NAT'L INST. OF STAND & TECH R.I.C
A11103 995458

NBS
PUBLICATIONS

NBSIR 78-1501

Quantified Occupant-Use Factors Affecting Energy Consumption in Residences

Roy E. Clark
S. Robert Hastings

nter for Building Technology
tional Engineering Laboratory
tional Bureau of Standards

Department of Commerce
Washington, D.C. 20234
July 1979

QC
100
.U56
78-1501
C.2

National Bureau of Standards
SEP 20 1979

NBSIR 78-1501

QUANTIFIED OCCUPANT-USE FACTORS AFFECTING ENERGY CONSUMPTION IN RESIDENCES

Roy E. Clark
S. Robert Hastings

Center for Building Technology
National Engineering Laboratory
National Bureau of Standards
Washington, D.C. 20234

July 1979

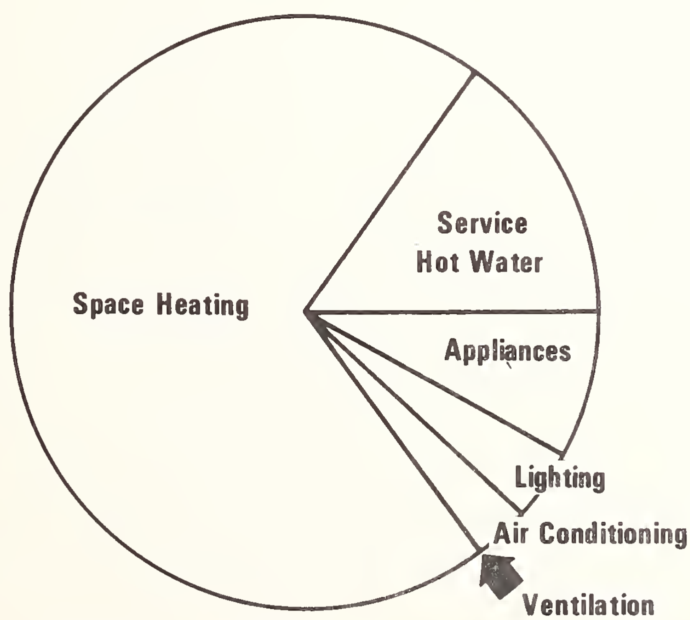
Prepared for
Department of Energy
20 Massachusetts Ave., N.W.
Washington, D.C. 20545

U.S. DEPARTMENT OF COMMERCE, Juanita M. Kreps, *Secretary*
Luther H. Hodges, Jr., *Under Secretary*
Jordan J. Baruch, *Assistant Secretary for Science and Technology*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Acting Director*

ABSTRACT

Predicting energy consumption for a building requires three types of data: climatic data, component performance data, and occupant-use data. Historically, few data on occupant use of a building have been collected, and the data which are collected are not easily referenced. Consequently, it is common for energy analysts to establish values for occupant variables merely on the basis of their own personal experience. In reponse to this dilemma, this report assembles residential energy-use data, as could be found, from field metering studies, surveys, utility company estimates, and government sponsored statistical projections. From these data the authors have determined recommended occupant-use values based on their analysis and judgements. These "recommended values" represent the best judgement of the present authors, but are not to be interpreted as "NBS recommended" values. Data are organized into six groups by energy end-use: (1) heating, (2) service hot water, (3) appliances, (4) lighting, (5) air conditioning, and (6) ventilation. The use of more soundly derived values for occupant use variables will result in a better correlation between the energy-use predicted for buildings being designed today and the actual energy-use of the buildings when occupied.

Key Words: Appliance energy consumption, energy consumption of residences, lighting energy consumption, occupant factors, residential air conditioning, service hot water, space heating, ventilation.



NATIONAL AVERAGE END-USES OF ENERGY IN RESIDENCES

CONTENTS

FOREWORD

This one of a series of reports planned to document National Bureau of Standards (NBS) research and analysis effort in developing energy and economic data in support of the Department of Energy (DOE)/NBS Building Energy Conservation Criteria Program. The preparation of this document was supported under Task Order No. A008-BCS of DOE/NBS Interagency Agreement No. EA-77-A-01-6010.

This publication comprises the final report of efforts related to residential buildings, that were earlier documented in two contract letter reports dated September, 1976, and June, 1977. The earlier effort was jointly supported by the Energy Research and Development Administration (ERDA), under ERDA Contract No. E(49-1)3800, and the Department of Housing and Urban Development, under Contract No. RT 193-12.

1.0 INTRODUCTION

Realistic building energy consumption predictions are becoming increasingly important to various people. Designers need predictions to enable them to evaluate building design alternatives and to select building equipment for efficient energy utilization. Building buyers and users and the general public need predictions as a basis for realistic anticipation of building operating costs. Building code writers and enforcers find predictions becoming increasingly necessary as energy standards for various types of buildings become more and more common.

The realism of energy consumption predictions depends upon the realism of the basic assumptions used in the predictive model, be it a simple hand calculation or a sophisticated computer program. There are three sets of input assumptions which are needed:

1. What is the climate in the immediate vicinity of the building (e.g., outside temperature, wind, solar radiation, etc.).

2. What are the performance properties of the building and its energy-using subsystems (e.g., U-values of envelope components, performance coefficients for mechanical equipment, etc.).

3. How do occupants use the building and operate energy-using subsystems (e.g., occupancy schedules, thermostat settings, usage patterns, etc.).

Data are generally available for establishing values for the first two sets of assumptions. Data are seriously deficient, however, for quantifying occupant use of buildings and operation of energy-using subsystems.

In response to the need for representative data of broad validity, this report surveys a variety of studies of occupant use of residences and their energy using systems, and assembles data from these studies. Data are in the form of explicit occupant use data, such as hourly records of thermostat settings or number of lights on, or of implicit occupant use information, such as appliance usage which can be estimated from the measured kWh consumption. Sources of these data include:

- ° Metered field studies, such as the Princeton Twin Rivers project and the Midwest Research Institute study.

- ° Surveys, such as the Newman and Day study.

- ° Utility and appliance industry research, such as studies by the Edison Electric Institute and the American Gas Association.

- ° Statistical projections, such as the Federal Energy Administration (FEA) "Project Independence" study and the Standford Research Institute "Patterns of Energy Consumption" study.

° Assumptions commonly used in recent energy analysis studies.

Residence as used in this report refers to both single-family and multi-family dwelling units. Wherever data is related to a particular type of residence, the type is so indicated. The energy consumed in residences can be divided into six end-use categories: space heating, service water heating, appliance operation, air conditioning, lighting, and mechanical ventilation. The accuracy of predictions of overall building energy consumption depends on the realism of the use projections for each of these categories. It is difficult to make realistic generalizations for use projections, however. Patterns of use among these categories vary, depending on such factors as geographical location (climate), type of dwelling unit, and income level and lifestyle of the occupants. As a consequence, it is necessary to consider separately for each end-use category the bases for prediction and the data available on which to base projections. At the same time, we must take note of interactions between the end uses--for example, lighting contributes heat, thereby increasing summer air conditioning load, but reducing winter heating load. Where such interactions may be significant, the list of data required for each end use includes pertinent information.

The report is divided into six chapters corresponding to the six end-use categories of energy consumption in residences. Each chapter is subdivided into a narrative section and a data section.

The narrative section discusses the relative importance of the particular category of energy-use relative to total residential consumption, lists needed occupant data and related physical data, provides an overview of available data, suggests additional data needs and collection methods, and gives recommended values for occupant variables. The listed values represent the best judgment of the authors, based on the data presented in the report. They do not constitute "NBS recommended" values.

The data section of each chapter provides reported numeric data on which the reader can base his own set of numeric values for occupant use of a building and its energy-using equipment. This particular project had neither the intention nor the resources to conduct any evaluation of the assembled data. Our purpose was simply to document the values and the ranges of values that appear in the current literature, as a starting point for efforts to develop a collated set of national indicators of energy use in buildings and as a first-cut reference manual for the use of building energy analysts. The reported data do exhibit inconsistencies and unexplainable variations. The sources of the data are listed, and readers are encouraged to obtain and review the original case studies or project reports and to form their own conclusions as to the probable validity of various data. The sources referenced are meant to be representative rather than exhaustive. The authors would welcome information from readers concerning other completed or ongoing field studies, surveys or statisitical projections.

For a table of conversions between different energy and time units, see page 154.

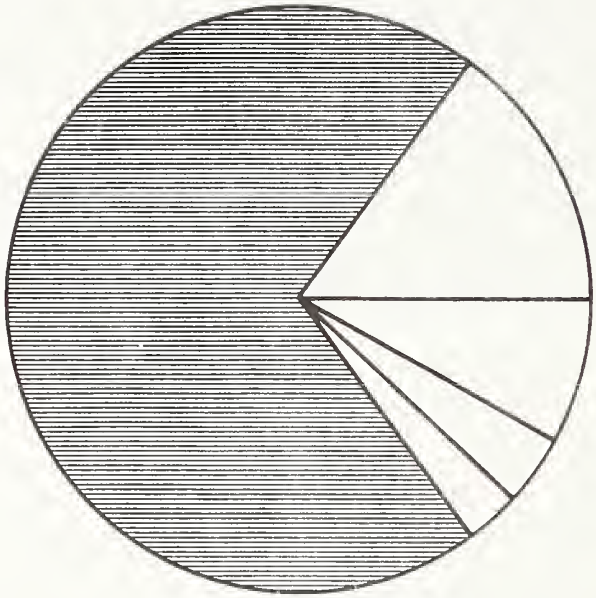
A word is in order concerning units for energy measurement. Energy consumption in residences is recorded and reported in various units--typically, in particular, kilowatthours (kWh) for electricity consumption and therms for natural gas usage. In order to facilitate comparisons of the (interacting) energy uses of a building, we wished to express all energy quantities in a single unit. Until such time as the International System unit, the joule, comes into more common use in this field, the British Thermal Unit (Btu) would appear to be the unit of choice for uniform expression of energy quantities. Consequently, we list data in this paper, first in the units in which it was orginally reported, and then converted into Btu (with an appropriate multiple in units of 10^3). Where carrying out this conversion is attended with uncertainties, they are discussed in the test.

One also encounters differences with respect to the time frame of reported measures. They may have been recorded per hour, per day, per week, per month, per year -- or in the form of the load imposed by the particular device or system. Obviously, data reported for a one-hour or one-day period cannot be projected to annual usage without substantial uncertainty. A daily average over a 20-or 30-day measurement period would constitute a more valid basis for projections--but even here such a figure might be representative of winter (or of summer) consumption patterns, but not of year-round average consumption. Here again we have reported all data in its orginal time units, and have appended such conversions to other time frames as seemed desirable to facilitate comparisons while also justified by the nature of the data.

We are aware that computer programs generally require day-profile (hourly) information in normalized form. However, rather than add additional columns to our day-profile tables, we have chosen to leave to users the straightforward task of calculating normalized profiles from the actual measured data given.

The benefits of improved dissemination of data on occupant use of buildings and energy-using systems will be improved reliability of energy consumption predictions used during the design phase and reduced energy consumption after a bulding is constructed. In addition, it will enable resources for conducting research to be more wisely allocated in order to collect data where serious deficiencies exist.

SPACE HEATING



2.0 SPACE HEATING

2.1 RELATIVE IMPORTANCE

Space heating consumes far more energy in U. S. residences than any other end use. Typically, a 1500 ft^2 house averages 20,000 Btu per day of gas or oil consumption for each degree (F) (36,000 Btu per day for each degree C) the outside average temperature is below 65° F (18°C) (1974, Carnahan, p. 65). The magnitude of this consumption relative to other energy uses is illustrted by figures complied by the Stanford Research Institute. Of the total energy consumed in the U.S. in 1969, 11 percent was consumed for space heating of residences. This amounted to 70 percent of all the energy consumed in residences (1972, Stanford Research Institute, p. 37).

The most important exterior factor affecting energy consumption for heating is outside air temperature. The second most dominant factor is wind. Infiltration/exfiltration, which is strongly influenced by wind, accounts for as much as one-third of the heating energy consumption. Finally, solar radiation, though currently not considered a dominating factor, has the potential to drastically alter energy consumption for heating. On a clear winter day the solar energy incident on an unshaded typical house is comparable to the energy required to heat the house for 24 hours on the coldest day of a 5000 degree day climate (1974, Carnaham, p. 65).

Occupants can significantly alter the effect of outside temperature, wind, and sun on heating energy consumption through the opening of exterior doors, the night-time covering of windows, the closing off of portions of a house when they are not being used, and the setting of thermostats. Thus, occupant-use data is important input into calculations of predicted energy consumption.

2.2 NEEDED OCCUPANT DATA

1. Hourly demand profiles (average room temperatures)

   weekday
   weekend
   unoccupied

   by region
   by family size
   by residence size

2. Exterior door openings (count and cumulative duration)

3. Window management

   opening (schedule)
   covering (schedule and U-value variations)

4. Isolation of room(s) from conditioning

5. Occupancy schedules (number of people and activities) (Btu)

   weekday
   weekend
   unoccupied

6. Hourly appliance and lighting demand profiles (see Appliance and Lighting sections)

2.3 RELATED PHYSICAL DATA

1. Climate data--air and ground temperatures, wind speed and direction, and direct and diffuse solar radiation (adjusted for cloudcover)

2. Area of living space or number of rooms heated

3. Areas and orientations of roof, walls, windows, doors

4. Color of roofing and siding

5. Extent of shading by trees or adjacent buildings

6. Mass of the building construction and contents

7. Airtightness of construction (general: detailing and workmanship, specific: window/door crack length)

8. U-values of building envelope elements

9. Equipment efficiency and fuel type

2.4 AN OVERVIEW OF AVAILABLE DATA

Considerable data have been collected by utility companies on the energy demands for space heating of residences, and by research groups on the energy consumed for space heating various "prototype" houses. However, in general, there is a serious shortage of available data on the occurence and effects of occupant factors, even though these factors can make a dramatic difference in heating energy consumption. (For the largest effort to date to fill this gap, see 1975, Socolow and Sonderegger, describing findings at Princeton University's Twin Rivers Study.) The energy consumed by a building's heating system, in a given climate, is basically determined by thermostat settings. ASHRAE Standard 90-75, Energy Conservation in New Buildings, recommends a single room temperature value of 72°F (22°C) be used for calculation purposes. This correlates with the daytime temperature preference of the greatest number of households in the 1973, nationwide survey of 1455 households reported by Newman and Day. (Fifty-two percent of households surveyed preferred 70° to 72°F (21° to 22°C)). However, this survey was conducted prior to the government and utility company campaign encouraging the lowering of thermostats. The rapid escalation of fuel prices coupled with the extensive campaign to lower thermostats to 68°F (20°C) during the day (even as low as 65°F (18°C)) have probably led to typical average indoor temperatures lower than 72°F (22°C).

In addition, ASHRAE Standard 90-75 does not provide a recommendation for an assumed night-time temperature set-back. The Newman and Day survey reports, however, that the greatest number of households set their thermostats lower than 70°F (32°C) at night. Furthermore, with the increasing trend of women being employed outside the home, there is a growing likelihood that thermostats are set back during the daytime when the house is unoccupied.

2.5 ADDITIONAL DATA NEEDS AND SUGGESTED COLLECTION METHODS

Data about all of the occupant factors listed at the beginning of this section are needed.

Data are needed to establish patterns of thermostat settings and, equally important, the average room air temperatures of occupied and unoccupied rooms for the reported thermostat settings. Room air temperature, not thermostat setting, is the direct determinant of energy consumption by the heating system. Such data could be collected in a house by attaching a recording device to the thermostat, installing temperature sensors at equal heights (the proper height is an important question) in principal rooms, and asking occupants to keep a log of blocks of time spent in various rooms. The selection of houses in the sample should include different family sizes and combinations of ages, different house sizes, and different climate regions. Results could also be affected by whether the data were collected in the beginning, middle or end of the heating season.

A method of obtaining limited interior temperature and thermostat setting data is to tap the data collected at occupied protytype energy conserving houses (such as the NASA Technology Uilization House in Hampton, Virginia or the NAHB "energy efficient residence" in Mr. Airy, Maryland) and the ongoing study at Princeton University in the Twin Rivers townhouse development. These heavily instrumented case studies can provide supplemental data on parameters which affect occupant preference of specific air temperatures (e.g., mean radiant temperature, drafts, and temperature variation with height).

Data on door openings could be gathered by using a cumulative timer activated when a door was opened and stopped when the door was closed. A counter device would be used to record the number of door openings. A sample of households should be metered. Data on window opening and night-time coverage could be similarily obtained, or recorded by survey questionnaries. Intuitively, it would be expected that privacy dictates the night time covering of windows, especially in suburban or urban settings. Research is needed, however, to estimate what percentage of windows in a house are covered, with what type of covering, and during which hours. The effects of window covering on heating energy consumption are especially noteworthy, since windows are likely to have the highest transmission losses (on a square foot basis) in comparison to all other exterior surfaces, and since the benefit of window covering occurs during the night when the inside/outside temperature difference is likely to be greatest.

Occupancy schedules are a key issue, with virtually no data available to substantiate or refute the numerous assumptions currently used. The typical procedure for arriving at an occupancy schedule is for the architect or engineer doing the heating analysis to use his own family or a hypothetical family and create an occupancy schedule based on his personal experience. Whether such assumed schedules are truly typical or representative is unknown. One source of information for the amount of time that occupants are away from home is the Department of Labor. Statistics on the percentage of working women vs. all women would be useful documentation for basing assumptions on occupancy, de facto. A more precise way of determining occupancy patterns would be to ask a sampling of households to keep a daily log of how many hours each member of the family was home.

Space heating

Occupant Datum	AUTHORS' RECOMMENDED VALUES Value(s)	Level of Confidence/Basis
1. Hourly demand profiles (average room temperatures)		
weekday	Daytime (0700-2200): 70°F Night (2200-0700): 66°F	Temperatures based on Newman and Day; present authors judgement of schedule and effect of "dial down" urgings.
weekend	The same	The same
unoccupied	No recommendation	No basis
by region by family size by residence size	No recommendation	No basis
2. Exterior door openings (count and cumulative duration)	Count (based on three bedroom house occupied by family of 6): 32/dy	Based on scenarios of occupant winter activities acted out and analyzed at the NBS test house.
	Duration: no recommendation	No basis
3. Window management		
opening (schedule)	No schedule recommendation (assume bedroom windows closed at night)	Based on 1975, Newman and Day.
window coverings	No schedule recommendation	No basis
	Window uncovered: U=1.13 Window shaded (drapery or roll shade): U=0.9	NBS window research

Space heating

AUTHORS'RECOMMENDED VALUES (cont.)

Occupant Datum	Value(s)	Level of Confidence/Basis
4. Isolation of room(s) from conditioning	No recommendation	No basis
5. Occupancy schedule (number of people and activities) (Btu)		
weekday	See profiles, following pages.	Based on hypothetical scenarios generated by the authors.
weekend	No recommendation	No basis
unoccupied	No recommendation	No basis
	Rates of metabolic heat release (Btu/hr):	Figures for adults taken from ASHRAE Handbook of Fundamentals. Others calculated using assumed body surface areas.
6. Hourly appliance and lighting demand profiles (see Appliance and Lighting sections)		

(Btu/hr):	sleeping	sitting	typical hsld.work
Adult	280	400	800
Teenager	225	320	640
Elem. sch. age	140	200	400

AUTHORS' RECOMMENDED VALUES (cont.)

DATA: MEAS. ______ ASSUM. X

DAILY PROFILE

METABOLIC HEAT RELEASE OF OCCUPANTS UNITS persons/Btu x 10^3

SEASONS Winter, weekday

BUILDING TYPE Residence LOCATION Urban/Suburban

		1	2	3	4
HOUR	1	2/0.6	2/0.6	4/0.9	6/1.3
	2	2/0.6	2/0.6	4/0.9	6/1.3
	3	2/0.6	2/0.6	4/0.9	6/1.3
	4	2/0.6	2/0.6	4/0.9	6/1.3
	5	2/0.6	2/0.6	4/0.9	6/1.3
	6	2/0.6	2/0.6	4/0.9	6/1.3
	7	2/0.6	2/0.6	4/0.9	6/1.3
	8	2/1.1	2/1.1	4/1.8	6/2.4
	9	0/0	2/1.2	3/1.1	3/1.3
	10	0/0	2/1.1	1/0.7	1/0.7
	11	0/0	2/1.0	1/0.5	1/0.5
	12	0/0	2/1.1	1/0.6	1/0.6
	13	0/0	2/0.9	1/0.5	1/0.5
	14	0/0	2/0.9	0/0	0/0
	15	0/0	0/0	0/0	0/0
	16	0/0	2/1.1	2/0.8	2/1.1
	17	0/0	2/1.2	2/1.4	4/2.1
	18	0/0	2/1.2	4/1.1	6/1.7
	19	1.5/1.2	2/1.0	4/1.7	6/2.3
	20	2/1.6	2/1.2	4/1.5	6/1.9
	21	2/0.8	2/0.8	4/1.1	6/1.4
	22	2/0.8	2/0.8	4/1.1	6/1.4
	23	2/0.8	2/0.8	4/0.9	6/1.2
	24	2/0.6	2/0.6	4/0.9	6/1.3
Day Total		11.1	20.2	22.0	29.5

Column 1. Two adults, both employed

Column 2. Two adults, neither employed: (e.g., "senior citizens")

Column 3. Family of four: father, mother, one teenager, one elementary school age

Column 4. Family of six: father, mother, two teen-agers, two elementary school age

Basis: These numbers have been calculated using the rates of metabolic heat release listed under Item 5 in combination with some assumptions about the kinds and extent of activities that might be carried out by various household members.

DATA

SPACE HEATING

SURVEY

Source: 1975, Newman and Day*

Location: Nationwide

Date: 1973 (i.e., before government urging to "dial down")

Data: Percent of households from interviews of national sample of 1455 households in 177 different locations

Usual Indoor Winter Temperature**
(percent of households)

	All households	Heating Degree Days <3500	3500-5499	>5500
Daytime:				
<70°F	12%	12	14	10
70°-72°F	52	51	51	56
>72°F	33	34	33	33
Nightime:				
<70°F	45	51	49	38
70°-72°	35	30	33	41
>72°	16	13	15	19

Usual Indoor Winter Temperature**
(percent of households)

	Income Bracket*			
	Poor	Lower middle	Upper middle	Well off
Usual daytime:				
<70°F	17%	14	14	13
70°-72°	49	52	53	55
73°-75°	23	24	24	26
>75°	11	10	9	6
Usual night:				
65°	36	20	13	13
65°-69°	21	31	33	33
70°-72°	28	34	36	38
72°	15	14	18	16

* For a description of this survey and definitions of terms and categories used, see page 151.
** Excludes unknowns.

