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A REVIEW OF ENERGY DEMAND AND
CONSERVATION SCENARIOS IN THE
RESIDENTIAL AND COMMERCIAL SECTORS

ARGONNE NATIONAL LABORATORY

ENERGY AND ENVIRONMENTAL SYSTEMS

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RESIDENTIAL AND COMMERCIAL SECTORS

by

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August 1978

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1 INTRODUCTION

1.1 PURPOSE

The purpose of this study is three-fold:

- A. To review and summarize existing data on energy demand, within the framework of geographical regions and specific residential or commercial building types, for the time frames of 1980-85, 1985-90, 1990-2000.
- B. To review and summarize a variety of proposed energy conservation scenarios. Apply each scenario to the energy consumption data for each time frame, and establish the amounts of energy conserved by each scenario.
- C. Establish a base energy demand model for specific residential or commercial building types within each geographical region. These base models could then be used in conjunction with existing steady-state energy demand models to help ascertain energy conservation strategies for individual buildings.

1.2 METHODOLOGY

In general, the residential and commercial sectors were studied independently of each other. Energy demand for each sector was divided into 100 cells along three dimensions: (a) geographic region (4 regions); (b) building types (5 types); and (c) end uses (5 uses). To the extent possible, with limited data and time, demand was established for each region by building type, and in each building type by end use.

Construction parameters for the residential and commercial sectors were divided into 140 cells along three dimensions: (a) geographic region (4 regions); (b) building type (5 types); and (c) construction variables (7 variables).

Energy conservation scenarios were drawn from a variety of sources and include prescriptive, performance, mechanical and passive approaches to energy conservation. Because the residential and commercial sectors were studied independently of each other, not all scenarios proposed for one sector occur in the other sector. In all, some 22 scenarios were proposed (12 residential and 10 commercial), of which 8 scenarios are identical in both sectors.

1.3 ASSUMPTIONS

Because of a lack of certain data, it was necessary to rely heavily on the assumptions and data established in three documents: (a) The National Plan, Vol-

ume 1¹; (b) Project Independence²; and (c) The MOPPS Report³. As better data becomes available it is possible to verify the assumptions or alter and refine the conclusions of this study accordingly.

Specific assumptions that apply to energy demand, construction variables or conservation scenarios are outlined in the Residential, Commercial, and Conservation Scenario Sections of this study. That is, sections 2.0, 3.0, and 4.0, respectively.

¹A National Plan for Energy RD&D, Vol. 1, USGPO, 1975, ERDA-48.

²Project Independence, Vol. 1, USGPO, 1974, FEA.

³MOPPS, ERDA Review Draft, 1977.

2 RESIDENTIAL SECTOR

2.1 GEOGRAPHIC REGIONS

Both Project Independence, and the MOPPS Report divided the continental U.S. into four geographic regions, shown in Fig. 1.

FIG. 1: FOUR RESIDENTIAL AND COMMERCIAL GEOGRAPHICAL REGIONS¹

These four regions were also used to evaluate both the Residential and Commercial Sectors in this study.

The use of these four regions incorporated the heating and cooling design assumptions shown in Table 1.

These assumptions were used in the Project Independence Report to help determine individual building energy consumption. In all residential building types annual energy consumption was established by the Degree-Day Method.²

¹Mopps Report, p. 3-13.

²ASHRAE, 1973 Systems Handbook, Ch. 43.

TABLE 1: REGIONAL HEATING & COOLING DESIGN ASSUMPTIONS

REGION	EXAMPLE CITY	HEATING			COOLING	
		Degree Days ¹	Design Δt ¹	tMean ²	Design Δt ¹	Equiv. Op. Hrs. ¹
Northeast	Norwalk, Conn.	5400	70	36	15	300
North Central	Detroit, Mich.	6200	75	37	15	500
South	Pine Bluff, Ark.	2800	50	50	25	1600
West	Boswell, N.M.	3800	55	48	25	1600

2.2 RESIDENTIAL BUILDING TYPES & INVENTORY

There were five residential building types proposed in Project Independence. These were: (a) mobile home (MH); (b) single-family - detached (SFD); (c) low density/single-family - attached (LD); (d) low rise (LR); and (e) high rise (HR).

The use of these building types incorporated the construction assumptions shown in Table 2.

TABLE 2: CONSTRUCTION ASSUMPTIONS

Building Type	Avg. Floor Area	Avg. U (Glazing)	Avg. R (Opaque)	Avg. No. Stories 1 Story = 8 ³	Glazing % of Total Wall Area	No. of DU'S Per. Bldg. Type
MH ¹	720	1.1	9	0.9	8.5	1
SFD ¹	1560	1.1	11	See Note	15	1
LD ¹	1100	1.1	11	1-2	12	2-4
LR ¹	900	1.1	11	3	15	24
HR ¹	900	1.1	11	10	40	60

Note: Avg. No. of stories for SFD is dependent upon the region: NE = 1.5, NC = 1.3, S = 1.1, W = 1.2⁴.

¹Project Independence, p. 79.

²ASHRAE, 1973 Systems Handbook, p. 43.3-43.8.

³Project Independence, p. 77.

⁴Project Independence, p. 78.

A crucial input to developing energy consumption is the quantification and projection of the building inventory. Project Independence projected its inventory only to 1990. The MOPPS data was projected to the year 2000. Fig. 2 shows a comparison between the MOPPS data and the Project Independence data.

Note: MOPPS = solid line.
P. Ind. = dashed and broken line.

FIG. 2: RESIDENTIAL INVENTORY (UNITS x 10⁶)^{1,2}

Because of the reasonable fit between the MOPPS and PI data, it was decided to use the PI data. This decision was made because the assumptions upon which the data was generated were similar, between MOPPS & PI, and the PI data was disaggregated to a greater extent.

Table 3 shows the Project Independence data extrapolated to the year 2000.

2.3 PERCENT OF RESIDENTIAL ENERGY CONSUMPTION BY END USE

In the residential sector, 5 end uses were identified in both the MOPPS & PI reports. These were: (a) space heating; (b) space cooling; (c) domestic hot water (DHW); (d) lighting and appliances; and (e) cooking.³

¹Project Independence, p. 56.

²MOPPS, p. 3-20.

³Project Independence, p. 32-35.

TABLE 3: RESIDENTIAL INVENTORY (D.U. x 10⁶)

	1985 INVENTORY ¹	1985-1990 NEW CONS. ¹ T. ¹	1985-1990 REMOVALS ¹	1990 INVENTORY ¹	1990-2000 NEW CONS. ¹ T. ²	1990-2000 REMOVALS ²	2000 INVENTORY ²
NORTH EAST U.S.	20.68	2.54	1.37	21.85	2.10	1.57	22.38
Mobile Home	0.92	0.27	0.17	1.02	0.17	0.21	0.98
Single Family	10.48	1.18	0.25	11.41	1.26	0.31	12.36
Low-Density	4.59	0.52	0.60	4.52	0.30	0.62	4.20
Low-Rise	2.31	0.33	0.13	2.50	0.21	0.17	2.54
High-Rise	2.38	0.24	0.22	2.40	0.16	0.26	2.30
CENTRAL U.S.	23.42	2.94	1.75	24.61	2.88	1.87	25.62
Mobile Home	1.88	0.52	0.35	2.05	0.44	0.47	2.02
Single Family	15.76	1.57	0.79	16.54	1.71	0.87	17.38
Low-Density	3.38	0.50	0.36	3.52	0.44	0.34	3.62
Low-Rise	1.68	0.24	0.16	1.76	0.24	0.10	1.90
High-Rise	0.72	0.11	0.09	0.74	0.05	0.09	0.70
SOUTHERN U.S.	29.35	4.80	2.04	32.11	4.26	1.98	34.89
Mobile Home	2.99	0.84	0.54	3.29	0.74	0.70	3.33
Single Family	19.94	2.73	0.99	21.68	3.01	0.75	23.94
Low-Density	3.58	0.75	0.34	3.99	0.73	0.34	4.38
Low-Rise	2.18	0.33	0.11	2.41	0.17	0.11	2.47
High-Rise	0.65	0.15	0.06	0.74	0.11	0.08	0.77
WESTERN U.S.	15.36	2.27	1.28	16.34	9.55	0.98	24.91
Mobile Home	1.04	0.24	0.19	1.09	1.59	0.18	2.50
Single Family	9.19	1.09	0.55	9.73	4.35	0.28	13.80
Low-Density	2.51	0.47	0.24	2.74	1.65	0.26	4.13
Low-Rise	2.06	0.34	0.24	2.15	1.21	0.15	3.21
High-Rise	0.56	0.13	0.06	0.63	0.69	0.07	1.25
U.S. TOTAL	88.81	12.55	6.45	94.90	19.23	6.33	107.78
Mobile Home	6.83	1.87	1.24	7.45	2.94	1.56	8.83
Single Family	55.37	6.57	2.59	59.36	10.33	2.21	67.48
Low-Density	14.06	2.25	1.54	14.77	3.12	1.56	16.33
Low-Rise	8.24	1.24	0.65	8.82	1.83	0.53	10.12
High-Rise	4.31	0.63	0.44	4.50	1.02	0.50	5.02

¹Project Independence, p. 56.²Extrapolated from Project Independence, p. 56.

