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Regression Analysis of Energy Consumption by End Use

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Residential Energy
Consumption Survey:

Regression Analysis of Energy Consumption by End Use

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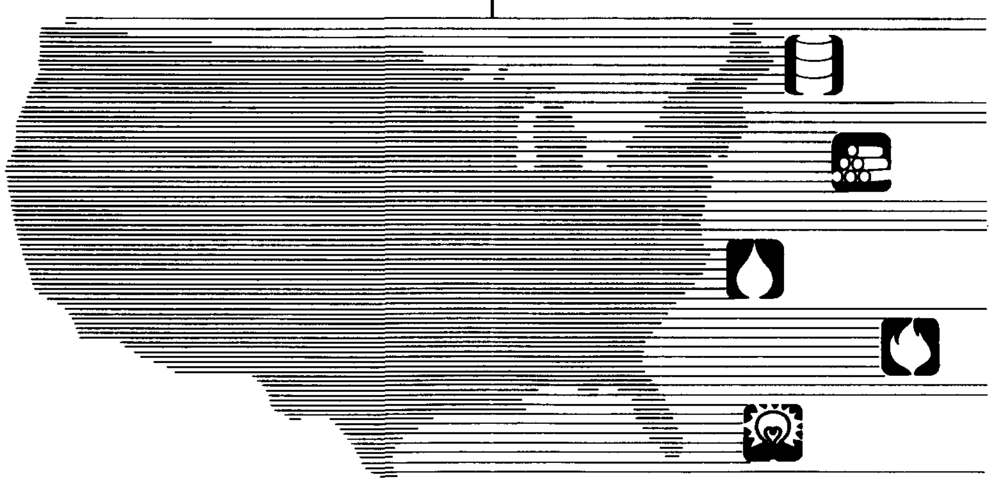

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1. INTRODUCTION

This report covers two main topics. The first is a description of a regression analysis of energy consumption data obtained from the Residential Energy Consumption Surveys (RECS). The sections that cover this topic are technical in nature and would appeal mainly to other researchers who plan to analyze the RECS data set. The second topic is a presentation of estimates of residential energy consumption by end use. The resulting estimates of consumption by end use will be of interest to a wide audience. This includes State and Federal agencies that are formulating programs for low-income energy assistance, utilities that need to forecast load demands, and other researchers who are studying the demand for energy in the residential sector. Readers who are mainly interested in the end-use estimates and not the methodology used to obtain the estimates can skip to Section 8.

The Residential Energy Consumption Surveys were designed by the Energy Information Administration (EIA) to provide information concerning energy consumption within the residential sector. Information concerning the housing unit is collected through personal interviews with adult residents of a representative national sample of households. Data concerning actual energy consumption are obtained from fuel records maintained by the households' fuel suppliers.

This report is based on the data obtained from the 1980 RECS. The energy consumption data are collected for four major fuels (electricity, natural gas, liquid petroleum gas (LPG), and fuel oil). Kerosene consumption is included in the fuel oil consumption figures. For each household in RECS, the consumption data are condensed and adjusted so that the amount reported reflects the consumption for the period from April 1980 to March 1981.

This report presents a discussion of the variability of energy consumption within the home. The variability of energy consumption for transportation may be the subject of later reports. Regression equations are presented that express the predicted home energy consumption for an individual housing unit as a function of main heating fuel, water-heating fuel, weather, dwelling size, appliance stock, and other variables. Separate equations are presented for electricity, natural gas, liquid petroleum gas, and fuel oil. These equations are then used to estimate the amount of energy consumed by end use.