Wintertime Window Opening Practices
(percent of households)

	Income Bracket			
Use of bedroom window	Poor	Lower middle	Upper middle	Well off
Open at night	31%	36	29	35
Not open at night	69	64	71	65

		Heating degree days		
	All	<3500	3500-5499	5500+
Sometimes open winter nights	33	38	30	32
room door usually shut	15	16	12	16
room door usually open	18	22	18	14
Almost never open	66	61	69	66

Windows in U. S. Dwellings

		Heating degree days		
	All	3500	3500-5499	5500+
Number: 0-4	6%	5	6	6
5-9	29	31	29	26
10-14	33	38	30	33
15-19	18	14	19	21
>19	14	10	16	14
Number of extra large: none	49	53	52	42
some	50	46	48	57
1	26	25	22	30
> 1	22	19	23	23
number unknown	3	2	2	5
Type: double hung	69	64	76	65
casement	11	11	7	16
sliding	19	21	16	20
other combinations	3	5	2	3
Storm windows or insulating glass:				
all windows	34	8	40	52
some	16	4	21	23
none	50	88	40	24
Without storm windows:				
weatherstripped	12	22	10	5
no	32	54	27	15
don't know	6	11	3	4

Doors in U. S. Dwellings

		Heating degree days		
	All	<3500	3500-5499	5500+
Number opening to unheated areas:				
0-1	13%	6	16	17
2	44	51	39	43
>2	42	42	45	40
Protection: storm doors	51	18	62	70
weatherstrip only	17	34	10	8
none	23	41	20	9
No protection needed	4	<0.5	5	8

UTILITY-COMPILED

Source: 1976, Camacho and Roat

Location: See "Reporting utility"

Dates: Unspecified

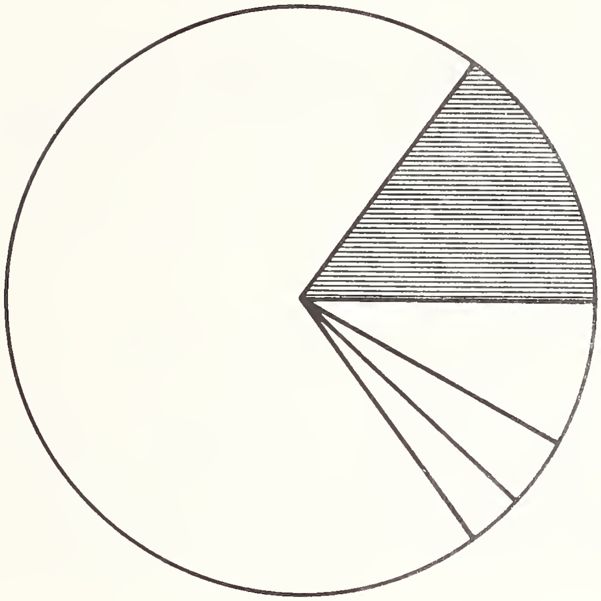
Data:

Furnace electricity consumption

	Reporting Utility*	KWh	Btu x/10^3
Minimum average (oil burner)	Phila. El	25/mo	85/mo
	Portl. GE	33/mo	113/mo
Maximum average (fan or pump)	W. Penn. P	100/mo	341/mo

*See page 153 for key to reporting utilities.

SERVICE HOT WATER



4.0 SERVICE HOT WATER

4.1 RELATIVE IMPORTANCE

Hot water heaters are the second largest consumer of energy in both residences and commercial buildings. They account for 4 percent of the nation's total energy consumption. They use about 15 percent of the energy consumed in residences and 7 percent of the energy consumed in commercial buildings (1972, Stanford Research Institute, p. 33, 66).

The energy stored in a 100-gallon tank of hot water at 150°F (66°C) relative to a room temperature of 70°F (32°C) is equal to the amount of heat delivered by a typical residential heating system in continuous operation for one hour. This stored heat is approximately equal to the heat gain in a house from all (other) uses of electricity for one day (1974, Carnahan, p. 95).

4.2 NEEDED OCCUPANT DATA

1. Hourly demand profiles (gal °F).

   weekday
   weekend
   unoccupied

by region
by season
by family size
by residence size

2. Inventory of hot water using appliances.

   by region
   by family size
   by residence size

4.3 NEEDED PHYSICAL DATA

1. Temperature of water entering the system (including seasonal variation)

2. Efficiency of the water heating system (net heat added to water vs. total energy input)

3. Amount of standby heat losses from tank and from hot water pipes

4.4 AN OVERVIEW OF AVAILABLE DATA

While some data are available on aggregate hot water consumption in residences, there is a lack of data more finely broken down. For example, data on hot water consumption in individual single-family detached houses could be located only in isolated case studies. Few data could be found which correlate hot water consumption with family size, house size, family income, or geographic location. Use schedules also were difficult to project with confidence, based on the limited data for single family detached houses. Better data were available for high rise and garden apartments, e.g., the Edison Electric study conducted by Werden and Spielvogel. Data are also becoming available for townhouses from the Princeton study of the Twin Rivers Development.

Finally, data on end uses of hot water in residences are very difficult to locate. Some data are available from the manufacturers of clothes washers and dishwashers. However, only rough estimates could be found for the amount of hot water consumed for bathing and general hygiene purposes, for hand washing pots and pans, for laundry, etc.

Currently available data can be categorized by the collection methods employed. The simplest and least precise method of determining hot water consumption is possible with the following data:

° average electric or gas consumption by hot water heaters (utility companies)

- average increase in water temperature required
- average efficiency of hot water system

For example, using the Edison Electric Institute's estimate of 4,811 kWh of electricity consumed for water heating annually in an average residence, and assuming an average ground water temperature of 55°F (17°C), an average tank setting of 140°F (60°C), and an average electric hot water heater efficiency of 95 percent, the calculated household hot water consumption would be 22,030 gallons per year or 60 gallons per day.

$$\text{Hot Water Cons. (gal)} = \frac{\text{Elec. Cons. (kWh)} \times \text{\% Efficiency} \times 3{,}413\ \text{(Btu/kWh)}}{\text{Temp. Rise (°F)} \times 8.4\ \text{(lb/gal)}}$$

This method of arriving at hot water consumption leaves unanswered the questions of when peaks in usage occur, and how consumption varies seasonally, geographically, with family size, or with house size. Finally, accuracy of the above calculation depends directly upon the reliability of the utility company estimate of electricity consumption for water heating.

A more accurate method of calculating hot water consumption is possible with a finer break-down of data including:

- frequency of use of dishwashers and clothes washers
- amount of hot water consumed per use
- amount of water consumed daily for pot washing and hand laundry
- amount of hot water consumed for personal hygiene
- amount wasted

For example, total hot water consumption can be calculated using the following data:

Activity/Appliance	Average hot water cons./use	x	Average freq. of use	=	consumption
Clothes Washer[1]	18.5 gallon	x	1.15/day	=	21
Dishwasher[1]	15.5 gallon	x	1.15/day	=	18
Hygiene[2]	13.5 gallon	x	4 people/day	=	54
			TOTAL CONSUMPTION		93 gal/day household

Notes:

1. Estimates developed by the Center for Consumer Product Technology, NBS, in support of the appliance energy labelling program.

2. U.S. hot water consumption inferred from U.K. consumption reported in 1973, G. E. Smith.

This method of arriving at hot water consumption is reliable only if all the uses of hot water in residences have been identified and if assumptions on hot water consumption for each type of use are representative. It addresses the question of average hot water consumption, and partially answers the question of variation with family size, but leaves unanswered the questions of when peaks in usage occur and what variation occurs seasonally and geographically. The principle advantage of this method is the ability to incorporate: the benefit of more conserving dishwashers or clothes washers as they are developed, the effectiveness of consumption limiting devices such as limited-flow shower heads, and changing consumption patterns of occupants.

A third method of obtaining hot water consumption is to monitor the electric or gas consumption and the inlet water temperature and then calculate the consumption. A number of studies have been conducted to monitor the energy consumption at the hot water tank. Estimating hot water consumption from these data is difficult, however. Frequently, the inlet water temperature is not included in the published literature. Furthermore, consideration must be given to the heat losses through the tank jacket, and the standby losses of hot water in the plumbing after each use.

A way of estimating hot water consumption without installing meters on hot water heaters is possible if a sample of residences can be found which use gas only for space heating and water heating. If the furnace pilot is turned off, or its known consumption subtracted, the summer gas consumption will be the energy expenditure for water heating alone. By estimating the summer ground water temperature, the hot water consumption can be calculated for summer and projected for winter.

Unfortunately, this method makes no provision for hot water use in the winter being different from that in the summer. Also, it misstates hot water consumption by the amount of heat lost from the water heater pilot flame up the flue (unless a sample of houses with pilotless gas water heaters is used), the gas consumed to compensate for heat loss at the tank, and the standby losses in the plumbing.

An example of this approach is a study by the Washington Gas Light Company which identified approximately 40 houses with gas used only for water heating and space heating. All had automatic clothes washers, several had dishwashers. The average family size was four. The average water temperature at the inlet was 60°F (15.6°C). Summer gas consumption averaged 32 therms/month. Assuming a 140°F delivery temperature (the common current recommendation, considering use of a dishwasher) and 60 percent efficiency (considering the stack losses of a gas water heater), this would imply average summer hot water consumption of 95 gal/day.

A fourth method of obtaining hot water consumption is to directly measure the hot water flow in a sample of residences.

An hourly schedule of hot water consumption was reported in a study by R. G. Werden and L. G. Spielvogel sponsored by the Edison Electric Institute. The study unfortunately did not include single-family residences. High rise and garden apratments are combined into one set of data published in the 1976 ASHRAE systems Handbook (1969, Werden and Spielvogel).

Smaller scale studies such as the measurements reported by Johnson and Angleton are valuable, but water consumption monitored for one house must be evaluated against a range of similar studies and the important confounding parameters factored out to arrive at generalizable data.

4.5 ADDITIONAL DATA NEEDS AND SUGGESTED COLLECTION METHODS

Data on geographic variations in hot water consumption are needed in order to place energy budgets set for various climate regions in perspective with current energy consumption. To obtain such data, a sampling procedure could be used to select houses in each climate region, and the energy consumption of the water heater, the incoming water temperature, and ideally, the flow from the water heater monitored. The sampling approach used could also provide information on the effect of family size or number of bedrooms (as a possible indicator of family size) upon energy consumption for water heating.

Data on the end use of hot water in residences are also needed if the consumption estimates are to be revised with changing technology and/or occupant consumption patterns. Almost no data could be located on how frequently people bathe or shower, the water flow rate and duration of each shower, or amount used for each bath. Some data are available for dishwasher and clothes washer use, but more detail is needed to correlate their hot water consumption with family size, and to establish time of use and seasonal and geographic variation in use. A means of obtaining such data is to ask a sample of households to maintain a daily log. Information requested might include number and duration of showers or baths, number and times of uses of the dishwasher, and number and times of uses of the clothes washer, including load and temperature settings.

Service Hot Water

Occupant Datum	AUTHORS' RECOMMENDED VALUES Value(s)	Basis
1. Hourly demand profiles (gal °F)	Hot water at 120°F (48.9°C) (assuming use of a pre-heater for dishwasher)	Present authors' estimate of of possible effect of energy conservation measures and the available measured data
weekday	For family of four of five, use 80-100 gal/day	
	No profile recommendation	Insufficient data on hot water consumption (See energy consumption profile, below.)
weekend	No recommendation	No basis
unoccupied	No recommendation	No basis
by region	No recommendation	No basis
by season	Use the same data for summer or winter.	Based on two sets of measurements (late summer, winter) each of two townhouses in Twin Rivers, N.J.).
by family size	For three to five occupants, use 20 gal/per•dy.	We do not at present know to what degree this is valid for larger or smaller households.
by residence size	No recommendation	No basis

AUTHORS' RECOMMENDED VALUES (cont.)

2. Inventory of hot water using appliances

by region	No recommendation	No basis
by family size	No recommendation	No basis
by residence type	Single family dwelling: washing machine (15 gal/load) dishwasher (15 gal/load) Apartment units: dishwasher (15 gal/load)	Based on present prevalence data and authors' judgement concerning installation in new dwellings

Resultant Energy Consumption (for water heating) (Btu)

Total:

single family dwelling (3 bedroom, detached or townhouse)	gas: average 115×10^3 Btu/dy range $92\text{–}138 \times 10^3$ Btu/dy electric: average 72×10^3 Btu/dy range $58\text{–}86 \times 10^3$ Btu/dy	Representative of the available measured data
Low rise apartment unit	gas: 66×10^3 Btu/dy electric: 41×10^3 Btu/dy	Representative of available estimates and the data in ASHRAE Handbook 1976 Systems
High rise apartment unit	gas: 40×10^3 Btu/dy electric: 25×10^3 Btu/dy	

Profile:

Single family dwelling, attached or detached, occupied by family of 4 or 5

Hours:	1	2	3	4	5	6
% of day total:	1.5	1.2	1.2	1.2	1.3	2.4
Hour:	7	8	9	10	11	12
% of day total:	9.3	6.8	6.9	6.9	6.3	5.6
Hour:	13	14	15	16	17	18
% of day total:	4.8	3.3	2.9	3.5	4.2	6.6
Hour:	19	20	21	22	23	24
% of day total:	7.6	6.3	3.8	2.4	2.2	1.8

Based on two sets of measurements (late summer, winter) each of two townhouses in Twin Rivers, NJ) (summer and winter profiles were very similar)

DATA

SERVICE HOT WATER

PREVALENCE

SURVEY AND CALCULATED

Source: 1972, Stanford Research Institute

Location: Nationwide

Dates: 1960, 1968

Data: Number of water heaters per household

	gas	electric
1960	0.53	0.20
1968	0.68	0.24

PREVALENCE (cont.)

SURVEY AND CALCULATED

Source: 1974, Federal Energy Administration

Location: Nationwide

Dates: 1970

Data: Percent of households

Fuel type	
natural gas	55 percent
electric	25
oil	10
LPG	5
coal	1
no water heater	4
	100 percent

ENERGY CONSUMPTION

MEASURED

Source: 1963, Phillips and Achenbach

Location: Myrtle Beach, N.C. and Columbus, Miss.

Dates: Winter 1959/60

Data: Measurements at 10 units of militry housing (5 at each location) (all-electric, heat-pump conditioned, detached houses).

Average daily consumption for electric water heater

	kWh/dy	10^3 Btu/dy
Myrtle Beach, N.C. (22 Dec '59-22 Jan '60)		
minimum (52 gal unit)	14.75	50.3
average (25.0% of avg. house total)	23.75	81.1
maximum (52 gal unit)	32.13	109.7
Columbus, Miss. (23 Feb '60-23 Mar '60)		
minimum (50 gal unit)	24.28	82.9
average (30.3% of avg. house total)	32.04	109.4
maximum (50 gal unit)	41.59	141.9

Source: Undated, Schmitt

Location: Cleveland, O. areas

Dates: Feb '73 to Feb '74

Data: One year water heater consumption of 3 BR house housing family of three.

5954 kWh 20.32×10^6 Btu

(This amounts to 21.4% of house total, and is equivalent to 16.3 kWh/day, 55.7 x 103 Btu/day.)

Source: 1975, Johnson and Angleton

Location: Washington, D.C. area

Dates: 1974

Data: Measurements made in a single house, occupied by 2 adults and 2 teenage children (plus 2 others college age, home for one month) between mid-September 1974 and mid-January 1975.

Daily usage:
- minimum - 8.5 gal/day
- average - 82.1 gal/day
- maximum - 210 gal/day

Number of times hot water used per dy:
- minimum - 9
- average - 36.6
- maximum - 93

How long hot water faucet opened:
- < 1 min. 75% of the times
- > 5 min. 3% of the times

Average consumption per use:
2.24 gal

Average daily consumption per person:
17.75 gal/person•day

Energy consumption (gas) to heat:
ca. 19.8×10^3 Btu/person•day

Source: Undated, Ultraflo Corp.

Location: Sandusky, Ohio, area

Dates: 1975

Data: Monitored hot and cold water usage in less than 40 households equipped with electrically operated push button water control systems.

The average shower lasted five minutes. Nearly all showers ranged from four to seven minutes. The longest recorded shower lasted 13 minutes.

Typical daily hot water consumption for a house with an electrically operated pushbutton water control system for a family of two adults and three children aged 12, 10, and 9.

Use	Number of Uses	Hot Water Consumption (gal/dy)
Kitchen sink	52	32
Lavatory	15	11
Showers	5	30
Dishwasher	1	20
Clotheswasher (automatic)	1.5	32 (variable)
	Total	125

Data from monitoring of less than 40 homes:

User Habits	Percent of Total Time Used
Blended H and C	55
Hot water only	15
Cold water only	30

Source: 1975, Robinson and Yeung

Location: Twin Rivers, NJ

Dates: Summer, 1974

Data: Measurements (at 20-min. intervals) of two townhouses, from 24 to 29 Aug and 4 to 19 Sept 1974 (22 days)

Daily electricity consumption for hot water

		kWh/dy	Btu x 10^3/dy
House no. 1*	minimum	11.1	37.9
	maximum	34.3	117.4
House no. 2+	minimum	7.0	23.9
	maximum	24.4	83.3

*Occupied by 2 adults and 3 young children
+Occupied by 2 adults and 2 young children

Source: 1976, Shookster

Location: Twin Rivers, NJ

Dates. Winter, 1973/4

Data: Measurements (at 20-minute intervals) of one townhouse from 20 Jan to 22 Mar 1974 (62 days)

Daily electricity consumption for hot water

	kWh/dy	Btu x 10^3/dy
minimum	2.4	8.2
maximum	10.2	34.8

Source: 1976, Socolow and Sonderegger

Location: Twin Rivers, NJ

Dates: as stated

Data: Average hourly winter water heater consumption for three townhouses (derived from measurements made on 97 days between 20 Jan and 30 Apr 1975)*

kW of Electricity*

	Omnibus house**		
Hour+	#1	#2	#3
1	.15	.51	.45
2	.11	.27	.42
3	.16	.26	.26
4	.14	.34	.36
5	.10	.34	.46
6	.55	.21	.36
7	1.82	.30	1.88
8	1.29	.63	1.72
9	1.59	.55	1.60
10	2.00	.49	1.26
11	1.56	.65	1.25
12	1.34	.84	.96
13	1.08	.72	.79
14	.92	.37	.65
15	.73	.40	.61
16	.72	.55	.59
17	.97	.75	.70
18	1.17	1.30	1.63
19	.83	1.08	1.86
20	1.29	.97	1.50
21	.70	1.04	.85
22	.43	1.22	.75
23	.42	1.70	.46
24	--	1.40	.51
Total: kWh	20.07	16.89	21.88
Btu x 10^3	68.50	57.65	74.68

* Values interpreted from a graph

** The houses instrumented for the collection of eight items of data in this experiment are referred to as "Omnibus houses."

\+ Hour given is the ending time, e.g.: 4 is the period 0300 to 0400

Average measured hourly rate of consumption and projected equivalent monthly and yearly consumption rates (for the above winter period)

Omnibus House

Average Consmption Rate	#1	#2	#3
kW	0.87	0.69	0.90
Btu x 10^3/hr	3.0	2.4	3.1

Equivalent Semi-annual (winter = 6 months) Consumption	#1	#2	#3
kWh	3811.	3022.	3942.
Btu x 10^6	13.0	10.3	13.5

Time* and magnitudes of maximum and minimum hourly consumption (for the above winter period)

	#1		#2		#3	
	Hour	kW	Hour	kW	Hour	kW
Maximum +	1000	2.00	2300	1.70	0700	1.88
Minimum +	0500	0.10	0600	0.21	0300	0.26

* Time given is the ending time for the hour, e.g. 0400 is the period 0300 to 0400.

\+ Note: Maxima occur both in the 6 a.m. to 10 a.m. period and in late evening; minima occur during the late night hours and during mid afternoon.

Average winter consumption rates in 6 "Omnibus" townhouses --
20 Nov to 18 Dec 1975

Omnibus house	min/hr+	kW	Btu/hr
1	14.4	1.18	4027
4	12.7	0.95	3242
7	16.6	1.24	4232
11	8.7	0.65	2218
16	11.7	0.88	3003
19	13.3	1.00	3413
Average of the six	12.9	0.98	3356

+ min/hr = minutes of heating element operation.

Monthly and yearly consumption projected from above measured data:

		Monthly		Yearly	
	House	kWh	Btu x 10^3	kWh	Btu x 10^6
minimum	11	468	1597	5694	19.4
maximum	7	893	3048	10862	37.1

Average hourly summer water heater consumption for two town houses (derived from measurements made on 22 days between 25 Aug and 19 Sep 1974)

kW of Electricity*

Omnibus House

Hour		#1	#3
1		.12	.20
2		.10	.13
3		.07	.28
4		.09	.13
5		.05	.19
6		.74	.14
7		1.55	1.32
8		1.31	.68
9		1.32	.76
10		1.88	.50
11		1.24	.76
12		1.03	.65
13		1.20	.50
14		.80	.21
15		.65	.19
16		.62	.56
17		.70	.58
18		.55	1.12
19		1.14	1.60
20		1.20	.72
21		.70	.48
22		.17	.35
23		.37	.27
24		.20	.46
Total:	kWh	17.80	12.78
	Btu x10^3	60.75	43.62

* Data interpreted from graphs.

Average measured hourly rate of consumption and projected equivalent monthly and yearly consumption (for the above summer period)

		Omnibus house	
		#1	#3
Average Consumption Rate			
	kW	0.74	0.53
	Btu x 10^3/hr	2.5	1.8
Equivalent Semi-Annual (summer = 6 months) Consumption			
	kWh	3241	2321.
	Btu x 10^6	11.06	7.92

Time and magnitude of maximum and minimum hourly consumption (for the above summer period)

	#1		#3	
	Hour	kW	Hour	kW
Minimum	0500	0.05	0200	.13
Maximum	1000	1.88	1900	1.60

Average measured early summer consumption for four additional townhouses.