End use is dependent upon consumption patterns by region and building type. Although some end uses (e.g.: DHW) have similar energy demands in all parts of the country, the DHW % of the total building consumption may vary considerably from one geographic region to another.

Table 4 shows the average percent of the total energy consumption for each end use by building type, in each region.

TABLE 4: PERCENT OF TOTAL ENERGY DEMAND BY END USE

		% OF TOTAL ENERGY DEMAND FOR EACH END USE				
Region	Bldg. Type	Heating ¹ (%)	Cooling ¹ (%)	DHW ¹ (%)	Light & App. ¹ (%)	Cooking ¹ (%)
NORTH EAST	MH	65.2	8.0	10.0	11.7	4.7
	SFD	65.0	8.1	14.5	10.0	2.4
	LD	67.5	8.3	11.4	9.7	3.1
	LR	55.7	7.1	17.8	13.7	5.7
	HR	52.4	7.2	19.4	14.8	6.2
NORTH CENTRAL	MH	57.2	11.1	11.9	13.9	5.9
	SFD	59.6	11.7	15.6	10.8	2.3
	LD	62.1	12.0	13.4	10.5	2.0
	LR	50.5	10.0	19.0	14.9	6.5
	HR	48.3	10.0	20.8	15.9	5.0
SOUTH	MH	39.4	26.8	12.9	15.0	5.9
	SFD	42.3	29.0	15.5	10.6	2.6
	LD	43.5	29.5	13.3	10.5	3.2
	LR	36.0	24.6	18.8	14.7	5.9
	HR	33.5	24.2	20.4	15.6	6.3
WEST	MH	48.5	17.8	12.9	14.9	5.9
	SFD	52.2	19.2	15.6	10.7	2.3
	LD	53.4	19.6	13.3	10.5	3.2
	LR	44.2	16.6	18.8	14.7	5.7
	HR	41.3	16.2	20.5	15.7	6.3

2.4 RESIDENTIAL ENERGY CONSUMPTION BY REGION AND BUILDING TYPE

Energy consumption by region is shown in Table 5 for the time frames of 1985, 1990, and 2000.

Within each region it is possible to summarize energy consumption by building type. See Table 6.

¹Extrapolated from Project Independence, p. 34 & 56.

TABLE 5: ENERGY CONSUMPTION, BY REGION

Region	Energy Consumption ($\times 10^{15}$ Btu)		
	1985	1990	2000
NORTH EAST	4.085 ¹	4.319 ²	4.788 ¹
NORTH CENTRAL	4.997 ¹	5.319 ²	5.955 ¹
SOUTH	3.556 ¹	3.918 ²	4.643 ¹
WEST	2.042 ¹	2.215 ²	2.562 ¹
U.S. TOTAL	14.680 ¹	15.768 ²	17.948 ^{3,1}

TABLE 6: ENERGY CONSUMPTION, BY BLDG. TYPE

Region	Building Type	Energy Consumption ($\times 10^{15}$ Btu)		
		1985	1990	2000
NORTH EAST	MH	0.182 ⁴	0.202 ⁵	0.210 ⁶
	SFD	2.070 ⁴	2.255 ⁵	2.644 ⁶
	LD	0.908 ⁴	0.893 ⁵	0.899 ⁶
	LR	0.456 ⁴	0.494 ⁵	0.543 ⁶
	HR	0.470 ⁴	0.475 ⁵	0.492 ⁶
	Regional Total	4.085 ⁷	4.319 ⁸	4.788 ⁹
NORTH CENTRAL	MH	0.401	0.443	0.470
	SFD	3.363	3.573	4.470
	LD	0.726	0.760	0.841
	LR	0.358	0.380	0.442
	HR	0.154	0.160	0.162
	Regional Total	4.997	5.316	5.955
SOUTH	MH	0.362	0.401	0.443
	SFD	2.416	2.645	3.186
	LD	0.434	0.487	0.583
	LR	0.265	0.294	0.329
	HR	0.079	0.091	0.102
	Regional Total	3.556	3.918	4.643
WEST	MH	0.138	0.148	0.257
	SFD	1.222	1.319	1.419
	LD	0.334	0.372	0.425
	LR	0.274	0.291	0.332
	HR	0.074	0.085	0.129
	Regional Total	2.042	2.215	2.562

¹Extrapolated from Project Independence, p. 33 & 35.²Project Independence, p. 35.³MOPPS, Table 3-16.⁴Extrapolated from Project Independence, p. 35,56.⁵Extrapolated from Project Independence, p. 33,56.⁶Extrapolated from Project Independence, p. 33,35,56 & MOPPS Table 3-16.⁷Extrapolated from Project Independence, p. 33 & 35.⁸Project Independence, p. 35.⁹MOPPS, Table 3-16.

2.5 SUBREGIONAL (LOCALIZED) DATA

Once energy demand and construction parameters have been established it is possible to develop localized data by considering subregional characteristics. Further, changes in specific construction variables also help localize data.

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3 COMMERCIAL SECTOR

3.1 GEOGRAPHICAL REGIONS

The geographical regions used to study the commercial sector correspond to those used to study the residential sector. See Fig. 1, Section 2.1.

3.2 COMMERCIAL BUILDING TYPES AND INVENTORIES

There were five commercial building types studied in Project Independence. There were: (a) office (O); (b) retail (R); (c) schools (S); (d) hospitals (H); and (e) commercial, not previously defined (C).

The category of office buildings include commercial office buildings, banks and government administration buildings. The retail category includes mercantile buildings and retail stores, warehouse (except industrial or mfg.), service stations, and restaurants. The school category includes public and private schools (K-12), colleges and universities, libraries and museums. The hospital category encompasses hospitals and other health treatment facilities, and convalescent facilities.¹ The remaining commercial category included such buildings as hotels, motels, religious, and recreational facilities.

The use of these categories of building type incorporated the construction assumptions shown in Table 7.

TABLE 7: CONSTRUCTION ASSUMPTIONS

Building Type	Avg. Floor Area	Avg. U Glazing	Avg. R Opaque	Avg. No. Stories	Glazing % of External Wall Area
O ²	40,000	0.7	11	3	30
R ²	67,000	.9	13	1	15
S ²	40,000	1.1	13	1	20
H ²	60,000	0.5	13	4	15
C ²	25,000	.9	13	1	15

The inventories for commercial buildings differed considerably between the MOPPS report and Project Independence. See Fig. 3.

¹Project Independence, p. 90.

²Project Independence, p. 90,91.

Note: MOPPS = Solid line.
PI = Dashed and broken line.

FIG. 3: COMMERCIAL INVENTORY, (SF x 10⁹)^{1,2}

In this case the growth pattern suggested in the MOPPS report was used to generate commercial inventories. This decision was based upon a review of the assumptions and growth patterns proposed by the two reports.

Table 8 shows commercial inventory data, following the MOPPS example, through the year 2000.

3.3 PERCENTAGE OF COMMERCIAL ENERGY CONSUMPTION BY END USE

In the commercial sector 5 end uses were identified in both the MOPPS and Project Independence reports. These were: (a) space heating; (b) space cooling; (c) DHW & appliances; (d) refrigeration; and (e) lighting.

Table 9 shows the average percent of the total energy consumption for each end use by building type, in each region.

¹Project Independence, p. 68.

²MOPPS, p. 3-20.

TABLE 8: COMMERCIAL INVENTORY ($\times 10^9$ SQ. FT.)

Region	Building Type	COMMERCIAL INVENTORY (10^9 SF)						
		1985 Inventory	1985 New	1985 Removals	1990 Inventory	1990 New	1990 Removals	2000 Inventory
NE	O	1.627	0.355	0.070	1.912	0.541	0.082	2.371
	R	2.135	0.518	0.092	2.561	0.802	0.110	3.253
	S	1.508	0.127	0.064	1.571	0.270	0.066	1.775
	H	0.579	0.089	0.025	0.640	0.098	0.030	0.735
	C	2.289	0.535	0.089	2.735	0.550	0.118	3.167
Regional Total		8.138	1.621	0.340	9.419	2.261	0.379	11.301
NC	O	1.479	.338	0.083	1.734	0.504	0.097	2.141
	R	2.305	.586	0.13	2.771	0.876	0.155	3.492
	S	1.728	.153	0.097	1.784	0.308	0.010	1.992
	H	0.562	.068	0.031	0.599	0.120	0.034	0.685
	C	2.565	.625	0.144	3.046	0.614	0.171	3.498
Regional Total		8.649	1.770	0.485	9.934	2.422	0.557	11.808
S	O	1.653	0.416	0.123	1.946	0.491	0.148	2.289
	R	2.193	0.628	0.163	2.458	0.916	0.198	3.376
	S	1.939	0.203	0.144	1.998	0.372	0.149	2.221
	H	0.561	0.074	0.042	0.593	0.124	0.044	0.673
	C	2.603	0.683	0.194	3.094	0.675	0.230	3.537
Regional Total		8.949	2.004	0.666	10.287	2.578	0.769	12.096
W	O	1.116	0.253	0.778	1.291	0.368	0.090	1.569
	R	1.431	0.383	0.100	1.714	0.565	0.120	2.159
	S	1.306	0.101	0.072	1.335	0.193	0.074	1.391
	H	0.273	0.035	0.019	0.289	0.059	0.020	0.328
	C	1.697	0.426	0.118	2.005	0.428	0.140	2.293
Regional Total		5.553	1.198	0.387	6.634	1.613	0.444	7.740
US	O	5.875	1.362	0.354	6.397	1.904	0.327	8.370
	R	8.074	2.115	0.485	9.504	2.403	0.583	12.280
	S	6.481	0.584	0.377	6.751	1.143	0.299	7.379
	H	1.975	0.266	0.177	2.121	0.401	0.128	2.421
	C	9.154	1.342	0.545	10.898	2.267	0.659	12.495
US Total		31.559	5.669	1.878	35.670	8.118	1.996	42.945

