RESIDENTIAL ENERGY REQUIREMENTS AND OPPORTUNITIES FOR ENERGY CONSERVATION

DR. JEROLD W. JONES
Member ASHRAE

BURKLEY J. HENDRIX
Student Member ASHRAE

Residential energy consumption is nearly as much a function of occupant "action" as it is of construction or heating and cooling systems. The present study was undertaken to provide Austin area residents information on conservation opportunities to encourage more energy-efficient operation of their homes. Since energy costs in Austin have increased dramatically in the past two years, consumers have considerable interest in conservation. However, much of the published residential conservation information available is not particularly applicable to the Texas climate. Therefore, more specific information was needed.

A computer-based model was chosen as a means of isolating the effects of various factors. In a computer simulation, one design or equipment feature can be varied at a time, holding all other influencing factors constant. This cannot be accomplished in actual experiments due to the variability of climatic and human factors. It is, however, also necessary to assure that the model used is realistic. Therefore, the computer model was used to simulate the energy needs of four existing homes. Construction plans, specifications, and equipment and appliance use data were obtained and used as the basis of the energy calculations. The simulation results were then compared with utility billing data for four or more years for each home. Although not a precise approach to verification of the computer model, it did provide a considerable amount of pertinent information. Also, the computer model is basically the National Bureau of Standards Load Determination (NBSLD) program, which has been validated in a number of other studies. Utility data for a larger sample of 200 homes were also examined to attempt to identify the range of variation in energy use which might occur due to differences in life-style and/or equipment types.

The results obtained in this study will be summarized and presented in terms of a single typical size (1630 ft^2) home. The influence of variations in insulation, infiltration of outside air, thermostat setting, glass type, attic ventilation, lighting and appliance loads, exterior shading, equipment efficiency, and occupant action will be presented.

MODEL DESCRIPTION

The computer analysis program, NBSLD, is described in detail elsewhere 1,2 . It is a dynamic program which calculates hour-by-hour heating and cooling loads. These calculations are based on hourly variations of climatic factors, occupancy, and lighting and appliance use. The program accounts for the

---

*This study was sponsored by the City of Austin through the Electric Utility Department.

Jerold W. Jones is in the Department of Architectural Engineering, The University of Texas, Austin, Texas, and Burkley J. Hendrix is a Graduate Research Assistant.

thermal capacitance of the structure, the interaction of the various load components, and variations in space temperature. The NBSLD program was modified somewhat for the present study, but most of the changes were only to facilitate running the program on a CDC 6600/6400 system and to provide additional input/output options.

The floor plan for the home used as an example in this paper is shown in Fig. 1. A summary of the monthly lighting and appliance energy use assumed for the model is given in Table 1, and hourly use and occupancy profiles are given in Fig. 2. The exterior walls of the sample home were 55% light-colored brick, 28% light-colored wood, and 17% glass. The major axis of the home runs north-south, so the major portion of the windows have an east or west exposure. The home is occupied by two adults and three children. The materials and quality of construction are typical of tract homes built in the Austin area during the past ten years.

A "base case" calculation was run for a "test weather year." The result is compared to billed utilities for the past four years in Fig. 3 and 4. This particular home is equipped with electric air conditioning, and natural gas is used for heating, water heating, and cooking. A specific comparison between the simulation and billed data is not possible because local hourly weather data are not available for corresponding years. However, the comparisons of Fig. 3 indicate that the model provides a reasonable simulation of the energy use.

The percentage of energy used for various functions is shown in Table 2. Table 2 also presents similar data from Ref. 3 for the Washington/Baltimore area. It should be noted that the totals and distribution are quite different for the two areas. In the Austin area, the total residential consumption is somewhat lower overall, and, as would be expected, there is a considerably different split between heating and cooling. Although the annual cooling load (Btu/year) is almost three times the annual heating load, the energy consumption for heating still exceeds that for cooling because of differences in equipment efficiency. When these efficiencies are accounted for, heating requires 31% of the energy used in the home, and cooling 22%. Water heating is the largest single consumer among the appliances and should be given adequate attention in any conservation program. (These same data, adjusted for energy production efficiencies, will be discussed further in a later section of this paper.)

RESULTS AND DISCUSSION

In presenting the results of this study, three specific areas of concern will be discussed: those factors which relate to the nature of the enclosure, those related to operation, and those related to equipment efficiency.