		Omnibus No. 10[1,2]	Omnibus No. 9[1,3]	An adjacent house[2,4]	Another adjacent house[3,4]
Daily energy use:					
kWh/dy		12.02	24.29	13.56	24.74
Btu x 10^3/dy		41.02	82.9	46.3	84.4
Daily hot water consumption:					
Total	gal	44.7	98.1	44.0	79.0
	liters	169.2	371.3	166.6	299.0
for dishwasher					
	gal	4.6	12.5	4.6	10.8
	liter	17.4	47.3	17.4	40.9
for clothes washer					
	gal	6.7	10.5	5.1	8.5
	liters	25.4	39.7	19.3	32.2

1 Water heaters retrofitted with R-7 insulation wrap
2 Averaged over a 64-day period.
3 Averaged over a 28-day period.
4 These houses were not in the Omnibus Experiment.

Source: 1969, Werdon and Spielvogel

Location: Unspecified

Dates: Unspecified

Data: Actual hot water usage was measured in 11 high rise apartment buildings and 15 garden apartments. The average, per apartment consumption for one building--not necessarily typical for all buildings--was:

Hour	all days (gallons)	day with maximum total use (gallons)	Hours	all days (gallons)	day with maximum total use (gallons)
1 am	1.7	1.8	1 pm	2.05	3.45
2	1.45	1.65	2	1.8	4.1
3	1.25	1.55	3	1.45	2.4
4	1.3	1.25	4	1.4	2.5
5	1.25	1.2	5	1.4	2.0
6	1.25	1.2	6	1.8	2.5
7	1.45	1.2	7	2.3	2.25
8	1.8	1.25	8	2.5	2.25
9	2.9	2.0	9	2.2	2.25
10	2.55	3.25	10	1.8	2.25
11	2.25	3.7	11	1.6	2.25
12(noon)	2.05	3.95	12(mid-night)	2.0	2.15

Note: values approximated from graphs.

Source: 1974, ASHRAE

Location: all of U.S. (47 cities)

Date: unspecified

Data: annual maximum and minimum of integrated average earth temperatures (surface to depth of 10 ft.)

Earth Temp Station	Maximum, °F	Minimum, °F
Auburn, Ala.	74	56
Decatur, Ala.	71	48
Tempe, Ariz.	81	59
Tucson, Ariz	85	65
Brawley, Calif.	90	68
Davis, Calif.	76	56
Ft. Collins, Colo.	64	36
Gainesville, Fla.	80	69
Athens, Ga.	77	57
Tifton, Ga.	80	62
Moscow, Idaho	57	37
Lemont, Ill	65	39
Urbana, Ill.	68	42
West Lafeyette, Ind.	66	38
Burlingotn, Iowa	71	38
Manhattan, Kans.	69	41
Lexington, Ky	70	46
Upper Marlboro, Md.	70	42
East Lansing, Mich.	63	37
St. Paul, Minn.	62	34
State Univ., Miss	79	55
Faucett, Mo.	65	43
Kansas City, Mo.	66	42
Sikeston, Mo.	71	43
Bozeman, Mont.	56	32
Huntley, Mont.	64	36
Lincoln, Nebr.	69	39
Norfolk, Nebr.	66	40
New Brunswick, N.J.	65	42
Ithaca, N.Y.	59	39
Raleigh, N.C.	73	52
Columbus, Ohio	65	41
Coshocton, Ohio	64	40
Lake Hefner, Okla.	77	51
Pawhuska, Okla.	74	50
Corvallis, Oreg.	66	46
Pendleton, Oreg.	67	39
Calhoun, S.C.	76	52
Union, S.C.	70	48
Madison, S.D.	61	33
Jackson, Tenn.	71	49

Temple, Texas	83	59
Salt Lake City, Utah	63	40
Burlington, Vt.	63	35
Pullman, Washington	60	36
Seattle, Washington	61	45

SURVEY

Source: 1973, ASHRAE (original source as noted)

Location: unspecified

Date: as noted

Data: A survey by electric utilities indicated 41 gal (155 L)/day based on readings from 60,000 meters.

A 1962 survey by 23 large gas utilitiees conducted by the American Gas Association in 1962 showed average gas consumption for water heating to be 255 therms per year, or hot water usage of 44.5 gal (168 L)/day based on the University of Illinois average service efficiency.

Source: 1972, Stanford Research Institute (from AGA, EEI)

Location: nationwide

Dates: 1960, 1968

Data: average annual consumption of water heaters

	Electric		Gas
	kWh	Btu x 10^6	Btu x 10^6
1960 yearly	4272.	14.5	25.5
1968 yearly	4490.	15.3	27.2

Source: 1975, Newman and Day (from AGA, EEI)

Location: nationwide

Dates: as noted

Data: average annual consumption

Year		Electric	Gas
		Btu X 10^6/yr	
1950		12.5	
1959		13.5	
1960			24
1966			27
1969		14.4	
1969	quick recovery	16.3	
1971			32

Source: 1973, Anderson

Location: Baltimore/Washington

Dates: early 1970's

Data: Typical annual consumption in single-family home (based on utility data):

	Btu x 10^6/yr
Electric	15.0
Gas	27.0

Source: 1974, Lokhmanhekim

Location: Baltimore/Washington

Dates: Early 1970's

Data: Typical annual consumption (based on utility data):

Dwelling type	Fuel type	Btu x 10^6/yr
townhouse	gas	43.2
lowrise	gas	24.0
highrise (1 or 2 BR)	gas	14.4

Source: 1975, Jones and Hendrix

Location: Austin, Texas

Dates: early 1970's

Data: Typical consumption (source ambiguous, but believed to be based on utility data):

Monthly gas consumption for water heating and cooking -- sample of 40 homes:

	ft^3 x 10^3/mo	approx. Btu x 10^6/mo
minimum	2	2
average	4.5	4.5
maximum	8	8

Average monthly energy consumption for various amounts of hot water consumption:

Water Consumption			Energy Consumption	
Hot water	temp.	Fuel type	Reported quantity	Equivalent Btu x 10^6/mo
70 gal/dy (265 l/sy)	150°F (66°C)	electric	505 kWh	1.7
		gas	2600 ft^3	2.6
	135°F (57°C)	electric	415 kWh	1.42
		gas	2100 ft^3	2.1
150 gal/dy (568 ℓ)	150°F (66°C)	electric	690 kWh	2.35
		gas	3400 ft^3	3.4

Source: 1976, Camacho and Roat

Locations: as specified

Dates: unspecified

Data: average monthly consumption

Overall*	kWh/mo	Btu x 10^6/mo	Reporting utility+
minimum	350	1.19	New Orl. PS
maximum	609	2.08	Carol. P&L (4 in the family)
"Standard"			
minimum	339	1.16	Tex. P&L
maximum	400	1.37	PSNJ
"Quick-recovery"			
minimum	373	1.27	Tex. P&L
maximum	467	1.59	PSNJ

* These are not individual house minima and maxima, but minimum/maximum averages (or estimates) over utility service areas.
+ For key to utility company abbreviations, see page 153.

Source: 1974, FEA

Location: Nationwide

Date: 1970

Data: National average annual household energy consumption for hot water (based on assumed 20 gal per person-day usage):

	Btu x 10^6/yr
electric	10.2
gas	31.5

Source: Present authors

Locations:

Dates:

Data: The hot water consumption for a five minute shower can be calculated assuming a flow rate of 3.5 gallons per minute for a conventional shower and a water temperature of 106°F (41°C) (note: five minutes is the average recorded shower duration in the Uniflo monitoring study).

Proportioning: Assumed cold water @ 55°F (12.8°C) = 32%
Assumed hot water @ 130°F (54.4°C) = 68%

H. W. consumption = 3.5 (gal/min) x 5 (min) x .68

= 11.9 gal

Source: 1960, Babbitt

Location: Unspecified

Date: 1920

Data: Recommended hot water capacities (gal/hr•fixture) to supply:

	apartment	private residence
lavatory	3	3
bathtub	15	15
kitchen sink	10	10
shower	100	100
dishwasher	15	15
Total likely to be drawn at one time	35	50

Date: 1954

Data: Estimated rates of use per dwelling unit:

		gal/day
single family (detached or attached)		30-60
	one bath	60-100
	two baths	100-200
large family,	two baths	200-300
multifamily	one bath	60-125
	two baths	100-200
	three baths	150-250

Source: 1973, Anderson

Location: Baltimore/Washington

Date: early 1970's

Data: assumed energy consumption for water heating (based on utility data) used in calculating total energy consumption of characteristic single family home

	Btu x 10^6/yr
electric	15.0
gas	27.0

Source: 1974, Lokhmanhekim

Location: Baltimore/Washington

Date:

Data: assumed energy consumption for water heating (based on utility data) used in calculating total energy consumption of characteristic multifamily dwellings

Dwelling type	fuel	Btu x 10^6/yr
townhouse	gas	43.2
lowrise	gas	24.0
highrise (1 or 2 Br)	gas	14.4

Source: 1976, Bernstein and Alereza

Location: as specified

Date: Mid-1970's

Data: assumed energy consumption for water heating used in calculating total energy consumption of characteristic residences.

Location	Dwelling type	Fuel	Btu x 10^6/yr
Atlanta	single family	gas	27.0
	townhouse	gas	27.0
Boston	single family	gas	27.0
	townhouse	electricity	15.4
	low rise	electricity	13.1
Chicago	single family	gas	27.0
	townhouse	gas	27.0
Denver	single family	gas	27.0
	townhouse	gas	27.0

Source: 1975, Jones and Hendrix

Location: Austin, texas

Date: early 1970's

Data: assumptions (based on utility data) used in analyzing energy consumption in Austin-area homes

		Energy Consumption		
		electric	gas	equivalent
water usage	temperatures	kWh/mo	ft^3 x 10^3/mo	Btu x 10^6/mo
70 gal/dy	150°F (66°C)	500		1.71
			2.6	2.6
	135°F (57°C)	410		1.40
			2.1	2.1
100 gal/dy	150°F (66°C)	700		2.39
			3.5	3.5
	135°F (57°C)	570		1.95
			2.8	2.8

Source: undated, Ultraflo Corp.

Location: unspecified

Date: unspecified

Data: assumed average flow rates for household users of conventional hand operated faucets

kitchen sink	3.0 to 3.5 gal/min
shower	3.0 to 3.75 gal/min
lavatory	2.25 gal/min nominal

Note:

Wide variations in flow rate occur as a result of user preferences and line pressures. The figures given are established on the low side.

---

average consumption per day (total water--hot and cold) when water runs continuously at the above flow rates while the task is being performed:

Lavatory tasks	40 gal
Showering	30
Kitchen tasks	91

For showering and handwashing, water temperatures can range from 102°F (39°C)--luke warm--to 114°F (46°C)--as hot as can be endured--with showers most commonly at 106 to 108°F (41.1 to 42.2°C).

Source: 1970, Todd

Location: unspecified

Date: unspecified

Data: water requirements for domestic use

Fixture	gal
fill lavatory	2
fill bathtub	30
shower bath	30-60
dishwashing Machine per load	
clothes Washing Machine per load	30-50
total daily hot water consumed per person in a residence	40

Source: 1973, ASHRAE

Location: Nationwide

Date: 1956

Data: The Building Advisory Board of FHA recommended a mean minimum required daily hot water supply for low income families of 55 gal, with an increase of 7 percent for each $1000 of income above $3000.

Possible maximum 24-hour hot water supply requirements for apartments and private homes:

	No. of Bathrooms			
No. of Rooms	1	2	3	4
1	60			
2	70			
3	80			
4	90	120		
5	100	140		
6	120	160	200	
7	140	180	220	
8	160	200	240	250
9	180	220	260	275
10	200	240	280	300

Source: 1976, ASHRAE

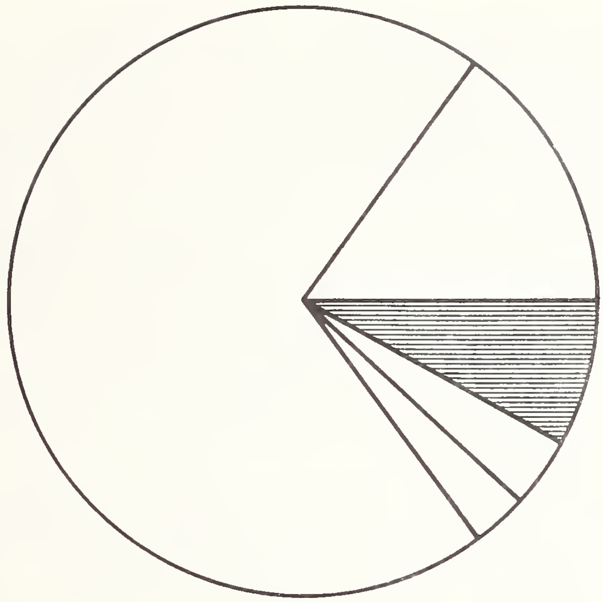
Location: unspecified

Dates: unspecified

Data: typical residential usage of hot water

food Preparation	3 dal
hand Dishwashing	4 gal
automatic Dishwasher	15 gal
clothes Washer	21 gal
shower or Bath	15 gal
face and Hand Washing	2 gal

APPLIANCES



5.0 APPLIANCES

5.1 RELATIVE IMPORTANCE

Gas and electric appliances (other than air conditioners, water heaters, or attic fans, which are being treated elsewhere in this report) accounted for roughly 9% of the total energy consumed in residences in the United States in 1968. However this fraction is likely to show considerable variation from dwelling to dwelling.

Unfortunately, little measured data is available documenting the overall energy consumption of appliances in U.S. households. There are difficulties attendant to measuring this consumption. Electrical appliances are likely to be numerous, and are energized through a distributed power network that also supplies lighting devices, furnace fans, and very possibly air conditioners and/or a water heater. Thus the whole-house electric meter does not provide the needed broken out data. If gas is used for cooling or clothes drying, it is probably also used for space heating and for water heating. Again, the whole-house meter does not give us appliance energy use data (and sub-metering of gas appliances is technically somewhat awkward and expensive).

However, we can get an idea of the energy consumption of appliances in American homes by looking at some of the calculated data that are available. Analyzing the patterns of residential energy consumption presented in Project Independence Blueprint, (1974, FEA) we can say that a national average 11.7% of residential energy consumption goes for appliances and lighting. Looking at different dwelling types, the range of consumption averages extends, in percentage terms, from a high of 19.6% of average unit demand for mobile homes to a low of 10.7% in single-family, detached dwellings. In absolute terms the range (of averages) is narrower, varying from 16.5 x 10^6 Btu/yr in the average low rise apartment unit to 10.5 x 10^6 Btu/yr in the average single family home.

That these figures, in purporting to include consumption for lighting, may be somewhat on the low side is suggested by the "in house" survey data of Newman and Day (1975, Newman and Day). These authors calculated individual household appliance energy consumption "indexes", based on appliance inventories from their interviews of 1,455 U.S. households and on data on the average consumption by various appliances, obtained from the Edison Electric Institute (EEI) and the American Gas Association (AGA). Newman and Day's survey findings suggest that the typical U.S. household has the following set of "major" (relatively heavy energy-using) appliances: an automatic washer, an electric clothes dryer, a color television, a frost-free refrigerator, and a gas stove. They calculate that this ensemble of equipment, on the average, consumes 45 x 10^6 Btu of energy per year (1975, Newman and Day). However, in this figure electricity consumption has been converted so as to include the electrical generation and distribution losses. In other words, it is expressed in terms of "primary energy" rather than energy at the point of demand or use. Subtracting the losses that occur outside a residence,* the consumption of electricity and gas is 20.1 x 10^6 Btu per year for this typical household. Note that this number includes only appliances--not lighting and not an air conditioner. Some biases that do affect this figure are discussed below.

The median of the 1,455 individual household appliance energy consumption "indexes" (in terms of "primary" energy consumed at electric generating plants, i.e., comparable to the 45 x 10^6 Btu per year figure above) was 51 x 10^6 Btu per year. However, air conditioners--even central units--were defined as appliances in this study, so their consumption (where present) is included in the individual household "indexes," and biases the median upward. For our purposes, two other possible biases in these figures must be noted: 1) they are biased downward somewhat by the fact that they include only the consumption of major appliances,** and 2) they may be biased upward by the EEI and AGA data not having been adjusted for the predominance of older, smaller appliances in the national inventory. (However, in view of the "graininess" of the underlying data--

* See page 143 for explanation of this calculation.

** Clearly such figures account for a large part of the energy consumed by appliances in residences. Project Independence Blueprint suggests that the total consumption of the minor appliances is less than 1 percent of total residential energy consumption. (1974, Federal Energy Administration) However, with the apparently growing popularity of such electric cooking devices as skillets, slow cookers, coffee makers, griddles, sandwich grills, toaster ovens, and rotisseries, the electrical energy consumed by small appliances in the homes may show significant growth over the coming decade.

i.e., annual consumption of individual appliances expressed in even numbers of 10^6 Btu--the latter point is probably irrelevant).

So far we have been discussing this segment of energy consumption in terms of averages or representative numbers. There are really no data useful to our purposes available regarding ranges of household consumption for appliances. The individual household indexes calculated by Newman and Day ranged from 0 (two dwellings did not have electricity) to 270 x 10^6 Btu per year. However, as we have mentioned, air conditioner energy usage is included in these figures. Air conditioner consumption was calculated (on the basis of equipment type and average cooling degree days at the household) to range from 1 x 10^6 to 194 x 10^6 Btu per year. Thus, this component of residential energy consumption, which we are considering separately in the present report, has heavily biased the upward end of the appliance consumption range reported by Newman and Day.

In the absence of data more specific than this, we presume that measured appliance energy usage in households would exhibit a substantial variability. Appliance energy consumption may not necessarily be relatable to size of dwelling, but might be more closely related to such factors as: number of occupants, income level, lifestyle, and values.

5.2 NEEDED OCCUPANT DATA

1. hourly demand profiles (watts or therms)
   - weekday
   - weekend
   - unoccupied

   - by region
   - by season
   - by family size
   - by residence size

2. inventory of appliances

5.3 RELATED PHYSICAL DATA

Measured energy consumption per use or per time unit of appliances, older as well as current models, when operating in typical normal household use.

5.4 OVERVIEW OF AVAILABLE DATA

Information about the prevalences of various major appliances has been obtained for several recent years from different sources. These data appear reasonably interconsistent (see Table I).

TABLE I

Saturations of Major Appliances

	1960* (SRI)	1968* (SRI)	1969* (SRI)	1970* (FEA)	1973+ (Newman & Day)
Range - gas	0.63	0.58		0.49	0.52 x 100
- electric	0.33	0.39		0.41	0.46
Refrigerator	0.86	0.96		1.00	
- electric					0.99
- gas					0.01
Dryer - gas	0.06		0.13	0.12	0.16
- electric	0.13		0.27	0.29	0.38
Freezer	0.20	0.27		0.28	0.34
Television				1.48	0.97
- black & white	0.91		1.39		0.64
- color	0.03		0.33		0.53
Dishwasher	0.06		0.20	0.18	0.25
Clothes washer	0.75		0.76	0.71	0.78

* Number per household.

\+ Percent of households with at least one.

The only information we have found that approximates individual household consumption of energy for appliances is that in The American Energy Consummer (1975, Newman and Day). These data, as has been observed, are based on 1) survey (by in-house interview) of the major appliances present in the dwelling and 2) average appliance energy use figures obtained from industry sources. Thus, only the appliance inventory data is true measured data. The per appliance consumption figures are "estimates" based on (undefined) "normal usage." Further, as already noted, the Newman and Day household totals, in their presently published versions, incorporate (estimated) air conditioner energy usage, a separate category for our purposes.

For individual major (electrical) appliances, it is not impractical to meter energy consumption during actual, normal household use. This can be done by attaching either a watthour meter or a clock (for recording elapsed "on" time) to the supply cord of the particular piece of equipment. With regard to these appliances, we find the following situation. There is (a limited amount of) actual measured data about the energy consumed by some appliances in normal use in homes. For clothes washers and dishwashers, data are available from four townhouses in Twin Rivers, New Jersey. For refrigerators, data have been reported from 156 households in seventeen cities and in Twin Rivers, New Jersey. For (electric) clothes dryers and (electric) ranges, in addition to some Twin Rivers measurements (recorded in 1974-1976), data are available from a study of five houses in Myrtle Beach, North Carolina, and five houses in Columbus, Mississippi, gathered in 1959-1960. Annual consumption of food freezers has been measured in nine residences around the country.

We have found no figures on directly measured energy consumption of television sets. For these relatively heavy users of electricity, the only available data are the industry (Edison Electric Institiute or individual utility-provided) "estimates."

The same limitation holds with regard to data on the energy consumption of "minor" appliances. We should note that some of the latter--particularly the various cooking devices-may be considerable users of electricity. Two points need to be kept in mind about these utility-compiled data: Firstly, each is based on some estimate of "normal" usage of the particular device. The original sources of the data contained in 1976, Camacho and Roat, have not yet been made available to us. Consequently, we are largely ignorant of how the utilities have arrived at these estimates. A factual basis for these data would require some type of activity log (or other frequency and length of use) surveys of a representative sample of users. We are not aware of any instances where utility companies have actually conducted such studies. We have been given to understand that, in at least some cases, these estimates are simply "off the top of the head" guesses by someone in a utility research department. The important concern of the utility companies has to do, of course, with the profiles of total load of households and groups of households and the patterns of such profiles, not the consumption of individual energy-using devices within the household. Finally, the exact coincidence of many of the numbers reported for the same type of appliance by utilities in different regions of the country (see 1976, Camacho and Roat) suggests to us that these are not data developed by a local utility, but rather "national averages," already "aggregated" (by Edison Electric Institute, presumably) and distributed back to the utilities. Thus they would represent fairly crude national averages, rather than (somewhat less crude?) utility service area averages.

Secondly, these data give us no clue, whatsoever, to the range of values of energy consumed by a given appliance when in ordinary use by different families or households.

5.5 ADDITIONAL DATA NEEDS AND SUGGESTED COLLECTION METHODS

The small amount of recorded appliance energy consumption data so far available from Twin Rivers, New Jersey, as well as the 1959/60 data recorded by Phillips and Achenbach, make clear that the energy consumed by similar appliances, when installed in and operated by different households, can vary significantly. One might presuppose that the electricity used by identical refrigerators in different households would be fairly similar. Twin Rivers data exhibit a 2 to 1 range of high to low consumption by refrigerators.

Cooking ranges could be expected to reflect, to a somewhat greater degree, the lifestyles and habits of their users. The early data from Twin Rivers (a community with relatively high cultural and economic homogeneity) reflect a 2 to 1 ratio of high to low average energy use in cooking ranges. The Air Force base communities where Phillips and Achenbach measured dwelling energy consumption probably embodied greater diversity of inhabitants, and these data display a 3 to 1 range between high and low individual household consumption by ranges.