TABLE 9: PERCENT OF TOTAL ENERGY DEMAND BY END USE

Region	Bldg. Type	% OF COMMERCIAL ENERGY DEMAND				
		Heating (%)	Cooling (%)	DHW & App. (%)	REF (%)	Light (%)
NORTH EAST	O	58.7	8.2	21.4	0	11.9
	R	37.5	8.3	10.4	32.6	11.2
	S	71.9	10.0	9.0	0	9.1
	H	34.4	8.0	26.6	17.5*	13.6
	C	52.1	16.6	17.5	0	13.8
NORTH CENTRAL	O	55.6	13.1	21.0	0	10.8
	R	35.3	11.3	10.3	32.1	11.0
	S	66.3	13.4	11.1	0	9.2
	H	35.1	10.0	24.9	17.0*	13.0
	C	58.0	23.0	9.0	0	11.0
SOUTH	O	43.2	31.3	13.2	0	12.3
	R	15.5	25.0	11.5	35.8	12.3
	S	43.4	31.0	13.7	0	11.9
	H	16.7	26.6	25.8	17.6*	13.2
	C	35.4	40.0	12.3	0	12.2
WEST	O	50.0	19.0	17.0	0	14.0
	R	25.0	18.0	16.0	38.0	13.0
	S	54.0	11.0	22.0	0	13.0
	H	31.0	22.0	20.0	15.0*	12.0
	C	54.0	14.0	17.0	0	14.0

*Note: In hospitals this "special load" is ventilation and special equipment in addition to REF.

3.4 ENERGY CONSUMPTION BY REGION AND BUILDING TYPE

Energy consumption, by region, is shown in Table 10 for the time frames of 1985, 1990 and 2000.

As with the residential sector, it is possible to summarize energy consumption by building type. See Table 11.

TABLE 10: ENERGY CONSUMPTION, BY REGION

Region	Energy Consumption (10 ¹⁵ Btu)		
	1985	1990	2000
NORTH EAST	1.669 ¹	1.960 ²	2.392 ¹
NORTH CENTRAL	1.772 ¹	2.067 ²	2.507 ¹
SOUTH	1.833 ¹	2.141 ²	2.602 ¹
WEST	1.150 ¹	1.381 ²	1.592 ¹
U.S. TOTAL	6.425 ¹	7.549 ²	9.093 ^{1,3}

TABLE 11: ENERGY CONSUMPTION BY BUILDING TYPE

REGION	BUILDING TYPE	ENERGY CONSUMPTION (10 ¹⁵ Btu)		
		1985	1990	2000
NORTH EAST	O	0.334	0.398	0.502
	R	0.438	0.533	0.689
	S	0.309	0.327	0.376
	H	0.119	0.133	0.155
	C	0.479	0.569	0.670
Regional Total		1.669	1.960	2.392
NORTH CENTRAL	O	0.303	0.361	0.455
	R	0.474	0.577	0.741
	S	0.354	0.371	0.424
	H	0.115	0.124	0.145
	C	0.526	0.634	0.742
Regional Total		1.772	2.067	2.507
SOUTH	O	0.339	0.405	0.492
	R	0.449	0.512	0.726
	S	0.397	0.416	0.478
	H	0.115	0.123	0.145
	C	0.533	0.645	0.761
Regional Total		1.833	2.101	2.602
WEST	O	0.229	0.269	0.322
	R	0.249	0.357	0.443
	S	0.268	0.278	0.286
	H	0.056	0.060	0.067
	C	0.348	0.417	0.471
Regional Total		1.150	1.381	1.589
U.S.	O	1.195	1.433	1.771
	R	1.610	1.979	2.286
	S	1.328	1.392	1.564
	H	0.405	0.440	0.512
	C	1.887	2.265	2.960
U.S. Total		6.425	7.509	9.093

¹Extrapolated from Project Independence, p. 33 & 35.²Project Independence, p. 35.³MOPPS, Table 3-16.

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4 ENERGY CONSERVATION SCENARIO'S

4.1 BASE DATA

Base data was derived from Section 2 and 3 of this study. Base data for the residential sector is shown in Table 12, the commercial sector, Table 13.

TABLE 12: BASE CONSUMPTION DATA: RESIDENTIAL

INVENTORY	CONSUMPTION BREAKDOWN (Btu x 10 ¹⁵)		
	1985	1990	2000
New construction, 1980-1985	2.15	2.17	2.20
New construction, 1985-1990	NA	2.09	2.11
New construction, 1990-2000	NA	NA	3.30
Total standing inventory	12.53	11.51	10.33
Total consumption, all inventory	14.68	15.76	17.94

TABLE 13: BASE CONSUMPTION DATA: COMMERCIAL

INVENTORY	CONSUMPTION BREAKDOWN (Btu x 10 ¹⁵)		
	1985	1990	2000
New construction, 1980-1985	1.049	1.070	1.114
New construction, 1985-1990	NA	1.72	1.791
New construction, 1990-2000	NA	NA	4.841
Total standing inventory	5.365	4.718	4.302
Total consumption, all inventory	6.414	7.509	9.048

A summation of this data is shown in Table 14.

TABLE 14: RESIDENTIAL AND COMMERCIAL CONSUMPTION

INVENTORY	CONSUMPTION (10 ¹⁵ Btu)		
	1985	1990	2000
Residential	14.680	15.76	17.945
Commercial	6.414	7.509	9.048
Total consumption	21.094	23.269	26.993
% residential	69.6	67.7	66.5
% commercial	30.4	32.3	33.5

4.2 SCENARIO A: RESIDENTIAL & COMMERCIAL INCREASED OVERALL EFFICIENCY

The key assumptions in scenario A were:

- Between 1980 and 2000 there will be a 10% general increase in the efficiency of all components of energy consumption in all new residential and commercial construction.¹
- There will be no change in the consumption patterns of the standing inventory.¹
- All inventory will increase consumption by 1%, in the residential sector and 2%, in the commercial sector over the previous time frame.²

Results of applying this scenario to the base data are shown in Table 15.

TABLE 15: SUMMARY, SCENARIO A

INVENTORY	CONSUMPTION (10 ¹⁵ Btu)		
	1985	1990	2000
RESIDENTIAL	14.670	15.740	17.710
Savings over base (10 ¹⁵ Btu)	0.01	0.02	0.235
% savings over base	0.1	0.1	1.3
COMMERCIAL	6.387	7.385	8.746
Savings over base (10 ¹⁵ Btu)	0.027	0.112	0.302
% savings over base	0.4	1.5	3.3
TOTAL R/C CONSUMPTION	21.057	23.125	26.456
Savings over base (10 ¹⁵ Btu)	0.037	0.132	0.537
% savings over base	0.2	0.6	2.0

4.3 SCENARIO B: LEGISLATED ENERGY CONSERVATION

The key assumptions in scenario B were:

- As of 1978, a total of 28 states have some form of energy legislation.³
- On average, the legislation requires that new construction be built at 1975 levels of consumption or lower.³

¹A National Plan for Energy R&D, 1975, Vol. 1, Scenario I.

²From base data.

³Energy Users News, June 1978, "Legislative Scoreboard".

- Assume that by the year 2000 all 50 states will have legislation requiring initial consumption to match, or be less than, 1975 levels.
- All inventory will increase consumption by 1%, in the residential sector, and 2%, in the commercial sector over the previous time frame.³

The results of applying this scenario to the base data are shown in Table 16.

TABLE 16: SUMMARY, SCENARIO B

INVENTORY	CONSUMPTION		
	1985	1990	2000
RESIDENTIAL	14.41	15.20	17.30
Savings over base	0.27	0.56	0.654
% savings over base	1.8	3.7	3.6
COMMERCIAL	6.385	7.392	8.899
Savings over base	0.029	0.117	0.149
% savings over base	0.5	1.6	1.6
TOTAL R/C CONSUMPTION	20.795	22.592	26.199
Savings over base	0.299	0.677	0.794
% savings over base	1.4	2.9	2.9

4.4 SCENARIO C: LEGISLATED TO MATCH GSA GUIDELINES

The key assumptions to scenario C were:

- As of 1978, a total of 28 states have some form of energy legislation, assume all 50 states will have energy legislation by 2000.¹
- Assume all residential construction and office construction will have to meet GSA guidelines by 2000.²

The results of applying this scenario to the base data are shown in Table 17.

¹From Scenario B.

²55,000 Btu/SF·y, from "Lighting and Thermal Operation", GSA, 1975.