Enclosure

Energy transfer through a residence enclosure is a function of the type and quantity of materials used, the quality of construction, and certain design features. The factors of importance are:

1 Insulation
2 Infiltration
3 Glass
4 Orientation and external shading
5 Thermal mass

The home used as the base model in this study is a relatively well-insulated brick veneer home. The amount and type of glass and the quality of construction are typical. Therefore, it is of interest to note some of the thermal characteristics of the home. Table 3 gives the distribution of energy flux through various components of the enclosure of the home for a 100 F summer day and for a cold 28 F and relatively clear winter day. Both peak hour and daily values are shown. If the model had been uninsulated these distributions would have shifted as shown in Table 4. These data indicate the relative impact of energy flux through walls, ceiling, and glass and by infiltration on heating and cooling requirements.

1. Insulation Three levels of insulation were considered: a) R19* in the ceiling and R11** in the walls, b) R11 in the ceiling and no insulation in the walls, and c) no insulation in either ceiling or walls. The results of these variations are shown by the data in Table 5 indicating peak hour, design day, and seasonal variation and the amount of change of total annual energy consumption for each case. As indicated, insulation to the levels shown makes a significant difference. The savings in the heating seasons are greater than in the cooling season due to a larger average temperature difference. In fact, the insulated case required more energy for cooling in April and October than the uninsulated case. This higher load could, however, be offset by using outside air for cooling during these periods. It was also determined that insulation in excess of the R19 ceiling and R11 walls would provide very little additional savings in the Austin area.

2. Infiltration Infiltration is the hardest factor to quantify. The considerable amount of research on this problem conducted in the past two years is difficult to apply to the present study. The NBSLD program takes into account variations in wind speed and temperature differential. However, the equation used has a fixed coefficient and is insensitive to some of the factors which influence infiltration. An effort was made to give some weight to the hourly and seasonal variations which would be expected to occur by adding an infiltration term which could be scheduled. Three cases were again considered--"tight," "average," and "loose" construction--to attempt to look at a reasonable range of variation. More study is needed in this area. The results obtained are presented in Table 6. As indicated in Tables 3 and 4 the infiltration load is significant, and the data of Table 6 show that substantial savings could be achieved by reducing it.

3. Glass Both the amount and type of glass used will influence the energy flux through a building enclosure. For the model home the walls included 17% single glazing. The effects of reducing the percentage to 10%, increasing it to 25%, or double-glazing the 17% were evaluated and are tabulated in Table 7. It is difficult to discuss the merits of more or less glass independently of aesthetic considerations and possible interactions with lighting requirements. However, these results clearly indicate that excessive amounts of glass should be avoided. Double glazing provided the largest saving in the winter, but the reduced percentage was best for the summer and on an annual basis. The double glazing provided a 12% overall energy saving even for the mild climatic conditions of this study. However, since double glazing increases initial costs significantly, it would be justifiable only for relatively large glass areas.

4. Orientation and External Shading As noted previously, the majority of the windows in the base case home had east or west exposure and were assumed to be unshaded. A 90° rotation of the home substantially reduced the peak cooling load as indicated in Table 8. However, it had a relatively small influence (3%) on the seasonal energy consumption. External shading of the east and west windows, on the other hand, had a greater impact on both the peak cooling load and on the seasonal energy requirement. It should also be noted that shading and orientation may interact. For instance, in Austin, at 30° north latitude, south windows and walls can be substantially shaded for the entire cooling season by a modest roof overhang. Such a design would still allow some solar heating of the south exposure during the winter months. Shading of east and west exposures, however, is not as easily achieved. Energy conservative designs must give careful consideration to both factors. It also should be pointed out that shading of exterior surfaces is more effective than using drapes or blinds on the inside.

5. Thermal mass Residential frame construction has relatively little thermal mass. Calculations indicated that whether the exterior was wood or brick veneer made little difference. The calculated peak cooling load for a brick home was

---

* Approximately six in. of fiberglass.

**Approximately 3 1/2 in. of fiberglass.

slightly lower, but there was virtually no difference in energy requirements over the season. The lack of difference between the brick veneer and frame construction is best explained by the data in Table 3. For a well-insulated home only about 10% of the energy flux is through the walls. Thus, any variation in the thermal mass of this one component will have relatively little effect on the overall heat gain or loss.

Operation

The factors which influence energy use and which may be categorized as operational are: thermostat set point, appliance use, and attic ventilation. The first two can have a significant influence on residential energy requirements.

