.6	125.7	27.53	13.76

TABLE I (Cont'd)
Cost of Heating and Cooling with Solar Energy

City	Total heat input for heating and cooling, million Btu/year	Total heating load, million Btu/year	Total heat input required for cooling, million Btu/year	% of heating with solar	% of cooling with solar	Collector area for 70% of heating and cooling load, ft ²	Collector area for 80% of hot water, ft ²	Total collector area, A _T ft ²	Solar heat supplied for heating and cooling 10 ⁶ Btu/yr, Q _{HC}	Q _T , Total solar heat delivered including hot water, Million Btu/year	Cost/10 ⁶ Btu = 2.25 x A _T /Q _T	Cost/10 ⁶ Btu = 1.125 x A _T /Q _T
18. Taunton, Massachusetts	138.2	112.2	30.0	62.1	100.0	843	97	940	96.1	114.2	18.52	9.26
19. El Paso, Texas	167.1	48.2	118.9	96.7	58.8	453	42	495	116.5	134.7	8.27	4.13
20. Ely, Nevada	152.4	140.7	11.7	67.1	100.0	447	50	497	106.1	124.3	9.00	4.50
21. Fort Worth, Texas	189.5	42.9	146.6	98.0	61.4	607	53	660	132.1	150.4	9.87	4.94
22. Fresno, California	142.3	47.7	94.7	76.0	66.6	438	57	495	99.3	117.7	9.46	4.73
23. Gainesville, Florida	195.5	19.5	176.0	100.0	66.2	883	56	939	136.0	154.2	13.70	6.85
24. Glasgow, Montana	186.3	161.4	24.8	65.0	100.0	790	64	854	129.8	148.0	12.98	6.49
25. Grand Junction, Colorado	165.5	100.9	64.6	65.3	76.1	464	53	517	115.1	133.6	8.71	4.35
26. Grand Lake, Colorado	194.5	194.5	0	70.0	100.0	791	67	858	135.5	153.7	12.56	6.28
27. Great Falls, Montana	156.9	137.7	19.2	65.4	100.0	690	70	760	109.3	127.5	13.41	6.71
28. Greensboro, N. Carolina	144.8	68.9	76.0	72.6	67.0	540	69	609	100.9	119.2	11.50	5.75
29. Experiment	149.7	50.5	99.2	86.6	61.1	520	60	580	104.3	122.5	10.65	5.33
30. Hatteras, N. Carolina	137.0	49.2	87.8	86.7	60.1	424	55	479	95.4	113.9	9.46	4.73
31. Indianapolis, Indiana	155.6	100.4	55.2	53.1	99.4	749	98	847	108.1	126.1	15.11	7.56
32. Trona, California	206.3	42.7	163.6	100.0	61.7	485	36	521	143.7	161.9	7.24	3.62
33. Ithaca, New York	148.7	126.9	21.7	64.3	100.0	1542	137	1679	103.4	121.5	31.09	15.55
34. Lake Charles, Louisiana	182.2	27.0	155.2	100.0	64.3	723	60	783	126.8	145.0	12.15	6.08

TABLE I (Cont'd)
Cost of Heating and Cooling with Solar Energy

City	Total heat input for heating and cooling, million Btu/year	Total heating load, million Btu/year	Total heat input required for cooling, million Btu/year	% of heating with solar	% of cooling with solar	Collector area for 70% of heating and cooling load, ft ²	Collector area for 80% of hot water, ft ²	Total collector area, A _T ft ²	Solar heat supplied for heating and cooling 10 ⁶ Btu/yr, Q _{HC}	Q _T , total solar heat delivered including hot water, Million Btu/year	Cost/10 ⁶ Btu = 2.25 x A _T /Q _T	Cost/10 ⁶ Btu x A _T /Q _T
35. Lander, Wyoming	163.3	141.6	21.7	64.8	100.0	528	54	582	113.5	131.7	9.94	4.97
36. Las Vegas, Nevada	213.8	46.8	166.9	100.0	61.1	586	41	627	148.8	167.0	8.46	4.22
37. Morrison, Illinois	145.3	95.9	49.4	58.9	90.8	614	86	700	101.3	119.4	13.19	6.60
38. Lexington, Kentucky	152.9	85.1	67.8	60.3	81.6	512	68	580	106.7	125.1	10.43	5.22
39. Lincoln, Nebraska	177.0	111.9	65.1	61.8	83.6	664	69	733	123.6	141.8	11.63	5.82
40. Little Rock, Arkansas	169.5	60.4	109.1	78.1	64.8	668	70	738	117.8	136.1	12.20	6.10
41. Los Angeles, California	89.6	22.4	67.2	100.0	59.6	287	53	340	62.3	80.5	9.50	4.75
42. Madison, Wisconsin	165.2	139.1	26.1	64.1	100.0	1102	95	1197	115.2	133.3	20.20	10.10
43. Medford, Oregon	113.2	88.9	24.3	61.3	100.0	609	95	704	78.8	96.9	16.35	8.17
44. Miami, Florida	232.5	3.7	228.8	100.0	69.2	885	51	936	162.1	180.3	11.68	5.84
45. Midland, Texas	174.7	47.2	217.5	97.5	59.4	524	49	573	121.7	140.0	9.21	4.60
46. Nashville, Tennessee	162.5	66.5	96.0	68.6	70.2	647	79	726	113.0	131.2	12.45	6.23
47. Kingston, Rhode Island	131.9	111.6	20.3	64.1	100.0	757	87	844	91.8	110.0	17.26	8.63
48. New York, New York	147.8	87.3	60.5	60.3	83.5	758	98	856	103.1	121.1	15.90	7.95
49. Oak Ridge, Tennessee	148.5	71.0	77.5	65.4	73.6	617	82	699	103.4	121.5	12.94	6.47
50. Oklahoma City, Oklahoma	178.8	62.2	116.6	85.9	61.0	525	54	579	124.5	142.8	9.12	4.56
51. Phoenix, Arizona	226.7	27.9	198.8	100.0	65.5	709	41	750	158.0	176.2	9.58	4.79

TABLE I (Cont'd)
Cost of Heating and Cooling with Solar Energy

City	Total heat input for heating and cooling, million Btu/yr	Total heating load, million Btu/year	Total heat input required for cooling, million Btu/year	% of heating with solar	% of cooling with solar	Collector area for 70% of heating and cooling load, ft ²	Collector area for 80% of hot water, ft ²	Total collector area, A _T ft ²	Solar heat supplied for heating and cooling 10 ⁶ Btu/yr, Q _{HC}	Q _T , Total solar heat delivered including hot water, Million Btu/year	Cost/10 ⁶ Btu = 2.25 x A _T /Q _T	Cost/10 ⁶ Btu x A _T /Q _T
52. Portland, Maine	149.3	135.0	14.3	66.5	100.0	870	83	953	104.0	122.2	17.55	8.77
53. Rapid City, South Dakota	163.6	123.8	39.8	61.8	94.4	504	60	564	114.2	132.4	9.58	4.79
54. Riverside, California	109.6	34.5	75.1	97.2	56.9	293	48	341	76.3	94.7	6.96	3.48
55. St. Cloud, Minnesota	183.8	159.6	24.1	65.2	100.0	972	78	1050	128.1	146.3	16.15	8.07
56. Salt Lake City, Utah	160.2	107.7	52.5	60.8	88.1	595	72	667	111.7	129.9	11.55	5.78
57. San Antonio, Texas	197.9	28.3	169.7	100.0	64.4	875	62	937	137.6	155.8	13.53	6.77
58. Santa Maria, California	59.7	55.0	4.8	67.9	100.0	133	47	180	42.0	60.2	6.73	3.36
59. Sault Ste. Marie, Mich.	173.4	165.5	7.9	68.2	100.0	1404	110	1514	120.8	138.9	24.52	12.26
60. Sayville, New York	137.0	103.2	33.8	59.9	99.9	604	80	684	95.6	113.8	13.52	6.76
61. Schenectady, New York	160.0	123.6	36.4	60.7	100.0	1460	144	1604	111.4	129.5	27.87	13.93
62. Seattle, Washington	92.0	80.8	11.3	65.4	100.0	1475	244	1719	64.1	82.1	47.11	23.56
63. Seabrook, New Jersey	143.6	85.8	57.9	60.8	82.4	646	86	732	99.8	117.9	13.97	6.98
64. Spokane, Washington	145.0	123.0	22.0	64.1	100.0	800	93	893	100.8	118.9	16.90	8.45
65. State College Penn.	143.4	110.4	33.0	60.4	100.0	1047	114	1161	99.7	117.7	22.19	11.10
66. Still Water, Oklahoma	175.7	65.4	110.3	78.9	64.0	577	61	638	122.2	140.5	10.22	5.11
67. Tampa, Florida	203.7	12.9	190.7	100.0	67.6	794	51	845	141.9	160.1	11.88	5.94
68. Tucson, Arizona	194.8	30.7	164.1	100.0	63.9	639	43	682	135.5	153.7	9.98	4.99

TABLE I (Cont'd)
Cost of Heating and Cooling with Solar Energy

City	Total heat input for heating and cooling, million Btu/yr	Total heating load, million Btu/year	Total heat input required for cooling, million Btu/year	% of heating with solar	% of cooling with solar	Collector area for 70% of heating and cooling load, ft ²	Collector area for 80% of hot water, ft ²	Total collector area, A _T ft ²	Solar heat supplied for heating and cooling 10 ⁶ Btu/yr, Q _{HC}	Q _T , Total solar heat delivered including hot water, Million Btu/year	Cost/10 ⁶ Btu = 2.25 x A _T /Q _T	Cost/10 ⁶ Btu = A _T /Q _T x 1.125
69. Washington, D. C.	156.0	75.8	80.2	69.3	70.0	660	79	739	108.7	126.9	13.10	6.55

Envelope of solar heating, cooling, and
 hot water system cost versus N. Latitude
 position

Figure 1

Figure 2: Envelope of the cost of usable heat output per total collector cost versus N. Latitude location

IV. Performance of water-type collectors for space heating in twelve climatic regions of the United States:

Solar system and building were assumed to have the following characteristics:

- A. South facing collectors at a tilt angle of latitude + 15°.
- B. No reflectors included as part of the system.
- C. Building floor area = 10,000 ft²
- D. Building heat load = 100,000 Btu/degree day.

Collector areas were obtained to supply 15 to 85 percent, in steps of 10 percent, of the average annual heat load. The results of the analyses are presented in Figures 3 to Figure 14 and a brief summary appears in Table II. Figures 3 to 14 represent the collector area required to carry a certain percentage of annual load by solar energy. It may be observed that in several cases, the slope of the curve suddenly changes. This can be due to the following reasons:

1. Assumption that all the heat collected in a month is either fully utilized or is not carried over to the next month.
2. When the load carried by solar is a small fraction of total load, most of the collector is fully utilized during the entire heating season. As we go to the requirement that higher percentages of annual loads be carried by solar, utilization of the total installed collector area goes down. Beyond a certain point, collectors are utilized fully only in December, January, and possibly in February.

The Figures 3 to 14 are for $A_F = 10,000$ square feet floor area and $H = 10$ Btu per square foot per heating degree day. For any other A_F and H , the collector area can be obtained as follows:

$$\text{Collector Area} = A_C \times \frac{H}{10} \times \frac{A_F}{10,000}$$

Where A_C = Collector area read from the plots corresponding to a percentage solar heating.

TABLE II
Water Type Collectors For Space Heating

City	Collector Area, ft ²		Useful Heat, Btu/ft ² /yr		Heat Load at 10 Btu Per Sq Ft of Building Per Degree-Day 10 ⁶ Btu/year
	70% Heating	35% Heating	70% Heating	35% Heating	
Bismarck	5100	1932	124130	163840	904.4
Boston	5825	2130	67550	92360	562.1
Nashville	3400	1257	80170	108420	389.4
Charleston	1240	545	121150	137630	214.6
Omaha	4000	1538	108820	141410	621.8
Phoenix	870	360	190690	230000	237.0
Seattle	10600	1975	29630	79340	448.7
Madison	6400	2269	84550	119170	773.0
Los Angeles	1960	701	100680	140500	281.9
Fort Worth	1280	559	143340	163960	262.1
Miami	126	49	114440	148000	20.6
Washington, D. C.	3450	1314	85440	112010	421.1

Assumptions

Building floor area = 10,000 square feet

Heat load = 10 Btu/ft²/degree-day

$\alpha \tau = 0.75$ at zero incidence, $\epsilon \approx 0.4$

Tilt angle = Latitude + 15°

BISMARCK.