The design of RECS is briefly discussed in Section 2. A reference is given in Section 2 to reports containing more detailed discussion. The National Interim Energy Consumption Survey (NIECS) was a preliminary survey that preceded RECS. Two reports[1] on the variability in energy consumption

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[1]Energy Information Administration, National Interim Energy Consumption Survey: Exploring the Variability in Energy Consumption, DOE/EIA-0272 (Washington, D.C., July 1981) and Energy Information Administration, National Interim Energy Consumption Survey: Exploring the Variability in Energy Consumption--A Supplement, DOE/EIA-0272/S (Washington, D.C., October 1981).

were produced by using the data in NIECS. These studies are discussed in Section 3 and referenced repeatedly throughout this report. Section 4 discusses what subset of the households surveyed in RECS is used to develop the regression equations and why this subset was chosen. The model that was fit and the procedure used to fit the model are discussed in Section 5. The resulting regression equations are given in Section 6, along with a measure of their goodness of fit. Section 7 presents a discussion of the regression equations, in particular the limitations that one must realize before interpreting the results. The estimation of energy consumption by end use is discussed in Section 8. Tables of end-use energy consumption by Census division, income, dwelling size, and weather are also given in Section 8. Section 9 contains a discussion of the end-use estimates including the trends that appear in the results. The effects of electricity prices on electricity consumption are discussed in Section 10. Section 11 presents a procedure for adjusting the April 1980 through March 1981 consumption amounts to reflect the consumption for the 1980 calendar year.

2. DESCRIPTION OF THE RESIDENTIAL ENERGY CONSUMPTION SURVEYS

Before RECS, two surveys were conducted by Response Analysis Corporation (RAC) for EIA. These were the National Interim Energy Consumption Survey (NIECS) and the Household Screener Survey (SCREENER). Several reports[1] have been produced using the results of these surveys. Both surveys used the same sample design. It was not custom tailored to EIA's needs, but created previously as an all-purpose design. The design did not cover households in Alaska, in Hawaii, or on military bases. The experience gained in conducting these two surveys was used in designing RECS.

The sample design for RECS was specifically constructed to obtain data on residential energy consumption and related housing characteristics. It covers all households in the United States, including those living in Alaska and in Hawaii and those living on military bases. The households used in the survey were selected by using probability sampling. The probability of selection varied across the country. This variation was partly a result of oversampling in some areas to insure a minimum level of precision for energy consumption estimates in those areas.

The sample design included many stages. Initially, the country was divided into 1,782 primary sampling units (PSU's). The PSU's were grouped into 131 strata with roughly the same population. Thirty-one strata contained only one PSU; the rest contained two or more PSU's. Within each stratum, one PSU was selected.

A number of intermediate probability sampling stages preceded the final selection of RECS households. These stages included the selection of minor civil divisions (MCD's) within each PSU. Within the MCD's, Census tracts or enumeration districts (ED's) were selected. A segment of 25 or more housing units was selected within a tract or ED. A cluster of 25 housing units was selected from the sample segments. The ultimate cluster to be contacted for interviews (averaging about four housing units) was systematically selected from the cluster. The number of ultimate clusters totaled 1,667.

From the 1,667 ultimate clusters, 7,338 units were selected to be in the sample. Of these units, 106 were found to be nonresidential units, 430 were vacant residential units, and 168 were seasonal or vacation units. This left 6,634 eligible residential units. From these units, the occupants of 5,804 units were personally interviewed, either during the initial

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[1]A list of these reports is given in Energy Information Administration, Residential Energy Consumption Survey: 1978-1980 Consumption and Expenditures, Part 2: Regional Data, DOE/EIA-0262/2 (Washington, D.C., May 1981).

attempt or during follow-up contacts. Finally, mail followup resulted in responses from 247 additional households. In the end, 6,051 households responded, 551 occupied units were classed as nonrespondents, and the occupants of 32 units moved between the initial contact and the end of possible followups.

Most of the questions asked for RECS were similar to those asked for NIECS. The SCREENER survey was much briefer and was employed primarily to obtain a panel of households to use in running a residential transportation survey. Two of the major changes between NIECS and RECS concern square footage and wood consumption.

In NIECS, the respondent estimated the square footage for the dwelling, which proved to be an unsatisfactory way of obtaining data. In RECS, the interviewer's measurements were used to obtain the square footage of the dwelling.