1. Thermostat Set Point Two types of variation in control were considered: a constant seasonal set point and a resetting during unoccupied hours or at night. Table 9 summarizes the effects of various seasonal set points. The data clearly show the advantage of this conservation option indicating a 28% annual reduction in heating and cooling energy.

Setting the thermostat up to 95 F for 8 hr a day, five days a week, during the cooling season decreased the air-conditioning energy consumption by almost a third but increased the peak load by about 10%. The increased peak may have an adverse effect on utility system demand and may, in some cases, require additional cooling system capacity.

Heating season night setback increases the peak heating load by only 5%. The overall heating energy savings calculated for the heating season amounted to approximately 35%. No additional capacity would be required in this case as heating systems in the Austin area are invariably oversized.

2. Appliance Use The main impact of increased lighting and appliance use in a residence is on the direct energy consumption rather than on the cooling or heating load. However, there is some interaction with the cooling load. The effects of a 50% increase in lighting use and a 25% increase in appliance energy are reflected in a 4% increase in cooling energy and a 30% increase in appliance energy as shown in Table 10.

3. Attic Ventilation Attic ventilation is meant to imply circulation of outside air through the attic space alone. It does not include additional circulation of outside air through the conditioned space. When defined in this way, attic ventilation was found to reduce attic temperatures significantly but to have negligible effect on the total cooling load. The energy flux through a well-insulated ceiling represents less than 10% of the daily load for the summer design day. Thus, even a relatively large reduction in attic temperature will have little effect on the total load.

Equipment Efficiency and Type

It was difficult to find specific information on the energy efficiency of the usual household appliances. However, the information available, 4,5 indicates the possibility of significant variations between various brands and models and is reviewed in Appendix A. Table 11 indicates the possible variations for lighting and appliance choices and use patterns for the model home used in this study as observed from the utility bills of a sample of forty similarly equipped homes in Austin.

The efficiency of the heating and air-conditioning equipment will have a significant effect on the amount of energy required for heating and cooling. (Table 2). At present some air conditioners have an energy efficiency ratio (EER) of less than four, while some of the new high-efficiency units have EER values as high as nine. Similarly, proper design and maintenance of gas-warmed air furnaces can provide meaningful savings. Table 12 compares the energy requirement for a standard unit to that for a unit with improved efficiency. Possible variation in heat pump energy requirements are also indicated.

The energy source utilized for heating, water heating, and cooling affects not only equipment efficiency but also prime energy costs, including production and distribution efficiencies. Although this was not the major focus of this study, the results shown in Table 13 were developed through the use of the model. Table 14 also gives comparable data gathered for approximately 200 homes by the local utilities over a one-year period. The data are presented in terms of thousand Btu/ft^2/year. Similar data were also gathered for the past year and the consumption was uniformly lower (8%). On the basis of square feet, the smaller homes consumed more energy than the larger homes in the sample. However, the computer analysis indicated that this difference is primarily due to appliance use and not to any difference in heating and cooling requirements.

The "average" appliance use data of Table 15 were input to the comparisons of Tables 13 and 14. There were no data available for local gas distribution losses, so a 2% figure was assumed. Most of the gas air-conditioned homes in the area also have at least one gas yard light, and often a gas grill, so additional gas consumption for these two items was included for that case. Again, it it should be noted that the energy use of individual homes in the sample varied considerably.

A direct comparison between the model and the sample data cannot be made because the weather data input to the model does not correspond to that for either of the two years during which the sample data were obtained. The purpose of Table 15 is to indicate the relative success of the model in predicting residential energy requirements for homes equipped with various heating and cooling systems. The model most closely estimates the energy consumption of the gas-heat/electric-air home. It overpredicts the energy requirement of the all-electric homes relative to the observed data. A possible explanation of this is that all-electric homes have traditionally been tighter and better insulated than homes heated with gas. The model, however, assumed the same level of insulation in both and increased the infiltration in the gas-heated home only enough to supply the necessary air for combustion and stack gas dilution in the furnace. If the heating and cooling loads on the all-electric homes had been reduced to account for such possible differences, a better result would have been obtained. As noted in Tables 5 and 6, both insulation and infiltration have a significant influence on these loads.