To consider clothes dryers, the energy used by similar machines would be influenced by such factors as: 1) number of family members contributing dirty clothes to the task, and 2) household practices regarding the use of the machine (e.g., are clothes always dried in the dryer or are they hung for drying when feasible). For these devices, both Twin Rivers and Myrtle Beach researchers recorded ranges of more than 3 to 1 between high and low users. (It might be noted that both of these sets of data were recorded during winter months, when the possibility of hanging clothes to dry might not even have been available.)

We have mentioned the problems attendant to measuring the energy consumption of appliances, since they are energized by distributed networks that also supply lighting, cooling, or heating devices. Unless we are dealing only with all-electric dwellings, and can be satisfied with aggregated data for appliances and lights (with possibly the major appliances metered separately), it will be necessary to "construct" household appliance energy use data much as Newman and Day did. However, instead of constructing these data on the basis of somewhat hypothetical national "average" consumptions for particular types of appliances, we would want to base them on observed or recorded data about frequencies and durations of use of appliances and measured unit-time consumption (i.e., rate of consumption or "load") of the specific equipment in question.

In order to be able to assemble, with reasonable confidence, averages and ranges of aggregated household energy consumption for appliances, there is a clear need for more data on: 1) typical inventories of appliances for households in different geographic regions and at different socioeconomic levels, and 2) typical energy consumption of different appliances in actual use in homes.

Some of the latter type of data will come out of the Midwest Research Institute study now being carried out in 16 cities around the country. More data will be coming from more town houses in Twin Rivers, which will give us some stronger clues to the ranges and patterns exhibited by appliance energy use, but still reflecting a rather homogeneous community, not necessarily representative of the Nation as a whole.

The types of instrumentation and techniques developed in the Twin Rivers Project would appear to be very effective and efficient for recording the energy consumed by the larger (electrical) appliances in actual use in dwellings. Measuring gas usage by appliances is a more technically difficult task. Gas meters can be installed on individual gas-using appliances, but a simpler way of obtaining indicative data--and certainly the only way of getting a handle on household use of electricity for minor appliances--would be the use of activity logs. Suitably designed forms would make it a reasonably easy matter for residents to record their frequency and duration of use of various household devices. Combined with measured data on the rate of energy consumption of the devices, such information would enable us to develop a much better picture of the patterns of use of energy for appliances in the Nation's residences.

Appliances

AUTHORS' RECOMMENDED VALUES

Occupant Datum	Value(s)	Basis
1. Hourly demand profiles (Btu).		
weekday weekend unoccupied	no recommendation	No basis
by region	no recommendation	No basis
by season	no recommenadation	No basis
by family size	For suggestion of variation in day totals, see Table, next page.	Surveys by Newman and Day and individual appliance data from industry.
2. Inventory of appliances	See Table, next page.	Surveys by Newman and Day and other prevalence data.
Resultant Energy consumption	See Table, next page.	Surveys by Newman and Day, other prevalence data, and individual appliance consumption data from industry.

AUTHORS' RECOMMENDED VALUES (cont.)

2. Inventory of appliances:	3. Energy consumption (10^3 Btu/dy) gas* & electric	all-electric
basic major appliances: refrigerator, range/oven, clothes washer, clothes dryer, black and white television (1.5 per household), color television	55-73	38-51
basic minor appliances: clocks (2), toaster, radio-phonograph, iron, vacuum cleaner#	2.9	2.9
TOTALS for basic appliances	58-76	41-54
possible add-on major appliances:		
food freezer	13	13
dishwasher	2	2
possible add-on minor appliances: bed covering; blender; broiler, griddle or hot plate; coffee maker; curling iron; electrostatic air cleaner; deep fat fryer or frypan; hair dryer; roaster or rotisserie#	11.4	11.4
Upper TOTALS for appliances	84-102	67-80

* Range/oven and clothes dryer.

Obviously each of these appliances would not necessarily be used every day. The figures used are 1/365th of the estimated annual consumption for the devices. We know virtually nothing about the extent to which daily energy consumption of a household for appliances varies from the average for that household.

DATA

APPLIANCES

PREVALENCE

(CENSUS, INDUSTRY, AND CALCULATED)

Source: 1972, Stanford Research Institute (SRI)

Location: nationwide

Dates: See below.

Data: numbers of major appliances per household

	Number per household+			
	gas		electric	
Appliance	1960	1968	1960	1968
Cooking range	0.63	0.58	0.33	0.39
Refrigerator			0.87	0.96
12 ft^3				1/6*
12 ft^3 frostless				1/3*

PREVALENCE
(CENSUS, INDUSTRY, AND CALCUALTED) (Cont.)

	Number per household+			
	gas		electric	
Appliance	1960	1968	1960	1968
Refrigerator-freezer				
14 ft^3				1/6*
14 ft^3 frostless				1/3*
Clothes dryer	0.06	0.13*	0.13	0.27*
Food freezers			0.20	0.27
Television sets				
black and white			0.91	1.39*
color			0.03	0.33*
Dishwashers			0.06	0.20*
Clothes washers			0.75	0.76*

+ Orginal Sources:
Statistical Abstract of the United States; Edison Electric Institute and American Gas Association with SRI estimates; Census of Housing

* 1969

Source: 1974, Federal Energy Administration

Location: nationwide

Date: 1970

Data:

Appliance	Units per household* gas	electric
Range & oven	0.49	0.41
Refrigerator	-	1.00
Television	-	1.48
Clothes dryer	0.12	0.29
Food freezer	-	0.28
Clothes washer	-	0.71
Dishwasher	-	0.18

* A. D. Little estimates

Source: 1975, Newman and Day

Location: nationwide

Date: 1973

Data:

households with major appliances, 1973*

	Percent of households
Clothes washer	78%
automatic	70
non-automatic	10
Dishwasher	25
Television	97
black and white	64
color	53
Clothes dryer	53
gas	16
electric	38
Refrigerator	100
electric frostfree	51
electric manual defrost	48
gas	1
Stove	97
gas	52
electric	46
Freezer	34

* Source: Washington Center for Metropolitan Studies' "Lifestyles and Energy" Surveys (based on interviews of national sample of 1455 households).

ENERGY CONSUMPTION

AGGREGATED

SURVEY

Source: 1975, Newman and Day

Location: nationwide

Date: 1973

Data:

Annual consumption of households for appliances--including air conditioning (47 percent of households had at least some air conditioning) (NOTE: These data are expressed in terms of primary energy consumption, and--since it includes both electricity and gas--there is no way to convert it to point of demand equivalents). Figures derived by summing for each of the (1,455) surveyed households, the national average primary energy consumption of each appliance present in the household:

Variation: 0 - 270 x 10^6 Btu/yr (primary energy)

Average: 51 x 10^6 Btu/yr

Typical household:
Automatic washer, electric dryer, color TV, frostfree refrigerator, gas stove = 45 x 10^6 Btu/yr
(equivalent to 20.1 x 10^6 Btu/yr at the residence.)

Annual energy consumption of households for appliances (including air conditioning):

Annual consumption	Percent of households				
Primary Btu x 10^6	All	Poor	L. Midd.	U. Midd.	Well off
<40	33%	65%*	39%*	13%*	10%*
40-59	30	21	30	40	26
>59	38	14	31	47	64

* The following percentages of households have no air conditioning: Poor--78 percent; L. Middle--55 percent; U. Middle--42 percent; Well off--36 percent.

Source: 1973, Anderson

Location: Baltimore/Washington

Date: early 1970's

Data: Typical annual household consumption for appliances:

	Primary energy Btu x 10^6/yr	Point of demand Btu x 10^6/yr
all electric	69.9	21.9
gas and electric	59.6	23.5

CALCULATED

Source: 1974, Federal Energy Administration

Location: nationwide

Date: 1970

Data: 1970 national average energy demand by end use (in percent of unit total demand)*

Residence type	Cooking	Other appliances and lighting	(Sum)
Mobile homes	8.6%	11.0%	19.6%
Single family detached	3.3	7.4	10.7
Low density	5.0	7.5	12.5
Multi-family low rise	7.5	10.9	18.4
Multi-family high rise	6.6	8.5	15.1
All residences	4.0	7.7	11.7

* Note that these are weighted, nationwide averages.

ASSUMPTIONS

Source: 1976, Bernstein and Alereza

Locations: Atlanta, Boston, Chicago, Denver

Date: unspecified

Data: Assumptions used for assessing energy consumption of dwellings in specified locales (based on average consumption of appliances obtained from industry sources and data complied in Baltimore/Washington area, published in 1974, Hittman):

Typical annual consumption for appliances

	Electricity kWh/yr	Gas therms	Total Btu x 10^6/yr
Atlanta			
single family	6586	90	31.5
townhouse	9223	--	31.5
low rise	3180	68	17.7
high rise	5180	--	17.7
Boston			
single family	4246	195	34.0
townhouse	6816	--	23.3
low rise	4180	--	14.3
high rise	4180	--	14.3
Chicago			
single family	4246	180	32.5
townhouse	4246	180	32.5
low rise	3180	68	17.7
high rise	5180	--	17.7
Denver			
single family	6586	90	31.5
townhouse	6586	90	31.5
low rise	5180	--	17.7
high rise	5180	--	17.7

Source: 1975, Jones and Hendrix

Location: Austin, Texas

Date: early 1970's

Data: Typical monthly appliance energy consumption--used for assessment of energy consumption of homes in Austin area:

	kWh/mo	Btu x 10^3/mo
basic (refregerator, dish-washer, TV (color, solid state), clothes washer, miscellaneous)	290	990
typical total (including freezer or electric dryer or electric range and oven)	390	1331

DATA: Meas._____ Assumed X

DAILY LOAD PROFILE

EQUIPMENT/SYSTEM appliance FUEL TYPE electricity UNITS Btu x 10^3

SEASON See column headings

BUILDING TYPE Residence LOCATION Urban/suburban

		1	2
HOUR	1	1.3	1.25
	2	1.3	1.25
	3	1.3	1.25
	4	1.3	1.25
	5	1.3	1.25
	6	1.3	1.25
	7	1.75	1.3
	8	2.45	3.7
	9	3.35	6.5
	10	4.65	6.4
	11	1.85	4.85
	12	3.1	4.35
	13	2.2	3.6
	14	1.35	1.25
	15	1.35	1.25
	16	3.05	1.25
	17	3.05	1.35
	18	5.3	4.2
	19	4.9	4.3
	20	3.6	6.55
	21	3.6	3.6
	22	3.6	3.6
	23	2.7	3.2
	24	1.2	1.25
Day Total		60.85	70.0

Column 1. Winter weekday.
Occupancy: Father, mother, girls (ages 16, 12), boys (ages 9, 6)

Column 2. Summer weekday.
Occupancy: The same.
Profiles derived from scenarios of occupant activities developed for use with NBS test house.
Note: Data taken from graphs.

Reference: 1975, Peavy, et all

INDIVIDUAL APPLIANCES

(for prevalences see tables at beginning of Data section)

Source: 1976, Camacho and Roat (utility-complied data), except where otherwise noted.

Locations: various (note Reporting Utility, where indicated)

Dates: various (not known for 1976, Camacho and Roat data)

Data:

MAJOR APPLIANCES

	Reporting utility	Consumption kWh	Btu x 10^3

CLOTHES WASHER:

MEASURED DATA

1976, Socolow and Sonderegger
measured data (by NBS) from four Twin Rivers, N.J., townhouses (either 28- or 64-day period)

		kWh	Btu x 10^3
Minimum (1 house)		0.10/dy	0.34/dy
Average		0.15/dy	0.51/dy
Maximum (1 house)		0.24/dy	0.82/dy

UTILITY-COMPLIED DATA

(Camacho and Roat)

		Reporting utility	kWh	Btu x 10^3
All types -	Minimum*	Mont. P	7/mo	12.9/mo
	Maximum*	N. Orl. PS	12/mo	41.0/mo
Non-automatic -	Minimum	Tex. P&L	4.2/mo	14.3/mo
	Maximum	CE, W. Tex. U	6.3/mo	21.5/mo

* Note that all such figures from Camacho and Roat are reported as utility systemwide averages. See Reporting Utility code on page 153.

		Reporting utility	kWh	Btu x 10^3
Automatic-minimum		Tex. P	5.4/mo	18.4/mo
maximum (cold wash & rinse)		Carol. P&L	10/mo	34.1/mo
maximum (hot wash, warm rinse-incl. 35 gal hot water)		Carol. P&L	236/mo	898/mo
Washer-dryer		PGE	125/mo	427/mo
1975, Newman and Day				
Non-automatic	1950	(EEI)*	45/yr	150/yr
	1969	"	76/yr	260/yr
Automatic	1959	"	60/yr	200/yr
	1969	"	103/yr	350/yr
1972, Standard Research Institute				
Average	1960	(EEI)	65/yr	220/yr
	1968	(EEI)	98/yr	330/yr
1974, FEA**				
Average	1970			300/yr

---

* EEI and AGA figures are averages for the units currently being manufactured and sold.

** The FEA figures are based on industry (primarily EEI and AGA) studies, but adjusted downward to compensate for the fact that the national inventories are largely comprised of earlier model appliances that generally are smaller and have lower consumption per unit than current models.

	kWh	Btu x 10^3
1973, Anderson		
Baltimore/Washington area, early 1970's data		340/yr
1975, Jones and Hendrix		
Austin, Tex., early 1970's data	10/mo	34.1/mo

hot water consumption: H wash, C rinse--ca. 25 gal.
W wash, C rinse--ca. 12 gal.

ASSUMPTIONS

	kWh	Btux10³
1973, Anderson		
for Baltimore/Washington area, early 1970's	102/yr	350/yr
1975, Jones and Hendrix		
Austin, Texas, area	10/mo	34.1/mo
(+h/w - 12-25 gal/load)		
1976, Bernstein and Alereza		
(used for assessment of residential energy consumption in Atlanta, Boston, Chicago, and Denver--single family detached and townhouse)	103/yr	350/yr

---

DISHWASHER:

MEASURED DATA

1976, Socolow and Sonderegger (measured data (by NBS) from four Twin Rivers, N.J., townhouses)		
Minimum (1 house)	0.12/dy	0.4/dy
Average	0.33/dy	1.12/dy
Maximum (1 house)	0.55/dy	1.88/dy

UTILITY-COMPILED DATA

(Camacho and Roat)	Reporting utility	kWh	Btu x 10^3
Minimum (used 1/dy, with heater unit)	Phila. El	21/mo	71.7/mo
Maximum	Portl. GE	36/mo	122.9/mo
(32 loads/mo; incl. hot water)	Portl. GE	102/mo	348.1/mo

		kWh	Btux10^3
1975, Newman and Day			
1959	(EEI)	355/yr	1210/yr
1969, 1973	(EEI)	363/yr	1240/yr
1972, SRI			
1960	(EEI)	338/yr	1150/yr
1968	(EEI)	360/yr	1230/yr
1974, FEA			
1970 average			1200/yr
1973, Anderson			
typical (in Baltimore/Washington area)			1250/yr
1975, Jones and Hendrix			
average (Austin, Tex. area)		30/mo 0.5-10/load	102/mo

ASSUMPTIONS

1973, Anderson			
Baltimore/Washington area		363/yr	1240/yr
1975, Jones and Hendrix			
Austin, Texas, area		30/mo	102/mo
1976, Bernstein and Alereza			
(used for assessment of residential energy consumption in Atlanta, Boston, Chicago, and Denver)			
Single family detached, townhouse		363/yr	1240/yr
Low rise, high rise units		280/yr	960/yr

	kWh	Btu x 10^3
DRYER (CLOTHES):		
MEASURED DATA		
1963, Phillips and Achenbach (data from 10 all-electric military base dwellings--averaged over 32-day intervals in winter, 1959/60):		
Myrtle Beach, N. C.		
Minimum	1.86/dy	6.35/dy
Average (4.3% of average house total	4.07/dy	13.9/dy
Maximum	6.4/dy	22.1/dy
Columbus, Miss.		
Minimum	2.77/dy	9.45/dy
Average (3.8% of average house total)	3.97/dy	13.5/dy
Maximum	5.83/dy	19.9/dy
1976, Socolow and Sonderegger (data from townhouses in Twin Rivers, N.J.)		
Used, on average: ca. 1/2 hr/day		
Based on average winter power load (3 houses):		
Minimum	0.96/dy	3.28/dy
Maximum	3.6/dy	12.3/dy
Average (of all Quad II, 3BR)	1.44/dy	4.91/dy
NBS data (4 townhouses):		
Minimum (1 house)	1.32/dy	4.5/dy
Average	1.85/dy	6.3/dy
Maximum (1 house)	2.23/dy	7.6/dy

		Reporting utility	kWh	Btu x 10^3
1976, Midwest Research Institute -- measured data from instrumented appliances in 150 residences -- 16 cities -- size of sub-samples unspecified				
family size				
4	47 loads/mo		2.31/load 108.4/mo	7.88/load 370/mo
5	32.7 loads/mo		2.57/load 84.0/load	8.77/load 287/mo
6	75.5 loads/mo		2.89/load 218.2/mo	9.86/load 745/mo
UTILITY-COMPILED DATA				
(Camacho and Roat)				
Minimum		Tex. P&L	80/mo	273/mo
Maximum		Carol. P&L	140/mo	478/mo
1975, Newman and Day				
Gas - with gas pilot	1960 average	(AGA)		8500/yr
	1966 "	(AGA)		9000/yr
	1971 "	(AGA)		7500/yr
- with electric pilot	1960 "	(AGA)		4500/yr
	1966 "	(AGA)		5200/yr
	1971 "	(AGA)		6000/yr
Electric -	1950 "	(EEI)	520/yr	1800/yr
	1959 "	(EEI)	910/yr	3100/yr
	1969 "	(EEI)	993/yr	3400/yr
1972, SRI				
Electric -	1960 "	(EEI)	960/yr	3280/yr
	1968 "	(EEI)	990/yr	3380/yr
Gas -	1960 "	(AGA)		9300/yr
	1968 "	(AGA)		9000/yr

	kWh	Btu x 10^3
1974, FEA — 1970 average - gas		8800/yr
- electric		3200/yr
1973, Anderson (typical SFD* in Baltimore/ Washington area): electric		3380/yr
gas		4000/yr
1974, Lokhmanhekim (typical apartment or townhouse in Baltimore/Washington area): gas		4800/yr
1975, Jones and Hendrix		
Averages in Austin, Tex. area		
electric	100/mo	341/mo
	ca.3/load	10.2/load
gas - 7 kWh + 470 ft^3/mo		494/mo
ca. 0.2 kWh + 14.5 ft^3/load		15.2/load

ASSUMPTIONS

	kWh	Btu x 10^3
1973, Anderson		
Used for assessment of consumption of multi-family units in Baltimore/ Washington area (gas)		4800/yr
1976, Bernstein and Alereza		
Used for assessment of residential consumption in Atlanta, Boston, Chicago, and Denver		
Atlanta--SFD*, townhouse (gas)		9000/yr
Boston--SFD (gas)		9000/yr
--townhouse (electric)	1400/yr	4800/yr
Chicago, Denver--SFD, townhouse (gas)		9000/yr
1975, Jones and Hendrix		
Used for assessment of residential consumption in Austin area:	100/mo	341/mo
	or (500 ft^3/mo)	500/mo

---

* single family detached

FURNACE FAN:	Reporting Utility	kWh	Btu x 10^3
UTILITY-COMPILED DATA			
(Camacho and Roat)			
Minimum average (oil burner)	Phila. El	25/mo	85/mo
	Portl. GE	33/mo	113/mo
Maximum average (fan or pump)	W. Penn. P	100/mo	341/mo

RANGE/OVEN:	kWh	Btu x 10^3
MEASURED DATA		
1963, Phillips and Achenbach		
(data from 10 all-electric military base dwellings-- averaged over 32-day intervals in winter, 1959/60)		
Myrtle Beach, N. C.		
Minimum	1.59/dy	5.4/dy
Average (3.3% of avg. house total)	3.15/dy	10.8/dy
Maximum	4.76/dy	16.2/dy
Columbus, Miss.		
Minimum	1.79/dy	6.1/dy
Average (2.7% of avg. house total)	2.83/dy	9.7/dy
Maximum	6.12/dy	20.9/dy
1976, Socolow and Sonderegger (data from townhouses in Twin Rivers, N.J.)		
Based on average winter load in 3 houses -		
Minimum (1 house)	1.44/dy	4.9/dy
Maximum (1 house)	2.88/dy	9.8/dy
Average (of Quad II, 3 BR townhouses)	1.92/dy	6.6/dy
NBS data (from 4 townhouses) (1976)		
Minimum (1 house)	1.42/dy	4.8/dy
Average	2.08/dy	7.1/dy
Maximum (1 house)	2.88/dy	9.8/dy
1975, Robinson and Yeung		
Data from 3 Twin Rivers, N.J., townhouses, measured at 20 min. intervals and averaged for 22 days, Aug/Sept 1974		

	Reporting utility	kWh	Btu x 10^3
House			
1 One day minimum		0.10/dy	0.34/dy
Average		1.77/dy	6.04/dy
One day maximum		5.81/dy	19.8/dy
2 One day minimum		0.72/dy	2.46/dy
Average		1.73/dy	5.90/dy
One day maximum		4.52/dy	15.4/dy
3 One day minimum		0.10/dy	0.34/dy
Average		1.73/dy	5.90/dy
One day maximum		9.39/dy	32.0/dy
UTILITY-COMPILED DATA			
(Camacho and Roat)			
non self-cleaning oven - minimum	K.C. P&L	61/mo	208/mo
non self-cleaning oven - multi-family dwelling - minimum	PGE	50/mo	171/mo
- maximum		129/mo	440/mo
with self-cleaning oven (SFD) -minimum	PGE	52/mo	177/mo
-maximum	SCE, Mont.P, W. Tex. U	100/mo	341/mo
microwave oven - minimum	SCE, Portl. GE	16/mo	55/mo
- maximum	PSNJ, PGE*, CE	25/mo	85/mo
1975, Newman and Day			
gas - in apartment: 1966	(AGA)		7400/yr
1971	(AGA)		8800/yr
- in house 1960	(AGA)		10,000/yr
1966	(AGA)		10,600/yr
1971	(AGA)		10,500/yr
electric 1950	(EEI)	1250/yr	4300/yr
1959	(EEI)	1225/yr	4200/yr
1969	(EEI)	1175/yr	4000/yr
microwave 1973	(EEI)	190/yr	650/yr

* replacing regular oven

		Reporting utility	kWh	Btu x 10^3
1972, SRI				
electric	1960 average	(EEI)	1225/yr	4180/yr
	1968 "	(EEI)	1180/yr	4030/yr
gas	1960 "	(AGA)		10,600/yr
1974, FEA	1968 "	(AGA)		10,600/yr
electric	1970 average			3900/yr
gas	1970 "			9500/yr
1973, Anderson				
Averages, for Baltiore/Washington area -				
electric				4000/yr
gas				5000/yr
1975, Jones and Hendrix				
Austin, Tex., area averages (based on: 6 hr/wk baking; 1/2 hr/wk broiling; 5 hr/wk operation of 2 surface elements -				
electric			100/mo	341/mo
gas (690 ft^3/mo)				690/mo

ASSUMPTIONS

1973, Anderson				
Used for assessment of consumption in single-family homes, Baltimore/Washington area.				9000/yr
1974, Lokhmanhekim				
Used for assessment of consumption in townhouses and apartments, Baltimore/Washington area.				7200/yr
1976, Bernstein and Alereza				
Used for assessment of consumption in residences.				
Altanta - SFD, townhouse (elect.)			2340/yr	8000/yr
- low rise unit (gas)				6800/yr
- high rise unit (elect.)			2000/yr	6800/yr

	kWh	Btu x 10^3
Boston - SFD (gas)		10500/yr
- townhouse (elect.)	1170/yr	4000/yr
- low rise, highrise units (elect.)	1000/yr	3400/yr
Chicago - SFD, townhouse (gas)		9000/yr
- low rise unit (elect.)	1400/yr	4800/yr
- high rise unit (elect.)	2000/yr	6800/yr
Denver - SFD, townhouse (elect.)	2340/yr	8000/yr
- low rise, high rise units (elect.)	2000/yr	6800/yr

1975, Jones and Hendrix

Used for assessment of residential consumption in Austin area.