³This 1% and 2% increased consumption for the residential and commercial sectors, respectively, is assumed for all subsequent scenarios.

TABLE 17: SUMMARY, SCENARIO C

INVENTORY	CONSUMPTION		
	1985	1990	2000
RESIDENTIAL	14.57	15.44	16.43
Savings over base	0.110	0.320	1.515
% savings over base	0.7	2.0	8.4
COMMERCIAL	6.379	7.156	8.197
Savings over base	0.035	0.336	0.851
% savings over base	0.5	4.5	9.4
TOTAL CONSUMPTION	20.949	22.596	24.627
Savings over base	0.145	0.673	2.366
% savings over base	0.7	2.9	8.8

4.5 SCENARIO D: ACTIVE SOLAR SYSTEMS

The key assumptions in scenario D were:

- Between 1985 and 2000, the number of active solar systems will be:

	(%) 1985	(%) 2000
Residential new construction	1/2% ¹	5% ^{2,3}
Office new construction	1	5
Retail new construction	1	5
School new construction	1/2	2 1/2
Hospital new construction	1/4	1
Other new commercial const.	1/2	2 1/2

- Energy conserved by an active solar system reduces the combined heating and DHW loads by 60% over nonsolar construction.³
- Assume no reduction for solar cooling systems.

The results of applying scenario D to the base data are shown in Table 18.

¹A National Plan for Energy R&D, Vol. 1, Scenario I.

²Extrapolated from the National Plan, Scenario I.

³BRE News, #43, 1976.

TABLE 18: SUMMARY, SCENARIO D

INVENTORY	CONSUMPTION (10^{15} Btu)		
	1985	1990	2000
RESIDENTIAL	14.68	15.56	17.64
Savings over base	0	0.2	0.3
% savings over base	0	1.2	1.6
COMMERCIAL	6.404	7.456	8.981
Savings over base	.01	0.036	0.067
% savings over base	.2	0.5	0.7
TOTAL	21.084	23.016	26.621
Savings over base	0.01	0.253	0.372
% savings over base	.05	1.0	1.3

4.6 SCENARIO E: SOLAR RETROFIT

The key assumptions of scenario E were:

- Assume new construction solar active systems, as suggested in scenario D.
- Assume a matching amount of retrofitting in all inventory.¹

The results of applying scenario E to the base data are shown in Table 19.

4.7 SCENARIO F: HEAT PUMP USAGE

The key assumptions to scenario F were:

- Heat pumps will be used in 10% of all new construction by 2000.²
- Heat pumps will be retrofitted to 5% of all standing inventory by 2000.³
- Assume that heat pumps reduce heating and cooling loads by 69%.²

The results of applying scenario F to the base data are shown in Table 20.

¹HUD-PDR- 296, April, 1978.

²BRE News #43, 1976.

³Westinghouse response to MOPPS, Section 3.3.3.

TABLE 19: SUMMARY, SCENARIO E

INVENTORY	CONSUMPTION (Btu x 10 ¹⁵)		
	1985	1990	2000
RESIDENTIAL	14.660	15.480	17.480
Savings over base	0.02	0.28	0.465
% savings over base	0.14	1.7	2.6
COMMERCIAL	6.403	7.421	8.907
Savings over base	.01	.071	0.141
% savings over base	.2	1.0	1.6
TOTAL	21.063	22.901	26.387
Savings over base	0.031	0.368	0.606
% savings over base	0.15	1.6	2.3

TABLE 20: SUMMARY, SCENARIO F

INVENTORY	CONSUMPTION (Btu x 10 ¹⁵)		
	1985	1990	2000
RESIDENTIAL	14.46	15.44	16.95
Savings over base	0.21	0.31	0.99
% savings over base	1.4	1.9	5.5
COMMERCIAL	6.322	7.360	8.549
Savings over base	0.092	0.148	0.499
% savings over base	1.4	1.9	5.5
TOTAL	20.782	22.800	28.499
Savings over base	0.302	0.458	1.494
% savings over base	1.4	1.9	5.5

4.8 SCENARIO G: HEAT RECLAIM

The key assumptions to scenario G were:

- Heat reclaim techniques will be utilized in from 1/2% (1985) to 10% (2000) of all new construction.¹

¹BRE News, #43, 1976.

- Assume that heat reclaim techniques reduce heating and DHW loads by 55%.¹

The results of applying scenario G are shown in Table 21.

TABLE 21: SUMMARY, SCENARIO G

INVENTORY	CONSUMPTION (Btu x 10 ¹⁵)		
	1985	1990	2000
RESIDENTIAL	14.630	15.300	17.150
Savings over base	0.04	0.46	0.789
% savings over base	0.2	3.0	4.4
COMMERCIAL	6.401	7.291	8.649
Savings over base	0.012	0.217	0.339
% savings over base	0.2	2.9	4.4
TOTAL	21.031	22.591	25.799
Savings over base	0.052	0.677	1.128
% savings over base	0.2	2.9	4.4

4.9 SCENARIO H: MAXIMUM REDUCTION OF BASE DEMAND, AS PROPOSED BY PROJECT INDEPENDENCE

The key assumptions to scenario H were:

- The maximum reduction of base demand by the following categories:

Heating - 25%²
 DHW - 25%³
 Lighting - 30%⁴ (commercial only)
 Cooling - 15%³
 Cooking - 25%³ (residential only)

- The total reduction in consumption is to be 0% in 1980 and 21.8% in 2000.⁵

The results of applying this scenario to the base data are shown in Table 22.

¹BRE News, #43, 1976.

²Project Independence, Table 1.4.

³Project Independence, Table 1.5.

⁴BRE News, #43, 1976.

⁵Extrapolated from Project Independence, Table 1.4 & 1.5.

TABLE 22: SUMMARY, SCENARIO H

INVENTORY	CONSUMPTION (Btu x 10 ¹⁵)		
	1985	1990	2000
RESIDENTIAL	14.58	15.44	16.92
Savings over base	0.1	0.32	1.025
% savings over base	0.68	2.0	5.7
COMMERCIAL	6.355	7.235	8.379
Savings over base	0.059	0.257	0.669
% savings over base	0.9	3.4	7.4
TOTAL	20.935	22.675	25.299
Savings over base	0.159	0.594	1.694
% savings over base	0.8	2.5	6.2

4.10 SCENARIO I: PASSIVE RESIDENTIAL

The key assumptions in this scenario were:

- By 1985 the number of passive solar residences will equal 1/4% of all new construction.¹
- By 2000 the number of passive solar residences will equal 2% of all new construction.²
- Average energy consumption for a passive solar home is 75% less for heating, cooling and DHW.³
- This scenario applies only to the residential sector.

Results of applying this scenario to the base data are shown in Table 23.

4.11 SCENARIO J: ACTIVE AND PASSIVE SOLAR RESIDENTIAL CONSTRUCTION OCCUR SIMULTANEOUSLY.⁴

The key assumptions to this scenario were:

- The number of active solar residences will correspond to scenario D (Section 4.5).⁵

¹"A Survey of Passive Solar Buildings", HUD-PDR-287, Feb., 1978.

²Extrapolated from HUD-PDR-287.

³The Avg. of 200 Case Studies listed in HUD-PDR-287.

⁴Suggested by "Passive Design Ideas for the Energy Conscious Architect"; National Solar Heating & Cooling Information Center & DOE (1977).

⁵A National Plan for Energy R&D, Vol. 1, Scenario I.

TABLE 23: SUMMARY, SCENARIO I

INVENTORY	CONSUMPTION (Btu x 10 ¹⁵)		
	1985	1990	2000
RESIDENTIAL	14.68	15.75	17.67
Savings over base	0.0	0.10	0.269
% savings over base	0.0	0.6	1.5

- The number of passive solar residences will correspond to scenario I (Section 4.10).¹
- Possible solar activity in the commercial sector were not considered in this scenario.

The results of applying Scenario J to the residential base data are shown in Table 24.

TABLE 24: SUMMARY, SCENARIO J

INVENTORY	CONSUMPTION (Btu x 10 ¹⁵)		
	1985	1990	2000
RESIDENTIAL	14.670	15.460	17.371
Savings over base	.010	.300	.569
% savings over base	.06	1.9	3.1

4.12 SCENARIO K: SIMULTANEOUS USE OF ACTIVE AND PASSIVE SOLAR SYSTEMS, AS WELL AS HEAT PUMPS, IN RESIDENTIAL CONSTRUCTION

The key assumptions in this scenario were:

- Scenario J occurs at the same time that Scenario F occurs.
- Assume that 1/3 of all solar active residences use heat pumps.

The results of applying Scenario K to the residential base data are shown in Table 25.

¹" A Survey of Passive Solar Buildings", HUD-PDR-287, Feb., 1978.

TABLE 25: SUMMARY, SCENARIO K

INVENTORY	CONSUMPTION		
	1985	1990	2000
RESIDENTIAL	14.61	15.36	17.223
Savings over base	.07	0.399	0.717
% savings over base	0.4	2.5	3.9

4.13 SCENARIO L: MANDATORY NATURAL LIGHTING REQUIREMENTS IN COMMERCIAL BUILDINGS

The key assumption in this scenario were:

- Energy legislation will include mandatory requirements to use natural light (i.e., daylight) during daytime hours in all new construction.^{1,2}

The result of applying scenario L to the commercial base data are shown in Table 26.