The model is particularly low relative to observed data in its prediction of the energy consumption of the gas heating/gas air-conditioning homes. An examination of the monthly billing records of these homes indicates that the assumptions made with regard to both the gas and electric consumption of the gas air-conditioning seem to be low. The energy requirement assumptions were based on a manufacturer's rating for a single model.

CONCLUSIONS

Several conclusions can be drawn from the results of this study. First, although the form of energy (fuel) used has an important effect on the quantities of energy required for a residence, the major opportunities for conservation are related to the quality of construction and the operation of appliances and equipment. As Tables 14 and 15 indicate, the gas/electric combination of appliances and the all-electric heat pump consume significantly less energy than the all-electric/resistance heating and the gas heat/gas air-conditioning combinations.

Second, and most important, the study shows that there are significant opportunities for conservation in Austin residences. This is perhaps best illustrated by combining the various factors considered in this analysis into two sample homes. The first is not the worst possible case, as it presumes at least R11 insulation in the ceiling and some internal shading of the windows, but it represents a "typical" wasteful residence. The search would represent an energy "conservative" home where a reasonable effort has been made in design, construction, and operation to reduce energy consumption. Most of the conservation features have been included, with the exception of double glazing and a variation in the daytime inside temperature during the cooling season.

The contrast between the two types of homes is rather startling, as illustrated by Table 16. There is a 56% decrease in annual energy consumption with conservation. When this difference in energy is translated into dollars and cents at current utility rates, the financial savings are also significant. Thus, conservation pays dividends both in terms of preserving natural (energy) resources and reducing the cost of utility services.

APPENDIX

Summary of Appliance Energy Data

Electric	Kwh/Mo	10^5Btu	Comments
Refrigerator	140	15.3	Frost-free may vary from 100 to 150 kwh/mo depending on size and model. Manual will run 80 to 100 kwh/mo if defrosted frequently enough to prevent extensive buildup on cooling coils.
TV	40	4.4	Color TV runs roughly twice the power consumption of black and white. Solid-state is approximately one-half tube type for both color and black and white. Thus, a solid-state color would use about the same power as a black and white tube type.
Miscellaneous	50	5.4	This includes small appliances such as: kwh/mo hand iron 12 coffee maker 10 electric skillet 12 vacuum cleaner 4 hair dryer 3 stereo/radio 3 toaster 3 disposal 2
Freezer	120	13.1	Approximately 25% of the residences in Texas have a home food freezer.
Dishwasher	30	3.3	Electric energy, exclusive of hot water. The dishwasher will use approximately 0.4 kwh/load for pumps, controls, etc., and 0.35 kwh/load for drying. Various models range from 0.5 to 1.0 kwh/load.
Clothes washer	10	10.9	Exclusive of hot water. Electric energy use will range from 0.2 to 0.3 kwh/load for various models. With a hot wash/cold rinse cycle, hot water consumption will be approximately 25 gal/load, while for warm wash, cold rinse it will be approximately 12 gal/load.
Lighting	250	272	Depending on the wattage bulbs used and the number of hours per month the lights are used, this could range from a low of 150 kwh/mo to a high of 350 kwh/mo.

Electric/Gas	Kwh/Mo	10^5Btu	Cf/Mo	10^5Btu	Comments
Range/oven	100	10.9	690	6.9	Based on approximately 6 hrs/wk oven baking, 1/2 hrs/wk broiling and 5 hrs/wk operation of two surface elements on the range
Dryer	100	10.9	470 +7 kwh electric	5.5	Electric approximately 3 kwh/load. Gas 14.5 cu ft/load plus 0.2 kwh/load electric

Summary of Appliance Energy Data, (Cont.)

Electric/Gas	Kwh/Mo	10^5Btu	Cf/Mo	10^5Btu	Comments
Yard light	18	19.6	1520	15	Gas yard lights burn continuously, using from 46 to 54 cu ft of gas per day. The electric yard light is 60 watts and is assumed to burn 10 hrs/day 365 days per year
Water Heater	505	550	2600	260	70 gal/day at 150°F.
	690	752	3400	340	100 gal/day at 150°F. Considerable savings could be achieved by reducing the hot water temperature to 135°F. For 70 gal/day use this would reduce the consumption to 415 kwh/mo electric or 2100 cu ft/mo gas.

* The energy requirement figure for the gas appliances listed here does not include the indirect energy use due to the increased cooling load which results from increased on-site energy use and infiltration of combustion air.