	100/mo	341/mo
	or (700 ft^3 mo)	700/mo

REFRIGERATOR:

MEASURED DATA

1976, Socolow and Sonderegger

Average for Twin Rivers, N.J., townhouses	2500/yr	8533/yr
Data from 4 Twin Rivers, N.J., townhouses (based on average winter load*) minimum (1 house)	4.1/dy	13.9/yr
maximum (1 house)	8.6/dy	29.5/dy
Average Quad II, 3 BR townhouse	4.8/dy	16.4/dy
NBS data (from 4 townhouses)		
Minimum (1 house)	4.3/dy	14.7/dy
Average	5.4/dy	18.3/dy
Maximum (1 house)	7.5/dy	25.6/dy

* Based on measurement of "time on", and includes power factor of 0.6 to take account of the impedance of the alternating current circuit.

1976, Midwest Research Institute		kWh	Btu x 10^3
Frost-free refrigerator/freezers, measured in 11 cities			
Sample (i.e., in one locale)			
44		5.8/dy	19.8/dy
27		6.1/dy	20.8/dy
34		6.6/dy	22.5/dy
18		6.7/dy	22.9/dy
31		6.7/dy	22.9/dy
36		6.1/dy	20.8/dy
30		6.0/dy	20.5/dy
29		5.8/dy	19.8/dy
33		5.5/dy	18.8/dy
31		5.6/dy	19.1/dy
29		6.4/dy	21.8/dy
Average daily consumption, by month			
Month	Avg. outdoor temp.		
June	74°F	6.5/dy	22.2/dy
July	75	6.6/dy	22.5/dy
Aug	74	6.5/dy	22.2/dy
Sep	71	6.4/dy	21.8/dy
Oct	61	6.1/dy	20.8/dy
Nov	45	6.1/dy	20.8/dy
Dec	44	5.8/dy	19.8/dy
Jan	39	5.9/dy	20.1/dy
Feb	38	5.8/dy	19.8/dy
Mar	45	5.8/dy	19.8/dy
Apr	55	6.0/dy	20.5/dy
May	64	6.1/dy	20.8/dy
Average	57	6.1/dy	20.8/dy
Average daily consumption per cubic foot of capacity, by refrigerator/freezer style			
Side-by-side arrangement		$0.38/dy \cdot ft^3$	$1.3/dy \cdot ft^3$
- with ice maker		$0.38/dy \cdot ft^3$	$1.3/dy \cdot ft^3$
- without ice maker		$0.38/dy \cdot ft^3$	$1.3/dy \cdot ft^3$
Top mounted freezer		$0.34/dy \cdot ft^3$	$1.2/dy \cdot ft^3$
- with ice maker		$0.36/dy \cdot ft^3$	$1.2/dy \cdot ft^3$
- without ice maker		$0.33/dy \cdot ft^3$	$1.1/dy \cdot ft^3$
All Units		$0.35/dy \cdot ft^3$	$1.2/dy \cdot ft^3$

Average daily consumption per cubic ft of capacity by total capacity		Reporting Utility	kWH	Btu x 10^3
Size	**Sample**			
12-13 ft^3	10		0.37/dy·ft^3	1.3/dy·ft^3
14-15	70		0.36/dy·ft^3	1.2/dy·ft^3
16-17	122		0.33/dy·ft^3	1.1/dy·ft^3
18-19	72		0.39/dy·ft^3	1.3/dy·ft^3
20-21	38		0.38/dy·ft^3	1.3/dy·ft^3
22-23	16		0.36/dy·ft^3	1.2/dy·ft^3
24-25	13		0.32/dy·ft^3	1.1/dy·ft^3

Range of average monthly energy consumption, by different manufacturers

Sample size (i.e. from one manufacturer)	kWH	Btu x 10^3
21	127-149/mo	433-509/mo
19	125-147/mo	427-502/mo
26	116-136/mo	396-464/mo
19	88-113/mo	300-386/mo

UILITY-COMPILED DATA

(Camacho and Roat)

	Reporting Utility	kWH	Btu x 10^3
refrigerator only - manual defrost			
-minimum	Tex. P	38/mo	130/mo
-maximum	PGE, CE	61/mo	208/mo
refrigerator only, frostfree			
-minimum	PSNJ	66/mo	225/mo
-maximum	PGE, CE	101/mo	345/mo
refrigerator freezer, manual defrost			
minimum	Phila. E	45/mo	154/mo
10-15 ft^3	W. Tex. U	45/mo	198/mo
10ft^3	Carol. P&L	58/mo	198/mo
maximum (16 ft^3	PGE	121/mo	413/mo
refrigerator-freezer, semi-defrost			
minimum (14 ft^3)	PSNJ	69/mo	235/mo
maximum	Phila. E	120/mo	410/mo
refrigerator-freezer, automatic defrost			
minimum	Carol. P&L	129/mo	440/mo
maximum	Phila. E	261/mo	891/mo

		Reporting utility	kWh	Btu x 10^3
1975, Newman and Day				
regular	1950	(EEI)	345/yr	1170/yr
	1959	(EEI)	420/yr	1430/yr
	1969	(EEI)	728/yr	2480/yr
frost-free	1969	(EEI)	1217/yr	4150/yr
refrigerator/freezer				
regular	1959	(EEI)	715/yr	2440/yr
	1969	(EEI)	1137/yr	3880/yr
frost-free	1969	(EEI)	1829/yr	6240/yr
1972, SRI				
electric (average)	1960	(EEI)	790/yr	2700/yr
gas	1960	(AGA)	--	13,000/yr
refrigerator	1961	(EEI)	460/yr	1570/yr
refrigerator/freezer	1961	(EEI)	1625/yr	5550/yr
electric (average)	1968	(EEI)	1270/yr	4330/yr
gas	1968	(AGA)	--	14,000/yr
refrigerator - 12 ft^3	1969	(EEI)	728/yr	2480/yr
14 ft^3	1969	(EEI)	1137/yr	3880/yr
refrig./freezer-12 ft^3	1969	(EEI)	1217/yr	4150/yr
14 ft^3	1969	(EEI)	1829/yr	6240/yr
1974, FEA				
average - 1970				3700/yr
1973, Anderson				
typical - Baltimore/Washington area			1830/yr	6250/yr
1975, Jones and Hendrix				
averages in Austin, Tex., area				
refrigerator - manual defrost				
(if regularly defrosted)			80-100/mo	273-341/mo
refrigerator/freezer			100-150/mo	341-512/mo
average			140/mo	478/mo

	kWh	Btu x 10^3
ASSUMPTIONS		
1973, Anderson		
Used for assessment of residential energy consumption in the Baltimore/Washington area.		6260/yr
1976, Bernstein and Alereza		
Used for assessment of residential consumption in Atlanta, Boston, Chicago, and Denver.		
Atlanta - SFD*, townhouse	1830/yr	6250/yr
- low rise, high rise units	1400/yr	4780/yr
Boston - SFD, townhouse	1830/yr	6250/yr
- low rise, high rise units	1400/yr	4780/yr
Chicago - SFD, townhouse	1830/yr	6250/yr
- low rise, high rise units	1400/yr	4780/yr
Denver - SFD, townhouse	1830/yr	6250/yr
- low rise, high rise units	1400/yr	4780/yr
1975, Jones and Hendrix		
Used for assessment of residential consumption in Austin area.	140/mo	478/mo

* Single-family detached.

FREEZER:

MEASURED DATA

1976, Midwest Research Institute

Annual consumption of nine freezers, in various locales (1975/76)

	Size (ft^3)	Auto-defrost	kWH	Btu x 10^3
Upright style	15.0	N	1521/yr	5191/yr
	15.6	N	1421/yr	4850/yr
	15.8	N	1277/yr	4358/yr
	16.0	N	1227/yr	4188/yr
	20.0	N	1038/yr	3543/yr
	20.0	N	1172/yr	4000/yr
	19.0	Y	2234/yr	7625/yr
	19.6	Y	1739/yr	5935/yr
Chest type	17.2	N	1254/yr	4280/yr

UTILITY-COMPILED DATA

(Camacho and Roat)	Reporting Utility	kWH	Btu x 10^3
Minimum	Phila. El	62/mo	212/mo
Maximum	Phila. El	209/mo	713/mo
Manual defrost - Minimum	SCE (16 ft^3), Portl. GE, PGE (15 ft^3)	100/mo	341/mo
Maximum	Carol. P&L (15 ft^3)	155/mo	529/mo
Frost-free			
Minimum	Mont. P (15 ft^3)	130/mo	444/mo
Maximum	Carol. P&L (16 ft^3)	210/mo	717/mo
1975, Newman and Day			
1950 (average	(EEI)	620/yr	2120/yr
1959 - regular (average)	(EEI)	860/yr	2940/yr
1969 - regular (average)	(EEI)	1195/yr	4080/yr
1969 - frost-free (average)	(EEI)	1761/yr	6010/yr
1972, SRI			
1960 average	(EEI)	845/yr	2880/yr
1961 "	(EEI)	915/yr	3120/yr
1968 "	(EEI)	1405/yr	4790/yr
1969 - 15 ft^3 (average)	(EEI)	1195/yr	4080/yr
- frost-free (average)	(EEI)	1761/yr	6010/yr
- average	(EEI)	1478/yr	5040/yr

	Reporting utility	kWh	Btu x 10^3
1974, FEA			
1970 (average)			4600/yr
1975, Jones and Hendrix			
average in Austin, Tex., area		120/mo	410/mo

ASSUMPTION

1975, Jones and Hendrix

Used for assessment of residential consumption in Austin area.		130/mo	444/mo

---

TELEVISION:

UTILITY-COMPILED DATA

(Camacho and Roat)

	Reporting utility	kWh	Btu x 10^3
Black and white:			
minimum	Tex. P	29/mo	99/mo
maximum	Carol. P&L	36/mo	123/mo
Tube type:			
minimum	West Tex. U	18/mo	61/mo
maximum (used 7 hr/dy)	W. Penn P	33/mo	113/mo
Solid State:			
minimum	SCE, Portl. GE, PGE	10/mo	34/mo
(used 2182 hr/yr)	OT	10/mo	34/mo
maximum	W. Penn P	15/mo	51/mo
Color:			
minimum	Tex. P&L, Mont. P	38/mo	130/mo
(used 4 hr/dy)	Phil. El	38/mo	130/mo
maximum (used 7 hr/dy)	Carol. P&L	72/mo	246/mo
Tube type:			
minimum	Portl. GE, W. Tex. U	44/mo	150/mo
maximum (used 7 hr/dy)	W. Penn P	64/mo	218/mo
Solid State:			
minimum	W. Tex. U	27/mo	92/mo
maximum (used 6 hr/dy)	SCE	37/mo	126/mo

	Reporting utility	kWh	Btu x 10^3
For instant-on add		11/mo	37.5/mo
1975, Newman and Day			
Black and white:			
1950 (average)	(EEI)	290/yr	990/yr
1959 "	(EEI)	325/yr	1110/yr
1969 "	(EEI)	362/yr	1240/yr
Color:			
1969 (average)	(EEI)	502/yr	1700/yr
1972, SRI			
Black and white:			
1960 (average)	(EEI)	345/yr	1180/yr
1968 "	(EEI)	360/yr	1230/yr
Color:			
1960 (average)	(EEI)	450/yr	1540/yr
1968 "	(EEI)	490/yr	1670/yr
1974, FEA			
1970 (average)			1500/yr
1973, Anderson			
Typical, in Baltimore/Washington area			1690/yr
1975, Jones and Hendrix			
Average in Austin, Tex., area		40/mo	137/mo

ASSUMPTIONS

		kWh	Btu x 10^3
1973, Anderson			
Used for assessment of residential consumption in the Baltimmore/Washington area.		500/yr	1710/yr
1976, Bernstein and Alereza			
Used for assessment of residential consumption in specified locales.			

	Reporting utility	kWh	Btu x 10^3
Atlanta, Boston, Chicago, Denver:			
SFD, townhouse (color)		500/yr	1710/yr
low rise, high rise units		400/yr	1370/yr
1975, Jones and Hendrix			
Used for assessment of residential consumption in Austin area.			
color, solid state		50/mo	171/mo

MINOR APPLIANCES
UTILITY-COMPILED DATA

(Data from 1974, Camacho and Roat, unless otherwise indicated.)

	Reporting utility	kWh	Btu x 10^3
BEDCOVERING - minimum	Portl. GE	12/mo	41/mo
- maximum	W. Penn P	37/mo	126/mo
(In 1972, SRI (for 1969), in 1975, Newman and Day (for 1973))	(EEI)	147/yr	500/yr
BLENDER - minimum	W. Tex. U	0.083/mo	0.28/mo
- maximum	CE	1.3/mo	44.4/mo
(In 1972, SRI (for 1969) in 1975, Newman and Day (for 1973))	(EEI)	15/yr	50/yr
BROILER - minimum	W. Tex. U	7/mo	24/mo
- maximum	PSNJ, PGE, CE	8.3/mo	28/mo
(In 1972, SRI (for 1969), in 1975, Newman and Day (for 1973))	(EEI)	100/yr	340/yr
CLOCK - minimum	SCE	1/mo	3.4/mo
- maximum	Portl. GE, W. Penn P	2/mo	6.8/mo
(In 1972, SRI (for 1969), in 1975, Newman and Day (for 1973))	(EEI)	17/yr	60/yr
COFFEE MAKER (electric)			
- minimum	Tex. P	8/mo	27/mo
(50 pots/mo)	SCE	8/mo	27/mo
(2 times/dy)	Phila. El	8/mo	27/mo
- maximum	Portl. GE	10/mo	34/mo

	Reporting utility	kWh	Btu x 10^3
(In 1972, SRI (for 1968), in 1975, Newman and Day (for 1973))	(EEI)	106/yr	360/yr
CORN POPPER	Portl. GR	1/mo	3.4/mo
CURLING IRON	SCE	<1/mo	<3.4/mo
DEHUMIDIFER - minimum	PSNJ	29/mo	99/mo
- maximum (22 pints/day)	Carol. P&L	36/mo	123/mo
(In 1972, SRI (for 1969), 1975, Newman and Day (for 1973))	(EEI)	337/yr	1290/yr
DISPOSER (food) - minimum	W. Tex. U	0.6/mo	2.0/mo
- maximum	Portl. GE	3/mo	10/mo
(used daily)	SCE	3/mo	10/mo
(In 1972, SRI (for 1969), 1975, Newman and Day (for 1973))	(EEI)	30/yr	100/yr
EGG COOKER			
(In 1975, Newman and Day (for 1973))	(EEI)	14/yr	50/yr
ELECTROSTATIC CLEANER	Tex. P	22/mo	75/mo
FAN, attic			
(In 1975, Newman and Day (for 1973))	(EEI)	291/yr	990/yr
FAN, circulating - minimum	PSNJ, Tex. P	3.3/mo	11/mo
- maximum	Portl. GE	4/mo	14/mo
(In 1972, SRI (for 1969), 1975, Newman and Day (for 1973))	(EEI)	43/yr	150/yr
FAN, roll about - minimum	Tex. P	9.2/mo 110/yr	31/mo 375/yr
- maximum	PGE, CE, W. Tex. U	11.5/mo	39/mo
(In 1975, Newman and Day (for 1973))	(EEI)	138/yr	471/yr

	Reporting utility	kWh	Btu x 10^3
FAN, window			
(In 1975, Newman and Day (for 1973))	(EEI)	170/yr	580/yr
FLOOR POLISHER	CE,W.Tex.U	1.3/yr	4.4/yr
(49 hr/yr)	OT	1.3/yr	4.4/yr
(In 1975, Newman and Day (for 1973))	(EEI)	15/yr	50/yr
FOOD MIXER - minimum	W.Tex. U	0.17/mo	0.58/mo
maximum	PSNJ, Tex.P, PGE, CE	1/mo	3.4/mo
(In 1972, SRI (for 1969), 1975, Newman and Day (for 1973))	(EEI)	13/yr	40/yr
FRYER, deep fat - minimum	Tex. P	6.3/mo	21.5/mo
maximum	PSNJ	8.3/mo	28.3/mo
(In 1975, Newman and Day (for 1973))	(EEI)	83/yr	280/yr
FRYPAN/SKILLET (electric)			
- minimum (8 times/mo)	SCE	8/mo	27.3/mo
- maximum	PSNJ	20/mo	68.3/mo
(In 1972, SRI (for 1969), 1975, Newman and Day (for 1973)	(EEI)	186/yr	630/yr
(In Jones and Hendrix) Austin, Tex., area		12/mo	41/mo
GRIDDLE (electric)	Portl. GE	8/mo	27/mo
GRILL, sandwich - minimum	PGE, CE, W.Tex. U	2.8/mo	9.6/mo
- maximum	PSNJ	3.3/mo	11/mo
(In 1975, Newman and Day (for 1973))	(EEI)	33/yr	110/yr
HAIR DRYER - minimum	Tex. P	0.6/mo	2.0/mo
- maximum - (used 51 hr/yr)	OT	3.2/mo	11/mo
(In 1972, SRI (for 1969), 1975, Newman and Day (for 1973))	(EEI)	14/yr	50/yr
HEAT LAMP - minimum	Tex. P	1/mo	3.4/mo
- maximum	PSNJ	1.25/mo	4.3/mo

	Reporting utility	kWh	Btu x 10^3
HEATER (portable, radiant)			
- minimum	Portl. GE	7.5/mo	26/mo
- maximum	Carol. P&L	18.3/mo	62/mo
(In 1972, SRI (for 1969), 1975 Newman and Day (for 1973))	(EEI)	176/yr	600/yr
HEATING PAD	Tex. P, PGE	0.8/mo	2.7/mo
(In 1975, Newman and Day (for 1973))	(EEI)	10/mo	34/mo
HOT PLATE - minimum	PGE, CE, W. Tex. U	7.5/mo	26/mo
- maximum	Tex. P	8.3/mo	28/mo
(2 burner)	PSNJ	8.3/mo	28/mo
(In 1972, SRI (for 1969), 1975 Newman and Day (for 1973))	(EEI)	90/yr	310/yr
HUMIDIFIER			
minimum average	Tex. P	140/yr	478/yr
Room type	Mont. P	14/mo	48/mo
maximum average (used 6 hr/dy)	Carol. P&L	21/mo	72/mo
(In 1972, SRI (for 1969)	(EEI)	163/yr	560/yr
INCINERATOR	Tex. P	55/mo	188/mo
IRON, hand			
- minimum	PGE	3.6/mo	12/mo
- maximum	PSNJ	12.5/mo	43/mo
(In 1972, SRI (for 1969), 1975, Newman and Day (for 1973))	(EEI)	144/yr	490/yr
(1975, Jones and Hendrix, Austin, Tex., area)		12/mo	41/mo
IRON, mangle	Tex. P, PGE	13.3/mo	45/mo
RADIO			
- minimum	W. Penn P	7/mo	25/mo
(used 3 hr/dy)	SCE	7/mo	24/mo
- maximum	Tex. P	7.5/mo	26/mo

	Reporting utility	kWh	Btu x 10^3
(In 1972, SRI (for 1969), 1975, Newman and Day (for 1973))	(EEI)	86/yr	300/yr
Tube type	PSNJ	7.1/mo	24/mo
Solid State	PGE	1.5/mo	5.1/mo
	PSNJ	1.7/mo	5.8/mo
Table model	Portl. GE	6/mo	20/mo
RADIO PHONOGRAPH - minimum	Tex. P	8.8/mo	30/mo
- maximum	PSNJ	9.6/mo	33/mo
(In 1975, Newman and Day (for 1973))	(EEI)	109/yr	370/yr
Solid state - minimum	PGE	2.1/mo	7.2/mo
- maximum	PSNJ	5/mo	17/mo
Hi fi (used 10 hr/wk)	Phila. El	9/mo	31/mo
ROASTER - minimum	W. Tex. U	5/mo	17/mo
- maximum	Portl. GE	40/mo	137/mo
(In 1975), Newman and Day (for 1973))	(EEI)	205/yr	700/yr
ROTISSERIE	Tex. P	42/mo	143/mo
SEWING MACHINE - minimum	PSNJ, Tex. P	0.8/mo	2.7/mo
- maximum	Portl. GE	1/mo	3.4/mo
(In 1975, Newman and Day (for 1973))			
	(EEI)	11/yr	40/yr
SLOW COOKER	SCE	12/mo	41/mo
SUN LAMP - minimum	Portl. GE	1/mo	3.4/mo
- maximum	PGE, CE, W. Tex. U	1.3/mo	4.4/mo
(used 57 hr/yr)	OT	1.3/mo	4.4/mo
(In 1975, Newman and Day (for 1973))	(EEI)	16/yr	50/yr
TOASTER - minimum	Tex. P	3/mo	10/mo
(used 6 min/dy)	SCE	3/mo	10/mo
(used 1 time/dy)	Phila. El	3/mo	10/mo
- maximum	PSNJ	3.1/mo	11/mo

	Reporting utility	kWh	Btu x 10^3
(In 1972, SRI (for 1969), and 1975, Newman and Day (for 1973))	(EEI)	39/yr	130/yr
TOASTER OVEN			
- minimum (toast: 4 min/dy; oven: 2 1/2 hr/wk)	SCE	8/mo	27/mo
- maximum (4 slices)	PSNJ	15/mo	51/mo
TRASH COMPACTOR	PGE, CE, W. Tex. U	4/mo	13.7/mo
(used daily)	SCE	4/mo	13.7/mo
(In 1975, Newman and Day (for 1973))	(EEI)	50/yr	170/yr
VACUUM CLEANER - minimum	Tex. P	3.3/mo	11/mo
- maximum	PSNJ	4/mo	14/mo
(6 hr/mo)	SCE	4/mo	14/mo
(In 1972, SRI (for 1969), 1975, Newman and Day (for 1973))	(EEI)	46/yr	160/yr
(1975, Jones and Hendrix) Austin, Tex., area		4/mo	14/mo
VIBRATOR	Tex. P, PGE, CE, W. Tex. U	0.17/mo	0.58/mo
		0.17/mo	0.58/mo
(used 50 hr/yr)	OT		
(In 1975, Newman and Day (for 1973))	(EEI)	2/yr	6/yr
WAFFLE IRON - minimum	W. Tex. U	1.7/mo	5.8/mo
- maximum	Portl. GE	2/mo	6.8/mo
(In 1975, Newman and Day (for 1973))	(EEI)	22/yr	75/yr

LIGHTING

6.0 LIGHTING

6.1 RELATIVE IMPORTANCE

Lighting consumed about 20 percent of the electrical energy used in the United States, in 1973, amounting to about 5 percent of all energy used. Although lighting energy consumption tends to be much greater in offices and other commercial and public buildings, the amount of residential energy consumption that goes to lighting is not insignificant. Approximately 20 percent of the energy consumption for lighting occurs in residences, or approximately 1 percent of total national energy consumption (General Electric Company figures, cited in 1974, Carnahan, et al.). Since the residential sector accounts for roughly 20 percent of total national energy use, something on the order of 4-5 percent of the energy consumed in residences is being used for lighting.