TABLE 26: SUMMARY, SCENARIO L

INVENTORY	CONSUMPTION (Btu x 10 ¹⁵)		
	1985	1990	2000
COMMERCIAL	6.391	7.392	8.793
Savings over base	0.023	0.1	0.255
% savings over base	0.4	1.3	2.8

4.14 RANK ORDERING OF CONSERVATION SCENARIOS

A rank ordering of the eight scenarios that were applicable to both the residential and commercial sectors would be as follows:

¹Robbins, C.C.; "Natural Light in Buildings", International Solar Energy Symposium, Cairo Egypt, June 1978.

²Personal Correspondence with BRS, Watford England.

TABLE 27: RANK ORDERING OF CONSERVATION SCENARIOS

Rank	Scenario	% Energy Saved in 2000
1	C: Legislated to meet GSA guidelines	8.8
2	H: Max. reduction of loads	6.2
3	F: Heat pump usage	5.5
4	G: Heat reclaim techniques	4.4
5	B: Legislated to match 1975 consumption	2.9
6	E: Active solar with retrofit	2.3
7	A: 10% increased overall efficiency	2.0
8	D: Active solar, new const. only	1.3

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5 ENERGY CONSUMPTION MODELS FOR R/C BUILDING TYPES

5.1 R/C BASE MODEL

Energy demand was studied along three dimensions: (a) geographic region; (b) building type; and (c) end use. Because energy consumption for each building type and end use, within each region, was different, it was necessary to establish a residential and a commercial base model for each region.

Using a modified Degree Day Method, as outlined by ASHRAE¹, it was possible to estimate seasonal heating and cooling loads and consumption. The variables listed in Table 1, 2, and 7 of Section 2 were also used in the Degree Day Method.

Energy consumption for internal loads (i.e., domestic hot water, lighting, and appliances) was determined following common engineering practices as suggested by ASHRAE and IES. Domestic hot water (DHW) loads were based on average daily consumption per person estimates.² Lighting and appliance loads, including cooking, were estimated in accordance with IES guidelines.³

Variations in average loads, for a given building type or region, could easily be adjusted for within the Degree Day calculation techniques. Thus, any city in a region that had either heating/cooling assumptions on construction assumptions that differed from average values could have an increased or decreased consumption depending upon the net overall effect of the modified assumptions.

Therefore, the base model could be used to:

1. Estimate average (i.e., normal) consumption and loads for a particular building type in a given region.
2. Estimate consumption for a change in heating/cooling variables without changing construction variables.
3. Estimate consumption for a change in construction variables without changing heating/cooling variables.
4. Estimate consumption with both heating/cooling and construction variables modified.

The four capabilities of the model are demonstrated in the following example. Given an office building in the North Central region, Table 28 and Table 29 show the application of items 1 and 3 above.

¹ASHRAE, 1973 Systems Handbook, Ch. 43.

²21 gal. per person per day for residential consumption.

³IES, IES Handbook, 5th Ed., 1975, Ch. 5.

By locating the office building in Chicago, Table 30 and 31 show the application of item 2 and 4.

TABLE 28: AVG. OFFICE CONSUMPTION, NORTH CENTRAL U.S.

End Use	Load/Consumption
Light	409,600 Btu/hr
DHW	100,000 Btu/hr
Internal consumption	1.23×10^9 Btu/yr
Heat load	1,928,560 Btu/hr
Heating consumption	5.97×10^9 Btu/ht. season
Cooling load	2,400,000 Btu/hr
Cooling consumption	1.2×10^9 Btu/cooling season
Yearly consumption	8.4×10^9 Btu/yr
Load per unit area	210,097 Btu/SF·yr

TABLE 29: AVG. OFFICE CONSUMPTION, NORTH CENTRAL U.S., WITH R-19 WALLS

End Use	Load/Consumption
Light .	409,600 Btu/hr
DHW	100,000 Btu/hr
Internal consumption	1.23×10^9 Btu/yr
Heating load	1,493,247 Btu/hr
Heating consumption	4.66×10^9 Btu/ht. season
Cooling load	2,010,625 Btu/hr
Cooling consumption	1.01×10^9 Btu/cooling season
Total consumption	6.9×10^9 Btu/yr
Load per unit area	172,581 Btu/SF·yr

TABLE 30: AVG. OFFICE IN CHICAGO

End Use	Load/Consumption
Lt. & App.	409,600 Btu/hr
DHW	100,000 Btu/hr
Internal consumption	1.23×10^9 Btu/yr
Heat load	2,130,904 Btu/hr
Heating consumption	6.39×10^9 Btu/hr. season
Cooling load	3,468,000 Btu/hr
Cooling consumption	1.73×10^9 Btu/cooling season
Yearly total	9.36×10^9 Btu/yr
Load per unit area	234,015 Btu/SF·yr

TABLE 31: OFFICE IN CHICAGO, R-19 WALLS

End Use	Load/Consumption
Lt. & App.	409,600 Btu/hr
DHW	100,000 Btu/hr
Internal consumption	1.23×10^9 Btu/yr
Heat load	1,664,769 Btu/hr
Heating consumption	4.99×10^9 Btu/ht. season
Cooling load	2,845,000 Btu/hr
Cooling consumption	1.42×10^9 Btu/cooling season
Yearly total	7.65×10^9 Btu/yr
Load per unit area	191,267 Btu/SF·yr

Specific climate variables that can be changed to correspond to given urban areas include: (a) Δt winter; (b) Δt summer; (c) t mean; and (d) the heating degree days. Similarly, specific construction variables that can be changed are: (a) glazing % of surface area; (b) avg. surface 'U' value; (c) enclosed area; (d) number of people; and (e) special loads (including refrigeration, ventilation, and equipment).

5.2 THE STEADY-STATE MODEL

The steady-state model is based upon the ASHRAE steady-state energy balance theories.¹ Differences between the base models and the steady state model are shown in Table 32.

TABLE 32: PROGRAMMABLE CALCULATOR PROGRAM INFORMATION

MODEL	VARIABLE					
	U Glazing	R Opaque	% Glazing	Orientation	Shading Coef.	Ventilation & Infiltration
Base	Avg. for bldg.	Avg. for bldg.	Avg. for bldg.	Not included	Assumed at 1.0	Avg. per person
Steady-state	Specific per surface	Specific per surface	Specific per surface	Specific per surface	Specific per surface	Specific per person (vent.) and by crack-method (infiltration) ²

¹ASHRAE, Handbook of Fundamentals, 1977, Ch. 21, 23, 24.

²ASHRAE, Handbook of Fundamentals, 1977, Ch. 21.

The steady-state model can be used in conjunction with the base models to better estimate energy consumption in a proposed building. The base model is used to establish 'normal' levels of consumption for the region, city, or construction technique. The steady-state model is then used to more accurately establish levels of consumption for a proposal building. Because the steady-state model allows for manipulation of data on a surface by surface basis it is possible to determine energy consumption much more accurately than the base model.

5.3 PROGRAMMABLE CALCULATOR USAGE

Both the base models and the steady-state models were designed for implementation through the use of programmable calculators (i.e., TI-59).

Table 33 lists each program and appropriate nomenclature.

TABLE 33: PROGRAM NOMENCLATURE

Model	Program Name	Running Time	Number of Steps	Registers Used	No. of Sub-routines	No. of Input Variables
Base Base	Residential base model	45 sec.	689	30	11	8
	Commercial base model	45 sec.	717	30	10	9
Steady-state	Heat loss model	1 min.				
		15 sec.	223	25	11	17
Steady-state	Heat gain model	2 min.	556	44	19	24
Steady-state	Internal loads	1 min.	515	30	14	10

Note: All programs are developed for TI-59 programmable calculators; PL-100A printer use is optional.

Appendix A contains the input instruction for each program.

6 CONCLUSIONS

6.1 SUMMARY OF EXISTING ENERGY DEMAND DATA

The majority of the information brought forth in the review of energy demand data was extrapolated from well known existing documents. However, the regional summary of energy consumption by percent of end use has not been seen in this form in other documents.

From a review of this data it seems obvious that any attempt to conserve energy must be approached on a regional basis. That is, conservation tactics must be tied to regional end use patterns.

6.2 SUMMARY OF ENERGY CONSERVATION SCENARIOS

An attempt was made, in establishing the various scenarios, to establish reasonable levels of market penetration for each proposed scenario. For example, in the active solar systems scenario (scenario D), penetration into the residential market was established at 5% by 2000. This seems low; however, it should be remembered that 5% of residential new construction by the year 2000 is roughly a million units. This then seems quite high when compared with the current penetration of about 1000 units a year.

One important aspect of all of the scenarios is that their impact is not as great as had been estimated in other reports. No scenario saves more than 8.8% of the total consumption -- on average the savings is around 3.5%. Certainly not spectacular.

In order to achieve energy conservation at greater levels will require either greater incentives or more mandatory control. The implementation rates of either incentives or control will have to be much accelerated over those suggested in the scenarios. Such acceleration may be difficult to achieve or sustain.