REFERENCES

1 M. Locmanhekim, ed. "Procedures for Determining Heating and Cooling Loads for Computerized Energy Calculations." New York: ASHRAE, 1971.

2 T. Kusuda, "NBSLD, Computer Program for Heating and Cooling Loads in Buildings." NBS112 74-574. Washington, D.C.: National Bureau of Standards, 1974.

3 Hittman Associates, Inc. "Residential Energy Consumption/Single Family Housing Final Report." Report HUD-HA1-2. Washington, D.C.: U.S. Department of Housing and Urban Development, 1973.

4 Consumer Reports. May, July, October, and November 1974.

5 Materials supplied by the American Gas Association (AGA), Arlington, Virginia.
cooking - AGA Res. Pub. 1132;
water heating - University of Illinois report to AGA (Res. Bul. 436);
space heating - results from Canton Test Homes.

TABLE 1

Summary of Monthly Lighting and Appliance Energy Use

Appliance Energy Requirement

	Electric	Gas
Refrigerator	140 Kwh/Mo	
Dishwasher	30 Kwh/Mo	
TV (color, solid state)	50 Kwh/Mo	
Clothes Washer	10 Kwh/Mo	
Miscellaneous	60 Kwh/Mo	
Basic Electric Consumption	290 Kwh/Mo	
Food Freezer	130 Kwh/Mo	
Dryer	100 Kwh/Mo	500 Cu Ft/Mo
Range and Oven	100 Kwh/Mo	700 Cu Ft/Mo
Coffee Maker	10 Kwh/Mo	

(The typical total appliance energy use is 390 kwh/mo.)

Lighting Energy Requirement

	Liberal Use	Conservative Use
100-watt bulbs	350 Kwh/Mo	240 Kwh/Mo
60-watt bulbs	220 Kwh/Mo	150 Kwh/Mo

Water Heating Energy Requirement

		70 Gal/Day	100 Gal/Day
Electric	@ 150 F	500 Kwh/Mo	700 Kwh/Mo
	@ 135 F	410 Kwh/Mo	570 Kwh/Mo
Gas	@ 150 F	2.6 Mcf/Mo	3.5 Mcf/Mo
	@ 135 F	2.1 Mcf/Mo	2.8 Mcf/Mo

TABLE 2

Residential Energy Use Profiles

Austin, Texas	On-Site Energy
Annual Energy Consumption 90 Thousand Btu/Ft^2/Year*	
Heating	31%
Air Conditioning	22%
Appliances and Lighting	25%
Hot Water Heating	22%

Washington-Baltimore Area	
Annual Energy Consumption 130 Thousand Btu/Ft^2/Year	
Heating	65%
Air Conditioning	6%
Appliances	16%
Hot Water Heating	13%

*A combination of gas and electric appliances have been assumed. This figure has not been adjusted for generating and transmission losses.

TABLE 3

Heat Gain Loss Distribution for Well-Insulated Residence (Thousand Btu)

	Heating		Cooling	
	Peak Hr	Day	Peak Hr	Day
Ceiling	2.8 (12%)	53.9 (14%)	1.6 (7%)	22.9 (8%)
Wall	2.8 (12%)	68.6 (17%)	1.1 (5%)	14.9 (6%)
Glass				
Conduction & Convection	9.3 (40%)	130.0 (33%)	2.1 (9%)	29.2 (10%)
Radiation	-	-	14.9 (60%)	117.6 (41%)
Infiltration	8.4 (36%)	144.7 (36%)	5.0 (19%)	101.3 (35%)
Total Load	23.3	397.2	24.7	286.0

TABLE 4

Heat Gain/Loss Distribution for Uninsulated Residence (Thousand Btu)

	Heating		Cooling	
	Peak Hr	Day	Peak Hr	Day
Ceiling	18.4 (42%)	338.8 (43%)	5.5 (18%)	84.0 (22%)
Wall	7.0 (16%)	177 (22%)	2.9 (10%)	44.0 (12%)
Glass				
Conduction & Convection	9.3 (22%)	130 (16%)	2.1 (7%)	29.2 (8%)
Radiation	-	-	14.9 (49%)	117.6 (31%)
Infiltration	8.4 (20%)	144.7 (19%)	5.0 (16%)	101.3 (27%)
Total Load	43.1	790.5	30.4	376.1