Whereas lighting in commercial and public buildings is largely determined by standards, if not regulations, the amount of lighting installed and used in residences is almost entirely governed by personal choice. It is indicative that ASHRAE Standard 90-75, Energy Conservation in New Building Design, specifies that the prescribed criteria for illumination levels and lighting systems do not apply to spaces in private residences or apartments, except for kitchens, bathrooms and laundry areas.

6.2 NEEDED OCCUPANT DATA

1. Hourly demand profiles (watts) (Btu)
   - weekday
   - weekend
   - unoccupied
   - by region
   - by season
   - by family size
   - by residence size
2. Window management (covering, schedule)
3. Inventory of luminaires.

6.3 RELATED PHYSICAL DATA

1. Availability of daylight regionally:
   - latitude
   - cloud cover
   - location in time zone
2. Availability of daylight within rooms:
   - window area and exposure compared to room depth and floor plan
   - local obstructions of daylight, e.g., overhangs, draperies
   - other obstructions, e.g., trees, nearby buildings

6.4 AN OVERVIEW OF AVAILABLE DATA

With the actual use of lights in residences largely determined by personal preference, there exists a presumption that actual lighting energy consumption figures would exhibit a wide range of variability. Unfortunately we find, in the words of the Federal Energy Administration's Project Independence Blueprint, that "very little data is available on residential lighting loads" (1974, Federal Energy Administration). This is not surprising, considering the difficulties inherent in trying to measure the use of lights. Lighting fixtures are commonly connected to the same circuits which serve such non-illuminating devices as clocks, vacuum cleaners, television sets, coffee makers, toasters, fans, hair dryers, etc. Consequently, there exists no fully satisfactory way of separating out energy consumed by lighting fixtures from energy consumed by appliances.

Most of the relevant data have been obtained through a metering approach. The drawback of this method has been discussed under appliances. While it is feasible to meter the consumption of the larger appliances, it is impractical to attach individual meters to all of the luminaires in a residence. Thus, the only practical way to meter the consumption by lights is to start from the whole-house electricity consumption, and subtract the power used by non-illuminating equipment. The electricity consumption of refrigerators, clothes washers, air conditioners, furnace fans, etc., can be fairly inexpensively determined by measuring the load of the device and then recording duration of "on time" in normal use and operation by means of a clock device wired in parallel to the controlling switch of the appliance. Cooking ranges, electric clothes dryers, and air conditioners are typically connected to a 220 volt circuit, simplifying the task of isolating and measuring the consumption of these devices for elimination from the whole house total. However, at this point we are left with a problem exactly like the one with which we were originally faced: how to measure (for deletion) the consumption of the plethora of electrical devices (for food preparation, personal care, entertainment, and housekeeping) that draw power from the same circuits that serve the lighting fixtures.

In view of this problem, it is not surprising that rather more data are available for "lights and small appliances" than for lights, alone. (See below, Illumination and Miscellaneous Appliances: 1963, Phillips and Achenbach; undated, Schmitt; and the Twin Rivers, N.J., reports--1975, Robinson and Yeung, and 1976, Socolow and Sonderegger).

Some reported data has been obtained by the survey approach (1975, Newman and Day--see page 137 for description of this survey). The method used in their study might be considered as a crude version of the "activity log" technique (discussed below), with questions along the lines of, "What wattage bulbs do you usually buy..?", "How many rooms in your home, if any, usually have lights on continuously during the evening before everyone goes to sleep?", or "Do you or your family keep any electric lights on all night outside or inside of your home?" This data provides a basis for calculating crude approximations of the range of lighting energy consumption.

6.5 ADDITIONAL DATA NEEDS AND SUGGESTED COLLECTION METHODS

The only available national data suggesting ranges of lighting energy consumption in residences is the survey data from Newman and Day. This represents a good beginning, but more precise information is needed in two regards:

1. Data on actual numbers and wattages of lighting fixtures used; and
2. Data relating the lighting energy consumption to the availability of natural light in various geographic areas.

Two possible methods of obtaining such data are discussed below

Activity logs could be used to gather data on light usage. Occupants could be asked to record, in some simple way, their time-use of lamps. (This method has been used in some types of social research.) A form could be provided--perhaps one for each room or associated group of rooms--that would list the various luminaires present, indicate the rated wattage of installed bulbs, and provide spaces for occupants to record "on" and "off" times. The data thereby obtained would, as well as providing a basis for calculating total consumption for lighting, also give us valuable information not easily obtained through the metering approach. On the other hand, in view of the human factor involved in occupants having to record many bits of data about fairly trivial activities, the information so obtained would have to be carefully assessed.

Light meters could be used to record "on-off" data. This is a possible way of gathering data about the use of lights in residences that has not, to our knowledge, been tried in practice, but might hold promise of deriving useful data. Simple light-level meters (threshold photocell devices) would be used. One would be placed in each room. Two or three might be placed in carefully selected locations and orientations in a large room with several lighting devices. An additional meter would be placed outdoors--perhaps several, on different sides of the house--to measure the ambient light level. The meters would be connected to appropriate electronic circuitry and devices to: 1) compare the reading of each interior meter with that of the appropriate exterior meter (i.e., the one measuring the natural light supply to that room), and 2) record "on" time for any room or area whenever the interior meter reading is higher. This would not record the exact number of luminaires in use, but would provide approximate data in terms of the number of interior spaces lighted at various times.

An alternative way of recording detailed luminaire "on-off" data would be to locate thermistors adjacent to the bulbs. The small devices could be taped to the base of incandescent bulbs (to the ballast of fluorescent units), and the heat emitted when a light is on would generate a signal. The devices could be connected by means of light-gauge wire to a fairly simple data-reduction and recording unit, and recorded in any desired format.

Lighting

AUTHORS' RECOMMENDED VALUES

Occupant Datum		Value(s)						Basis
1. Hourly demand profiles--(watts) Btu								
weekday (see "by season," below)								
weekend		no recommendation						no basis
by region		no recommendation						no basis
by season								
winter weekday	Hour:	1	2	3	4	5	6	Profiles derived from scenarios of occupant (2 adults, 4 children) activities developed for use with NBS test house.
	(watts) Btu:	---	---	---	---	---	---	
	Hour:	7	8	9	10	11	12	
	(watts) Btu:	(205)700	(660)2048	(277)945	(101)345	(234)799	(86)294	
	Hour:	13	14	15	16	17	18	Reference: 1975, Peavy, et al.
	(watts) btu:	(58)198	---	---	(119)406	(86)294	(148)505	
	Hour:	19	20	21	22	23	24	
	(watts) Btu:	(205)700	(353)1205	(469)1601	(234)799	(368)1256	---	
summer weekday	Hour:	1	2	3	4	5	6	
	(watts) Btu.	---	---	---	---	---	---	
	Hour:	7	8	9	10	11	12	
	(watts) Btu:	(219)747	(514)1754	(323)1102	(132)451	(146)498	(146)498	
	Hour:	13	14	15	16	17	18	
	(watts) Btu:	(351)1198	---	---	---	(191)652	(160)546	
	Hour:	19	20	21	22	23	24	
	(watts) Btu:	(177)604	(205)700	(337)1150	(219)747	(351)1198	---	

AUTHORS' RECOMMENDED VALUES (cont.)

by family size	no recommendaton	no basis
by residence size	no recommendation	no basis
2. Window management - (covering, schedule)	no recommendation	no basis
3. Inventory of luminaires	no recommendation	insufficient data
Resultant Energy consumption (Btu)		
winter	(3.6 kWh/dy) 12.3×10^3 Btu/day	Representative of available estimates.
summer	(3.5 kWh/dy) 11.9×10^3 Btu/day	

DATA

LIGHTING

LIGHTING

SURVEY

Source: 1975, Newman and Day

Date: 1973

Lighting practices*
Percent of households

	Poor	Lower middle	Upper middle	Well-off
Number of rooms lighted in evening:				
0-1	63%	53%	38	32
2	24	31	35	31
>2	13	16	27	37
Lights on all night	30	35	41	42
Buy only bulbs <100 W	70	61	50	46

* Based on interviews of national sample of 1455 households.

Source: 1975, Camacho and Roat

Locations: various

Dates: unspecified

Data: monthly consumption for lighting

	kWh/mo	Btu x 10^6/mo	Reporting Utility + and Comments
minimum*	56	0.19	Phila. El -- 5 rm. house winter
maximum	100	0.34	W. Penn , PG&E

* Note that these are systemwide (estimated) averages.
+ See code on page 153.

Source: 1973, Anderson

Location: Baltimore/Washington area

Date: Early 1970's

Data: Typical total annual consumption for lights: 6.8 x 10^6 Btu/yr
yard light (electric): 2.8 x 10^6Btu/yr.

Source: 1975, Jones and Hendrix

Location: Austin, Texas

Date: Early 1970's

Data: Source ambiguous, but believed to be utility data

Monthly Consumption	kWh/mo	Btu x 10^5/mo
minimum	50	0.17
average	250	0.85
maximum	350	1.19

Monthly Consumption for yard light:

electric (@ 60W, 10hr/dy)	18 kWh/mo	.061 x 0^6Btu/mo
gas*	1520 ft^3/mo	1.5 x 10^6Btu/mo

* 1975, Newman and Day attributes the same figure to AGA.

CALCULATED

Source: 1974, Federal Energy Administration

Location: nationwide

Date: 1970

Data: Average (household) annual consumption

2.6×10^6 Btu/yr.

ASSUMPTION

Source: 1975, Jones and Hendrix

Location: Austin, Texas

Date: early 1970's

Data: Assumptions used in analyzing energy consumption of Austin-area homes.

Size of bulbs	Use	Monthly consumption kWh/mo.	Btu x 10^6/mo.
100 W	liberal	350	1.19
	conservative	240	0.82
60 W	liberal	220	0.75
	conservative	150	0.51

Source: 1973, Anderson

Location: Baltimore/Washington area

Date: Early 1970's

Assumptions used in assessing energy consumption of residences in the specified locale (based on survey/statistical--i.e., utility--data)*:

single family dwelling--typical annual consumption:
2000 kWh/yr 6.8×10^6 Btu/yr,

* See daily load profile, on following page.

DATA: Meas.____ Assum. X____

DAILY DEMAND LOAD PROFILE

EQUIPMENT/SYSTEM lights FUEL TYPE electricity UNITS Btu

SEASON ________ DATE(S) ________

BUILDING TYPE detached house LOCATION Baltimore/Washington

Heat input to house from lights.

Occupancy: 4 people

HOUR	
1	0
2	0
3	0
4	0
5	0
6	0
7	3000
8	3000
9	100
10	100
11	100
12	100
13	100
14	100
15	100
16	100
17	100
18	100
19	100
20	1500
21	1500
22	3100
23	3100
24	3100

Note: Data taken from graph.

Day Total 19,400

Reference: 1973, Anderson

Source: 1976, Bernstein and Alereza

Location: Atlanta, Boston, Chicago, Denver

Date: Early 1970's

Assumptions used in assessing energy consumption of residences in the specified locales (based on data compiled in Baltimore/Washington, and published in 1974, Hittman*):

			Typical annual consumption kWh/yr	Typical annual consumption Btu x 10^6/yr
Atlanta:	single family dwelling		2020	6.9
	townhouse		1990	6.8
	lowrise		1600	5.5
	highrise	1 BR	1080	3.7
		2 BR	1270	4.3
Boston:	single family dwelling		1320	4.5
	townhouse		1570	5.4
	lowrise		1600	5.5
	highrise		860	2.9
Chicago:	single family dwelling		2020	6.9
	townhouse		1570	5.4
	lowrise	1 BR	1000	3.4
		2 BR	1410	4.8
	highrise	1 BR	1160	4.0
		2 BR	1370	4.7
Denver:	single family dwelling		2200	7.5
	townhouse		1570	5.4
	lowrise	1 BR	860	2.9
		2 BR	1170	4.0
	highrise	1 BR	1040	3.5
		2 BR	1290	4.4

* These assumptions are varied on the basis of average square footage of typical dwelling, but take no account of the differing hours of daylight in the various locations.

See additional assumed profiles on following pages.

DATA: Meas.____ Assum. X_______

DAILY DEMAND LOAD PROFILE

EQUIPMENT/SYSTEM lights FUEL TYPE electricity UNITS see notes
SEASON Year round DATE(S)
BUILDING TYPE Multifamily housing LOCATION Baltimore/Washington

HOUR	1	2	3	4
1	0.14	126	0.11	143
2	0.09	81	0.07	91
3	0.02	20	0.02	26
4	0.02	20	0.02	26
5	0.02	20	0.02	26
6	0.05	45	0.04	52
7	0.09	81	0.07	91
8	0.23	207	0.18	234
9	0.18	162	0.14	182
10	0.14	126	0.11	143
11	0.09	81	0.07	91
12	0.09	81	0.07	91
13	0.14	126	0.11	143
14	0.09	81	0.07	91
15	0.09	81	0.07	91
16	0.14	126	0.11	143
17	0.18	162	0.14	182
18	0.27	243	0.21	273
19	0.36	324	0.28	364
20	0.36	324	0.28	364
21	0.32	288	0.25	325
22	0.32	288	0.25	325
23	0.23	207	0.18	234
24	0.14	126	0.11	143
Day Total	----	3418	----	3874

Column 1. Lowrise (850-950 ft^2) - W/ft^2

Occupancy: Average middle income, number unspecified.

Column 2. Lowrise (900 ft^2) - total watts

Occupancy: Same.

Column 3. Townhouse (1300 ft^2) - w/ft^2

Occupancy: Same.

Column 4. Townhouse (1300 ft^2) - total watts

Occupancy: Same.

Note: Profiles taken from graphs

Reference: 1974, Lokhmanhekim, and private communication

DATA: Meas.____ Assum. X

DAILY DEMAND LOAD PROFILE*

EQUIPMENT/SYSTEM lighting FUEL TYPE electricity UNITS Btu x 10^{3*}

SEASON summer/winter DATE(S)

BUILDING TYPE 4 BR townhouse LOCATION Gaithersburg, MD

HOUR	1	2
1	--	--
2	--	--
3	--	--
4	--	--
5	--	--
6	--	--
7	0.75	0.7
8	1.75	2.25
9	1.1	0.95
10	0.45	0.35
11	0.5	0.8
12	0.5	0.3
13	1.2	0.2
14	--	--
15	--	--
16	--	0.4
17	0.65	0.3
18	0.55	0.5
19	0.6	0.7
20	0.7	1.2
21	1.15	1.6
22	0.75	0.8
23	1.2	1.25
24	--	--
Day	11.85	12.3

Column 1. Summer activities
Father, Mother, 2 girls (ages 12, 16), 2 boys (ages 6, 8)

Column 2. Winter activities
same occupancy

* Note: Data taken from graphs.

Reference 1975, Peavy, B.A. et al.

DATA: Meas.____ Assum. X

DAILY DEMAND LOAD PROFILE*

EQUIPMENT/SYSTEM lights FUEL TYPE ____ UNITS WATTS
SEASON unspecified DATE(S) ____
BUILDING TYPE detached residence LOCATION Ithaca, NY

HOUR	1	2	3
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0
5	0	0	0
6	0	0	0
7	1000	500	1500
8	1000	500	1500
9	500	500	100
10	0	0	0
11	0	0	0
12	0	0	0
13	0	0	0
14	0	0	0
15	0	0	0
16	0	0	0
17	500	0	500
18	500	1000	1500
19	1000	1000	2000
20	1000	1000	2000
21	1000	500	1500
22	200	500	700
23	200	500	700
24	0	0	0
Day Total			

Column 1. playroom/bedroom zone

Occupancy. 4 adults (equiv.)

Column 2. living/kitchen Zone

Occupancy: the same

Column 3. house total

Occupancy. the same

* Note: Based on observation of actual family of 2 adults and 3 children.

Reference: 1976, Nall

MEASURED

Sources: 1963, Phillips and Achenbach

Location: Myrtle Beach, N.C., and Columbus, Miss.

Dates: 1959/60

Average daily consumption for lights and appliances (excluding: water heater, range, clothes dryer):

	kWh/dy	Btu x 10^3/dy
Myrtle Beach, N.C. (5 dwelling units)		
minimum	8.30	28.3
average (12.7% of average house total*)	21.07	41.2
maximum	16.11	55.0
Columbus, Miss. (5 dwelling units)		
minimum	7.74	26.4
average (10.8% of average house total*)	11.45	39.1
maximum	18.42	62.9

* All-electric houses.

Source: undated, Schmitt

Location: Cleveland, Ohio area

Dates: Feb. 1973-Feb. 1974

Consumption in one year (excluding heat pumps, air handlers and water heater):

7,249 kWh   24.74 x 10^6Btu

(This amounts to 26.1% of house total.)

Source: 1976, Socolow and Sonderegger

Location: Twin Rivers, N.J.

Date: 20 Jan to 30 Apr 1975 (97 days)

Average winter load for lights and appliances--exclusive of water heater, range, and clothes dryer:

House	Measured load W	Measured load Btu/hr	Equivalent monthly consumption kWh/mo	Equivalent monthly consumption Btu x 10^6/mo	Equivalent 6-mo. (i.e., winter) consumption kWh	Equivalent 6-mo. (i.e., winter) consumption Btu x 10^6
1	1020	3481	734	2.5	4455	15.2
2	730	2491	526	1.8	3189	10.9
3	860	2935	619	2.1	3756	12.8
Average Quad-II, 3 BR townhouse	580	1980	418	1.4	2533	8.6

Average winter load for lights and minor appliances--above figures minus: refrigerator, furnance fan, and Princeton (i.e., data measuring and recording) equipment.

House	W	Btu/hr	kWh/mo	Btu x 10^6/mo	kWh	Btu x 10^6
1	390	1331	281	0.96	1704	5.82
2	380	1297	274	0.93	1660	5.66
3	320	1092	230	0.79	1398	4.77
Q-II, 3 BR avg.	300	1024	216	0.74	1310	4.47

Date: late summer 1974

Average daily consumption of three townhouses for lights and appliances, exclusive of: water heater, dryer, range (believed to include "air conditioner" fan)

House	kWh/dy	Btu x 10^3/dy
1	27.85	95.1
2	18.95	64.7
3	20.53	70.1

(See averaged daily load profile, next page.)

(These figures would imply monthly rates ranging from 569-836 kWh/mo (1.9-2.85 x 10^6 Btu/mo) and totals of 3449-6069 kWh (11.8-17.3 x 10^6 Btu) for the 6-month summer period.)

Average electric consumption except for water heating, air conditioning, and refrigerating:

3000-3500 kWh/yr or
10.2-12.0 x 10^6 Btu/yr

DATA: Meas. X Assum.____

DAILY DEMAND LOAD PROFILE

EQUIPMENT/SYSTEM light and appl.* FUEL TYPE electricity UNITS kWh
SEASON summer DATE(S) 24 Aug. - 19 Sep. 74 (22 days. with a gap)
BUILDING TYPE townhouse LOCATION Twin Rivers, N.J.

HOUR	1	2	3
1	0.78	0.46	0.70
2	0.75	0.39	0.64
3	0.80	0.42	0.67
4	0.85	0.34	0.66
5	0.81	0.44	0.48
6	0.95	0.43	0.47
7	1.34	0.62	0.73
8	1.23	0.72	0.87
9	1.26	0.78	0.97
10	1.13	0.75	0.89
11	1.01	0.77	0.86
12	0.99	0.78	0.78
13	1.10	0.67	0.78
14	1.16	0.71	0.91
15	1.17	0.76	0.78
16	1.32	0.80	1.06
17	1.14	0.82	0.81
18	1.38	1.02	1.00
19	1.59	1.41	1.26
20	1.74	1.26	1.23
21	1.65	1.24	1.25
22	1.35	1.45	1.12
23	1.27	1.09	0.90
24	1.07	0.82	0.71
Day Total	27.85	18.95	20.53

Column 1. House no. 1.

Column 2. House no. 2.

Column 3. House no. 3.

* i.e., all electric equipment except: water heater; dryer; range; A/C.

Reference: 1976, Socolow and Sonderegger

Source: 1975, Robinson and Young

Locations: Twin Rivers, N.J.