For NIECS and SCREENER, no attempt was made to obtain the amount of wood consumed as fuel; for RECS, the respondent was asked to estimate the amount of wood that the household used the previous year. In future RECS's, the wood consumption question may be changed to get a more reliable response.

For all three surveys, some form of heating degree-days (HDD) and cooling degree-days (CDD) was obtained for all households. Let T_1 be the highest temperature in degrees Fahrenheit for a particular day. Let T_2 be the lowest. Set $T = (T_1 + T_2)/2$. The heating degree-days for this particular day base 65°F equal the maximum of 0 and 65-T. The cooling degree-days equal the maximum of 0 and T-65. Degree-days for other bases are calculated in a similar manner. The annual degree-days (HDD and CDD) are obtained by summing the daily degree-days.

In NIECS and SCREENER, the only annual values for HDD and CDD that were calculated were those based at 65°F. For RECS, annual HDD and CDD values were calculated for bases of 50°, 55°, 60°, 65°, 70°, 75°, and 80°F. For NIECS, the values of HDD and CDD were long-term averages adjusted by Census division for April 1978 through March 1979 weather. For SCREENER and RECS, the values of HDD and CDD were calculated using the actual daily highs and lows experienced by weather stations in the same National Oceanic and Atmospheric Administration (NOAA) district.

For all surveys, the fuel consumption amounts were annualized to reflect the consumption from April of one year through March of the next year. In most cases, the annual amount was based on at least 330 days of actual fuel bills. In other cases, the annual amount was based on fewer days or imputed based on a preliminary regression estimate.

Missing values for variables such as household income, main heating fuel, and age of respondent were imputed in some cases, usually by a hot-deck procedure.

A previous report[2] gives more details on the sample design, imputation, etc., for RECS.

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[2]Energy Information Administration, Residential Energy Consumption Survey: Housing Characteristics, 1980, DOE/EIA-0314 (Washington, D.C., June 1982).

3. PREVIOUS REPORTS

The regression results presented in this report are similar to the results presented in two previous reports.[1] The two present an analysis of residential energy consumption data from NIECS covering the period from April 1978 through March 1979. Regression equations were developed that express the natural gas, electricity, fuel oil, and LPG consumption of individual households in terms of household, dwelling, and weather characteristics.

The theoretical model used for residential consumption of each fuel is

$$F_h = A_o + \sum_{k=1}^{K} A_k X_{hk} + \left(\sum_{m=1}^{M} B_m Y_{hm} \right) HDD_h + \left(\sum_{n=1}^{N} C_n Z_{hn} \right) CDD_h + E_h.$$

In this equation, A_o, A_k, B_m, and C_n are parameters that are estimated by using a regression technique; HDD_h is heating degree-days; CDD_h is cooling degree-days; X_{hk}, $Y_{hm}HDD_h$, and $Z_{hn}CDD_h$ are the independent variables used in the regression; E_h is the error term; and h the index for the households in the survey. The dependent variable is F_h, which is the energy consumption of household h.

Theoretically, all the space-heating and space-cooling characteristics are represented by Y_{hm} and Z_{hn}, respectively. In particular, if the fuel in question was not used for space heating, then all Y_{hm}'s equal zero; similarly, if the fuel in question was not used for air conditioning, then all Z_{hn}'s equal zero. In the actual models that were fit, some of the terms involving space-heating characteristics were not used in conjunction with HDD_h. For example, the fuel oil regression equation for households living in single-family detached dwellings contains an indicator variable for fuel oil heating that has a large coefficient.

The variance of E_h, the error term, depends on the predicted fuel consumption. For example, the variance of electricity consumption across households living in small apartments that use electricity only for appliances is much smaller than the variance of electricity consumption across households living in large, all-electric, single-family detached homes.