TABLE 5

Insulation

Thermal Resistance		Heating Btu			Cooling Btu			Annual Btu
Ceiling	Wall	Peak Hr	Day	Season	Peak Hr	Day	Season	
R19	R11	21,300	310,000	16.4×10^6	32,100	382,000	45.7×10^6	62.1×10^6
R11	0	28,900	464,000	25.6×10^6	35,600	430,000	46.9×10^6	72.5×10^6
0	0	41,300	699,000	44.0×10^6	39,900	490,000	51.1×10^6	95.1×10^6

Design Conditions: Cooling: 100 F maximum dry bulb with a 20 F daily temperature range

Heating: 28 F minimum dry bulb, 12 Mph wind velocity

TABLE 6

Infiltration

Infiltration Rate, Air Change/Hr*	Heating Btu			Cooling Btu			Annual Btu
	Peak Hr	Day	Season	Peak Hr	Day	Season	
Tight (.1 to .4)	18,200	248,900	12.7×10^6	29,500	320,000	40.9×10^6	53.6×10^6
Average (.2 to .6)	21,300	310,000	16.4×10^6	32,100	382,000	45.7×10^6	62.1×10^6
Loose (.5 to .9)	24,400	368,000	19.4×10^6	34,100	430,000	49.9×10^6	69.5×10^6

*The Achenbach-Coblentz Formula

$$I = a + bV + c\,|\Delta T|$$

was used in the calculation of infiltration rates.

TABLE 7
Glass

Glazing	Heating Btu			Cooling Btu			Annual Btu
	Peak Hr	Day	Season	Peak Hr	Day	Season	
Single, 10%	18,000	270,000	14.3×10^6	26,900	328,000	37.7×10^6	52.0×10^6
17%	21,300	309,000	16.4×10^6	32,100	381,000	45.7×10^6	62.1×10^6
25%	24,700	346,000	18.2×10^6	37,400	440,000	52.8×10^6	71.0×10^6
Double, 17%	17,200	241,000	12.1×10^6	28,600	348,000	42.9×10^6	55.0×10^6

NOTE: Both the single and double glazing used 1/8" double-strength sheet glass.

TABLE 8
Orientation and Shading

	Cooling Btu			Annual Btu
Major Exposure	Peak Hr	Day	Season	
East and West	32,100	381,000	45.7×10^6	62.1×10^6
North and South	26,800	356,000	44.5×10^6	60.9×10^6
Shading				
East and West	24,300	329,000	42.6×10^6	59.0×10^6

TABLE 9
Thermostat Set Point

Set Point	Heating			Cooling		
	Peak Hr	Season	Peak Hr	Day	Day	Season
70°	21,300	16.4×10^6	---	309,000	---	---
75°	24,600	23.9×10^6	34,400	387,000	435,100	55.6×10^6
78°	---	---	32,100	---	381,000	45.7×10^6
80°	---	---	30,500	---	346,200	---
Unoccupied Hrs 95°	---	---	35,100	---	285,300	30.3×10^6
Night Setback 65°	22,400	12.0×10^6	---	260,000	---	---

TABLE 13

Variation of Energy Use With Equipment Type

	Energy Input for Appliance and Lighting			
Appliances	**Electric**	**10^5 Btu/Yr**	**Gas**	**10^5 Btu/Yr**
Refrigerator	140 Kwh/Mo	15.3		
Dishwasher	30 Kwh/Mo	3.3		
TV	50 Kwh/Mo	5.4		
Clothes Washer	10 Kwh/Mo	1.1		
Miscellaneous	60 Kwh/Mo	6.5		
Range/Oven	100 Kwh/Mo	10.9	.7 Mcf/Mo	7.0
Dryer	100 Kwh/Mo	10.9	.5 Mcf/Mo	5.0
Hot Water	600 Kwh/Mo	65.4	3. Mcf/Mo	30.0
Lighting	250 Kwh/Mo	27.2		
Typical Total Energy Use for Home (with Electric and Gas Appliances):				
	550 Kwh/Mo	59.9	4.5 Mcf/Mo	45.0
Typical Total Energy Use for Home (with All-Electric Appliances):				
	1340 Kwh/Mo	146.0		

TABLE 14 (Cont.)

All-Electric (Heat Pump)

	Kwh/Yr
Appliances	5800
Water Heating	7200
Lights	3000
Heating (75 F)	1900
Cooling (78 F)	8300
	26200
Average Billed for 60 Homes	24300

* This value assumes a seasonal heat pump COP of 2.5.