6.3 SUMMARY OF THE BASE AND STEADY-STATE MODELS

As the purpose of the models were to establish a quick and easy means to make initial (rough) energy estimates, they are very successful. It should be remembered, however, that the models are not extremely accurate, probably within a range of $\pm 25\%$. However, for a first estimate at the beginning of a design process, this seems reasonably accurate.

Another positive attribute of the programs is that they can be used and manipulated by non-technical people. This is certainly an advantage if they were to be used "in the field".

APPENDIX A

- A.1 RESIDENTIAL BASE MODEL
- A.2 COMMERCIAL BASE MODEL
- A.3 HEAT LOSS MODEL
- A.4 HEAT GAIN MODEL
- A.5 INTERNAL LOAD MODEL

1				2	
RESIDENTIAL BASE MODEL I 3 op 17					
				INIT	
NE	NC	S	W	t. DATA	

CARD A

3					
RESIDENTIAL BASE MODEL II 3 op 17					
				INIT	
NE	NC	S	W	t. DATA	

CARD B

PROGRAM DESCRIPTION

For determining base heat, cooling and internal energy demand for:

- (1) mobil home, industrial modular and military or dormitory, (2) single family detached, (3) low density, including single family attached up to 4 units, (4) low density (3 levels or less), (5) high density (3+ levels)

STEP NO.	PROCEDURE or COMMENTS	ENTER	PRESS	DISPLAY	PRINTER LIST
1	Set partitioning at 719.29	3	op 17	719.29	-
2	Enter program card I, side 1	1	-	1.	-
	Enter program card I, side 2	2	-	2.	-
	Enter program card II, side 3	3	-	3.	-
3	Enter temp differential (Δt_w) between outside and inside <u>winter</u> temperature. If Δt_w is not known, enter NE-70, NC-75, S-50, W-55	Δt_w	E	Δt_w	-
4	Enter temp differential (Δt_s) between outside and inside <u>summer</u> temperature. If Δt_s is not known, enter: NE-15, NC-15, S-25, W-25	Δt_s	R/S	Δt_s	-
5	Enter mean winter temp (t_{mean})	t_m	R/S	t_m	-

STEP NO.	PROCEDURE or COMMENTS	ENTER	PRESS	DISPLAY	PRINTER LIST
6	Enter % glazing as a % of the <u>wall surface area</u> . If unknown, enter 0.15. <u>Enter as a decimal.</u>	% glaz.	E'	% glaz.	-
7	Enter avg. 'U' of all surfaces (combined). If unknown, enter: NE-0.28, NC-0.25, S=0.37, W=0.34	'U'	R/S	'U'	-
8	Enter gross enclosed floor area.	A	R/S	A	-
9	Enter heating degree days (HDD). If unknown, enter: NE-5400; NC-6200; S-2800; W-3800	HDD	R/S	HDD	-
10	Enter housing type, as follows: 1 = mobile home 2 = SF-detached 3 = low density 4 = low rise 5 = high rise and designate region: Northeastern U.S. = A Central U.S. = B Southern U.S. = C Western U.S. = D Example: SF-det. in central U.S.	2	B	see sample output	

NORTHEAST U.S. COMMERCIAL BASE MODEL

1			2	
NORTHEAST U.S. COMMERCIAL MODEL I 3 op 17				
			t • DATA	BLDG DATA
OFFICE	RETAIL	SCHOOL	HOSPITAL	OTHER

CARD A

3				
NORTHEAST U.S. COMMERCIAL MODEL II 3 op 17				
			t • DATA	BLDG DATA
OFFICE	RETAIL	SCHOOL	HOSPITAL	OTHER

CARD B

PROGRAM DESCRIPTION

For determining base energy data for the Northeastern U.S. commercial sector.

(printer use optional)

STEP NO.	PROCEDURE or COMMENTS	ENTER	PRESS	DISPLAY	PRINTER LIST
1	Set partitioning at 719.29	3	op 17	719.29	-
2	read program card I, side 1	1	-	1.	-
	read program card I, side 2	2	-	2.	
	read program card II, side 3	3	-	3.	
3	Enter "T•DATA" (4 entries)				
	A. Enter temperature differential (Δt_w) between outside and inside <u>winter</u> temp's. If unknown use $\Delta t_w = 70$	Δt_w	D'	2*	*Display indicates that calculator is ready for 2nd 't•DATA' entry.
	B. Enter temp. differential (Δt_s) between outside and inside <u>summer</u> temp's. If unknown, $\Delta t_s = 15$	Δt_s	R/S	3	
	C. Enter mean <u>winter</u> temp (t_{mean}) If unknown, $t_{mean} = 36$	t_{mean}	R/S	4	

[illegible]

STEP NO.	PROCEDURE or COMMENTS	ENTER	PRESS	DISPLAY	PRINTER LIST
6	To initiate calculations after 'T·DATA' and 'BLDG·DATA' has been input, use the bldg. type init. key. office - Key A retail - Key B school - Key C hospital - Key D other - Key E	- - - - -	A B C D E	see sample output	

1			2	
CENTRAL U.S. COMMERCIAL MODEL I 3 op 17				
			T-DATA	BLDG. DATA
OFFICE	RETAIL	SCHOOL	HOSPITAL	OTHER

CARD A

3				
CENTRAL U.S. COMMERCIAL MODEL II 3 op 17				
			T-DATA	BLDG. DATA
OFFICE	RETAIL	SCHOOL	HOSPITAL	OTHER

CARD B

PROGRAM DESCRIPTION

For determining base energy data for the Central U.S. commercial sector.

(printer use optional)

STEP NO.	PROCEDURE or COMMENTS	ENTER	PRESS	DISPLAY	PRINTER LIST
1	Set partitioning at 719.29	3	op 17	719.29	-
2	Read program card I, side 1	1	-	1.	
	Read program card I, side 2	2	-	2.	-
	Read program card II, side 3	3	-	3.	
3	Enter 'T-DATA' (4 entries)				
	A. Enter temperature differential (Δt_w) between outside and inside winter temperatures. If unknown use $\Delta t_w = 75$	Δt_w	D ⁺	2*	*Display indicates that calculator is ready for 2nd 'T-DATA' entry
	B. Enter temperature differential (Δt_s) between outside and inside summer temperatures. If unknown, $\Delta t_s = 15$	Δt_s	R/S	3	
	C. Enter mean winter temperature (t_{mean}). If unknown, $t_{mean} = 37$	t_{mean}	R/S	4	

STEP NO.	PROCEDURE or COMMENTS	ENTER	PRESS	DISPLAY	PRINTER LIST
4.	D. Enter heating degree days (HDD). If unknown, HDD = 6200	HDD	R/S	1**	**Indicates calculator is ready for BLDG. DATA. (Key E')
5	Enter 'BLDG. DATA' (5 entries)				
	A. Enter <u>decimal</u> ratio of glazing to surface area.				
	office = $\frac{\text{glazing area}}{\text{wall area}}$ Avg. = 0.30	glazing ratio	E'	2	
	retail = $\frac{\text{glazing area}}{\text{floor area}}$ Avg. = 0.035				
	school = $\frac{\text{glazing area}}{\text{wall area}}$ Avg. = 0.20				
	hospital = $\frac{\text{glazing area}}{\text{wall area}}$ Avg. = 0.15				
	other = $\frac{\text{glazing area}}{\text{wall area}}$ Avg. = 0.15				
	NOTE: If glazing ratio is unknown, use average values listed.				
	B. Enter average surface 'U' value. If unknown, use:	U	R/S	3	
	office U = 0.32				
	retail U = 0.29				
	school U = 0.37				
	hospital U = 0.25				
	other U = 0.38				
	C. Enter gross <u>enclosed</u> floor area.	Area	R/S	4	
	D. Enter average number of people in building. Use the following guidelines:				
	office - enter number of employees	People	R/S	5	
	retail - enter number of employees				
	school - enter number of students				
	hospital - enter number of beds				
	other - as appropriate				
	E. Enter any special loads (SL) (in BN/br.) - use the following guidelines	SL	R/S	1	
	office - usually no special loads				
	retail - refrigeration or ventilation (avg. = 2,000,000 Btu/hr)				
	school - ventilation				
	hospital - about 13.65 Btu/sq.ft. x floor area				
	other - as appropriate				

1		2		
SOUTHERN U.S. COMMERCIAL MODEL I 3 op 17				
			t-DATA	BLDG DATA
OFFICE	RETAIL	SCHOOL	HOSPITAL	OTHER

CARD A

3				
SOUTHERN U.S. COMMERCIAL MODEL II 3 op 17				
			t-DATA	BLDG DATA
OFFICE	RETAIL	SCHOOL	HOSPITAL	OTHER

CARD B

PROGRAM DESCRIPTION

For determining base energy data for the Southern U.S. commercial sector.