The models were fit under the assumption that the variance of E_h was proportional to $F_h - E_h$, which equals the predicted consumption for household h. Examination of residual plots reveals that this assumption is approximately valid.

For the NIECS reports,[1] the regression equations were fit by using an iterative procedure. The regressions were initially fit by using a standard unweighted least squares procedure. The predicted consumption

[1] National Interim Energy Consumption Survey: Exploring the Variability in Energy Consumption (July 1981) and National Interim Energy Consumption Survey: Exploring the Variability in Energy Consumption--A Supplement (October 1981).

based on the initial regression results was computed for each household. The regression was next fit by using a weighted regression where the weights were equal to the inverse of the predicted consumption. Next, outliers were deleted from the data set. The weighted regression and outlier deletion were alternatively performed until no more outliers were found or seven weighted regressions were run.

Only part of the data was used in the regression procedure. The subset used for the regression procedure varied from fuel to fuel. For all fuels, the households whose characteristics were obtained by mail questionnaire were not used because many of the responses for these households were imputed. In addition, for each fuel, only those households that used the fuel in question but did not use it for nonresidential purposes were used in the regression procedure. For electricity, only those households whose annual electricity consumption was based on at least 330 days of billing data were used. Similarly, for natural gas, only those households whose annual natural gas consumption was based on at least 330 days of billing data were used. For fuel oil, kerosene, and LPG, only those households where the annual consumption was not imputed by a regression estimate were used.

In only three instances were there enough cases to fit a model with many dependent variables. These were electricity consumption, natural gas consumption, and fuel oil consumption for households living in single-family detached homes. In the rest of the cases, only a few independent variables were used. The ones that were used were either the predicted consumption based on one of the three major cases or parts of the predicted consumption.

Tables 3 through 7 in the NIECS report supplement[2] show the number of cases available for regression runs. Tables 2 through 5 in the NIECS report[3] and Table 9 in the NIECS report supplement[2] give the final regression estimates.

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[2]National Interim Energy Consumption Survey: Exploring the Variability in Energy Consumption--A Supplement (October 1981).

[3]National Interim Energy Consumption Survey: Exploring the Variability in Energy Consumption (July 1981).

4. AVAILABILITY OF DATA FOR FITTING REGRESSION EQUATIONS

The quality of the response obtained from households covered by the 1980 RECS varies from household to household, and the quality of the energy consumption data varies depending on the fuel as well as on the household. For these reasons, not all households were used in fitting the regression equations and the set of households varies from fuel to fuel. A procedure similar to that in the NIECS analysis was employed to determine which households to use in the regression procedures.

The set of households was first reduced to the set with type I overall data. Type I data are defined as data that are acceptable for use in a regression procedure.[1] Most of the data for households that were interviewed by mail were imputed. Hence, all households whose responses were obtained by mail questionnaire were dropped from the set of households with type I overall data. Any household where the main space-heating fuel, secondary space-heating fuel, or water-heating fuel was imputed was dropped from the set of households with type I overall data because space heating and water heating are two of the most important end uses. The fact that the listed fuel for one or both of these end uses was imputed makes the observation flawed for purposes of fitting regression equations. The remaining households were denoted as the set of households with type I overall data. This set consists of 5,769 households out of the 6,051 households that responded in the 1980 RECS. It includes a large number of households with at least one variable that was imputed. A desire to preserve a large number of households in the set used to fit the regression equations prevented the deletion of all households with any imputed data. Even if these households were deleted, the resulting set would still contain errors due to coding, responses, and other reasons.

In fitting the regression equations for each fuel, the researchers started with the set of households with type I overall data and then deleted those households that did not use the fuel, those households with flawed consumption data for that fuel, and those households with square footage data based on a regression estimate when the fuel in question was used as the main heating fuel. The last deletion was made because square footage will be used in conjunction with main heating fuel in fitting the regression equation. The resulting set was denoted as the set of households with type I consumption data for that fuel.