Floor Area = 10.000 square feet

Collector Tilt Angle = Latitude + 15° = 61.8°

Annual Heat Load = 904.4×10^6 Btu @ 10 Btu/ft²/Deg.Day

FIGURE 3: Solar Performance for Heating Only Application Employing Flat Plate Water Collectors

FIGURE 4: Solar Performance for Heating Only Application Employing Flat Plate Water Collectors

FIGURE 5: Solar Performance for Heating Only Application Employing Flat Plate Water Collectors

CHARLESTON

Floor Area = 10,000 square feet

Collector Tilt Angle = Latitude + 15° = 47.9°

Annual Heat Load = 214.6 x 10⁶ Btu @ 10 Btu/ft²/Deg. Day

FIGURE 6: Solar Performance for Heating Only Application Employing Flat Plate Water Collectors

FIGURE 7: Solar Performance for Heating Only Application Employing Flat Plate Water Collectors

FIGURE 8: Solar Performance for Heating Only Application Employing Flat Plate Water Collectors

SEATTLE

Floor Area = 10,000 square feet

Collector Tilt Angle = Latitude + 15° = 61°

Annual Heat Load = 448.7 x 10⁶ Btu @ 10 Btu/ft²/Deg. Day

FIGURE 9: Solar Performance for Heating Only Application Employing Flat Plate Water Collectors

FIGURE 10: Solar Performance for Heating Only Application Employing Flat Plate Water Collectors

LOS ANGELES

Floor Area= 10,000 square feet

Collector Tilt Angle= Latitude +15° =53.5°

Annual Heat Load= $281.9 \times 10^6 \text{ Btu@ } 10 \text{ Btu/ft}^2/\text{Deg. Day}$

FIGURE 11: Solar Performance for Heating Only Application Employing Flat Plate Water Collectors

FIGURE 12: Solar Performance for Heating Only Application Employing Flat Plate Water Collectors

MIAMI

Floor Area = 10,000 square feet

Collector Tilt Angle = Latitude + 15° = 40.8°

Annual Heat Load = 20.6×10^6 Btu @ 10 Btu/ft²/Deg. Day

FIGURE 13: Solar Performance for Heating Only Application Employing Flat Plate Water Collectors

FIGURE 14: Solar Performance for Heating Only Application Employing Flat Plate Water Collectors

V. Performance of air type collectors for space heating in twelve climatic regions of the United States.

Solar system and building were assumed to have the following characteristics:

A. South facing collectors at a tilt angle of latitude + 15°.

B. No reflectors included as part of the system.

C. Building floor area = 10,000 ft²

D. Building heat load = 100,000 Btu/degree day.

Collector areas were obtained to supply 15 to 85 percent, in steps of 10 percent, of the average annual heat load. The results of the analyses are presented in Figure 15 to 25 and a brief summary appears in Table III. The Figures 15 to 25 represent the collector area required to carry a certain percentage of the average annual load by solar energy. It may be observed that in several cases, the slope of the curve suddenly changes. This can be due to the following reasons:

1. Assumption that all the heat collected in a month is either fully utilized or is not carried over to the next month.

2. When the load carried by solar is a small fraction of the total load, most of the collector is fully utilized during the entire heating season. As we go to the requirement that higher percentages of annual loads be carried by solar, the utilization of the total installed collector area goes down. Beyond a certain point, collectors are fully utilized only in December, January, and possibly in February.

The Figures 15 to 25 are for $A_F = 10,000$ square feet floor area and $H = 10$ Btu per square foot per heating degree day. For any other A_F and H , the collector area can be obtained as follows:

$$\text{Collector Area} = A_C \times \frac{H}{10} \times \frac{A_F}{10,000}$$

Where A_C = Collector area read from the plots corresponding to a percentage solar heating.

TABLE III
Performance of Air Type Collectors for Space Heating

City	Collector Area, ft ²		Useful Heat, Btu/ft ² /yr		Heat Load at 10 Btu Per Sq Ft of Building Per Degree-Day 10 ⁶ Btu/year
	70% Heating	35% Heating	70% Heating	35% Heating	
Bismarck	4243	1581	149573	199742	904.4
Boston	4007	1511	98402	130128	562.1
Nashville	2517	939	108522	144857	389.4
Charleston	1052	460	142971	163044	214.6
Omaha	3191	1233	136402	176018	621.8
Phoenix	816	332	205530	249925	237.0
Seattle	4302	1251	74494	125382	448.7
Madison	4730	1717	114766	157118	773.0
Los Angeles	1534	571	129572	172390	281.9
Fort Worth	1132	488	162666	187965	262.1
Washington, D. C.	2623	1025	112682	143601	421.1

Assumptions

Building floor area = 10,000 square feet

Heat load = 10 Btu/ft²/degree-day

$\alpha \tau = 0.75$ at zero incidence, $\epsilon \approx 0.4$

Tilt angle = Latitude + 15°

FIGURE 15: Solar Performance for Heating Only Application Employing Flat Plate Air Collectors

BOSTON

Floor Area = 10,000 square feet

Collector Tilt Angle = Latitude + 15° = 57.4°

Annual Heat Load = 562.1 x 10⁶ Btu @ 10 Btu/ft²/Deg. Day

FIGURE 16: Solar Performance for Heating Only Application Employing Flat Plat Air Collectors

NASHVILLE

Floor Area = 10,000 square feet

Collector Tilt Angle = Latitude + 15° = 51°

Annual Heat Load = 389.4 x 10⁶ Btu @ 10 Btu/ft²/Deg. Day

FIGURE 17: Solar Performance for Heating Only Application Employing Flat Plate Air Collectors

FIGURE 18: Solar Performance for Heating Only Application Employing Flat Plate Air Collectors

OMAHA

Floor Area = 10,000 square feet

Collector Tilt Angle = Latitude +15° = 55.8°

Annual Heat Load = 621.8x10⁶Btu@ 10Btu/ft²/Deg.Day

FIGURE 19: Solar Performance for Heating Only Application Employing Flat Plate Air Collectors

PHOENIX

Floor Area = 10,000 square feet

Collector Tilt Angle = Latitude + 15° = 50.7°

Annual Heat Load = 237 x 10⁶ Btu @ 10 Btu/ft²/Deg.Day

FIGURE 20: Solar Performance for Heating Only Application Employing Flat Plate Air Collectors.

FIGURE 21: Solar Performance for Heating Only Application Employing Flat Plate Air Collectors

MADISON

Floor Area = 10,000 square feet

Collector Tilt Angle = Latitude + 15° = 58.1°

Annual Heat Load = 773 x 10⁶ Btu @ 10 Btu/ft²/Deg. Day

FIGURE 22: Solar Performance for Heating Only Application Employing Flat Plate Air Collectors

FIGURE 23: Solar Performance for Heating Only Application Employing Flat Plate Air Collectors

FIGURE 24: Solar Performance for Heating Only Application Employing Flat Plate Air Collectors

WASHINGTON, D.C.

Floor Area = 10,000 square feet

Collector Tilt Angle = Latitude + 15° = 53.8°

Annual Heat Load = $421.1 \times 10^6 \text{ Btu} @ 10 \text{ Btu/ft}^2/\text{Deg. Day}$

FIGURE 25: Solar Performance for Heating Only Application Employing Flat Plate Air Collectors

VI. Performance of water type collectors for space heating and cooling in twelve climatic regions of the United States.

Solar system was assumed to have the following characteristics:

- A. South facing collectors at a tilt angle equal to the latitude.
- B. Reflector angle equal to $56.75 - 1/2 \times \text{latitude}$, except for Bismarck where the reflector angle is 23.3° .

Characteristics of the building are:

- 1. Floor area = 10,000 square feet
- 2. Heat load is proportional to floor area and the degree days.
- 3. For cooling load, buildings were divided into four types. For each building type, the cooling load had a fixed component and another component which was proportional to the floor area and the cooling degree days. The cooling load can be represented as follows:

Cooling load per square foot per month = $UU + VV \times CDD$

where

UU = fixed component, Btu/ft² - month

VV = cooling requirement, Btu/ft² - cooling degree day

CDD = cooling degree days/month

Building type #	UU	VV
	Btu/ft ² /month	Btu/ft ² -degree day
1	5100	17.2
2	8770	19.2
3	7030	12.4
4	7352	24.5

The results of the analysis are presented in Figures 26 to 37. If the heating requirement in terms of Btu/ft²/heating degree day is known, the collector area for 70 percent solar heating can be obtained from the figures. The cooling load that will be carried by solar corresponding to the collector area for 70 percent heating can be read on the right hand side ordinate for each of the four building types. The numbers on the cooling curves appear as A (B) where A is the building type and B is the annual cooling load in million Btu.

The data for Miami Region is presented in a different fashion because there is practically no heating load. Here the ordinate is the fixed component of cooling load and different curves correspond to fixed value of cooling requirements which is proportional to the cooling degree days and floor area. Each curve gives the collector area for 70 percent of cooling by solar.

VII. Performance of air and water type collectors for space heating.

Data from Sections IV and V are presented in Table IV. This table presents the ratio of the air collector area to the water type collector area required to carry 70 percent and 35 percent of the annual heat load.

TABLE IV
Air Collector Area/Liquid Collector Area

<u>City</u>	<u>70% Heating</u>	<u>35% Heating</u>
Bismarck	0.832	0.818
Boston	0.688	0.709
Nashville	0.711	0.747
Charleston	0.848	0.844
Omaha	0.798	0.802
Phoenix	0.938	0.922
Seattle	0.406	0.633
Madison	0.739	0.757
Los Angeles	0.782	0.815
Fort Worth	0.884	0.873
Washington, D. C.	0.760	0.780

Collector area required for air type collectors is consistently lower than water type collectors because the air type collectors operate at significantly lower temperatures by virtue of very strong stratification that can be achieved in rock-bed storage.

FIGURE 26: Solar Performance for Heating and Cooling Application Employing Flat Plate Water/Absorption System

BOSTON

FIGURE 27: Solar Performance for Heating and Cooling Application Employing Flat Plate Water/Absorption System

FIGURE 28: Solar Performance for Heating and Cooling Application Employing Flat Plate Water/Absorption System

FIGURE 29: Solar Performance for Heating and Cooling Application Employing Flat Plate Water/Absorption System

FIGURE 30: Solar Performance for Heating and Cooling Application Employing Flat Plate Water/Absorption System

FIGURE 31: Solar Performance for Heating and Cooling Application Employing Flat Plate Water/Absorption System

FIGURE 32: Solar Performance for Heating and Cooling Application Employing Flat Plate Water/Absorption System

MADISON

FIGURE 33: Solar Performance for Heating and Cooling Application Employing Flat Plate Water/Absorption System

FIGURE 34: Solar Performance for Heating and Cooling Application Employing Flat Plate Water/Absorption System

MIAMI

92

FIGURE 36: Solar Performance for Heating and Cooling Application Employing Flat Plate Water/Absorption System

2

FIGURE 35: Solar Performance for Heating and Cooling Application Employing Flat Plate Water/Absorption System

FIGURE 37: Solar Performance for Heating and Cooling Application Employing Flat Plate Water/Absorption System

APPENDIX D

200 DEMONSTRATION SITE INSTALLATION SCHEDULES

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APPENDIX D

200 DEMONSTRATION SITE INSTALLATION SCHEDULES

1. Need For Schedules

As can be seen on the site schedules presented in this Appendix, a site is identified by six parameters: the type of building, its location as identified by one of the 12 climatic regions, whether it is a heating only or heating and cooling demonstration, whether it is a new or retrofit application, the purpose it is intended to serve, and the time frame (schedule) assigned to it. The first five parameters have been discussed in detail in the Technical Report. A general discussion of schedule timing constraints can also be found in that report.

We would obviously have preferred not to assign schedules to each site, as this additional constraint will no doubt mean that implementation will be more difficult. We could not, however, ignore the fact that smooth program implementation and compliance with the law would not be guaranteed through ad hoc selection of sites, disregarding the effect each site's implementation would have on the program as a whole. We have, therefore, assigned each site a "preferred" time frame which places that site into the context of the whole plan.

The most difficult scheduling obviously occurs when attempting to comply with P.L. 93-409 which mandates that heating only be "demonstrated" by the end of FY1977. While we have defined a demonstration as being truly complete only after data has been gathered for one full season, relevant to the particular application (heating or cooling), practical implementation of the program insists that this definition be waived in the sense that the heating only sites cannot be completed in time to permit accumulation of a full heating season's operational data before the end of FY1977. However, we have assumed that Testing and Evaluation equipment will not be removed at the end of FY1977, and that heating only data gathering will spill over into FY1978. We have scheduled the heating only demonstrations so that as much data as possible can be obtained prior to the end of FY1977.

In terms of management flexibility, smooth funding, and opportunity for R & D cycle input, the heating only portion of the program provides essentially none. Only the number of heating only demonstrations significantly affects these considerations; however, this number is established by program design considerations and cannot be reduced. Program funding and program management must adjust itself to these constraints essentially imposed by law.

Fortunately, the heating and cooling portion of the program provides significantly greater flexibility. Because of this flexibility, several funding scenarios were considered: continuously increasing the funding level over the program's life, maintenance of a relatively constant funding level, and decreasing the funding level over the program's life. Evaluation of the first scenario suggested the following drawbacks:

1. Sudden stoppage of a continually increasing program may cause a depression in the solar industry, small business being particularly hard-hit.
2. This scenario may encourage "get rich quick" entrants into the field who are not seriously interested in developing quality solar equipment. It would inhibit cost reductions.
3. The program management function would require continuous expansion, thereby requiring the continuous training of new personnel.
4. Greater central processing facilities and staff would be required to handle the larger number of Test and Evaluation systems toward the end of the program than would be required under a constant level program.