(printer use optional)

STEP NO.	PROCEDURE or COMMENTS	ENTER	PRESS	DISPLAY	PRINTER LIST
1	Set partitioning at 719.29	3	op 17	719.29	-
2	Read program card I, side 1	1	-	1.	
	Read program card I, side 2	2	-	2.	
	Read program card II, side 3	3	-	3.	
3	Enter 'T-DATA' (4 entries)				
	A. Enter temperature differential (Δt_w) between outside and inside <u>winter</u> temperatures. If unknown use $\Delta t_w = 50$	Δt_w	D [^]	2*	*Display indicates that calculator is ready for 2nd 'T-DATA' entry.
	B. Enter temperature differential (Δt_s) between outside and inside <u>summer</u> temperatures. If unknown, $\Delta t_s = 25$	Δt_s	R/S	3	
	C. Enter mean <u>winter</u> temperature (t_{mean}). If unknown, $t_{mean} = 50$	t_{mean}	R/S	4	

STEP NO.	PROCEDURE or COMMENTS 44	ENTER	PRESS	DISPLAY	PRINTER LIST
4	Enter 'T.DATA' - continued D. Enter heating degree days (HDD). If unknown, HDD - 2800	HDD	R/S	1**	
5	Enter 'BLDG. DATA' (5 entries)				
	A. Enter <u>decimal</u> ratio of glazing to surface area.				
	office = $\frac{\text{glazing area}}{\text{wall area}}$ Avg. = 0.30	glazing ratio	E	2	
	retail = $\frac{\text{glazing area}}{\text{floor area}}$ Avg. = 0.035				
	school = $\frac{\text{glazing area}}{\text{wall area}}$ Avg. = 0.20				
	hospital = $\frac{\text{glazing area}}{\text{wall area}}$ Avg. = 0.15	NOTE: If glazing ratio is unknown use average values listed.			
	other = $\frac{\text{glazing area}}{\text{wall area}}$ Avg. = 0.15				
	B. Enter average surface 'U' value. If unknown, use:				
	office U = 0.37	U	R/S	3	
	retail U = 0.38				
	school U = 0.31				
	hospital U = 0.30				
	other U = 0.38				
	C. Enter gross <u>enclosed</u> floor area	Area	R/S	3	
	D. Enter average number of people in building. Use the following guidelines:				
		People	R/S	5	
	office - enter number of employees				
	retail - enter number of employees				
	school - enter number of students				
	hospital - enter number of beds				
	other - as appropriate				
	E. Enter any special loads (SL) (in BN/br.) - use the following guidelines:				
	office - usually no special loads	(avg. = 2,000,000 Btu/hr.)			
	retail - refrigeration or ventilation				
	school - ventilation				
	hospital - about 13.65 Btu/sq.ft. x				
	floor area				
	other - as appropriate				

**Indicates calculator is ready for bdg. data. (Key E)

STEP NO.	PROCEDURE or COMMENTS	ENTER	PRESS	DISPLAY	PRINTER LIST
6	<div data-bbox="826 44 863 71">45</div> <p data-bbox="204 191 906 296">To initiate calculations after '<u>T·DATA</u>' and '<u>BLDG·DATA</u>' have been input, use the bldg. type initial key.</p> <p data-bbox="204 310 470 478"> office - Key A retail - Key B school - Key C hospital - Key D other - Key E </p>	<div data-bbox="986 310 1007 457"> - - - - - </div>	<div data-bbox="1134 302 1155 457"> A B C D E </div>	<div data-bbox="1235 348 1334 443"> see sample output </div>	

1			2	
WESTERN U.S. COMMERCIAL MODEL I 3 op 17				
			T·DATA	BLDG DATA
OFFICE	RETAIL	SCHOOL	HOSPITAL	OTHER

CARD A

3				
WESTERN U.S. COMMERCIAL MODEL II 3 op 17				
			T·DATA	BLDG DATA
OFFICE	RETAIL	SCHOOL	HOSPITAL	OTHER

CARD B

PROGRAM DESCRIPTION

For determining base energy data for the Western U.S. commercial sector.

(printer use optional)

STEP NO.	PROCEDURE or COMMENTS	ENTER	PRESS	DISPLAY	PRINTER LIST
1	Set partitioning at 719.29	3	op 17	719.29	-
2	Read program card I, side 1	1	-	1.	-
	Read program card I, side 2	2	-	2.	-
	Read program card II, side 3	3	-	3.	-
3	Enter 'T·DATA' (4 entries)				
	A. Enter temperature differential (Δt_w) between outside and inside <u>winter</u> temperatures. If unknown use $\Delta t_w = 55$	Δt_w	D ¹	2*	* Display indicates that calculator is ready for 2nd 'T·DATA' entry
	B. Enter temperature differential (Δt_s) between outside and inside <u>summer</u> temperatures. If unknown, $\Delta t_s = 25$	Δt_s	R/S	3	
	C. Enter mean <u>winter</u> temperature (t_{mean}). If unknown, $t_{mean} = 48$	t_{mean}	R/S	4	

STEP NO.	PROCEDURE or COMMENTS	ENTER	PRESS	DISPLAY	PRINTER LIST
4	D. Enter heating degree days (HDD). If unknown, HUDD = 3800	HDD	R/S	1**	** indicates calculator is ready for bldg. data. (key E')
5	Enter 'BLDG. DATA' (5 entries)				
	A. Enter decimal ratio of glazing to surface area.				
	office = $\frac{\text{glazing area}}{\text{wall area}}$ avg. - 0.30	glazing ratio	E'	2	
	retail = $\frac{\text{glazing area}}{\text{floor area}}$ avg. - 0.035				
	school = $\frac{\text{glazing area}}{\text{wall area}}$ avg. = 0.20				
	hospital = $\frac{\text{glazing area}}{\text{wall area}}$ avg. - 0.15				
	other = $\frac{\text{glazing area}}{\text{wall area}}$ avg. = 0.15				
	B. Enter avg. surface "U" value. If unknown, use:	V	R/S	3	
	office U = 0.31				
	retail U = 0.33				
	school U = 0.31				
	hospital U = 0.28				
	other U = 0.38				
	C. Enter gross enclosed floor area	Area	R/S	4	
	D. Enter avg. no. of people in bldg. Use the following guidelines:				
	office = enter no. of employees				
	retail = enter no. of employees	people	R/S	5	
	school = enter no. of students				
	hospital = enter no. of beds				
	other = as appropriate				
	E. Enter any special loads (SL) (in Btu/hr.) - use the following guidelines:	SL.	R/S	1	
	office = usually no special loads				
	retail = refrigeration or ventilation (avg. = 2,000,000 Btu.hr.)				
	school = ventilation				
	hospital = about 13.65 Btu/sq.ft. x floor area				
	other = as appropriate				

STEP NO.	PROCEDURE or COMMENTS	48	ENTER	PRESS	DISPLAY	PRINTER LIST
6.	To initiate calculations after 'T·DATA' and 'BLDG·DATA' have been input, use the bldg. type unit key.					
	office = Key A retail = Key B school = Key C hospital = Key D other = Key E		- - - - -	A B C D E	see sample output	

1		2		
Heat Loss Model				
or	AA.GG	U		Init
Call				T-DATA

CARD A

PROGRAM DESCRIPTION

To determine heat loss through opaque and transparent surfaces, for 5 specified orientations

(printer use optional)

$$Q = UA \Delta t$$

STEP NO.	PROCEDURE or COMMENTS	ENTER	PRESS	DISPLAY	PRINTER LIST
1.	Make sure partitioning is at normal 479.59		op 16	479.59	(test)
		6	op 17	479.59	
2.	Enter program card - Side 1	1	-	1.	
	Enter program card - Side 2	2	-	2.	
3.	Initialize input	-	E'	1*	
				ready for first 't.data input'	

STEP NO.	PROCEDURE or COMMENTS	ENTER	PRESS	DISPLAY	PRINTER LIST
4	Enter 'T-DATA' a. U value for glazing b. Enter temperature differential between outside and inside <u>winter</u> temps.	U Δt_w	R/S R/S	2 1* ready for orientation data	
5	Enter orientation of surface - orientation code: Code Orientation (OR) 1 N 2 NNE 3 NE 4 ENE 5 E 6 ESE 7 SE 8 SSE 9 S 18 SSW 17 SW 16 WSW 15 W 14 WNW 13 NW 12 NNW 0 HORIZONTAL	OR	A'	2 Enter 5 orientations by pressing A'. After the 5th entry the calculation will display 1. - meaning it is ready for next set of data.	
6	Enter surface area (AA) and % of surface covered by glazing (GG) as follows: a. Enter surface area, rounded to nearest whole number, enter % of glazing as a decimal to this number (AA.GG) example: A = 101.3 (round to 101) G = 15% enter <u>101.15</u> ↙ ↘ area decimal % of glazing (There is no limit to the area.)	AA.GG	B'	1-5	Heat Loss Model

STEP NO.	PROCEDURE or COMMENTS	ENTER	PRESS	DISPLAY	PRINTER LIST
	<div data-bbox="842 37 874 69">51</div> <p>Enter 1. vertical area, % G 2. vertical 3. vertical 4. vertical 5. <u>FLOOR AREA</u></p> <p>Last entry (5th) must be <u>FLOOR AREA</u>.</p> <p>If a building has less than 4 vertical surface, enter '0' (zero) in lieu of AA.GG.</p>				
7.	<p>Enter '0' value for opaque surfaces (max. = 5)</p> <p>Enter 1. vertical '0' 2. vertical surf. '0' 3. vertical surf. '0' 4. vertical surf. '0' 5. <u>Roof</u> '0'</p>	0	C	1-5	
8.	<p>To initiate calculations</p>	-	A	see sample output	