For fuel oil, kerosene, and LPG, the reported consumption was the amount purchased, not the amount actually consumed. Hence, some households have an annual consumption amount equal to zero, really zero purchases, yet are still classified as users of fuel oil, kerosene, or LPG. This convention differs from the NIECS analysis, in which households with zero purchases were classified as nonusers.

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[1]In the NIECS report, data that were acceptable for regression analysis were denoted as good data.

Two criteria were used for electricity to determine if the consumption data were acceptable or flawed for regression purposes. If the electricity bill had to be adjusted for nonresidential uses, the consumption data were deemed to be flawed. If the annual consumption amount was obtained by a regression estimate or by a ratio estimate where fewer than 330 days of actual data were available, then the consumption data were deemed to be flawed. The latter criterion can be determined by looking at the variable ORIGELQ on the 1980 RECS public-use tape.

If the natural gas bill had to be adjusted for nonresidential use, the natural gas consumption for that household was deemed to be flawed. If the annual consumption amount was obtained by a regression estimate or a ratio estimate where fewer than 330 days of actual data were available, then the consumption data were deemed to be flawed.

For LPG, the same two criteria that were used with natural gas were used to determine if the LPG consumption data were acceptable or flawed.

The fuel oil and kerosene consumption amounts were combined when the data were condensed into annual consumption figures, because some equipment can burn both fuel oil and kerosene. In most cases, only one of the two fuels was used. The fuel used can be determined by looking at the variables that describe fuel oil uses and those that describe kerosene uses. Those households that appear to use both fuel oil and kerosene were classified as using only fuel oil, but their consumption was classified as flawed data. The two criteria employed for the other fuels were also used to determine additional households with flawed consumption data for fuel oil consumption or kerosene consumption.

Tables 1 to 5 give the number of households in the data set that used each fuel, and the number for each fuel with both type I overall data and type I consumption data for that fuel. These two numbers are also given for the case where the only households that are considered are those whose main heating fuel is the fuel in question. These numbers are shown for each main housing type. The two types of single-family attached homes were merged into one set. The three types of dwelling in small apartment buildings were also merged into a single set.

Table 1. Total Households in the Sample That Use Electricity, Have Type I Electricity Data, Use Electricity for Main Heating Fuel, and Use Electricity for Main Heating Fuel and Have Type I Electricity Data (Classified by Housing Type)

Housing Type	Use Electricity	Have Type I Electricity Data	Use Electricity for Main Heating Fuel	Use Electricity for Main Heating Fuel and Have Type I Electricity Data
Mobile Home	348	227	80	53
Single-Family Detached Unit	4,068	3,177	584	430
Single-Family Attached Unit	215	151	39	23
Units in Building with Two to Four Units	709	402	107	52
Units in Building with Five or More Units	708	277	256	98

Table 2. Total Households in the Sample That Use Natural Gas, Have Type I Natural Gas Data, Use Natural Gas for Main Heating Fuel, and Use Natural Gas for Main Heating Fuel and Have Type I Natural Gas Data (Classified by Housing Type)

Housing Type	Use Natural Gas	Have Type I Natural Data Gas	Use Natural Gas for Main Heating Fuel	Use Natural Gas for Main Heating Fuel and Have Type I Natural Gas Data
Mobile Home	116	64	111	62
Single-Family Detached Unit	2,439	1,918	2,277	1,794
Single-Family Attached Unit	164	104	122	73
Units in Building with Two to Four Units	538	215	447	160
Units in Building with Five or More Units	468	67	324	48

Table 3. Total Households in the Sample That Use Fuel Oil, Have Type I Fuel Oil Data, Use Fuel Oil for Main Heating Fuel, and Use Fuel Oil for Main Heating Fuel and Have Type I Fuel Oil Data (Classified by Housing Type)