Evaluation of the third scenario suggested that such a program would inhibit R & D in the private sector since income levels would be continually decreasing (assuming the demonstration program is, for the first few years, the primary market). Furthermore, the same problems for program management and Testing and

Evaluation will be present under this scenario as described above, only in reverse time sequence. An additional problem with this scenario is that fewer and fewer opportunities would be available on which to test solutions and system improvements identified on the greater number of "first" demonstrations. The program would be inefficient.

The second scenario was selected as being the most balanced, having the least risk of failure, and providing the greatest opportunity for Test and Evaluation of system improvements. We have thus scheduled the demonstrations to smooth, as reasonably as possible, the total funding level, management manpower, and Test and Evaluation system requirements. This was a very difficult task because to smooth one generally resulted in a peak in one of the other two. What our schedules represent is a trade-off among these three. Thus while peaks and valleys exist for these factors we have attempted to minimize the difference between them.

We have also taken into consideration the introduction of new technology for heating and cooling systems. Introduction of technology derived from current R & D cannot occur during the heating only phase due to timing constraints. Two iterations are possible in the heating and cooling portion of this plan. The primary source of new technology will be inputs derived from the on going NASA studies. The incorporation of the new technology into the plan will require an approximate one year time period from the conclusion of a specific NASA sponsored program to the incorporation into a practical design. Compressing the program or making it more front end loaded will inhibit these cycles from consideration. We have also considered our recommended promising technologies study as representing anticipated R & D results. We have attempted to schedule these promising technologies within the time frame likely to represent R & D requirements.

2. Flexibility Considerations

We are quick to point out that the recommended schedules are not "cast in concrete". No significant impact will be noticed if a number of demonstrations are rescheduled a quarter ahead or back, except that in certain cases, slipping a schedule by this amount may result in the loss of opportunity to collect data during the heating or cooling season.

The primary purpose of the schedules presented here has been to provide a mechanism to

1. comply with the law
2. estimate resources, management manpower, and T&E requirements, and
3. provide opportunity for R & D cycles

and should be viewed in this light. Scheduling is basically a function of available resources and the size of the management staff. Thus we leave final scheduling decisions to the Program Manager, since it is he who must deal with the "real world".

We suspect that it may be difficult to find demonstrations which agree with all six identifying parameters previously discussed. Therefore, it is necessary to provide this flexibility provided that the program as a whole is frequently evaluated to ensure that the overall parameters recommended are reasonably followed. Thus, for example, the program will not be seriously jeopardized should 80 new and 120 retrofit demonstrations be ultimately demonstrated. Any decision to unbalance the program greater than this should be carefully considered, however.

3. The Schedules

The following schedules are a result of the considerations described above. We have identified three phases to each. The first two months represent a contract negotiation period which would be required should all demonstrations be conducted employing the RFP mechanism. Under the PON mechanism, conceivably negotiation and contract signing could occur some months prior to initiation of construction. The second phase represents building construction (for new buildings) and solar system installation (assumed to occur during last five months of construction). As discussed in the Technical Report, periods of construction have been assumed based on averages for each building type. The final phase is the data collection phase which is assumed to last for 12 months.

[illegible]

LEGEND: H-Heating Only
H/C-Heating & Cooling
N-Install on New Bldg.
R-Install on Existing Bldg.

EOS-Economy of Scale Study
LIS-Local Industry Stimulation
PS-Parametric Study
ILS-Installation Learning Study

PT-Promising Technology, See Text
-Contract Negotiation Period
-Bldg. Constr. and Sys. Installation
-Operation and Data Collection

[illegible]

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PS-Parametric Study
ILS-Installation Learning Study

PT-Promising Technology, See Text
▨-Contract Negotiation Period
■-Bldg. Constr. and Sys. Installation
□-Operation and Data Collection

Region: Boston			SCHEDULES FOR 200 COMMERCIAL DEMONSTRATIONS																																																
			Fiscal 1976&1977TQ												Fiscal 1977												Fiscal 1978												Fiscal 1979												
BUILDING TYPE			O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	
1. School (PS)	H	R																																																	
2. Nursing Home (PS)	H	R																																																	
3. Store (PS)	H	R																																																	
4. Store (PT)	H	N																																																	
5. School (PS)	H/C	R																																																	
6. Shopping Center (PS)	H/C	R																																																	
7. Office (PS, ILS)	H/C	R																																																	
8. Office (ILS)	H/C	R																																																	
9. Office (ILS)	H/C	R																																																	
10. Office (ILS)	H/C	R																																																	
11. Office (ILS)	H/C	R																																																	
12. Office (ILS)	H/C	R																																																	
13. Office (EOS)	H/C	N																																																	
14. Office (EOS)	H/C	N																																																	
15. Office (EOS)	H/C	N																																																	
16. School (PT)	H/C	N																																																	
17. Library (PT)	H/C	N																																																	
18. School	H/C	N																																																	
19. School	H/C	N																																																	
20. School	H/C	N																																																	
21. School	H/C	R																																																	
22. Office	H/C	N																																																	
23. Office	H/C	N																																																	
24. Store	H/C	N																																																	

LEGEND: H-Heating Only
H/C-Heating & Cooling
N-Install on New Bldg.
R-Install on Existing Bldg.

EOS-Economy of Scale Study
LIS-Local Industry Stimulation
PS-Parametric Study
ILS-Installation Learning Study

PT-Primising Technology, See Text
-Contract Negotiation Period
-Bldg. Constr. and Sys. Installation
-Operation and Data Collection

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SCHEDULES FOR 200 COMMERCIAL DEMONSTRATIONS

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LEGEND: H-Heating Only
H/C-Heating & Cooling
N-Install on New Bldg.
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-Operation and Data Collection

REGION: Phoenix			SCHEDULES FOR 200 COMMERCIAL DEMONSTRATIONS																																																
			Fiscal 1976&1977T												Fiscal 1977												Fiscal 1978												Fiscal 1979												
BUILDING TYPE			O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	
1. Office (PS, LIS)	H	R																																																	
2. Hospital (PS, LIS)	H	R																																																	
3. Church (PS, LIS)	H	R																																																	
4. Restaurant (PS, LIS)	H	N																																																	
5. Store (ILS, LIS)	H	R																																																	
6. Store (ILS, LIS)	H	R																																																	
7. Store (ILS, LIS)	H	R																																																	
8. Store (ILS, LIS)	H	R																																																	
9. Store (ILS, LIS)	H	R																																																	
10. Store (ILS, LIS)	H	R																																																	
11. Office (LIS)	H	R																																																	
12. Office (LIS)	H	R																																																	
13. Office (LIS)	H	R																																																	
14. Store (LIS)	H	N																																																	
15. Restaurant (LIS)	H	N																																																	
16. Restaurant (LIS)	H	R																																																	
17. Church (LIS)	H	R																																																	
18. Church (LIS)	H	R																																																	
19. Warehouse (PT)	H	N																																																	
20. Office (PS)	H/C	N																																																	
21. Store (PS)	H/C	N																																																	
22. Store (PS)	H/C	R																																																	
23. Church (PS)	H/C	N																																																	
24. Restaurant (PS)	H/C	N																																																	

LEGEND:

H-Heating Only

H/C-Heating & Cooling

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SCHEDULES FOR 200 COMMERCIAL DEMONSTRATIONS

[illegible]

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APPENDIX E

CLIMATIC REGIONS AND CHARACTERISTIC SITES

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CLIMATIC REGIONS AND CHARACTERISTIC CITIES

1. Climatic Regions

The twelve climatic regions forming the background for this study have been adapted from those identified by General Electric under their Phase 0 contract with ERDA. In-house analysis indicated that these regions appear to reasonably represent regionalized differences in insolation and weather patterns. Figure 1 shows the boundaries of these regions. Well into this program, a decision was made to change the designator of these regions because ERDA felt the use of a city to identify regions might be misleading. The new designators are indicated in Table 1.

2. Identification of Characteristic Cities

In order to compare performance of solar systems among the various climatic regions, solar insolation and weather data characteristics of each region needed to be established. That is, we wished to identify a city within each climatic region whose location characterized the climate for that region. This was accomplished by first locating each of the 69 cities for which solar design data was available in their respective climatic regions. Refer to Appendix C for details. Simple averages of the following parameters were obtained for all cities within each region: heating degree days, 10^3 Langleys/heating season, usable Btu/ft² collector, cost/ 10^6 Btu-ft²-collector. The city which more nearly matched the averages of the parameters was chosen to represent the region. In most cases, a close match was readily found. In several cases, a match of three out of the four parameters had to suffice. This exercise pointed up one important fact: the climatic region concept can only be used to illustrate a gross average of many parameters which are highly variable within a given region. While it was relatively easy to find a city which represented the "average" of all cities under consideration, the standard deviation of the data for these cities (within a given region) was large. Nevertheless, variation in the performance of solar systems among the 12 regions is reflected by these cities. A summary of the pertinent climatic parameters is illustrated in Table 2.

Figure 1 : Climatic Regions

Source: General Electric/ERDA Phase 0 Study,
 "Phase 0 Feasibility and Planning Study Final
 Report, Volume 2, Technical Report", NSF-RA-N-74-021B

TABLE 1

LOCATIONS EMPLOYED TO CHARACTERIZE SOLAR SYSTEM
PERFORMANCE AND BUILDING SPACE HEATING/COOLING LOADS

<u>Zones</u>	<u>Old Designator</u>	<u>New Designator</u>	<u>Location Characterizing Regional Climate</u>
1	Boston	Eastern/Great Lakes	Boston, Massachusetts
2	Washington, D. C.	Mid Atlantic	Washington, D. C.
3	Madison	Midwest/Down East	Madison, Wisconsin
4	Los Angeles	Far West	Davis, California
5	Charleston	Southeast	Charleston, South Carolina
6	Bismarck	Northern Plain	Bismarck, North Dakota
7	Nashville	Central Humid	Oak Ridge, Tennessee
8	Fort Worth	Southern Plain	Midland, Texas
9	Omaha	Central Plain	Lincoln, Nebraska
10	Seattle	Pacific Northwest	Seattle, Washington
11	Phoenix	Southwest	Trona, California
12	Miami	Southern Florida	Miami, Florida

TABLE 2

CLIMATIC PARAMETERS FOR CHARACTERISTIC CITIES WITHIN CLIMATIC REGIONS.

Region Number	Representative City	Characteristic Location	Heating Degree-Days	Cooling Degree-Days	Hours in Heating Season	Hours in Cooling Season	Average Change in Humidity Ratio*
1	Boston	Boston, Mass.	5634	661	6480	2160	.0037
2	Wash., D.C.	Wash., D. C.	4211	1415	5040	3600	.0024
3	Madison	Madison, Wisc.	7863	460	6480	2160	0
4	Los Angeles	Davis, Calif.	2819	1063	5760	2880	0
5	Charleston	Charleston, S.C.	2033	2078	4320	4320	.0055
6	Bismarck	Bismarck, N.D.	8851	487	7200	1440	.0003
7	Nashville	Oak Ridge, Tenn.	3944	1367	5040	3600	.0035
8	Ft. Worth	Midland, Texas	2621	2250	4320	4320	.0037
9	Omaha	Lincoln, Neb.	6218	1148	5760	2880	.0003
10	Seattle	Seattle, Wash.	5145	200	7200	1440	0
11	Phoenix	Trona, Calif.	2370	2888	4320	4320	0
12	Miami	Miami, Fla.	214	4038	720	7920	.0046

*Relative to indoor design conditions of 78°F dry bulb and 50% relative humidity.

APPENDIX F

PARAMETRIC STUDY ALTERNATIVES

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APPENDIX F

PARAMETRIC STUDY ALTERNATIVES

The Technical Report describes in detail the concept behind the parametric studies. Those sites recommended to participate in the studies have been selected based upon their superior cost savings and potential for regional energy savings. Refer to Section II.B.1 of the Technical Report for details.

The purpose of this Appendix is to present those buildings which are candidates for each element of the parametric studies. The buildings recommended in the Technical Report for participation in these studies have been selected from these groupings.

The intent is to provide ERDA Program Management with the flexibility to make substitutions of building types on a rational basis. While the cost savings for real sites will undoubtedly be different from those in the tables, the tables do serve to indicate the relative economics for each site as well as to indicate the impact that a site is likely to have on buildings of that type in a given region. Thus any decision to substitute a site which is different from the one recommended may be made in view of all possible substitutions.

It is important to note that the data in the tables are simply a re-ordering of the computer screening outputs presented in Appendix A, which are based upon flat plate water systems with direct heating and for cooling, coupled with an absorption system.