Gas Heating/Gas Air Conditioning

	Kwh/Yr	Mcf/Yr
Appliances	3500	16
Water Heating		36
Lights	3000	18*
Heating (75 F)	150	36
Cooling (78 F)	1600**	122
Totals	8250	228
Average Billed for 17 Homes	12200	281

* Gas yard light.

** Electric input to run condenser and evaporator fans, etc.

Condensing unit	875 watts
Air circulation	375 watts
	1250 watts

TABLE 15

Primary Energy Use Comparison

HVAC Equipment	Billed Average Thousand Btu/Ft^2/Yr	Model Thousand Btu/Ft^2/Yr
Gas Heat/Electric Air	153	151
Electric (Heat Pump)	157	168
Electric (Resistance Heat)	165	188
Gas Heat/Gas Air	247	192

Natural Gas		Electric Generation	
Heat Content	980 Btu/Cu Ft	Heat Rate	10,440 Btu/Kwh
Local Distribution Loss	2% (assumed)	Local Distribution Loss	4.2%

TABLE 16

Energy Consumption in Two Homes (1600 Ft^2)

	Wasteful		Conservative	
	Kwh/Yr	Mcf/Yr	Kwh/Yr	Mcf/Yr
Appliances	7200	18	4200	12
Lights	4200		1800	
Water Heating		41		24
Space Heating		85*		25+
Air Conditioning	13,100**		4700++	
Total	24,500	144	10,700	61
Annual Consumption adjusted for generation and transmission efficiency	252 Thousand Btu/Ft^2/Yr		110 Thousand Btu/Ft^2/Yr	

*Based on a calculated annual heating load of 37.5 x 10^6 Btu and a seasonal heating efficiency of 50%.

**Based on a calculated annual cooling load of 65.3 x 10^6 Btu and an EER equal to 5.

+Based on a calculated annual heating load of 12.6 x 10^6 Btu and a seasonal efficiency of 65%.

++Based on a calculated annual cooling load of 37.9 x 10^6 Btu and an EER equal to 8.