Housing Type	Use Fuel Oil	Have Type I Fuel Oil Data	Use Fuel Oil for Main Heating Fuel	Use Fuel Oil for Main Heating Fuel and Have Type I Fuel Oil Data
Mobile Home	35	18	27	13
Single-Family Detached Unit	688	438	605	385
Single-Family Attached Unit	48	27	47	26
Units in Building with Two to Four Units	144	35	132	34
Units in Building with Five or More Units	144	1	121	1

Table 4. Total Households in the Sample That Use Kerosene, Have Type I Kerosene Data, Use Kerosene for Main Heating Fuel, and Use Kerosene for Main Heating Fuel and Have Type I Kerosene Data (Classified by Housing Type)

Housing Type	Use Kerosene	Have Type I Kerosene Data	Use Kerosene for Main Heating Fuel	Use Kerosene for Main Heating Fuel and Have Type I Kerosene Data
Mobile Home	24	10	22	10
Single-Family Detached Unit	57	12	27	10
Single-Family Attached Unit	2	0	0	0
Units in Building with Two to Four Units	4	1	2	1
Units in Building with Five or More Units	2	0	1	0

Table 5. Total Households in the Sample That Use LPG, Have Type I LPG Data, Use LPG for Main Heating Fuel, and Use LPG for Main Heating Fuel and Have Type I LPG Data (Classified by Housing Type)

Housing Type	Use LPG	Have Type I LPG Data	Use LPG for Main Heating Fuel	Use LPG for Main Heating Fuel and Have Type I LPG Data
Mobile Home	142	76	85	49
Single-Family Detached Unit	396	253	177	109
Single-Family Attached Unit	7	4	3	2
Units in Building with Two to Four Units	22	7	8	2
Units in Building with Five or More Units	7	2	4	1

The following fact, similar to that noted about the NIECS data set, was noted concerning the 1980 RECS data set. All households with good data paid their own utility bills. As a result, the regression equations that were developed apply only to households that pay for their energy use directly. The energy consumption was imputed for households whose utility bills were part of the rent. Therefore, comparing the energy use of households that did pay their own bills with those that did not would be difficult using the NIECS or RECS data sets.

The following facts can be gleaned from Tables 1 to 5:

- Most households live in single-family detached units.

- Out of a total of 6,051 households that were interviewed, only 3 did not use electricity in the home.

- The dominant heating fuel is natural gas.

- The survey produces type I energy consumption data for most households living in single-family detached units but not for households living in multifamily units.

- The fuel oil, kerosene, and LPG consumption values are less likely to be acceptable for regression purposes than the electricity and natural gas consumption values.

- Most households that use natural gas use it as their main heating fuel. The same applies to fuel oil.

Separate regression equations were fit for electricity, natural gas, fuel oil, and LPG consumption for households living in single-family detached homes. The regression equations for mobile homes and multiunit buildings used parts of the regression equations for the single-family detached cases as indexes for energy consumption. This fact will be discussed in more detail in Section 6.

5. DESCRIPTION OF REGRESSION PROCEDURE

The theoretical model used for the RECS analysis is the same as the one used for the NIECS analysis. There are changes in the independent variables. The amount of heated floorspace is used in the RECS analysis. Reliable estimates of this quantity were not available for use in the NIECS data set. Other changes include additional information on appliances. The degree-days base used in RECS is different from that used in NIECS. Heating degree-days base 60°F and cooling degree-days base 75°F are used for the RECS analysis. The new bases result in a slightly higher value of R^2 than the results for which degree-days base 65°F are used. For NIECS, both degree-days were based at 65°F.

An additional reason for using degree-days bases other than the more commonly used base of 65°F involves consumer behavior. The author felt that the average household did not turn on the main space-heating source when the average daily outdoor temperature was just below 65°F (for example, a high of 75°F and a low of 55°F) and turn on the air conditioning when the average daily temperature was just above 65°F. There should be a range of temperature where the household used other means, such as opening or closing windows, to moderate indoor temperature. This suggests using a base for cooling degree-days that is higher than the base for heating degree-days.