TABLE 1

HEATING ONLY PARAMETRIC STUDY ALTERNATIVES

Insolation Range: (10-60) 10^3 Langleys/heating season
 Heat Load Range: (0-45) 10^3 Btu/ft²

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg*	POTENTIAL ENERGY SAVINGS, 10^{12} Btu	COLLECTOR AREA: ROOF AREA
Miami	School	0.003	0.06	0.0
	Office	0.003	0.04	0.01
	Store	0.013	0.16	0.01
	Shopping Center	0.0	0.0	0.0
	Hospital	0.007	0.02	0.04
	Church, Social	0.007	0.05	0.01
	Restaurant	0.031	0.04	0.03
	Motel, Nursing Home	0.004	0.03	0.0
	Warehouse	0.0	0.03	0.0
	Supermarker	0.001	0.0	0.0
	Library	0.002	0.0	0.01
Nashville	Shopping Center	0.015	0.85	0.12
	Warehouse	0.021	4.86	0.14
	Library	0.017	0.32	0.41
Charleston	School	0.029	3.67	0.06
	Office	0.029	2.89	0.22
	Shopping Center	0.006	0.13	0.01
	Hospital	0.037	0.94	0.44
	Church, Social	0.045	2.54	0.18
	Motel, Nursing Home	0.03	1.64	0.12
	Warehouse	0.016	0.33	0.03
	Supermarket	0.021	0.15	0.04
	Library	0.021	0.14	0.12
Ft. Worth	School	0.036	3.19	0.07
	Office	0.036	2.52	0.28

*For 35% replacement of load with solar, comparison with electrical energy costs, and an annualized solar cost of 1\$/ft²-yr

TABLE 1 (CONT'D)
HEATING ONLY PARAMETRIC STUDY ALTERNATIVES

Insolation Range (10-60) $\cdot 10^3$ Langleys/heating season
Heat Load Range: (0-45) $\cdot 10^3$ Btu/ft²

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg*	POTENTIAL ENERGY SAVINGS, 10^{12} Btu	COLLECTOR AREA: ROOF AREA
Ft. Worth (cont.)	Shopping Center	0.015	0.21	0.03
	Hospital	0.044	0.76	0.51
	Church, Social	0.050	2.60	0.02
	Motel, Nursing Home	0.035	1.34	0.14
	Warehouse	0.023	1.55	0.04
	Supermarket	0.031	0.15	0.06
	Library	0.025	0.22	0.15

*For 35% replacement of load with solar, comparison with electrical energy costs and an annualized solar cost of 1\$/ft²-yr

TABLE 1 (CONT'D)
HEATING ONLY PARAMETRIC STUDY ALTERNATIVES

Insolation Range: (60-80) 10^3 Langleys/heating season
Heat Load Range: (0-45) 10^3 Btu/ft²

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg*	POTENTIAL ENERGY SAVINGS, 10^{12} Btu	COLLECTOR AREA ÷ ROOF AREA
Washington, D.C.	Shopping Center	0,066	1.62	0.13
Ft. Worth	School	0.036	3.19	0.07
	Office	0.036	2.52	0.28
	Shopping Center	0.015	0.21	0.03
	Hospital	0.044	0.76	0.51
	Motel, Nursing Home	0.035	1.34	0.14
	Warehouse	0.023	1.55	0.04
	Supermarket	0.031	0.15	0.06
	Library	0.025	0.12	0.15
Los Angeles	School	0.056	6.05	0.08
	Office	0.056	4.76	0.31
	Shopping Center	0.014	0.23	0.02
	Hospital	0.073	1.54	0.61
	Motel, Nursing Home	0.059	2.72	0.16
	Warehouse	0.032	2.62	0.04
	Supermarket	0.043	0.26	0.06
	Library	0.039	0.22	0.16
Nashville	Shopping Center	0.015	0.85	0.12
	Library	0.017	0.32	0.41
	Warehouse	0.018	4.86	0.14

*For 35% replacement of load with solar, comparison with electrical energy costs, and an annualized solar cost of 1\$/ft² - yr.

TABLE 1 (CONT'D)
HEATING ONLY PARAMETRIC STUDY ALTERNATIVES

Insolation Range: (60-80) 10^3 Langleys/heating season
Heat Load Range: (0-45) 10^3 Btu/ft²

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg*	POTENTIAL ENERGY SAVINGS, 10^{12} Btu	COLLECTOR AREA : ROOF AREA
Phoenix	School	0.063	1.03	0.04
	Office	0.063	0.81	0.17
	Shopping Center	0.022	0.06	0.02
	Hospital	0.078	0.25	0.32
	Church, Social	0.091	0.66	0.12
	Motel, Nursing Home	0.062	0.41	0.09
	Warehouse	0.04	0.50	0.03
	Supermarket	0.051	0.05	0.03
	Library	0.045	0.04	0.09

*For 35% replacement of load with solar, comparison with electrical energy costs, and an annualized solar cost of 1\$/ft²-yr

TABLE 1 (CONT'D)

HEATING ONLY PARAMETRIC STUDY ALTERNATIVES

Isolation Range: (>80) 10^3 Langleys/heating season
 Heat Load Range: ($0-45$) 10^3 Btu/ft²

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -Bldg*	POTENTIAL ENERGY SAVINGS, 10^{12} Btu	COLLECTOR AREA ÷ ROOF AREA
Seattle	Shopping Center	-0.079	0.16	0.15

*For 35% replacement of load with solar, comparison with electrical energy costs, and an annualized solar cost of 1\$/ft²-yr

TABLE 1 (CONT'D)
HEATING ONLY PARAMETRIC STUDY ALTERNATIVES

Isolation Range: (10-60) 10^3 Langleys/heating season
Heat Load Range: (45-90) 10^3 Btu/ft²

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg*	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ROOF AREA
Nashville	School	0.024	8.62	0.19
	Office	0.024	6.78	0.76
	Hospital	0.026	1.85	1.26
	Church, Social	0.029	4.60	0.46
	Motel, Nursing Home	0.021	3.32	0.34
	Supermarket	0.024	0.48	0.19
Charleston	Store	0.065	6.07	0.13
Ft. Worth	Store	0.075	4.83	0.15
	Church, Social	0.050	2.60	0.20

*For 35% replacement of load with solar, comparison with electrical energy costs and an annualized solar cost of 1\$/ft²-yr

TABLE 1 (CONT'D)
HEATING ONLY PARAMETRIC STUDY ALTERNATIVES

Isolation Range: (60-80) 10^3 Langleys/heating season
Heat Load Range: (45-90) 10^3 Btu/ft²

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg*	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ROOF AREA
Washington, D.C.	School	0.100	16.17	0.20
	Office	0.100	12.73	0.80
	Hospital	0.110	3.46	1.31
	Church, Social	0.121	8.55	0.48
	Motel, Nursing Home	0.089	6.20	0.36
	Warehouse	0.075	9.20	0.15
	Supermarket	0.100	1.31	0.20
	Library	0.072	0.61	0.43
Ft. Worth	Store	0.075	4.83	0.15
	Church, Social	0.050	2.60	0.20
Los Angeles	Store	0.125	9.84	0.17
	Church, Social	0.088	4.13	0.24
Nashville	School	0.024	8.62	0.19
	Office	0.024	6.78	0.76
	Hospital	0.026	1.85	1.26
	Church, Social	0.029	4.60	0.46
	Motel, Nursing Home	0.021	3.32	0.34
	Supermarket	0.024	0.48	0.19
Phoenix	Store	0.134	1.60	0.09
Boston	School	0.165	45.28	0.30
	Office	0.165	35.67	1.21
	Shopping Center	0.095	3.98	0.17
	Motel, Nursing Home	0.153	18.03	0.56

*For 35% replacement of load with solar, comparison with electrical energy costs and an annualized solar cost of 1\$/ft²-yr

TABLE 1 (CONT'D)

HEATING ONLY PARAMETRIC STUDY ALTERNATIVES

Isolation Range: (60-80) 10^3 Langleys/heating season
 Heat Load Range: (45-90) 10^3 Btu/ft²

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg*	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ROOF AREA
Boston (cont'd)	Warehouse	0.118	24.49	0.22
	Supermarket	0.158	2.41	0.29
	Library	0.118	1.71	0.65
Madison	Shopping Center	0.129	2.42	0.23
	Library	0.138	0.90	0.76
Omaha	Shopping Center	0.063	0.80	0.15
	Motel, Nursing Home	0.090	3.19	0.42
	Warehouse	0.074	4.62	0.17
	Library	0.070	0.31	0.49

*For 35% replacement of load with solar, comparison with electrical energy costs, and an annualized solar cost of 1\$/ft²-yr.

TABLE 1 (CONT'D)

HEATING ONLY PARAMETRIC STUDY ALTERNATIVES

Isolation Range: (>80) 10^3 Langleys/heating season
 Heat Load Range: ($45-90$) 10^3 Btu/ft²

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg*	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ROOF AREA
Madison	Shopping Center	0.129	2.42	0.23
	Library	0.138	0.90	0.76
Bismarck	Shopping Center	0.083	1.42	0.19
Omaha	Shopping Center	0.063	0.80	0.15
	Motel, Nursing Home	0.090	3.19	0.42
	Warehouse	0.074	4.62	0.17
	Library	0.070	0.31	0.49
Seattle	School	-0.154	2.00	0.30
	Office	-0.154	1.58	1.21
	Hospital	-0.182	0.46	2.14
	Motel, Nursing Home	-0.146	0.82	0.57
	Warehouse	-0.106	1.04	0.21
	Supermarket	-0.141	0.10	0.28
	Library	-0.110	0.08	0.65

*For 35% replacement of load with solar, comparison with electrical energy costs and an annualized solar cost of 1\$/ft²-yr.

TABLE 1 (CONT'D)
HEATING ONLY PARAMETRIC STUDY ALTERNATIVES

Isolation Range: (10-60) 10^3 Langleys/heating season
Heat Load Range: (>90) 10^3 Btu/ft²

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg*	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ROOF AREA
Nashville	Store Restaurant	0.044	11.60	0.35
		0.115	3.35	0.92
Charleston	Restaurant	0.173	1.78	0.34
Ft. Worth	Restaurant	0.195	1.40	0.38

*For 35% replacement of load with solar, comparison with electrical energy costs, and an annualized solar cost of 1\$/ft²-yr

TABLE 1 (CONT'D)

HEATING ONLY PARAMETRIC STUDY ALTERNATIVES

Isolation Range: (60-80) 10^3 Langleys/heating seasonHeat Load Range: (>90) 10^3 Btu/ft²

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg*	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ROOF AREA
Washington, D.C.	Store	0.184	26.13	0.37
	Restaurant	0.480	6.22	0.96
Ft. Worth	Restaurant	0.195	1.40	0.38
Los Angeles	Restaurant	0.352	3.04	0.49
Nashville	Store	0.044	11.60	0.35
	Restaurant	0.115	3.35	0.92
Phoenix	Restaurant	0.372	0.49	0.25
Boston	Store	0.317	67.59	0.58
	Hospital	0.189	10.09	2.07
	Church, Social	0.209	25.12	0.77
	Restaurant	0.842	18.52	1.54
Madison	School	0.193	23.81	0.35
	Office	0.193	18.71	1.41
	Store	0.354	31.76	0.65
	Hospital	0.211	5.07	2.31
	Church, Social	0.232	12.49	0.85
	Restaurant	0.922	9.31	1.68
	Motel, Nursing Home	0.172	9.09	0.63
	Warehouse	0.146	13.63	0.27
	Supermarket	0.195	1.34	0.36

*For 35% replacement of load with solar, comparison with electrical energy costs, and an annualized solar cost of 1\$/ft²-yr.

TABLE 1 (CONT'D)
HEATING ONLY PARAMETRIC STUDY ALTERNATIVES

Isolation Range: (60-80) 10^3 Langleys/heating season
Heat Load Range: (>90) 10^3 Btu/ft²

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg*	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ROOF AREA
Omaha	School	0.099	8.22	0.23
	Office	0.099	6.46	0.92
	Store	0.184	11.10	0.43
	Hospital	0.109	1.76	1.51
	Church, Social	0.121	4.36	0.56
	Restaurant	0.482	3.21	1.12
	Supermarket	0.098	0.46	0.23

*For 35% replacement of load with solar, comparison with electrical energy costs, and an annualized solar cost of 1\$/ft²-yr

TABLE 1 (CONT'D)

HEATING ONLY PARAMETRIC STUDY ALTERNATIVES

Isolation Range: (>80) 10^3 Langleys/heating seasonHeat Load Range: (>90) 10^3 Btu/ft²

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg*	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ROOF AREA
Omaha	School	0.099	8.22	0.23
	Office	0.099	6.46	0.92
	Store	0.184	11.10	0.43
	Hospital	0.109	1.76	1.51
	Church Social	0.121	4.39	0.56
	Restaurant	0.482	3.21	1.12
	Supermarket	0.098	0.46	0.23
Seattle	Store	-0.305	3.50	0.60
	Church Social	-0.207	1.18	0.81
	Restaurant	-0.826	0.86	1.62
Madison	School	0.193	23.81	0.35
	Office	0.193	18.71	1.41
	Store	0.354	31.76	0.65
	Hospital	0.211	5.07	2.31
	Church Social	0.232	12.49	0.85
	Restaurant	0.922	9.31	1.68
	Motel, Nursing Home	0.172	9.09	0.63
	Warehouse	0.146	13.63	0.27
	Supermarket	0.195	1.34	0.36
Bismarck	Motel, Nursing Home	0.112	5.37	0.52
	Warehouse	0.095	8.06	0.22
	Supermarket	0.126	0.79	0.29
	Library	0.090	0.53	0.62
	School	0.125	13.99	0.29
	Office	0.125	11.02	1.15
	Store	0.228	18.61	0.53
	Hospital	0.136	2.97	1.88
	Church, Social	0.149	7.34	0.69
	Restaurant	0.596	4.86	1.38

*For 35% replacement of load with solar, comparison with electrical energy costs, and an annualized solar cost of 1\$/ft²-yr.