Dates: late summer, 1974

Data: Daily consumption for lights and minor appliances, based on measurements (at 20 min. intervals) of three townhouses, each occupied by two adults and by, respectively, 3, 1, and 1 small children, from 24 to 29 August and 4 to 19 Sept., 1974 (22 days):

	Minimum		Average		Maximum	
House	kWh/dy	Btu x 10^3/dy	kWh/dy	Btu x 10^3/dy	kWh/dy	Btu x 10^3/dy
1	15.1	51.5	28.9	98.6	43.6	148.8
2	11.4	38.9	20.1	68.6	32.5	110.9
3	16.6	56.7	21.6	73.7	30.8	105.1

UTILITY-COMPILED

Source: 1975, Jones and Hendrix

(Origin ambiguous, but suggested to be "billing data", from 40 homes.)

Location: Austin, Texas

Date: early 1970's

Data: Annual consumption for lights and appliances

	kWh/mo	Btu x 10^6/mo
minimum	400	1.37
average	650	2.22
maximum	1200	4.10

Source: 1974, Lokhmanhekim

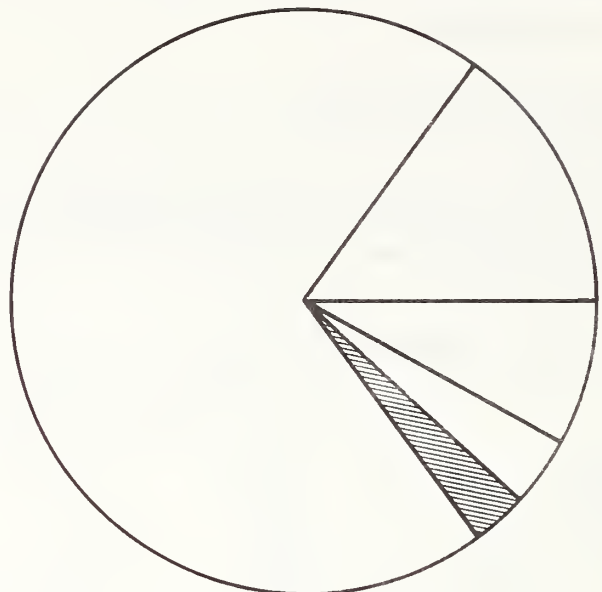
Location: Baltimore/Washington area

Date: early 1970's

Data: Assumptions (based on utility and statistical data) used for the assessment of energy consumption of residences in the specified locale

Total annual consumption for lights and appliances:

	kWh/yr	Btu x 10^6/yr
Townhouse	4900	16.7
Lowrise	4300	14.7
Highrise - 1 BR	4160	14.2
- 2 BR	4660	15.9



7.0 AIR CONDITIONING

7.1 RELATIVE IMPORTANCE

The relative importance of air cooling in residential energy consumption varies widely between regions of the nation, and among housing units within regions. The variation begins with the presence or absence of air conditioning equipment in a residence. The Federal Energy Administration has estimated air conditioner saturations, as of 1970, at 52% in the South, 31% in the Northeast, and only 24% in the West. (It should be noted that saturations in 1990 are projected to range from 81% in the Northeast to 100% in the South (1974, Federal Energy Administration). Newman and Day reported figures for 1973 of 58% for locales with 1000 or more cooling degree days*, and 33% for locales with less than that figure (1975, Newman and Day).

Consequently, on a region-wide, year total basis, energy consumption for air conditioning in the South (estimated at 4.2% of average energy use per residence, as of 1970) may be about as large as consumption for lighting. However, in all other regions of the nation, average consumption for air conditioning clearly ranks below that for any of the other

---

* Such locales comprise roughly that part of the U.S. lying south and east of a line running through Philadelphia, Washington, Knoxville, Columbus, Chicago, Des Moines, Albuquerque, Grand Junction, to just east of San Diego, plus the New York metropolitan area, an area around and west of Salt Lake City, and an area extending northwest through central California from Bakersfield.

uses we are considering in this report (with the exception of ventilation). The estimated figures for the other regions for 1970 range from 2.2% of average unit consumption in the West to 0.14% in the Northeast (1974, Federal Energy Administration). The Stanford Research Institute estimated national energy use for air conditioning, as of 1968, as 1.5% of residential consumption (1972, Stanford Research Institute). However, the saturations being as low as they are, the energy actually used for air cooling must constitute a rather larger part of total consumption for those dwellings that have this equipment.

Further contributing to the difficulty of assessing the relative importance of energy consumption for air cooling is the fact that air conditioning equipment is typically operated for only three or four months of the year. The consequence of this is that air conditioning use tends to account for a relatively large part of the total energy consumed during the summer months. For example, in the months of June through September, the typical Twin Rivers, New Jersey, townhouse expends on the order of 30-35% of its total energy on air cooling (1976, Socolow and Sonderreger). In a more southern climate, researchers at the University of Texas calculated air conditioner consumption of a typical house (with gas heat) in the Austin area to be as high as 36% of total year consumption (44% if gas is also used for air conditioning) (1975, Jones and Hendrix).

7.2 NEEDED OCCUPANT DATA

1. Hourly demand profiles (average room temperatures)

   weekday
   weekend
   unoccupied
   by region
   by family size
   by residence size

2. Exterior door openings (count and cumulative time open/dy)

3. Window management

   opening (schedule)
   covering (schedule and U-value variations)

4. Isolation of room(s) from conditioning

5. Occupancy schedules (number of people and activities) (Btu)

   weekday
   weekend
   unoccupied

6. Hourly appliance and lighting demand profiles (see Appliance and Lighting Sections)

7. Ventilation schedules (see Ventilation Section)

7.3 NEEDED PHYSICAL DATA

1. Climate data--including temperature, humidity, wind speed, and solar radiation (adjusted for cloud cover)

2. Area of living space or number of rooms cooled

3. Areas and orientations of roof, walls, windows, doors

4. Color of roofing and siding

5. Extent of shading by trees or adjacent buildings

6. Mass of building construction and contents

7. Air tightness of construction (detailing and workmanship)

8. R-value of building envelope elements

9. Equipment COP and fuel type

7.4 AN OVERVIEW OF AVAILABLE DATA

Since most residential air conditioning equipment is electric powered (97.2% of all central units as of 1968--1972, Stanford Research Institute), it is reasonably simple to measure the energy consumption for air conditioning in residences. This can be done directly, by connecting a meter into the air conditioner supply line (always a separate line from the service entry box for central equipment), or by connecting an elapsed time recorder (such as a clock) in parallel at the compressor control switch. In the latter case, the load imposed by the compressor must be determined; then, multiplying this figure by the total running time gives the power consumption for the period in question. With this approach, the power used by the fan must also be added in. If the fan is operated in "automatic" mode, the running time is identical to that measured for the compressor; if it is on "manual", its running time must be recorded separately.

In spite of the ease of recording, little data apparently have been obtained. Schmitt, in Cleveland, as part of a sales promotion for houses heated and cooled with electric heat pumps, measured the monthly consumption of the heating/cooling equipment in one house for an entire year. (However, this was not a "typical" house, but one built to relatively high standards of thermal performance.) The most extensive measurements have been made at Twin Rivers, New Jersey, where data collection is still proceeding (see 1975, Robinson and Yeung; 1976, Socolow and Sonderegger). This project has already produced some valuable information about the variability of energy consumption for air cooling in very similar dwellings, even though detailed data for only a small number of units has been obtained--or at least analyzed--so far.

The Twin Rivers townhouses have been instrumented to collect crude data on door and window opening activity, although none of this has yet been published. (Newman and Day reported some door and window use data for the winter season, but not for summertime.) Newman and Day have reported survey data on the number of rooms typically cooled in warmer and in cooler climates.

The Edison Electric Institute prepares and publishes estimated annual consumption figures for electric air conditioners. These are in part based on estimates developed by individual electric utility companies around the country, and some of these companies have published their own figures. However, we know of no instance where such data are based on direct metering and measurement of the electric consumption. They are generally derived from load research studies. In this approach, total billings to a residence provide the data. The households in the overall sample are subdivided into various groupings, permitting comparison, for instance, of the average consumption of households using air conditioning with that for households not having such equipment. However, the size of the various sub-samples is generally fairly small. Thus the average consumption figures derived in this way carry a degree of uncertainty, and ranges of typical consumption values cannot be developed with any confidence.

7.5 ADDITIONAL DATA NEEDS AND SUGGESTED COLLECTION METHODS

Basically, what is needed is information as to average values and ranges of values of consumption for air cooling in residences in various climatic conditions throughout the nation. A step in this direction is represented by a project currently being conducted by the Midwest Research Institute (Kansas City, Kansas). In 150 homes located in 16 cities throughout the United States, major electrical appliances, including air conditioners, have been instrumented to record energy consumption. Data are to be recorded over a one year period. Billing data (giving overall consumption) are being obtained, for comparison, from some 2000 residences in the cities. However, no air conditioner usage data have yet been received from this project.

Consideration should be given to the use of "activity log" studies to obtain representative data about occupant activites affecting air conditioner energy consumption. A sample of households would be provided with appropriate forms, and would be asked to record such information as: daytime and nighttime thermostat settings and times (if any) of switchover, exterior door openings, use of interior doors to close off unused rooms, times of opening and closing windows, and times of opening or closing drapes or blinds (at least on the sunward side). This data might well be recorded over a 7-day period in the early part of the cooling season and again at the height of the hot weather. Such data, in combination with measured air conditioner energy usage data for the same households and time periods, would permit a beginning to be made on analyzing and demonstrating the ways in which occupant behaviors influence the consumption of energy for summer comfort conditioning.

Air Conditioning

AUTHORS' RECOMMENDED VALUES

Occupant Datum	Value(s)	Basis
1. Hourly demand profiles (average room temperatures)		
weekday	78°F (25.6°C) day or night.	ASHRAE Standard 90-75 (No data available regarding actual usage)
weekend	the same	
unoccupied	no recommendation	no basis
by region	no recommendation	no basis
by family size	the same as "weekday" above	authors' judgment
by residence size	the same as "weekday" above	authors' judgment
2. Exterior door opening (count and cumulative duration)	Count (based on three bedroom house occupied by family of 6): 32/dy.	Based on scenario of ocupant summer activities generated at NBS.
	Duration: no recommendation	no basis
3. Window management		
opening (schedule)	no schedule recommendation	no basis
coverings	no schedule recommendation	no basis
	Window uncovered: U=1.13 Window covered (drapery or or shade): U=0.9	NBS window research (1977, Hastings and Crenshaw).

AUTHORS' RECOMMENDED VALUES (cont.)

Occupant Datum	Value(s)	Basis
4. Isolation of room(s) from conditioning	no recommendation	no basis
5. Occupancy schedule (number of people and activities) (Btu)		
weekday	See profiles, following pages.	Based on hypothetical secenarios generated by the authors.
weekend	no recommendation	no basis
holiday	no recommendation	no basis
	Rates of metabolic heat release (Btu/hr): (see table below)	Figures for adults taken from ASHRAE Handbook of Fundamentals. Others calculated using assumed body area.
6. Hourly appliance and lighting demand profiles (See Appliances and Lighting Sections.)		

	sleep-ing	sit-ting	typical hsld work
Adult	280	400	800
Teenager	225	325	640
Elem. sch. age	140	200	400

AUTHORS' RECOMMENDED VALUES (cont.)

DATA: MEAS._____ ASSUM. X

DAILY LOAD PROFILE

METABOLIC HEAT RELEASE OF OCCUPANTS — UNITS Btu x 10^3

SEASON Summer, weekday

BUILDING TYPE Residence — LOCATION Urban/Suburban

	1	2	3	4
HOUR 1	0.6	0.6	1.1	1.1
2	0.6	0.6	1.1	1.1
3	0.6	0.6	1.1	1.1
4	0.6	0.6	1.1	1.1
5	0.6	0.6	1.1	1.1
6	0.6	0.6	1.1	1.1
7	0.6	0.6	1.1	1.1
8	1.1	1.1	2.0	2.0
9	0	1.2	1.7	1.7
10	0	0	1.7	0.7
11	0	1.0	1.0	0
12	0	1.1	1.5	1.5
13	0	0.9	1.5	0.5
14	0	0.9	1.5	0.5
15	0	1.1	1.2	0.4
16	0	1.1	1.3	0.5
17	0	1.2	1.5	0.7
18	0	1.2	1.4	1.4
19	1.2	1.0	2.0	2.0
20	1.6	1.2	1.7	1.7
21	0.8	0.8	1.4	1.4
22	0.8	0.8	1.3	1.3
23	0.8	0.8	1.0	1.0
24	0.6	0.6	1.1	1.1
Day Total	11.1	20.2	32.5	26.1

Column 1. Two adults, both employed.

Column 2. Two adults, neither employed (e.g., "senior citizens").

Column 3. Family of five: father, mother, one teenager, two elementary school age (assuming children stay in air conditioned residence most of the day)

Column 4. Family of five: father, mother, one teenager, two elementary school age (assuming children out of the house most of the day)

Basis: These numbers have been calculated using the rates of metabolic heat release listed under Item 5 in combination with some assumptions about the kinds and extent of activities that might be carried out by various household members.

DATA

AIR CONDITIONING

PREVALENCE

CENSUS, INDUSTRY AND CALCULATED

Source: 1972, Stanford Research Institute

Dates: 1960, 1968

	Units per household			
	gas		electric	
	1960	1968	1960	1968
room units	--	--	0.14	0.30
central units	--	0.003	0.02	0.09

Source: 1974, FEA

Location: nationwide

Dates: 1970, 1990

Data:

Percent of households with units

	1970			1990		
	room	central	total	room	central	total
All	27%	11%		35%	55%	
Northeast	27	4	31	53	28	81
North central	25	9	34	47	38	85
South	34	18	52	25	75	100
West	14	10	24	36	54	90

ENERGY CONSUMPTION

MEASURED

Source: 1976, Schmitt

Location: Cleveland

Dates: Feb 73 - Feb 74

3 BR, 1 floor, 1990 ft^2; well insulated and thermal treated; two-zone, cooled with two 2-ton heat pumps.

Total electricity consumption for cooling, 7 Feb 73 - 7 Feb. 74 (1 year):

kWh/yr	Btu x 10^6/yr (at house)
1971	6.72

Source: 1975, Robinson and Yeung

Location: Twin Rivers, N.J.

Date: late summer 1974

Daily consumption of 3 townhouses: identical 3 BR, except that no. 3 is an end unit.

Measured over 24-29 Aug and 4-19 Sep 1974 (total of 22 days)

House	Number of days during which A/C operated	Average consumption for operating days		Maximum day consumption	
		kWh/dy	Btu x 10^3/dy	kWh/dy	Btu x 10^3/dy
1	14	30.4	103.7	51.4	175.4
2	14	34.8	118.8	68.3	233.1
3	8	28.5	97.3	60.0	204.8

Note: We believe that these figures are for compressor consumption only, and do not include the consumption of the fan needed to move the cooled air throughout the house. The comfort-conditioning fan in a Twin Rivers townhouse draws 470 W when operating in the air conditioning (or manual) mode.

SURVEY

Source: 1975, Newman and Day

Location: Nationwide

Date: 1973

Data based on interviews of national sample of 1455 households in 177 different locations.

Number of rooms cooled, by percentage of households.

	Percent of households		
		annual cooling degree days	
	all	< 1000	1000+
1-4 rooms	23%	18	28
> 4 rooms	22	14	29

Source: 1972, Stanford Research Institute (from Edison Electric Institute).

Location: Nationwide

Dates: 1960; 1968

	Average Annual Consumption 1960		1968	
Type of unit	kWh/yr	10^6Btu/yr	kWh/yr	10^6Btu/yr
room	1250	4.27	1375	4.69
central	3600	12.29	3600	12.29
central-gas				20

Source: 1975 Newman and Day (from EEI)

Location: Nationwide

Date: 1969

Average annual consumption of air conditioners

Type	kWh/yr	10^6Btu/yr
Window	1389	4.74

Source: 1976, Camacho and Roat

Average monthly consumption

	kWh/mo	10^3Btu/mo	unit size	reporting utility	comments
minimum average*	94	320	10K Btu	SCE+	used 3 hr/dy
minimum average*	1800	2050	12K Btu	W.Tex.U	used 6 mo.

* Systemwide averages.
\+ See code on page 153.

Source: 1974, FEA

Location: Nationwide--by four regions

Climate and engineering design parameters:

Region	Representative city	Equivalent full load operating hours	Design ΔT
Northeast	Norwalk, CT	300	15
North central	Detroit, MI	500	15
South	Pine Bluff, AK	1600	25
West	Roswell, NM	1600	25

Data based on characteristic dwelling units and other statistical information.
Weighted average annual dwelling unit energy consumption for cooling

			Dwelling unit designed for: electric heat*	Dwelling unit designed for: gas or oil heat
Single family:	in NE.	1 floor	3.5×10^6 Btu/yr	4.0×10^5 Btu/yr
		2 floor	3.9	4.6
	in N.C.	1 floor	6.0	7.0
		2 floor	6.5	7.6
	in S.	1 floor	28.1	32.0
		2 floor	28.0	30.1
	in W.	1 floor	29.0	31.4
		2 floor	28.5	32.0
Mobile home:	in NE.		3.4	
	in N.C.		5.9	
	in S.		19.2	
	in W.		18.7	
Low density:	in NE.	1 floor	2.4	2.7
		2 floor	2.2	3.2
	in N.C.	1 floor	4.1	5.3
		2 floor	4.5	5.2
	in S.	1 floor	18.3	22.1
		2 floor	19.7	20.0
	in W.	1 floor	18.3	19.5
		2 floor	20.5	20.8
Low rise:	in NE.		1.3	1.6
	N.C.		2.2	2.9
	S.		9.3	11.5
	W.		9.9	10.7
High rise:	in N.E.		1.1	1.5
	N.C.		2.7 (?)	1.9
	S.		7.9	10.3
	W.		8.7	9.1

* Typically insulated to higher standards.

Source: 1974, Hittman

Location: Baltimore/Washington area

Data: early 1970's

Data calculated for characteristic dwellings in the specified area.

Unit Type	Annual energy consumption 10^6Btu/unit.yr	10^6Btu/ft^2.yr
single family home	12.5	0.0084
townhouse	20.6	0.0158
lowrise	10.5	0.0093
highrise	5.0	0.0052

Source: 1974, Lokhmanhekim and Harvey

Location: Baltimore, MD

Date: Early 1970's

Data calculated for characteristic dwellings in the specified location.

Type of unit		Fuel type*	Annual energy consumption kWh/yr	10^6Btu/yr
Townhouse		electric	2200	7.51
	2 BR	gas		59.4
	3 BR	gas		66.0
Low-rise		electric	1950	6.66
	1 BR	gas		46.2
	2 BR	gas		52.8
	3 BR	gas		66.0
High-rise	1 BR	electric	1620	5.53
	1 BR	gas		33.0
	efficiency	gas		19.8
	2 BR	electric	1800	6.14
	2 BR	gas		39.6
	3 BR	gas		52.8

* Data on gas units based on "billing data and load computations."

Source: 1976, Bernstein and Alereza

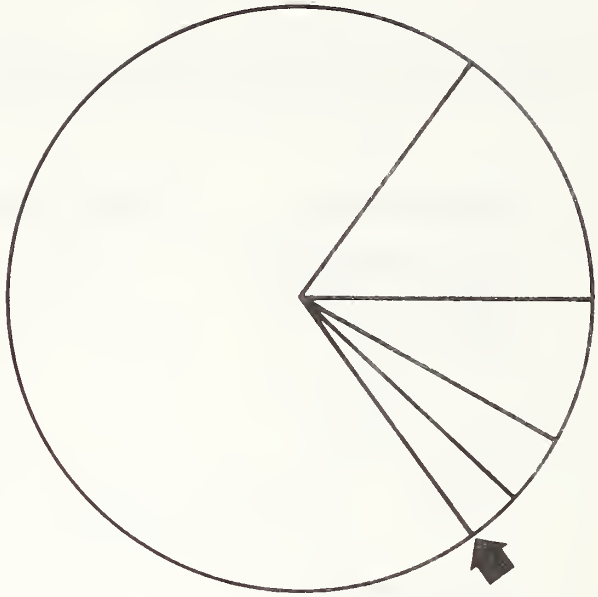
Location: selected -- see below

Dates: early 1970's

Data calculated for characteristic dwellings in the specified locations.

City	Dwelling Type	Annual consumption-10^6Btu/yr
Atlanta	single family	57.4
	townhouse	40.1
	lowrise	29.3
	highrise	37.9
Boston	single family	9.1
	townhouse	9.9
	lowrise	15.5
	highrise	17.4
Chicago	single family	17.8
	townhouse	17.7
	lowrise	14.5
	highrise	18.5
Denver	single family	36.1
	townhouse	18.6
	lowrise	12.3
	highrise	13.3

VENTILATION



8.0 VENTILATION

8.1 RELATIVE IMPORTANCE

Electricity consumed for mechanical ventilation of residences accounts for a very small percentage of typical total energy consumption. There are commonly four situations where mechanical ventilation may occur in residences:

1. Whole-house fans (ventilate whole house through the attic).
2. Window fans and the economizer cycle of some air conditioners.
3. Power attic ventilators (ventilate attic only).
4. Kitchen and bathroom exhaust fans.

The last three of these ventilators consume small amounts of electricity due to their small motor capacity, typically 150 W or less. Also, in the case of the kitchen and bathroom fans, they are used only a small fraction of the time.

Power attic ventilators and whole-house fans, though consuming more electricity than bathrooms or kitchen fans, are still comparatively low energy users. An attic ventilator typically has a wattage similar to that of a portable window fan--150 to 250 watts. A whole-house fan may range from 500 to 1000 watts. By comparison, however, a five-ton central air conditioner may require 8,700 watts, or 9 to 17 times more electricity than a whole-house fan.

What is significant about mechanical ventilation in residences is not the electricity consumption of the fan motors, but the indirect effect of the ventilation upon energy consumed for air conditioning.

Whole house fans, window fans and the economizer cycle of air conditioners can substantially reduce the number of hours an air conditioner (compressor) must operate seasonally. Their effectiveness is due to the fact that, during much of the Spring and Autumn, outside air is temperate in contrast to the inside air that is warmed by heat accumulated from the sun as well as heat from occupants and electrical appliances. By merely circulating the temperate outside air through the otherwise too warm house interior, the need for air conditioner operation is sharply reduced. The possible reduction in hours of air conditioning has been calculated to range from 12 to 47 percent in various climates (1974, Nelson p. 38). Whole house fans which exhaust through the attic afford the additional advantage of providing positive air flow through attic spaces, thereby reducing attic temperatures and consequent heat gain through the ceiling. In a study by the American Ventilation Association, an example house was calculated to seasonally consume 35 percent less electricity for air conditioning when a whole house fan was used (1976, American Ventilation Assoc., p. VII-4).