1		2		
Heat Gain Model I 5 op 17				
OR	AA.GG	U	SC	INIT.
CALC.				t.DATA

CARD A

3				
Heat Gain Model II 5 op 17				
OR	AA.GG	U	SC	INIT.
CALC.				t.DATA

CARD B

PROGRAM DESCRIPTION

To determine heat gain on opaque and translucent surfaces, for five specified orientations, with given shading (SC) and ' ' values for each orientation (latitude specific)

(printer use is optional) $Q = UA TETD'$ $Q = [(U)(\Delta t) + (SHGF)(SC)] A$

STEP NO.	PROCEDURE or COMMENTS	ENTER	PRESS	DISPLAY	PRINTER LIST
1	Set partitioning at 559.49	5	op.17	559.49	-
2	Initialize input	-	E'	0	-
3.	ENTER 't.DATA'				
	Enter U value for glazing	U	E	U	-
	Enter design outside t	t _o	R/S	to	
	Enter design Δt (to - tl)	Δt _s	R/S	Δts	
	Enter latitude (DD.MMSS)	Lat.	R/S	1	
	Note: display after entering lat. shows '1'. This indicates that the calculator is ready for building input.				
	This input includes:				
	A. Surface orientations				
	B. Surface areas				
	C. % glazing on surfaces				
	D. U value of surfaces				
	E. Shading coef. of surface				

STEP NO.	PROCEDURE or COMMENTS	ENTER	PRESS	DISPLAY	PRINTER LIST																																				
	<p>This data may be entered in any order, except that SURFACE AREA and glazing % are coupled.</p>																																								
4	<p>Enter orientation of surface - orientation code to be followed:</p> <table><thead><tr><th>Code</th><th>Orientation (OR)</th></tr></thead><tbody><tr><td>1</td><td>N</td></tr><tr><td>2</td><td>NNE</td></tr><tr><td>3</td><td>NE</td></tr><tr><td>4</td><td>ENE</td></tr><tr><td>5</td><td>E</td></tr><tr><td>6</td><td>ESE</td></tr><tr><td>7</td><td>SE</td></tr><tr><td>8</td><td>SSE</td></tr><tr><td>9</td><td>S</td></tr><tr><td>18</td><td>SSW</td></tr><tr><td>17</td><td>SW</td></tr><tr><td>16</td><td>WSW</td></tr><tr><td>15</td><td>W</td></tr><tr><td>14</td><td>WNW</td></tr><tr><td>13</td><td>NW</td></tr><tr><td>12</td><td>NNW</td></tr><tr><td>0</td><td>HORIZONTAL</td></tr></tbody></table> <p>NOTE: Horizontal surface must be <u>last</u> (5th) entry.</p>	Code	Orientation (OR)	1	N	2	NNE	3	NE	4	ENE	5	E	6	ESE	7	SE	8	SSE	9	S	18	SSW	17	SW	16	WSW	15	W	14	WNW	13	NW	12	NNW	0	HORIZONTAL	OR.	A'	2*	<p>Display will show next orientation to be entered, Max. of 5.</p> <p>After the 5th entry the display will show a '1' indicating that the next set of input data is to be entered.</p>
Code	Orientation (OR)																																								
1	N																																								
2	NNE																																								
3	NE																																								
4	ENE																																								
5	E																																								
6	ESE																																								
7	SE																																								
8	SSE																																								
9	S																																								
18	SSW																																								
17	SW																																								
16	WSW																																								
15	W																																								
14	WNW																																								
13	NW																																								
12	NNW																																								
0	HORIZONTAL																																								
5.	<p>Enter surface area (AA) and % of surface covered by glazing (GG) as follows:</p> <p>a. Enter surface area, rounded to nearest whole number, enter % of glazing as a decimal to this number (AA.GG)</p> <p>Example: A = 101.3 (round to 101) G = 15%</p> <p>Enter <u>101.15</u></p> <div><div>↑</div><div>↓</div><div>Area</div><div>Decimal % of Glazing</div></div> <p>(There is no limit to the area)</p> <p>Enter: 1. Vertical Area, %G 2. Vertical 3. Vertical 4. Vertical 5. <u>FLOOR AREA</u></p> <p>Last entry (5th) must be <u>FLOOR AREA</u>.</p>																																								

STEP NO.	PROCEDURE or COMMENTS	ENTER	PRESS	DISPLAY	PRINTER LIST																								
	<p>If a building has less than 4 vertical surface, enter '0' (zero) in lieu of AA.GG.</p>																												
6	<p>Enter 'U' value for each surface</p> <p>Enter: 1. Vertical U 2.. Vertical U 3. Vertical U 4. Vertical U 5. <u>ROOF U</u></p>	U	C'	1-5																									
7	<p>Enter shading coef. (SC) for each surface. If calculated SC's are unavailable, use the following values:</p> <p>Surface is shaded from Sun, the following hours per day:</p> <table><thead><tr><th><u>hr/day of Shade</u></th><th><u>SC</u></th></tr></thead><tbody><tr><td>0</td><td>1.0</td></tr><tr><td>1</td><td>0.9</td></tr><tr><td>2</td><td>0.8</td></tr><tr><td>3</td><td>0.7</td></tr><tr><td>4</td><td>0.6</td></tr><tr><td>5</td><td>0.5</td></tr><tr><td>6</td><td>0.4</td></tr><tr><td>7</td><td>0.3</td></tr><tr><td>8</td><td>0.2</td></tr><tr><td>9</td><td>0.1</td></tr><tr><td>10</td><td>0.0</td></tr></tbody></table>	<u>hr/day of Shade</u>	<u>SC</u>	0	1.0	1	0.9	2	0.8	3	0.7	4	0.6	5	0.5	6	0.4	7	0.3	8	0.2	9	0.1	10	0.0	SC	D'	1-5	
<u>hr/day of Shade</u>	<u>SC</u>																												
0	1.0																												
1	0.9																												
2	0.8																												
3	0.7																												
4	0.6																												
5	0.5																												
6	0.4																												
7	0.3																												
8	0.2																												
9	0.1																												
10	0.0																												
8	<p>To calculate heat gain, for each surface -</p> <p>Typical Output: (printer)</p> <p>OR = orientation OP = opaque surface heat gain GL = glazed surface heat gain E = sum of opaque and glazed heat gain, per surface HG = total heat gain for all surfaces</p>	-	A	see note OR OP GL E HG																									

STEP NO.	PROCEDURE or COMMENTS	ENTER	PRESS	DISPLAY	PRINTER LIST
	<div>55</div> <div>1.00 OR</div> <div>7286.00 OP</div> <div>5380.00 GL</div> <div>12666.00 E</div> <div>5.00 OR</div> <div>6904.00 OP</div> <div>19380.00 GL</div> <div>26284.00 E</div> <div>9.00 OR</div> <div>7286.00 OP</div> <div>10553.33 GL</div> <div>17839.33 E</div> <div>15.00 OR</div> <div>8024.00 OP</div> <div>19380.00 GL</div> <div>27404.00 E</div> <div>0.00 OR</div> <div>27891.20 OP</div> <div>0.00 GL</div> <div>27891.20 E</div> <div>112084.53 TG</div>				

1 <		> 2		
Northeast U.S. Internal Load Model I 30p17				
Residential	Load Data	People Data	Bldg. Data	t.Data
Office	Retail	School	Hospt'l.	Other

CARD A

3 <		>		
Northeast U.S. Internal Load Model II 30p17				
Residential	Load Data	People Data	Bldg. Data	t.Data
Office	Retail	School	Hospt'l.	Other

CARD B

PROGRAM DESCRIPTION

Used in tandem with Heat Loss Model and Heat Gain Model I & II, for determining internal loads for buildings in the northeast U.S.

STEP NO.	PROCEDURE or COMMENTS	ENTER	PRESS	DISPLAY	PRINTER LIST
1	Set partitioning at 719.29	3	op. 17	719.29	-
2	Enter 'LOAD.DATA'				
	A. Enter <u>MX</u> <u>Winter</u> load from <u>Heat Loss Model</u>	MX	B'	2	
	B. Enter <u>HG</u> <u>Summer</u> Load from <u>Heat Gain Model</u>	HG	R/S	1	
3	Enter 'PEOPLE-DATA'				
	A. Enter no. of people in bldg.	people	C'	2	
	B. Enter <u>CFM</u> ventilation load	CFM	R/S	1	
4	Enter 'BLDG.DATA'				
	A. Enter gross enclosed floor area	area	D'	2	
	B. Enter any special load (SL) in Btu/hr.	SL	R/S	3	
	C. Enter WATT/S.FOOT (W/SF) lighting load	W/SF	R/S	1	

STEP NO.	PROCEDURE or COMMENTS	ENTER	PRESS	DISPLAY	PRINTER LIST
5	Enter 't.DATA' A. Enter <u>winter</u> , inside-outside temp. differential B. Enter <u>summer</u> temp. differential (Δt_s) C. Enter mean winter temp (t_{mean})	Δt_w ΔT_s t_{mean}	E' R/S R/S	2 3 1	
6	For output - press bldg. type <u>Unit</u> key - residential - office - retail - school - hospital - other commercial		A' A B C D E	see sample output