TABLE 2

HEATING AND COOLING PARAMETRIC STUDY ALTERNATIVES

Insolation Range: (100-130) 10^3 Langleys/year
 Cooling Load Range: (0-50) 10^3 Btu/ft²
 Ratio of Heating to Cooling Load Range: 0-5

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg.*	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ROOF AREA
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None available

*For system designed to supply 70% of heating load while letting % of cooling load vary, depending on region and building type, comparison with electrical energy costs, and an annualized solar cost of 1\$/ft²-yr.

TABLE 2 (CONT'D)

HEATING AND COOLING PARAMETRIC STUDY ALTERNATIVES

Insolation Range: (130-160) 10^3 Langleys/yearCooling Load Range: (0-50) 10^3 Btu/ft²

Ratio of Heating to Cooling Load Range: 0-.5

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg.*	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ROOF AREA
Los Angeles	Shopping Center	0.034	1.01	0.06

*For system designed to supply 70% of heating load while letting % of cooling load vary, depending on region and building type, comparison with electrical energy costs, and an annualized solar cost of 1\$/sq. ft - year.

TABLE 2 (CONT'D)
HEATING AND COOLING PARAMETRIC STUDY ALTERNATIVES

Insolation Range: (>160) 10^3 Langleys/year
Cooling Load Range: (0-50) 10^3 Btu/ft²
Ratio of Heating to Cooling Load Range: 0-.5

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg *	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ROOF AREA
Los Angeles	Shopping Center	0.034	1.01	0.06

*For system designed to supply 70% of heating load while letting % of cooling load vary, depending on region and building type, comparison with electrical energy costs, and an annualized solar cost of \$1/sq. ft-year.

TABLE 2 (CONT'D)

HEATING AND COOLING PARAMETRIC STUDY ALTERNATIVES

Insolation Range: (100-130) 10^3 Langleys/yearCooling Load Range: (50-100) 10^3 Btu/ft²

Ratio of Heating to Cooling Load Range: 0-5

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg.*	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ROOF AREA
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None available

*For system designed to supply 70% of heating load while letting % of cooling load vary, depending on region and building type, comparison with electrical energy costs, and an annualized solar cost of 1\$/ft²-yr.

TABLE 2 (CONT'D)

HEATING AND COOLING PARAMETRIC STUDY ALTERNATIVES

Insolation Range: (130-160) 10^3 Langleys/yearCooling Load Range: (50-100) 10^3 Btu/ft²

Ratio of Heating to Cooling Load Range: 0-5

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg*	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ROOF AREA
Ft. Worth	Library	0.065	0.41	0.36
	Shopping Center	0.039	0.73	0.07
	Warehouse	0.066	5.89	0.11
	Office	0.084	8.79	0.72
	School	0.084	11.20	0.18
Charleston	Library	0.050	0.53	0.33
	Shopping Center	0.023	0.54	0.03
	Warehouse	0.036	1.18	0.08
	Office	0.051	9.02	0.06
	School	0.069	13.72	0.15
	Church	0.117	9.57	0.46
Los Angeles	Supermarket	0.096	1.05	0.18

*For system designed to supply 70% of heating load while letting % of cooling load vary, depending on region and building type, comparison with electrical energy costs, and an annualized solar cost of 1\$/sq. ft-year.

TABLE 2 (CONT'D)

HEATING AND COOLING PARAMETRIC STUDY ALTERNATIVES

Insolation Range: (>160) 10^3 Langleys/year
 Cooling Load Range: (50-100) 10^3 Btu/ft²
 Ratio of Heating to Cooling Load Range: 0-.5

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg *	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ROOF AREA
Miami	Warehouse	-0.272	23.16	0.56
Phoenix	Library	0.109	0.14	0.24
	Shopping Center	0.059	0.22	0.04
	Warehouse	0.098	1.73	0.07
	Office	0.164	3.08	0.44
	School	0.146	3.69	0.12
Ft. Worth	Library	0.065	0.41	0.36
	Shopping Center	0.030	0.73	0.07
	Warehouse	0.066	5.89	0.11
	Office	0.084	8.79	0.72
	School	0.084	11.20	0.18
Los Angeles	Supermarket	0.096	1.05	0.18

*For system designed to supply 70% of heating load while letting % of cooling load vary, depending on region and building type, comparison with electrical energy costs, and an annualized solar cost of 1\$/sq. ft. - year.

TABLE 2 (CONT'D)

HEATING AND COOLING PARAMETRIC STUDY ALTERNATIVES

Insolation Range: (100-130) 10^3 Langleys/yearCooling Load Range: (>100) 10^3 Btu/ft²

Ratio of Heating to Cooling Load Range: 0-5

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg. *	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ROOF AREA
None available				

*For system designed to supply 70% of heating load while letting % of cooling load vary, depending on region and building type, comparison with electrical energy costs, and an annualized solar cost of 1\$/sq. ft - year.

TABLE 2: (CONT'D)

HEATING AND COOLING PARAMETRIC STUDY ALTERNATIVES

Insolation Range: (130-160) 10^3 Langleys/yearCooling Load Range: (>100) 10^3 Btu/ft²

Ratio of Heating to Cooling Load Range: 0-.5

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg *	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ROOF AREA
Ft. Worth	Motel, Nursing Home	0.090	4.74	0.34
	Supermarket	0.073	0.52	0.15
	Store	0.116	12.84	0.37
	Hospital	0.095	2.53	1.32
Charleston	Motel, Nursing Home	0.078	6.15	0.30
	Supermarket	0.052	0.58	0.11
	Store	0.137	19.78	0.33
	Hospital	0.074	2.95	1.14
	Restaurant	0.268	4.89	0.89

*For system designed to supply 70% of heating load while letting % of cooling load vary, depending on region and building type, comparison with electrical energy costs, and an annualized solar cost of 1\$/sq. ft - year.

TABLE 2 (CONT'D)

HEATING AND COOLING PARAMETRIC STUDY ALTERNATIVES

Insolation Range: (>160) 10^3 Langleys/yearCooling Load Range: (>100) 10^3 Btu/ft²

Ratio of Heating to Cooling Load Range: 0-.5

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg*	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ROOF AREA
Miami	Library	-0.390	0.53	2.42
	Office	-0.465	9.89	3.97
	Church, Social	-0.298	3.72	1.34
	Restaurant	-1.582	3.12	3.30
	Shopping Center	-0.520	1.85	1.02
	Hospital	-0.693	3.37	8.56
	Supermarket	-0.615	0.85	1.24
	Motel, Nursing Home	-0.547	6.24	2.32
	School	-0.366	9.78	0.78
	Store	-0.747	15.58	1.67
Phoenix	Motel, Nursing Home	0.160	1.50	0.22
	Hospital	0.199	0.93	0.84
	Supermarket	0.135	0.18	0.09
	Store	0.326	5.67	0.24
Ft. Worth	Motel, Nursing Home	0.090	4.74	0.34
	Hospital	0.095	2.53	1.32
	Supermarket	0.073	0.52	0.15
	Store	0.116	12.84	0.37

*For system designed to supply 70% of heating load while letting % of cooling load vary, depending on region and building type, comparison with electrical energy costs, and an annualized solar cost of 1\$/sq. ft. - year.

TABLE 2 (CONT'D)

HEATING AND COOLING PARAMETRIC STUDY ALTERNATIVES

Insolation Range: (100-130) 10^3 Langleys/yearCooling Load Range: (0-50) 10^3 Btu/ft²

Ratio of Heating to Cooling Load Range: .5 - 2.0

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg*	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ROOF AREA
Washington, D.C.	Warehouse	0.134	31.02	0.42
	Church	0.211	28.72	1.35
Boston	Library	0.168	5.49	1.91
	Shopping Center	0.135	12.58	0.51
	Motel, Nursing Home	0.215	58.58	1.67
	Office	0.231	113.27	3.54
Seattle	Shopping Center	-0.604	0.52	0.79

*For system designed to supply 70% of heating load while letting % of cooling load vary, depending on region and building type, comparison with electrical energy costs, and an annualized solar cost of 1\$/sq. ft - year.

TABLE 2 (CONT'D)

HEATING AND COOLING PARAMETRIC STUDY ALTERNATIVES

Insolation Range: (130-160) 10^3 Langleys/yearCooling Load Range: (0-50) 10^3 Btu/ft²

Ratio of Heating to Cooling Load Range: .5 - 2.0

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg*	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ROOF AREA
Los Angeles	Library	0.074	0.84	0.51
	Warehouse	0.052	9.03	0.14
	Office	0.119	19.10	0.96
	School	0.110	23.08	0.24
Nashville	Warehouse	-0.011	17.16	0.41
Omaha	Library	0.099	0.97	1.37
	Shopping Center	0.094	2.58	0.41
	Office	0.144	20.62	2.57
Washington, D.C.	Warehouse	0.134	31.02	0.42
	Church, Social	0.211	28.72	1.35

*For system designed to supply 70% of heating load while letting % of cooling load vary, depending on region and building type, comparison with electrical energy costs, and an annualized solar cost of 1\$/sq. ft.-year.

TABLE 2 (CONT'D)
HEATING AND COOLING PARAMETRIC STUDY ALTERNATIVES

Insolation Range: (>160) 10^3 Langleys/year
Cooling Load Range: (0-50) 10^3 Btu/ft²
Ratio of Heating to Cooling Load Range: .5-2.0

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg *	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ROOF AREA
Phoenix	Church, Social	0.211	2.26	0.34
Los Angeles	Library	0.074	0.84	0.51
	Warehouse	0.052	9.03	0.14
	Office	0.119	19.10	0.96
	School	0.110	23.08	0.24

*For system designed to supply 70% of heating load while letting % of cooling load vary, depending on region and building type, comparison with electrical energy costs, and an annualized solar cost of 1\$/sq. ft. - year.

TABLE 2 (CONT'D)
HEATING AND COOLING PARAMETRIC STUDY ALTERNATIVES

Insolation Range: (100-130) 10^3 Langleys/year
Cooling Load Range: (50-100) 10^3 Btu/ft²
Ratio of Heating to Cooling Load Range: .5 - 2.0

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg*	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ROOF AREA
Washington, D. C.	Library	0.136	2.12	1.20
	Shopping Center	0.116	5.53	0.37
	Motel, Nursing Home	0.164	21.11	0.99
	Office	0.186	44.60	2.25
	School	0.178	55.63	0.56
	Supermarket	0.182	4.42	0.56
Boston	Hospital	0.106	22.56	6.02
	Supermarket	0.212	7.67	0.85

*For system designed to supply 70% of heating load while letting % of cooling load vary, depending on region and building type, comparison with electrical energy costs, and an annualized solar cost of 1\$/sq. ft.-year.

TABLE 2 (CONT'D)

HEATING AND COOLING PARAMETRIC STUDY ALTERNATIVES

Insolation Range: (130-160) 10^3 Langleys/yearCooling Load Range: (50-100) 10^3 Btu/ft²

Ratio of Heating to Cooling Load Range: .5 - 2.0

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg *	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ROOF AREA
Ft. Worth	Church, Social	0.125	9.34	0.50
Los Angeles	Motel, Nursing Home	0.077	8.00	0.50
	Hospital	0.165	6.34	1.86
	Store	0.267	40.08	0.54
Nashville	Library	-0.008	1.14	1.17
	Shopping Center	-0.002	2.99	0.35
	Motel, Nursing Home	-0.012	12.14	1.01
	Office	-0.023	24.24	2.25
	School	-0.021	31.05	0.56
	Church, Social	-0.041	16.53	1.40
	Supermarket	-0.008	1.78	0.56
Omaha	Motel, Nursing Home	0.124	10.29	1.18
	Supermarket	0.148	1.49	0.64
Washington, D.C.	Library	0.136	2.12	1.20
	Shopping Center	0.116	5.53	0.37
	Motel, Nursing Home	0.164	21.11	0.99
	Office	0.186	44.60	2.25
	School	0.178	55.43	0.56
	Supermarket	0.182	4.42	0.56

*For system designed to supply 70% of heating load while letting % of cooling load vary, depending on region and building type, comparison with electrical energy costs, and an annualized solar cost of 1\$/sq. ft.-year

TABLE 2 (CONT'D)
HEATING AND COOLING PARAMETRIC STUDY ALTERNATIVES

Insolation Range: (>160) 10^3 Langleys/year
Cooling Load Range: (50-100) 10^3 Btu/ft²
Ratio of Heating to Cooling Load Range: .5-2.0

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg*	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ROOF AREA
Ft. Worth	Church	0.125	9.34	0.50
Los Angeles	Motel, Nursing Home	0.077	8.00	0.50
	Store	0.267	40.08	0.54

*For system designed to supply 70% of heating load while letting % of cooling load vary, depending on region and building type, comparison with electrical energy costs, and an annualized solar cost of 1\$/sq. ft.-year.