Scatter Plots of Consumption Versus Degree-Days

Figures 1 through 6 show the rough relationship between degree-days and fuel consumption. The figures use only these households with type I overall data and that live in a single-family detached house with a heated square footage of between 1,000 and 3,000 square feet. This set was further constricted for each plot according to which consumption trend was being investigated.

Figure 1 is a plot of electricity consumption versus cooling degree-days base 75°F. Only those households with good electricity consumption data, whose main space-heating fuel, secondary heating fuel, and water-heating fuel were not electricity, and that had electric central air conditioning were used. A slight upward trend is visible in Figure 1, which suggests increased use of electricity among those houses with central air conditioning as the number of cooling degree-days increases. The small slope in the trend and the scatter about the trend indicate that many factors will have to be considered if the effect of cooling degree-days on annual electricity consumption for air conditioning is to be noticeable.

Figures 2 through 5 show the consumption of electricity, natural gas, fuel oil, and LPG, respectively, versus heating degree-days. For Figures 2 through 5, only those households whose main heating fuel is the fuel in question and that had type I consumption data for that fuel were used. In each of Figures 2 through 5, there is an upward trend in consumption as heating degree-days increase. For all fuels the upward trend in consumption is partially hidden by the large scatter about the trend. This is especially true for fuel oil and electricity.

The large amount of scatter about the trends in Figures 2 through 5 indicates that factors beside annual heating degree-days have a great influence on annual energy consumption for space heating. As a result the regression equations will contain many variables as well as degree-days in conjunction with indicator variables for the main space-heating fuels.

Figure 6 shows cords of wood burned versus heating degree-days for households where the main heating fuel is wood. The consumption amount for wood is an estimate provided by the household and is subject to many sources of errors.[1] No analysis of wood data is presented in this report, but Figure 6 confirms the intuitive idea that consumption is higher in cooler climates.

Theoretical Model for RECS

Figures 1 through 5 suggest that the theoretical model used for the NIECS analysis[2] is still useful when analyzing the RECS data. In addition, the figures can be used to suggest many other theoretical models that take into account the upward trend in energy consumption for space heating as heating degree-days increase. For instance,

$$\log(F_h) = A_o + \sum_{k=1}^{K} A_k X_{hk} + \left(\sum_{m=1}^{M} B_m Y_{hm}\right) HDD_h + \left(\sum_{n=1}^{N} C_n Z_{hn}\right) CDD_h + E_h \qquad (1)$$

or

$$\sqrt{F_h} = A_o + \sum_{k=1}^{K} A_k X_{hk} + \left(\sum_{m=1}^{M} B_m Y_{hm}\right) HDD_h + \left(\sum_{n=1}^{N} C_n Z_{hn}\right) CDD_h + E_h. \qquad (2)$$

The NIECS model was used because any nonlinear transformation of the consumption variable F_h will result in a nonadditive model when it is solved for F_h. For instance, model 1 is a log-linear or multiplicative