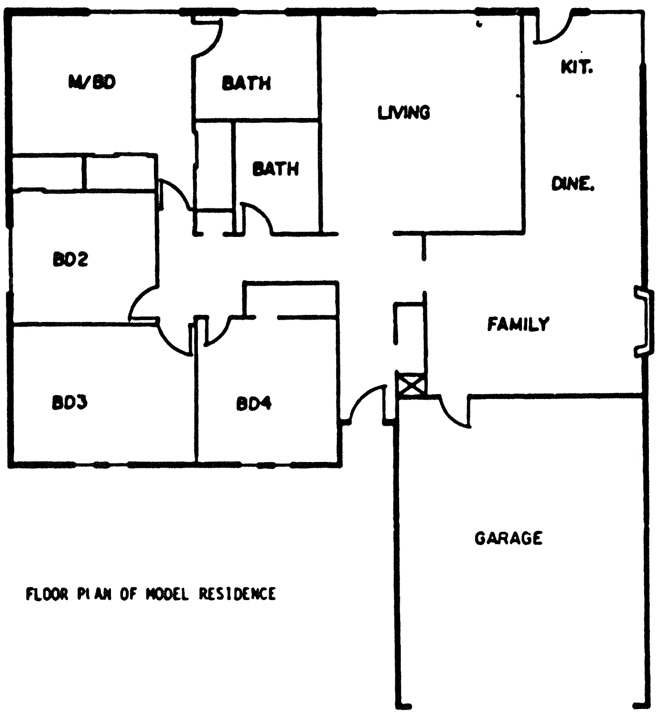

Fig. 1 Floor plan of model residence

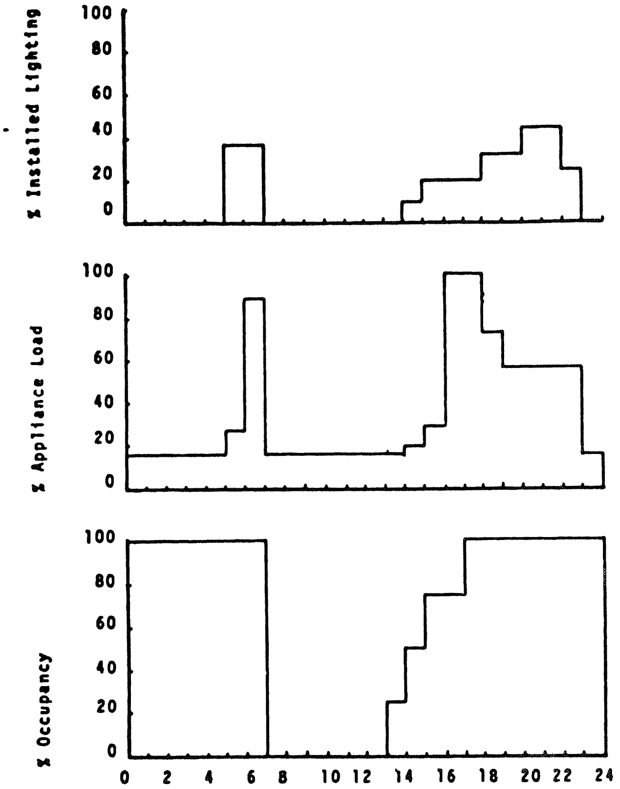

Fig. 2 Hourly schedule

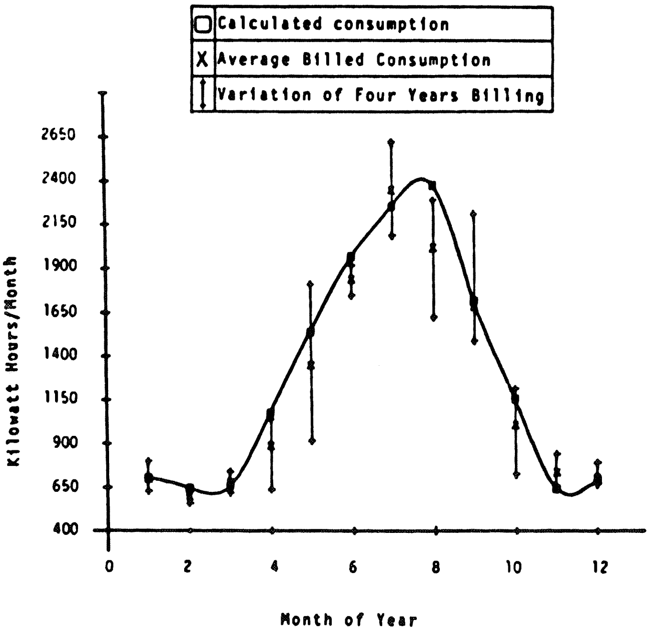

Fig. 3
Electric energy consumption of model residence

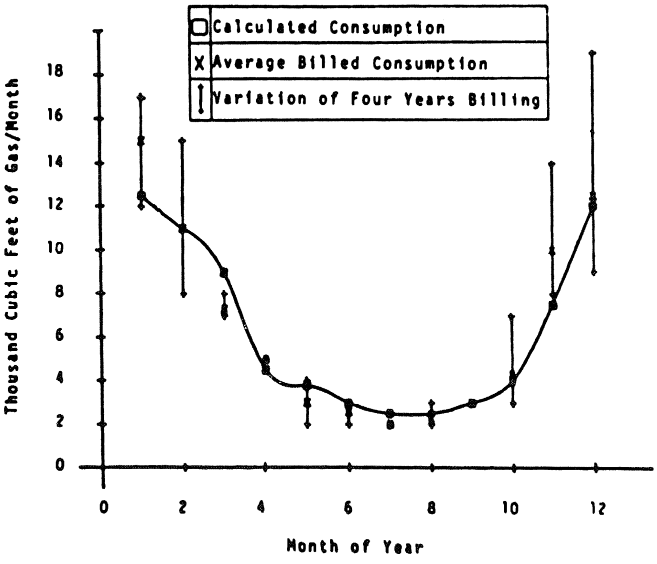

Fig. 4 Gas energy use of model residence

DISCUSSION

RALPH C. STEELE, Vice President, Heyem Assoc., Inc., Bloomfield Hills, MI: Was free cooling considered? If so, what were the results? If not, why was it not included?

JONES: By "free cooling" I assume you mean the use of an attic fan which draws outside air through the house and out through the attic. Unfortunately we did not have a mechanism built into our computer model to account for this option. Therefore it was not considered. However one of the four homes we studied in detail had an attic fan and its use during periods when the outside air temperature and relative humidity were suitable reduced cooling season electrical requirements by approximately 15 to 50%