TABLE 2 (CONT'D)
HEATING AND COOLING PARAMETRIC STUDY ALTERNATIVES

Insolation Range: (100-130) 10^3 Langleys/year
Cooling Load Range: (>100) 10^3 Btu/ft²
Ratio of Heating to Cooling Load Range: .5-2.0

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg*	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ... ROOF AREA
Washington, D.C.	Hospital	0.190	11.50	3.67
	Store	0.262	80.59	1.04
	Restaurant	0.852	21.53	2.68

*For system designed to supply 70% of heating load while letting % of cooling load vary, depending on region and building type, comparison with electrical energy costs, and an annualized solar cost of 1\$/sq. ft.-year.

TABLE 2 (CONT'D)

HEATING AND COOLING PARAMETRIC STUDY ALTERNATIVES

Insolation Range: (130-160) 10^3 Langleys/yearCooling Load Range: (>100) 10^3 Btu/ft²

Ratio of Heating to Cooling Load Range: .5-2.0

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg *	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ROOF AREA
Ft. Worth	Restaurant	0.239	3.14	0.96
Los Angeles	Restaurant	0.53	9.42	1.46
Nashville	Hospital	-0.059	5.56	3.65
	Store	-0.078	36.15	1.02
	Restaurant	-0.569	7.11	2.69
Washington, D.C.	Hospital	0.190	11.50	3.67
	Store	0.262	80.59	1.04
	Restaurant	0.852	21.03	2.68

*For system designed to supply 70% of heating load while letting % of cooling load vary, depending on region and building type, comparison with electrical energy costs, and an annualized solar cost of 1\$/sq. ft.-year.

TABLE 2 (CONT'D)
HEATING AND COOLING PARAMETRIC STUDY ALTERNATIVES

Insolation Range: (>160) 10^3 Langleys/year
Cooling Load Range: (>100) 10^3 Btu/ft²
Ratio of Heating to Cooling Load Range: .5-2.0

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg *	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ROOF AREA
Phoenix	Restaurant	0.614	1.08	0.68
Ft. Worth	Restaurant	0.239	3.14	0.96
Los Angeles	Restaurant	0.530	9.42	1.46

*For system designed to supply 70% of heating load while letting % of cooling load vary, depending on region and building type, comparison with electrical energy costs, and annualized solar costs of 1\$/sq. ft.-year.

TABLE 2 (CONT'D)
HEATING AND COOLING PARAMETRIC STUDY ALTERNATIVES

Insolation Range: (100-130) 10^3 Langleys/year

Cooling Load Range: (0-50) 10^3 Btu/ft²

Ratio of Heating to Cooling Load Range: >2

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg *	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ROOF AREA
Bismarck	Library	0.037	1.36	1.84
	Shopping Center	0.056	3.92	0.56
	Motel, Nursing Home	0.065	14.29	1.51
	Warehouse	0.018	18.80	0.65
	Office	0.054	27.41	3.36
	Hospital	0.070	7.96	5.59
	School	0.039	33.31	0.84
	Church, Social	0.010	16.36	2.04
	Supermarket	-0.038	2.06	0.96
	Store	0.060	45.41	1.56
Madison	Library	0.100	2.42	2.32
	Shopping Center	0.111	6.78	0.71
	Motel, Nursing Home	0.164	26.49	1.91
	Warehouse	0.068	32.83	0.82
	Office	0.130	49.47	4.30
	Hospital	0.201	15.01	7.09
	School	0.105	60.08	1.08
	Church, Social	0.080	28.46	2.58
	Supermarket	0.164	3.85	1.10
	Store	0.191	81.67	2.00
Boston	Warehouse	0.143	73.54	0.64
	School	0.225	143.07	0.89
	Church, Social	0.278	78.66	2.26

*For system designed to supply 70% of heating load while letting % of cooling load vary, depending on region and building type, comparison with electrical energy costs and an annualized solar cost of 1\$/sq. ft.-year.

TABLE 2 (CONT'D)
HEATING AND COOLING PARAMETRIC STUDY ALTERNATIVES

Insolation Range: (100-130) 10^3 Langleys/year
Cooling Load Range: (0-50) 10^3 Btu/ft² (continued)
Ratio of Heating to Cooling Load Range: >2

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ROOF AREA
Seattle	School	-1.238	5.09	1.56
	Office	-1.229	4.22	6.23
	Store	-2.441	8.85	3.08
	Hospital	-1.432	1.41	11.07
	Church, Social	-1.714	2.65	4.26
	Restaurant	-6.746	1.97	8.42
	Motel, Nursing Home	-1.173	2.42	3.00
	Warehouse	-0.885	2.58	1.11
	Supermarket	-1.119	0.31	1.44
	Library	-0.882	0.21	3.37

*For system designed to supply 70% of heating load while letting % of cooling load vary, depending on region and building type, comparison with electrical energy costs, and an annualized solar cost of 1\$/sq. ft.-year.

TABLE 2 (CONT'D)

HEATING AND COOLING PARAMETRIC STUDY ALTERNATIVES

Insolation Range: (130-160) 10^3 Langleys/yearCooling Load Range: (0-50) 10^3 Btu/ft²

Ratio of Heating to Cooling Load Range: >2

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg *	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ROOF AREA
Los Angeles	Church, Social	0.132	13.68	0.76
Omaha	Warehouse	0.092	13.96	0.48
	School	0.125	25.34	0.65
	Church, Social	0.098	11.66	1.58
Bismarck	School	0.039	33.31	0.84
	Office	0.054	27.41	3.36
	Store	0.060	45.41	1.56
	Shopping Center	0.056	1.36	0.56
	Hospital	0.070	7.96	5.59
	Church, Social	0.010	16.36	2.04
	Motel, Nursing Home	0.065	14.29	1.51
	Warehouse	0.018	18.80	0.65
	Supermarket	-0.038	2.06	0.96
	Library	0.037	1.36	1.84

*For system designed to supply 70% of heating load while letting % of cooling load vary, depending on region and building type, comparison with electrical energy costs, and an annualized solar cost of 1\$/sq. ft.-year.

TABLE 2 (CONT'D)

HEATING AND COOLING PARAMETRIC STUDY ALTERNATIVES

Insolation Range: (>160) 10^3 Langleys/yearCooling Load Range: (0-50) 10^3 Btu/ft²Ratio of Heating to Cooling Load Range: >2

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg*	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ROOF AREA
Los Angeles	Church, Social	0.132	13.68	0.76

*For system designed to supply 70% of heating load while letting % of cooling load vary, depending on region and building type, comparison with electrical energy costs, and an annualized solar cost of 1\$/sq. ft.-year.

TABLE 2 (CONT'D)

HEATING AND COOLING PARAMETRIC STUDY ALTERNATIVES

Insolation Range: (100-130) 10^3 Langleys/year
 Cooling Load Range: (50-100) 10^3 Btu/ft²
 Ratio of Heating to Cooling Load Range: >2

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg*	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ROOF AREA
Bismarck	Restaurant	0.024	11.03	4.11
Madison	Restaurant	0.341	21.43	5.13
Boston	Store	0.199	170.00	1.75

*For system designed to supply 70% of heating load while letting % of cooling load vary, depending on region and building type, comparison with electrical energy costs, and an annualized solar cost of 1\$/sq. ft.-year.

TABLE 2 (CONT'D)

HEATING AND COOLING PARAMETRIC STUDY ALTERNATIVES

Insolation Range: (130-160) 10^3 Langleys/yearCooling Load Range: (50-100) 10^3 Btu/ft²

Ratio of Heating to Cooling Load Range: >2

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg *	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ROOF AREA
Omaha	Store	0.202	32.40	1.20
Bismarck	Restaurant	0.024	11.03	4.11

*For system designed to supply 70% of heating load while letting % of cooling load vary, depending on region and building type, comparison with electrical energy costs, and an annualized solar cost of 1\$/sq. ft.-year.

TABLE 2 (CONT'D)

HEATING AND COOLING PARAMETRIC STUDY ALTERNATIVES

Insolation Range: (>160) 10^3 Langleys/yearCooling Load Range: (50-100) 10^3 Btu/ft²Ratio of Heating to Cooling Load Range: >2

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg.*	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ROOF AREA
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None available

*For system designed to supply 70% of heating load while letting % of cooling load vary, depending on region and building type, comparison with electrical energy costs, and an annualized solar cost of 1%/sq. ft-year

TABLE 2 (CONT'D)

HEATING AND COOLING PARAMETRIC STUDY ALTERNATIVES

Insolation Range: (100-130) 10^3 Langley's/yearCooling Load Range: (>100) 10^3 Btu/ft²

Ratio of Heating to Cooling Load Range: >2

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg *	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ROOF AREA
Boston	Restaurant	0.229	38.21	4.58

*For system designed to supply 70% of heating load while letting % of cooling load vary, depending on region and building type, comparison with electrical energy costs, and an annualized solar cost of 1\$/sq. ft.-year.

TABLE 2 (CONT'D)

HEATING AND COOLING PARAMETRIC STUDY ALTERNATIVES

Insolation Range: (130-160) 10^3 Langleys /year
 Cooling Load Range: (>100) 10^3 Btu/ft²
 Ratio of Heating to Cooling Load Range: >2

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg *	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ROOF AREA
Omaha	Restaurant	0.082	6.67	3.16

*For system designed to supply 70% of heating load while letting % of cooling load vary, depending on region and building type, comparison with electrical energy costs, and an annualized solar cost of 1\$/sq. ft.-year.

TABLE 2 (CONT'D)

HEATING AND COOLING PARAMETRIC STUDY ALTERNATIVES

Insolation Range: (>160) 10^3 Langleys/yearCooling Load Range: (>100) 10^3 Btu/ft²Ratio of Heating to Cooling Load Range: >2

CLIMATIC REGION	BUILDING TYPE	COST SAVINGS \$/ft ² -bldg.*	POTENTIAL ENERGY SAVINGS, 10^{12} BTU	COLLECTOR AREA ÷ ROOF AREA
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None available

*For system designed to supply 70% of heating load while letting % of cooling load vary, depending on region and building type, comparison with electrical energy costs, and an annualized solar cost of 1\$/ft²-yr.

APPENDIX G

SOLAR HEATING AND COOLING DEMONSTRATION ACT OF 1974

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Public Law 93-409
93rd Congress, H. R. 11864
September 3, 1974

An Act

88 STAT. 1069

To provide for the early development and commercial demonstration of the technology of solar heating and combined solar heating and cooling systems

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the "Solar Heating and Cooling Demonstration Act of 1974".

FINDINGS AND POLICY

SEC. 2. (a) The Congress hereby finds that—

(1) the current imbalance between supply and demand for fuels and energy is likely to persist for some time;

(2) the early demonstration of the feasibility of using solar energy for the heating and cooling of buildings could help to relieve the demand upon present fuel and energy supplies;

(3) the technologies for solar heating are close to the point of commercial application in the United States;

(4) the technologies for combined solar heating and cooling still require research, development, testing and demonstration, but no insoluble technical problem is now foreseen in achieving commercial use of such technologies;

(5) the early development and export of viable solar heating equipment and combined solar heating and cooling equipment, consistent with the established preeminence of the United States in the field of high technology products, can make a valuable contribution to our balance of trade;

(6) the widespread use of solar energy in place of conventional methods for the heating and cooling of buildings would have a significantly beneficial effect upon the environment;

(7) the mass production and use of solar heating and cooling equipment will help to eliminate the dependence of the United States upon foreign energy sources and promote the national defense;

(8) the widespread introduction of low-cost solar energy will be beneficial to consumers in a period of rapidly rising fuel cost;

(9) innovation and creativity in the development of solar heating and combined solar heating and cooling components and systems can be fostered through encouraging direct contact between the manufacturers of such systems and the architects, engineers, developers, contractors, and other persons interested in installing such systems in buildings;

(10) evaluation of the performance and reliability of solar heating and combined solar heating and cooling technologies can be expedited by testing under carefully controlled conditions; and

(11) commercial application of solar heating and combined solar heating and cooling technologies can be expedited by early commercial demonstration under practical conditions.

(b) It is therefore declared to be the policy of the United States and the purpose of this Act to provide for the demonstration within a three-year period of the practical use of solar heating technology, and to provide for the development and demonstration within a five-year period of the practical use of combined heating and cooling technology.

Solar Heating
and Cooling Dem-
onstration Act
of 1974.
42 USC 5501
note.
42 USC 5501.

Schedule of
demonstrations.