Bathroom and kitchen exhaust fans have little effect upon energy consumed for air conditioning and heating for two reasons: their air moving capacity is small, and they are only used a small fraction of the time. Some benefit is obtained from exhausting warm and humid air resulting from cooking or bathing, but this is partially offset by the infiltration of an equal amount of unconditioned outside air.

8.2 NEEDED OCCUPANT DATA

1. Hourly demand profiles (ft^3)
   - whole house ventilation
   - window fan/air conditioner economizer cycle
   - attic fan
     - by residence size
     - by region

2. Exterior door openings (cumulative time open/dy)
3. Window management schedules
4. Inventory of mechanical ventilating equipment

8.3 NEEDED PHYSICAL DATA

1. Climate data--including temperature, humidity, and wind speed
2. Air flow per kWh under given indoor/outdoor conditions
3. Typical interior temperature and humidity when fan is operating
4. Air tightness of construction (detailing and workmanship)
5. Insulation amounts (ceiling and roof)

8.4 AN OVERVIEW OF AVAILABLE DATA

Few data are available on either the use of mechanical ventilation in residences or the direct and indirect effects of mechanical ventilation on total energy consumption. Design data and code requirements, such as the Federal Housing Administration's (FHA) Minimum Property Standards, set the minimum capacities for ventilation of bathrooms and kitchens. Such data are merely capacities, however. The issues that need to be addressed by field studies are: How frequently and for how long are the exhaust fans operated; and what is the actual effect of such operation on heating and air conditioning energy consumption. The best such study which could be found on the use of bathroom ventilating fans is a monitoring study by Princeton University of three townhouses in Twin Rivers, New Jersey (not yet published).

Data on attic fans and whole-house fans are similarly limited to a small sampling. Energy savings estimates are frequently based on measured consumption of a house with a fan compared to calculated consumption for the same house without the fan, such as the study by Nelson and Tobias. Studies of the effectiveness of attic ventilation are currently being conducted in three heavily instrumented houses in Houston, Texas and two occupied houses in Twin Rivers, New Jersey, and by Lawrence Berkeley Laboratory.

8.5 ADDITIONAL DATA NEEDS AND SUGGESTED METHODS OF COLLECTION

Because of the infrequent use of kitchen and bathroom fans, coupled with their low exhaust rate, these two ventilator types are not an urgent subject of research. At best, a small study is justified to confirm the assumption of infrequent use and the findings of the Princeton study. The investigation could incorporate some of the procedures discussed in the following paragraph on attic and whole-house ventilation. This would provide data on the in-place versus the laboratory determined exhaust rate of such fans.

Data on the effects of attic ventilation are needed, because present findings are conflicting and too few studies have been conducted to permit a resolution. The effectiveness of attic fans in conserving energy is substantially affected by the air tightness and R-value of the ceiling between the habitable space below and the attic. If little air leakage occurs through the ceiling and perimeter joints, operation of an attic fan concurrent with air conditioning may save energy on still days. (This presupposes that vent area meets or exceeds the specifications.) However, if NBS-recommended levels of insulation are present, the rate of downward conducted heat flow is likely to be so small that an attic fan has no significant effect in the occupied spaces.

Additional data are needed 1) for specifying the appropriate size (capacity) of a whole-house fan, and 2) for determining how much less energy a residence with a whole-house fan actually consumes seasonally compared to a similar house dependent on air conditioning alone. Handbook of Moving Air lists a fan capacity recommendation of 1 cublic foot per minute per cubic foot of living space (or one air change per minute) (1976, American Ventilation Association). While this quantity of air movement is probably necessary in humid, southern locations for obtaining the desired breeze effect, it seems excessive for less humid, more temperate areas. Studies are needed to refine whole-house fan capacity selection on the basis of local climate conditions.

For both the attic fan and the whole-house fan, experiments should be conducted in several climates, and should consider continuous daytime operation, thermostat-controlled operation, and occupant-controlled operation. Sky clearness, wind velocity and direction, and outdoor temperature and humidity are the key climatic factors. The performance of the fan could be evaluated using an anemometer to measure air flow when fan is operating under actual conditions. Tracer gas monitoring could be used to measure the air change rate, both in the attic and in the habitable parts of the house when the fan is operating and when it is turned off. Finally, the temperature of the attic air, and at various points in the habitable areas below the attic, and the heat flow through the insulated ceiling, could be monitored.

Conclusions from such data would be valuable because, in much of the nation, comfortable outdoor tempertures occur during part or all of the day for a surprisingly large percentage of the year. (See the "House Beautiful Climate Control Project" (1950, American Institute of Architects).) During such periods, however, internal heat gain may make the indoor temperature uncomfortable. Under such circumstances, mechanical ventilation of a house with unconditioned outside air is obviously much less energy demanding than closing up a house and refrigerating the air. How much energy could be saved seasonally and how occupants could effectively select one system versus the other on a day-to-day basis are needed information.

AUTHORS' RECOMMENDED VALUES

Occupant datum	Value(s)	Basis
1. Hourly demand profiles (ft^3)		
a. mechanical ventialtion rate for whole house ventilation	no recommendation	insufficient data
b. window fan or air conditioner eonomizer cycle	no recommendation	insufficient data
c. attic fan capacity		
by residence size light colored roof	54 $ft^3/hr \cdot ft^2$ of attic floor, or 10 air changes/hour.	FHA Minimum Property Standards, Revision No. 4, March 1976
dark color roof	Increase the above by 15 percent.	no differentiated data
by region	no recommendation	
d. room exhaust fan capacity (in lieu of window ventilation)		
kitchen	15 air changes/hour	
range hood	2400 $ft^3/hr \cdot ft$ of hood length (3000 $ft^3/hr \cdot ft$ over range located in island or peninsula)	FHA Minimum Property Standards, Revision No. 4, March 1976
bathroom	8 air changes/hour	
2. Exterior door openings (count and cumulative duration)	Count based on three bedroom house occuied by family of 6): 32/dy Duration: no recommendation	Based on scenarios of summer activities acted out at the NBS test house. (1975, Peavy)

AUTHORS' RECOMMENDED VALUES (cont.)

Occupant datum	Value(s)	Basis
3. Window management		
opening (schedule)	Coordinate with window fan or whole house fan use and with outdoor dry-bulb temperature.	Authors' judgement.
4. Inventory of mechanical ventilating equipment		
single family (detached or attached)	whole house fan, kitchen exhaust fan, bathroom exhuast fans	Authors' judgement.
multi-familv units	window fan, bathroom exhaust fan	

DATA

VENTILATION

MEASURED

Source: 1976, American Ventilation Association

Location: Austin, Texas

Dates: Unspecified

Observations of one house over two cooling seasons for the effects of attic ventilation:

	thermostat setting	reduction of electricity consumption
First season	76°F	--
Two fourteen inch turbo ventilators were then installed in attic roof		
Second season (beginning)	76°F	17%
With lowered ceiling radiant temperature, occupants than felt cool enough that they reset thermostat at	78°F	additional 10%

Source: 1976, Camacho and Roat

Location: various

Dates: unspecified

Annual electricity consumption for attic fan

	Reporting utility	kWh/yr	Btu x 10^6/yr
minimum average*	PSNJ+	270	0.92
maximum average	Texas P	310	1.06

*Note that these figures are utility systemwide averages.

+See page 153 for code.

Source: 1976, American Ventilation Association

Location: Austin, Texas

Example energy consumption figures
for an actual house

Unit	Size	Electrical load (e.g., energy use rate)
whole house fan	42 inch	500 W
air conditioner (upstairs)	5 ton	6000 W (total)
air conditioner (lower floor)	3 ton	

Resultant energy savings for each hour of use of fan instead of air conditioners 5.5 KWh

In practice the owner of this house generally uses the fan instead of air conditioning whenever the temperature is less than about 85°F. The electrical energy saved by this practice in comparison with using air conditioning alone is shown below:

	Energy consumption	
month	air conditioners only	whole house fan/ air conditioners
Jan	400 kWh	400 kWh
Feb	500	400
Mar	700	300
Apr	760	320
May	800	400
Jun	900	560
Jul	1000	700
Aug	1000	800
Sep	700	300
Oct	600	300
Nov	400	360
Dec	400	400
Totals	8610 kWh	5240 kWh

Typical yearly savings 2920 kWh

Source: 1974, Nelson and Tobias

Location: various cities (see below)

Date: various (typical weather year, out of 10, for each city)

Data: Predicted reduction in air conditioner compressor operating time by using air economizer system.

Calculated For: 1-story, 900 ft^2, stucco house; wall insulation R=9.3; ceiling insulation R=13.8; windows, all double-glazed, equal to 11 percent of floor area; occupied by family of 4 (2 adults, 2 children); calculated using "bin' method, with dry bulb temperature frequencies from Air Force/Army/Navy Manual AFM 88-8 Chap. 6., with economizer (instead of compressor) operating when outside temperature is 65-74°F.

City	Yearly compressor operating hours (conventional system)	Yearly economizer vice compressor operating hours	Percent savings of compressor operating time
Akron, OH	825 hrs.	272 hrs	32.9 %
Albany, NY	747	224	30.0
Augusta, GA	1625	302	18.6
Chicago, IL	804	220	27.3
Columbus, OH	1019	272	26.7
Dallas, TX	1903	219	11.5
Denver, CO	820	180	22.0
Des Moines, IA	954	218	22.8
Detroit, MI	759	244	32.1
Kansas City, MO	1295	196	15.2
Los Angeles, CA	857	491	57.3
Louisville, KY	1251	251	20.0
Madison, WI	782	209	26.7
Miami, FL	3488	510	14.6
Minneapolis, MN	781	212	27.1
New Orleans, LA	2372	377	15.9
Omaha, NE	970	214	22.1
Pittsburgh, PA	851	273	32.0
Portland, OR	426	158	37.0
Roanoke, VA	1162	281	24.2
Salt Lake City, UT	948	189	19.9
San Francisco, CA	526	219	41.6
Seattle, WA	222	127	57.1
Syracuse, NY	792	243	30.7
Washington, D.C.	1066	277	26.0

THE NEWMAN AND DAY STUDY

The data on energy consumption patterns reported in The American Energy Consumer (1975, Newman and Day) is based on inteviews conducted in 1,455 U.S. households in May and June 1973. Households in 1977 different locations--representing metropolitan areas, smaller urban places, and rural areas--were selected through the use of multistage area probability sampling procedures. In reporting the data, weights were calculated and used (1) to compensate for differences in probability of selection by socioeconomic quartile (households in the lowest quartile having been purposely over-sampled), (2) to adjust for the experienced differences in interview completion rates in different locations, and (3) to expand the data from sample households to the total universe of households in the United States at the time. Where comparable, estimates based on the sample are generally close to those based on the Current Population Survey of the U.S. Bureau of Census.

For purposes of breaking out data by socioeconomic group, the population was divided into quartiles. The lowest group was identified by the U.S. Government's definition of the poor and near poor in 1972: all those with incomes of 125 percent of the low income or poverty threshold or lower. This definition takes account of family size in relation to income, and thus does not reflect a single income cutoff. Using income cutoffs tied to family size and derived from census data, the survey found that, while the lowest quartile included all those with family incomes less than \$3,000, it included 30 percent of families with incomes between \$3,000 and \$4,999, 9 percent of those with incomes between \$5,000 and \$6,999, and just 3 percent of those with incomes between \$7,000 and \$8,999.

This lowest quartile--termed "poor"--comprised 18 percent of all households. The nonpoor were divided into: "lower middle" (the remainder with family income under \$12,000) (42 percent), "upper middle" (income \$12,000 to \$15,999) (19 percent), and "well off" (20 percent).

Some data is reported geographically in terms of the "heating degree days" or "cooling degree days" of the locale. Heating degree days are variously defined and calculated, but for the purpose of this study they were calculated (on the most recently published 30-year average data--1931-1960) using the standard day-by-day, 65°F base procedure. In this method, the mean temperature, T_m, is calculated for each day (from the high and low for the day). For every day on which the mean is below 65°F, the difference ($65°F-T_m$) is obtained, and the cumulated differences over a period of time (e.g., month, year) are the degree days for that period. Cooling degree days are similarly calculated, using those days on which the mean temperature is above a specified reference. In this case, 65°F was used as the base, and the computation done on summer, 1972, weather data.

In the Newman and Day study, electricity measurements were converted at the rate of 1 kWh=10,910 Btu. This rate incorporates the industry experience of energy losses in the generation of electricity and its transmission to the end user. If we are considering only the energy content of electricity that has reached and crossed the building perimeter (as is the case throughout our report), the relationship is 1 kWh=3,413 Btu.

UTILITY/INDUSTRY SOURCES

(AGA)	American Gas Association
Carol. P&L	Carolina Power and Light
CE	Consolidated Edison of New York
(EEI)	Edison Electric Institute
K.C. P&L	Kansas City Power and Light Company
Mont. P.	Montana Power Company
N. Orl. PS	New Orleans Public Service
OT	Otter Trail Power Company
PGE	Pacific Gas and Electric
Phila. El	Philadelphia Electric Company
Portl. GE	Portland General Electric Company
PSNJ	New Jersey Public Service
SCE	Southern California Edison
Tex. P&L	Texas Power and Light Company
W. Penn P	West Pennsylvania Power
W. Tex. U	West Texas Utilities

UNITS CONVERSION TABLE

To convert from	to	multiply by
Watt hour	Btu	3.413
Kilowatt hour	Btu	3.413×10^3
Cubic foot of natural gas	Btu	1.03×10^3
Therm (natural gas)	Btu	10^5
(unit)/day	(unit)/mo	30.4
(unit)/day	(unit)/yr	365.
(unit)/mo	(unit)/yr	12.
(unit)/yr	(unit)/mo	0.083
(unit)/yr	(unit)/day)	0.00274
(unit/mo	(unit)/day)	0.033
gal	L (liter)	3.785
L	gal	0.264
°F	°C	0.556 after substracting 32
°C	°F	1.8 and add 32.

LIST OF SOURCES

Listed by year of publication, alphabetically by author within years.

Undated, Schmitt, R.F., There is, indeed an energy problem. And we're doing something about it! Bob Schmitt Homes, Inc., Strongsville, OH. (data reproduced by permission).

Undated, Ultraflo Corporation, Ultraflow saves energy - saves water - saves money. Ultraflo Corp., Box 2284, Sandusky, OH 44870 (data reproduced by permission).

1950, American Institute of Architects, Regional Climate Analyses and Design Data: The House Beautiful Climate Control Project. Bulletin of the American Institute of Architects, September 1949-January 1952.

1960, Babbitt, H.E., Plumbing. New York: McGraw Hill (Copyright 1960 by the McGraw Hill Book Company. Used with permission.)

1963, Phillips, C.W., and Achenbach, P.R., The heating performance of air-to-air heat pumps in military housing. National Bureau of Standards Report 8000, National Bureau of Standards, Washington, D. C. 20234.

1969, Werden, R.G. and Spielvogel, L.G., Part 2 - Sizing of service water heating equipment in commerical and institutional buildings. ASHRAE Transactions, Vol., 75, P. II, 1969, p. IV.1.1 (data reproduced in ASHRAE Handbook and Product Directory: 1976 Systems). American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., New York, N.Y. Copyright by ASHRAE. Data reproduced by permission.)

1970, Todd, Keith David, editor, The water encyclopedia. Water Information Center, Huntington, N.Y. 11743. (Copyright 1970 by the Water Information Center. Data reproduced by permission.)

1972, Stanford Research Institute (MacDonald, R.E.), Patterns of energy consumption in the United States. Washington: U.S. Government Printing Office.

1973, Anderson, R.W., Residential energy consumption, single family housing-Final report. Washington: U.S. Government, Department of Housing and Urban Development.

1973, ASHRAE, ASHRAE Handbook and Product Directory--1973 Systems. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., New York, N.Y. (Copyright by ASHRAE. Data reproduced by permission.

1973, Grot, R.A., and Socolow, R.H., Energy utilization in a residential community. Princeton University, Center for Environmental Studies, Princeton, N.J.

1973, Smith, G.E., Economics of water collection and recycling. Working Paper No. 6, Technical Research Division, University of Cambridge Department of Architecture, Cambridge, England.

1974, ASHRAE, ASHRAE Handbook and Product Directory--1974 Applications. American Society of Heating, Refrigerating and Air-Conditioning Engineers, New York, N.Y. (Copyright by ASHRAE. Data reproduced by permission).

1974, Carnahan, Walter, et al., The efficient use of energy - a physics perspective. A.I.P. Conference Proceedings, Vol. 25, American Institute of Physics, NTIS Report PB 242-733 or 242-116.

1974, Federal Energy Administration, Project Independence blueprint--Final report, Appendix: Residential and commercial energy use patterns, 1970-1990. Washington: U.S. Government Printing Office.

1974, Hittman Associates, Inc., Residential energy conservation (a summary report). Hittman Associates, Inc. (for U.S. Department of Housing and Urban Development), Columbia, Md.

1974, Lokhmanhekim, M., and Harvey, D.G., Residential energy consumption, multifamily housing -- Final report. Washington: U.S. Government, Department of Housing and Urban Development.

1974, Nelson, L.W., and Tobias, J.R., Energy savings in residential buildings. ASHRAE Journal, February, American Society of Heating Refrigerating and Air-Conditioning Engineers, New York, N.Y. (Copyright by ASHRAE. Data reproduced by permission.)

1975, Edison Electric Institute, Annual energy requirements of electric household appliances. Edison Electric Institute, 90 Park Avenue, New York, N.Y. 10016.

1975, Johnson, R.J., and Angelton, H.D., Hot water usage in a typical single-family residence. NAHB Research Foundation, Inc., Rockville, Maryland.

1975, Jones, J.W., and Hendrix, B., Residential energy requirements and opportunities for energy conservation. University of Texas, Center for Energy Studies, Austin, Tx.

1975, Newman, D.K., and Day, D., The American energy consumer. Cambridge, Massachusetts: Ballinger Publishing Company. (Copyright 1975, The Ford Foundation. Data reproduced with permission of Ballinger Publishing Company.)

1975, Peavy, B.A., Burch, D.M., Powell, F.J., and Hunt, C.M., Comparison of measured and computer-predicted performance of a four bedroom wood-frame townhouse. NBS Building Science Series 57, National Bureau of Standards, Washington, D.C. 20234.

1975, Robinson, J.A., and Yeung, J., Summer air conditioning and appliance use patterns: a graphical analysis. Princeton University, Center for Environmental Studies, Princeton, N.J.

1976, American Ventilation Association, The Handbook of Moving Air. American Ventilation Association, Houston, Texas.

1976, ASHRAE, ASHRAE Handbook and Product Directory -- 1976 Systems. American Society of Heating, Refrigerating and Air-conditioning Engineers, Inc., New York, N.Y. (Copyright by AHSRAE. Data reproduced by permission).

1976, Bernstein, H.M., and Alereza, T., Atlanta residential energy consumption; Boston residential energy consumption; Chicago residential energy consumption; Denver residential energy consumption. Hittman Associates, Inc., Columbia, Maryland.

1976, Camacho, A.A., and Roat, C.L., Electrical energy consumption of household appliances: Survey of U.S. utilities. National Bureau of Standards, Washington, D. C. (unpublished).

1976, HUD, Minimum property standards for one- and two-family dwellings, revision no. 4. March, Department of Housing and Urban Development, Federal Housing Administration, Washington, D.C. 20411.

1976, Midwest Research Institute, Patterns of energy use by electrical appliances study - Preliminary first season report, Midwest Research Institute, Kansas City, MO 64110.

1976, Nall, D.H., Private communication, Cornell University, Ithaca, N.Y.

1976, Shookster, L.A., An analysis of winter furnace and appliance use patterns. Princeton University, Center for Environmental Studies, Princeton, N.J.

1976, Socolow, R.H., and Sonderegger, R.C., The Twin Rivers project on energy conservation in housing: Four year summary report. Princeton University, Center for Environmental Studies, Princeton, N.J.

1977, Hastings, S.R., and Crenshaw, R.W., Window design strategies to conserve energy. NBS Building Science Series 104. National Bureau of Standards, Washington, D.C. 20234.

NBS-114A (REV. 7-73)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBSIR 78-1501	2. Gov't Accession No.	3. Recipient's Accession No.
4. TITLE AND SUBTITLE Quantified Occupant-Use Factors Affecting Energy Consumption in Residences			5. Publication Date July 1979
			6. Performing Organization Code
7. AUTHOR(S) Roy E. Clark & S. Robert Hastings			8. Performing Organ. Report No.
9. PERFORMING ORGANIZATION NAME AND ADDRESS NATIONAL BUREAU OF STANDARDS DEPARTMENT OF COMMERCE WASHINGTON, D.C. 20234			10. Project/Task/Work Unit No.
			11. Contract/Grant No. EA-77-A-01-6010
12. Sponsoring Organization Name and Complete Address *(Street, City, State, ZIP)* Department of Energy 20 Massachusetts Avenue, NW. Washington, D.C. 20545			13. Type of Report & Period Covered
			14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

Predicting energy consumption for a building requires three types of data: climatic data, component performance data, and occupant-use data. Historically, few data on occupant use of a building have been collected, and the data which are collected are not easily referenced. Consequently, it is common for energy analysts to establish values for occupant variables merely on the basis of their own personal experience. In response to this dilemma, this report assembles residential energy-use data, as could be found, from field metering studies, surveys, utility company estimates, and government sponsored statistical projections. From these data the authors have determined recommended occupant-use values based on their analysis and judgements. These "recommended values" represent the best judgement of the present authors, but are not to be interpreted as "NBS recommended" values. Data, and assessment of their validity for input in models for predicting energy consumption, are organized into six groups by energy end-use: (1) heating, (2) service hot water, (3) appliances, (4) lighting, (5) air conditioning, and (6) ventilation. The use of more soundly derived values for occupant-use variables will result in a better correlation between the energy use predicted for buildings being designed today and the actual energy use of the buildings when occupied.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Appliance energy consumption, energy consumption of residences, lighting energy consumption, occupant factors, residential air conditioning, service hot water, space heating, ventilation.

18. AVAILABILITY	19. SECURITY CLASS (THIS REPORT)	21. NO. OF PAGES
[X] Unlimited [ ] For Official Distribution. Do Not Release to NTIS	UNCLASSIFIED	142
[ ] Order From Sup. of Doc., U.S. Government Printing Office Washington, D.C. 20402, SD Cat. No. C13 [ ] Order From National Technical Information Service (NTIS) Springfield, Virginia 22151	20. SECURITY CLASS (THIS PAGE) UNCLASSIFIED	22. Price $7.25

USCOMM-DC 29042-P74