DEFINITIONS

42 USC 5502.

SEC. 3. For purposes of this Act—

(1) the term “solar heating”, with respect to any building, means the use of solar energy to meet such portion of the total heating needs of such building (including hot water), or such portion of the needs of such building for hot water (where its remaining heating needs are met by other methods), as may be required under performance criteria prescribed by the Secretary of Housing and Urban Development utilizing the services of the Director of the National Bureau of Standards, and in consultation with the Director of the National Science Foundation, and the Administrator of the National Aeronautics and Space Administration;

(2) the terms “solar heating and cooling” and “combined solar heating and cooling”, with respect to any building, mean the use of solar energy to provide both such portion of the total heating needs of such building (including hot water) and such portion of the total cooling needs of such building, or such portion of the needs of such building for hot water (where its remaining heating needs are met by other methods) and such portion of the total cooling needs of a building, as may be required under performance criteria prescribed by the Secretary of Housing and Urban Development utilizing the services of the Director of the National Bureau of Standards, and in consultation with the Director of the National Science Foundation, and the Administrator of the National Aeronautics and Space Administration; and such term includes cooling by means of nocturnal heat radiation, by evaporation, or by other methods of meeting peakload energy requirements at nonpeakload times;

(3) the term “residential dwellings” includes previously occupied and new single family and multifamily dwellings, mobile homes, and publicly assisted housing owned by a private sponsor or a State or local housing authority not covered by section 17;

(4) the term “Administrator” means the Administrator of the National Aeronautics and Space Administration;

(5) the term “Secretary” means the Secretary of Housing and Urban Development; and

(6) the term “Director” means the Director of the National Science Foundation.

CONDUCT OF ACTIVITIES IN SOLAR HEATING AND COOLING TECHNOLOGIES BY NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

72 Stat. 429.

SEC. 4. Section 203 of the National Aeronautics and Space Act of 1958 (42 U.S.C. 2473) is amended by redesignating subsection (b) as subsection (c), and by inserting immediately after subsection (a) the following new subsection:

“(b) The Administration shall initiate, support, and carry out such research, development, demonstrations, and other related activities in solar heating and cooling technologies (to the extent that funds are appropriated therefor) as are provided for in sections 5, 6, and 9 of the Solar Heating and Cooling Demonstration Act of 1974.”

DEVELOPMENT AND DEMONSTRATION OF SOLAR HEATING SYSTEMS TO BE USED IN RESIDENTIAL DWELLINGS

42 USC 5503.

SEC. 5. (a) The Administrator and the Secretary shall promptly initiate and carry out a program, as provided in this section, for the development and demonstration of solar heating systems (including

collectors, controls, and thermal storage) for use in residential dwellings.

(b) (1) Within 120 days after the date of the enactment of this Act, the Secretary, utilizing the services of the Director of the National Bureau of Standards and in consultation with the Administrator and the Director, shall determine, prescribe, and publish—

Publication
of performance
criteria.

(A) interim performance criteria for solar heating components and systems to be used in residential dwellings, and

(B) interim performance criteria (relating to suitability for solar heating) for such dwellings themselves, taking into account in each instance climatic variations existing between different geographic areas.

(2) As soon as possible after the publication of the performance criteria prescribed under paragraph (1), the Secretary, in consultation with the Director of the National Bureau of Standards and the Administrator, will select on the basis of open competition a number of designs for various types of residential dwellings suitable for and adapted to the installation of solar heating systems meeting the performance criteria prescribed under paragraph (1) (A).

Design
selection.

(c) The Administrator, in accordance with the applicable provisions of title II of the National Aeronautics and Space Act of 1958 and under program guidelines established jointly by the Administrator and the Secretary, shall, after consultation with the Secretary—

Contracts
and grants.
72 Stat. 427.
42 USC 2471 et
seq.

(1) enter into such contracts and grants as may be necessary or appropriate for the development (for commercial production and residential use) of solar heating systems meeting the performance criteria prescribed under subsection (b) (1) (A) (including any further planning and design which may be required to conform with the specifications set forth in such criteria); and

(2) enter into contracts with a number of persons or firms for the procurement of solar heating components and systems meeting such performance criteria (including adequate numbers of spare and replacement parts for such systems).

(d) The Secretary shall (1) arrange for the installation of solar heating systems procured by the Administrator under subsection (c) (2) in a substantial number of residential dwellings and (2) provide for the satisfactory operation of such installations during the demonstration period. Title to and ownership of any dwellings constructed hereunder and of solar heating systems installed hereunder may be conveyed to purchasers or owners of such dwellings under terms and conditions prescribed by the Secretary, including an express agreement that any such purchaser or owner shall, in such manner and form and on such terms and conditions as the Secretary may prescribe, observe and monitor (or permit the Secretary to observe and monitor) the performance and operation of such system for a period of five years, and that such purchaser or owner (including any subsequent owner and occupant of the property who also makes such an agreement) shall regularly furnish the Secretary with such reports thereon as the agreement may require.

Installation
and monitoring.

(e) The Secretary of Defense shall arrange for the installation of solar heating systems procured by the Administrator under subsection (c) (2) in a substantial number of residential dwellings which are located on Federal or federally administered property where the performance and operation of such systems can be regularly and effectively observed and monitored by designated Federal personnel.

Federal prop-
erty installa-
tions.

(f) The Secretary and the Secretary of Defense, and officials responsible for administering Federal or federally administered property, shall coordinate their activities under this section to assure that solar heating systems are installed in a substantial number of resi-

Variety of in-
stallations.

dential dwellings and in a sufficient number of different geographic areas under varying climatic conditions to constitute a realistic and effective demonstration in support of the objectives of this Act.

DEVELOPMENT AND DEMONSTRATION OF COMBINED SOLAR HEATING AND COOLING SYSTEMS TO BE USED IN RESIDENTIAL DWELLINGS

42 USC 5504.

SEC. 6. (a) The Administrator and the Secretary shall promptly initiate and carry out a program, as provided in this section, for the development and demonstration of combined solar heating and cooling systems (including collectors, controls, and thermal storage) for use in residential dwellings.

Publication
of performance
criteria.

(b) (1) As soon as possible after the date of the enactment of this Act, the Secretary, utilizing the services of the Director of the National Bureau of Standards and in consultation with the Administrator and the Director, shall determine, prescribe, and publish—

(A) interim performance criteria for combined solar heating and cooling components and systems to be used in residential dwellings, and

(B) interim performance criteria (relating to suitability for solar heating and cooling) for such dwellings themselves, taking into account in each instance climatic variations existing between different geographic areas.

Design selec-
tion.

(2) As soon as possible after the publication of the performance criteria prescribed under paragraph (1) (and if possible before the completion of the research and development provided for in subsection (c)), the Secretary, in consultation with the Director of the National Bureau of Standards and the Administrator, will select on the basis of open competition a number of designs for various types of residential dwellings suitable for and adapted to the installation of combined solar heating and cooling systems meeting the performance criteria prescribed under paragraph (1) (A).

Technological
research and
development.

(c) During the period immediately following the publication of performance criteria under subsection (b) (1), the Administrator, in coordination with the Director, shall undertake and conduct with respect to solar heating and cooling a program of research, development, and testing designed to provide the additional technological resources necessary for the development and commercial application of combined solar heating and cooling systems as contemplated by the program under this section.

Contracts and
grants.
72 Stat. 427.
42 USC 2471 et
seq.

(d) The Administrator, in accordance with the applicable provisions of title II of the National Aeronautics and Space Act of 1958 and under program guidelines established jointly by the Administrator and the Secretary, and at the earliest possible time during or immediately after the period specified in subsection (c), shall, after consultation with the Secretary—

(1) enter into such contracts and grants as may be necessary or appropriate for the development (for commercial production and residential use) of combined solar heating and cooling systems meeting the performance criteria prescribed under subsection (b) (1) (A) (including any further planning and design which may be required to conform with the specifications set forth in such criteria or to reflect the results of the activities conducted under subsection (c)); and

(2) enter into contracts with a number of persons or firms for the procurement of combined solar heating and cooling systems meeting such performance criteria (including adequate numbers of spare and replacement parts for such systems).

Installation and
monitoring.

(e) The Secretary shall (1) arrange for the installation of combined solar heating and cooling systems procured by the Administrator

under subsection (d)(2) in a substantial number of residential dwellings and (2) provide for the satisfactory operation of such installations during the demonstration period. Title to and ownership of any dwellings constructed hereunder and of combined solar heating and cooling systems installed hereunder may be conveyed to purchasers or owners of such dwellings under terms and conditions prescribed by the Secretary, including an express agreement that any such purchaser or owner shall, in such manner and form and on such terms and conditions as the Secretary may prescribe, observe and monitor (or permit the Secretary to observe and monitor) the performance and operation of such system for a period of five years, and that such purchaser or owner (including any subsequent owner and occupant of the property who also makes such an agreement) shall regularly furnish the Secretary with such reports thereon as the agreement may require.

(f) The Secretary of Defense shall arrange for the installation of combined solar heating and cooling systems procured by the Administrator under subsection (d)(2) in a substantial number of residential dwellings which are located on Federal or federally administered property where the performance and operation of such systems can be regularly and effectively observed and monitored by designated Federal personnel.

Federal property installations.

(g) The Secretary and the Secretary of Defense, and officials responsible for administering Federal or federally administered property, shall coordinate their activities under this section to assure that combined solar heating and cooling systems are installed in a substantial number of residential dwellings and in a sufficient number of geographic areas under varying climatic conditions to constitute a realistic and effective demonstration in support of the objectives of this Act.

Variety of installations.

COMPREHENSIVE PROGRAM DEFINITION

SEC. 7. (a) The Administrator and the Secretary are authorized and directed to prepare a comprehensive plan for the conduct of the development and demonstration activities under sections 5 and 6. In the preparation of such plan, the Administrator and Secretary shall consult with the Director of the National Bureau of Standards, the Director, the Secretary of Defense, and other Federal agencies and private organizations as appropriate.

42 USC 5505.

(b) The Administrator and the Secretary shall transmit such comprehensive program plan to the President and to each House of the Congress. The plan shall be transmitted within 120 days after the date of the enactment of this Act.

Report to President and Congress.

TEST PROCEDURES AND DEFINITIVE PERFORMANCE CRITERIA

SEC. 8. As soon as feasible, and utilizing data available from the demonstration programs under sections 5 and 6, the Secretary, utilizing the services of the Director of the National Bureau of Standards and in consultation with the Administrator and the Director shall determine, prescribe, and publish in the Federal Register in accordance with the applicable provisions regarding rulemaking prescribed by section 553 of title 5, United States Code—

42 USC 5506.

(1) definitive performance criteria for solar heating and combined solar heating and cooling components and systems to be used in residential dwellings, taking into account climatic variations existing between different geographic areas;

Publication in Federal Register.

80 Stat. 383.

(2) definitive performance criteria (relating to suitability for solar heating and for combined solar heating and cooling) for

such dwellings, taking into account climatic variations existing between different geographic areas; and

(3) procedures whereby manufacturers of solar heating and combined solar heating and cooling components and systems shall have their products tested in order to provide certification that such products conform to the performance criteria established under paragraph (1).

DEVELOPMENT AND DEMONSTRATION OF SOLAR HEATING AND COMBINED SOLAR HEATING AND COOLING SYSTEMS FOR COMMERCIAL BUILDINGS

42 USC 5507.

SEC. 9. The Administrator, in consultation with the Secretary, the Director, the Administrator of General Services, and the Director of the National Bureau of Standards and concurrently with the conduct of the programs under sections 5 and 6, shall enter into arrangements with appropriate Federal agencies to carry out such projects and activities (including demonstration projects) with respect to apartment buildings, office buildings, factories, crop-drying facilities and other agricultural structures, public buildings (including schools and colleges), and other non-residential, commercial, or industrial buildings, taking into account the special needs of and individual differences in such buildings based upon size, function, and other relevant factors, as may be appropriate for the early development and demonstration of solar heating and combined solar heating and cooling systems suitable and effective for use in such buildings.

SOLAR HEATING AND COOLING RESEARCH BY NATIONAL SCIENCE FOUNDATION

42 USC 5508.

SEC. 10. (a) The Director shall conduct a program of applied research relevant to (1) the improvement of solar heating components and systems and (2) the development and commercial application of combined solar heating and cooling components and systems as contemplated by the programs under this Act.

(b) The Director shall apprise the Secretary and the Administrator on a continuing basis of the results of the programs being conducted in accordance with subsection (a), and the Secretary and the Administrator shall insure that such results, where appropriate, are incorporated into the development and demonstration programs established by this Act.

COORDINATION, MONITORING, AND LIAISON

42 USC 5509.

SEC. 11. (a) The Secretary, utilizing the services of the Director of the National Bureau of Standards and in coordination with such other Government agencies as may be appropriate, shall—

(1) monitor the performance and operation of solar heating and combined solar heating and cooling systems installed in residential dwellings under this Act;

(2) collect and evaluate data and information on the performance and operation of solar heating and combined solar heating and cooling systems installed in residential dwellings under this Act; and

(3) from time to time, carrying out such studies and investigations and take such other actions, including the submission of special reports to the Congress when appropriate, as may be necessary to assure that the programs for which the Secretary is responsible under this Act effectively carry out the policy of this Act.

Reports to Congress.

(b) In the development of the performance criteria and test procedures required under sections 5, 6, and 8, the Secretary shall work

closely with the appropriate scientific, technical, and professional societies and industry representatives to insure the best possible use of available expertise in this area.

(c) The Secretary shall also maintain continuing liaison with the building industry and related industries and interests, and with the scientific and technical community during and after the period of the programs carried out under this Act, in order to assure that the projected benefits of such programs are and will continue to be realized.

DISSEMINATION OF INFORMATION AND OTHER ACTIONS TO PROMOTE PRACTICAL USE OF SOLAR HEATING AND COOLING TECHNOLOGIES

SEC. 12. (a) The Secretary shall take all possible steps to assure that full and complete information with respect to the demonstrations and other activities conducted under this Act is made available to Federal, State, and local authorities, the building industry and related segments of the economy, the scientific and technical community, and the public at large, both during and after the close of the programs under this Act, with the objective of promoting and facilitating to the maximum extent feasible the early and widespread practical use of solar energy for the heating and cooling of buildings throughout the United States. In accordance with regulations prescribed under section 16 such information shall be disseminated on a coordinated basis by the Secretary, the Administrator, the Director of the National Bureau of Standards, the Director, the Commissioner of the Patent Office, and other appropriate Federal offices and agencies. 42 USC 5510.

(b) In addition, the Secretary shall—

(1) study and investigate the effect of building codes, zoning ordinances, tax regulations, and other laws, codes, ordinances, and practices upon the practical use of solar energy for the heating and cooling of buildings;

(2) determine the extent to which such laws, codes, ordinances, and practices should be changed to permit or facilitate such use, and the methods by which any such changes may best be brought about; and

(3) study the necessity of a program of incentives to accelerate the commercial application of solar heating and cooling technology.

(c) (1) In carrying out his functions under subsections (a) and (b) the Secretary, utilizing the capabilities of the National Aeronautics and Space Administration, the Department of Commerce, and the National Science Foundation to the maximum extent possible, shall establish and operate a Solar Heating and Cooling Information Data Bank (hereinafter in this subsection referred to as the "bank") for the purpose of collecting, reviewing, processing, and disseminating solar heating and cooling information and data in a timely and accurate manner in support of the objectives of this Act.

Solar Heating
and Cooling In-
formation Data
Bank.
Establishment.

(2) Information and data compiled in the bank shall include—

(A) technical information (including reports, journal articles, dissertations, monographs, and project descriptions) on solar energy research, development, and applications;

(B) technical information on the design, construction, and maintenance of buildings compatible with solar heating and cooling concepts;

(C) physical and chemical properties of the materials required for solar heating and cooling;

(D) climatic conditions in appropriate areas of the United States, including those areas where the demonstrations are to be located; and

(E) engineering performance of devices utilized in solar heating and cooling or to be employed in the demonstrations.

(3) In accordance with regulations prescribed under section 16, the Secretary shall provide retrieval and dissemination services to cover the solar heating and cooling information described under paragraph (2) for—

(A) Federal, State, and local government organizations that are active in the area of energy resources (and their contractors);

(B) universities, colleges, and other nonprofit organizations; and

(C) private persons, upon request, in appropriate cases.

(4) In carrying out his functions under this subsection, the Secretary shall utilize, when feasible, the existing data base of scientific and technical information in Federal agencies, adding to such data base any information described in paragraph (2) which does not already reside in such base.

Reports to
President and
Congress.

(d) Each Federal officer and agency having functions under this Act shall include in his or its annual report to the President and the Congress a full and complete description of his or its activities (current and projected) under this Act, along with his or its recommendations for legislative, administrative, or other action to improve the programs under this Act or to achieve the objectives of this Act more promptly and effectively. In addition, the Secretary shall submit annually to the President and the Congress a special report summarizing in appropriate detail all of the activities (current and projected) of the various Federal officers and agencies having functions under this Act, with the objective of presenting a comprehensive overall view of such programs.

LIMITATIONS ON FEDERALLY ASSISTED OR FEDERALLY CONSTRUCTED HOUSING

42 USC 5511.

SEC. 13. (a) (1) In determining the maximum dollar amount of any federally assisted mortgage loan (as defined in subsection (b)) or the maximum per unit or other cost or floor area limitation of any federally constructed housing (as defined in subsection (c)), where the law establishing the program under which the loan is made or the housing is constructed specifies such maximum per unit or other cost or floor area limitation and the structure involved is furnished with solar heating or combined solar heating and cooling equipment under the demonstration program established by section 5, 6, or 9, the maximum amount or cost or floor area limitation so specified which is applicable to such structure shall be deemed to be increased by the amount by which (as determined by the Secretary or the Secretary of Defense, as appropriate) the price or cost or floor area limitation of the structure including such solar heating or combined solar heating and cooling equipment exceeds the price or cost or floor area limitation of the structure with such equipment replaced by conventional heating equipment or conventional heating and cooling equipment (as the case may be).

(2) In addition, in the case of a federally assisted mortgage loan, the cost excess specified in subsection (a) shall be fully taken into account in determining the value or cost of the structure involved for purposes of applying any statutory provision specifying the maximum loan-to-value or -cost ratio; except that, if the law specifies different rates of downpayment for successive increments of such value or cost, the lowest such rate shall apply to the additional cost attributable to the solar heating or combined solar heating and cooling equipment, and such equipment shall otherwise be excluded in determining the total value or cost of the structure.

(b) As used in subsection (a), the term "mortgage loan" means a loan which is made to finance the purchase or construction of a residence or any other building or structure; and the term "federally assisted mortgage loan" means a mortgage loan which—

"Mortgage loan" and "federally assisted mortgage loan."

(1) is made in whole or in part by any lender the deposits or accounts of which are insured by any agency of the Federal Government, or is made in whole or in part by any lender which is itself regulated by any agency of the Federal Government; or

(2) is made in whole or in part, or insured, guaranteed, supplemented, or assisted in any way, by the Secretary or any other officer or agency of the Federal Government or under or in connection with a housing, urban development, or related program administered by the Secretary or a housing or related program administered by any other such officer or agency; or

(3) is eligible for purchase by the Federal National Mortgage Association, the Government National Mortgage Association, or the Federal Home Loan Mortgage Corporation, or from any financial institution from which it could be purchased by the Federal Home Loan Mortgage Corporation; or

(4) is made in whole or in part by any "creditor," as defined in section 103(f) of the Consumer Credit Protection Act of 1968 (15 U.S.C. 1602(f)), who makes or invests in residential real estate loans aggregating more than \$1,000,000 per year.

82 Stat. 147.

(c) As used in subsection (a), the term "federally constructed housing" means (1) residential or multifamily housing which is constructed by agencies of the Federal Government to provide dwelling accommodations for particular types or classes of persons under programs administered by such Federal agencies (including all housing constructed by the Department of Defense to provide dwelling accommodations for personnel of the armed services or for such personnel and their families), and (2) residential or multifamily housing which is constructed by agencies of State or local government, with financial assistance in any form from the Federal Government, to provide dwelling accommodations for particular types or classes of persons under programs administered by such State or local agencies.

"Federally constructed housing."

ENCOURAGEMENT AND PROTECTION OF SMALL BUSINESS

SEC. 14. In carrying out their functions under this Act, all Federal officers and agencies shall take steps to assure that small business concerns will have realistic and adequate opportunities to participate in the programs under this Act to the maximum extent possible.

42 USC 5512.

PRIORITIES

SEC. 15. The Secretary shall set priorities as far as possible consistent with the intent and operation of this Act in accordance with the following criteria:

42 USC 5513.

(a) The residential dwellings and other buildings which will be part of the demonstration programs referred to in sections 5, 6, and 9 shall be located in a sufficient number of different geographic areas in the United States to assure a realistic and effective demonstration of the solar heating systems and combined solar heating and cooling systems involved, and of the dwellings and other buildings themselves, in both rural and urban locations and under climatic conditions which vary as much as possible.

Variety of locations and conditions.

88 STAT. 1078

Costs. (b) Consideration shall be given to projected costs of commercial production and maintenance of the solar heating systems and combined solar heating and cooling systems utilized in the demonstration programs.

Cost sharing. (c) Encouragement should be given in the conduct of programs under this Act to those projects in which funds, appropriated by any State or political subdivision thereof for the purpose of sharing costs with the Federal Government for the purchase and installation of solar heating or combined solar heating and cooling components and systems, are committed before or after the date of the enactment of this Act.

REGULATIONS

42 USC 5514. SEC. 16. The Administrator and the Secretary in consultation with the Director of the National Bureau of Standards, the Director, the Administrator of the General Services Administration, the Secretary of Defense, and other appropriate officers and agencies, shall prescribe such regulations as may be necessary or appropriate to carry out this Act promptly and efficiently. Each such officer or agency, in consultation with the Administrator and the Secretary, may prescribe such regulations as may be necessary or appropriate to carry out his or its particular functions under this Act promptly and efficiently.

USE OF PUBLICLY ASSISTED HOUSING

42 USC 5515. SEC. 17. The Secretary shall make appropriate use of publicly assisted housing and particularly low-rent housing assisted under the United States Housing Act of 1937 in demonstrating solar heating systems and combined solar heating and cooling systems under this Act.

TRANSFER OF FUNCTIONS

42 USC 5516. SEC. 18. Within sixty days after the effective date of the law creating the Energy Research and Development Administration or any other law creating a permanent Federal organization or agency having jurisdiction over the energy research and development functions of the United States (or within sixty days after the enactment of this Act if the effective date of such law occurs prior to the enactment of this Act), the energy research and development functions vested in the National Aeronautics and Space Administration and the National Science Foundation under this Act and any funds which may have been appropriated pursuant to section 19 of this Act, to the extent necessary or appropriate, may, in accordance with regulations prescribed by the Office of Management and Budget, be transferred to and vested in the Energy Research and Development Administration or such other organization or agency.

AUTHORIZATION OF APPROPRIATIONS

42 USC 5517. SEC. 19. (a) There is hereby authorized to be appropriated to the National Aeronautics and Space Administration for the fiscal year ending June 30, 1975, \$5,000,000, to remain available until expended, to carry out the functions vested in the Administrator by this Act. (b) There is hereby authorized to be appropriated to the Department of Housing and Urban Development for the fiscal year ending June 30, 1975, \$5,000,000, to remain available until expended. Any

September 3, 1974

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sums so appropriated shall be available (1) to carry out the functions vested in the Secretary of Housing and Urban Development by this Act, and (2) for transfer to the Department of Defense, the National Bureau of Standards, and the General Services Administration to enable them to carry out their respective functions under this Act.

(c) There is hereby authorized to be appropriated for the fiscal years ending June 30, 1976, 1977, 1978, and 1979, \$50,000,000 in the aggregate to carry out the programs established by this Act.

Approved September 3, 1974.

LEGISLATIVE HISTORY:

HOUSE REPORTS: No. 93-769 (Comm. on Science and Astronautics) and No. 93-1278 (Comm. of Conference).

SENATE REPORTS: No. 93-734 (Comm. on Aeronautical and Space Sciences), No. 93-847 (Comm. on Banking, Housing and Urban Affairs and Comm. on Labor and Public Welfare) and No. 93-1083 (Comm. of Conference).

CONGRESSIONAL RECORD, Vol. 120 (1974):

Feb. 13, considered and passed House.

May 21, considered and passed Senate, amended.

Aug. 12, Senate agreed to conference report.

Aug. 21, House agreed to conference report.

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FIGURE A.9

COLLECTOR AREA FOR 70% COMBINED HEATING & COOLING AND 80% HOT WATER FOR CHARACTERISTIC BUILDING OF 2000 FT² FLOOR AREA AND 9 AND 17 BTU/FT² PER DEGREE-DAY BUILDING HEATING AND COOLING REQUIREMENTS, RESPECTIVELY.

FIGURE B.1

COST IN $\$/10^6$ BTU FOR DELIVERABLE AND
USABLE SOLAR ENERGY FOR 70% OF HEATING
REQUIREMENT, PER $\$/\text{FT}^2$ OF COLLECTOR
IN YEARLY FIXED CHARGES (I.E. ABOUT
 $\$7/\text{FT}^2$ OF COLLECTOR, FOR SOLAR SYSTEM
FIRST COST); OR, FT^2 OF COLLECTOR PER
 10^6 BTU PER YEAR.

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FIGURE B.6

SAVINGS, $\$/\text{ft}^2$ OF COLLECTOR ACCUMULATED OVER 25-YEAR PERIOD BY 70% SOLAR ENERGY REPLACEMENT OF ELECTRIC RESISTANCE HEATING, LESS $\$15/\text{ft}^2$ OF COLLECTOR FOR SOLAR SYSTEM FIRST COSTS, ASSUMING 5% ANNUAL INCREASE IN ELECTRICITY COST.