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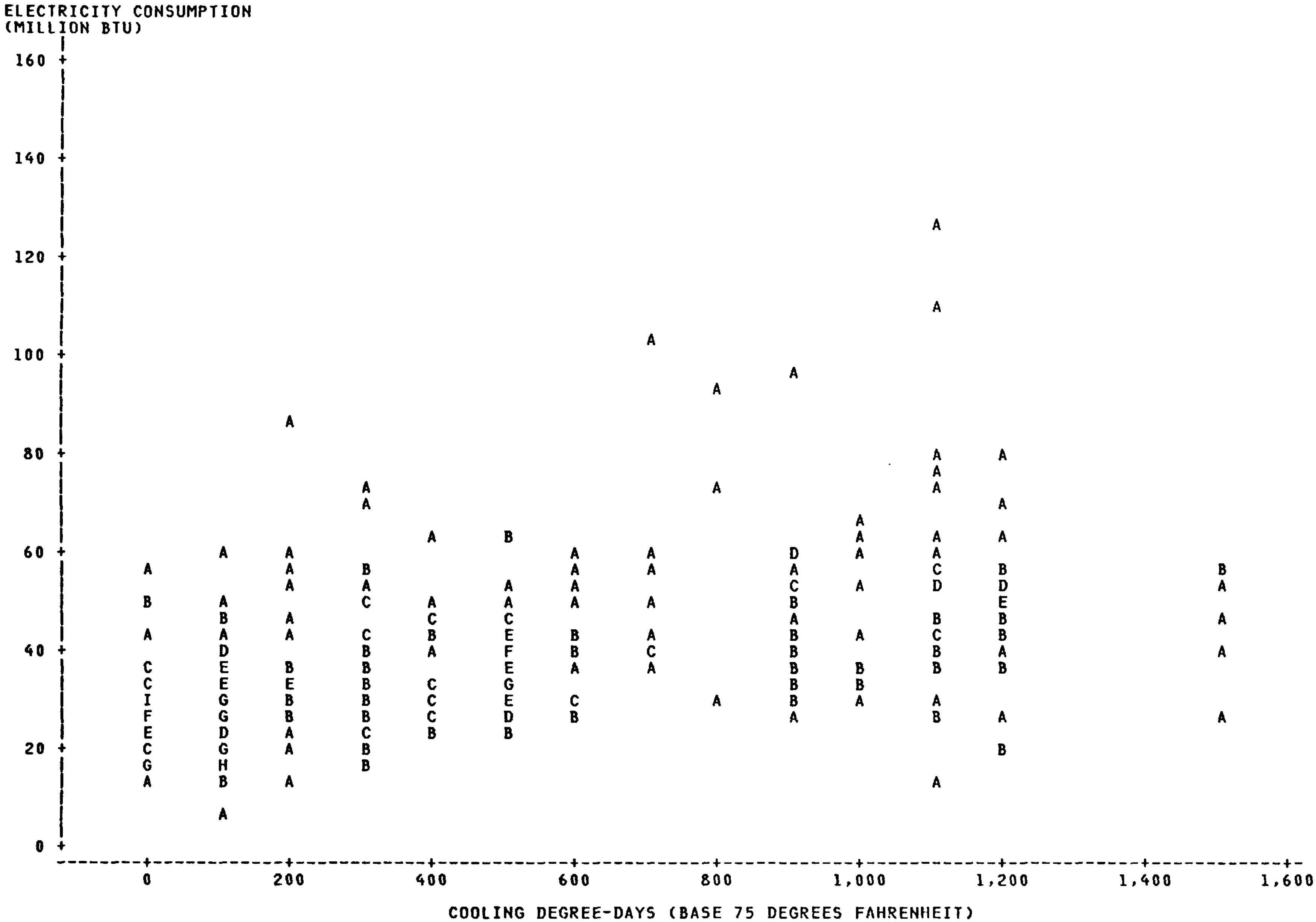
[1]Residential Energy Consumption Survey: Housing Characteristics, 1980 (June 1982).

[2]National Interim Energy Consumption Survey: Exploring the Variability in Energy Consumption (July 1981) and National Interim Energy Consumption Survey: Exploring the Variability in Energy Consumption--A Supplement (October 1981).

FIGURE 1. ELECTRICITY CONSUMPTION BY COOLING DEGREE-DAYS FOR HOUSEHOLDS THAT USE ELECTRICITY FOR CENTRAL AIR CONDITIONING BUT NOT FOR SPACE HEATING OR WATER HEATING (MILLION BTU)



NOTE: LETTERS OF THE ALPHABET REPRESENT THE NUMBER OF OBSERVATIONS: A = ONE OBSERVATION, B = TWO OBSERVATIONS, ETC.

FIGURE 2. ELECTRICITY CONSUMPTION BY HEATING DEGREE-DAYS FOR HOUSEHOLDS WHOSE MAIN SPACE-HEATING FUEL IS ELECTRICITY (MILLION BTU)

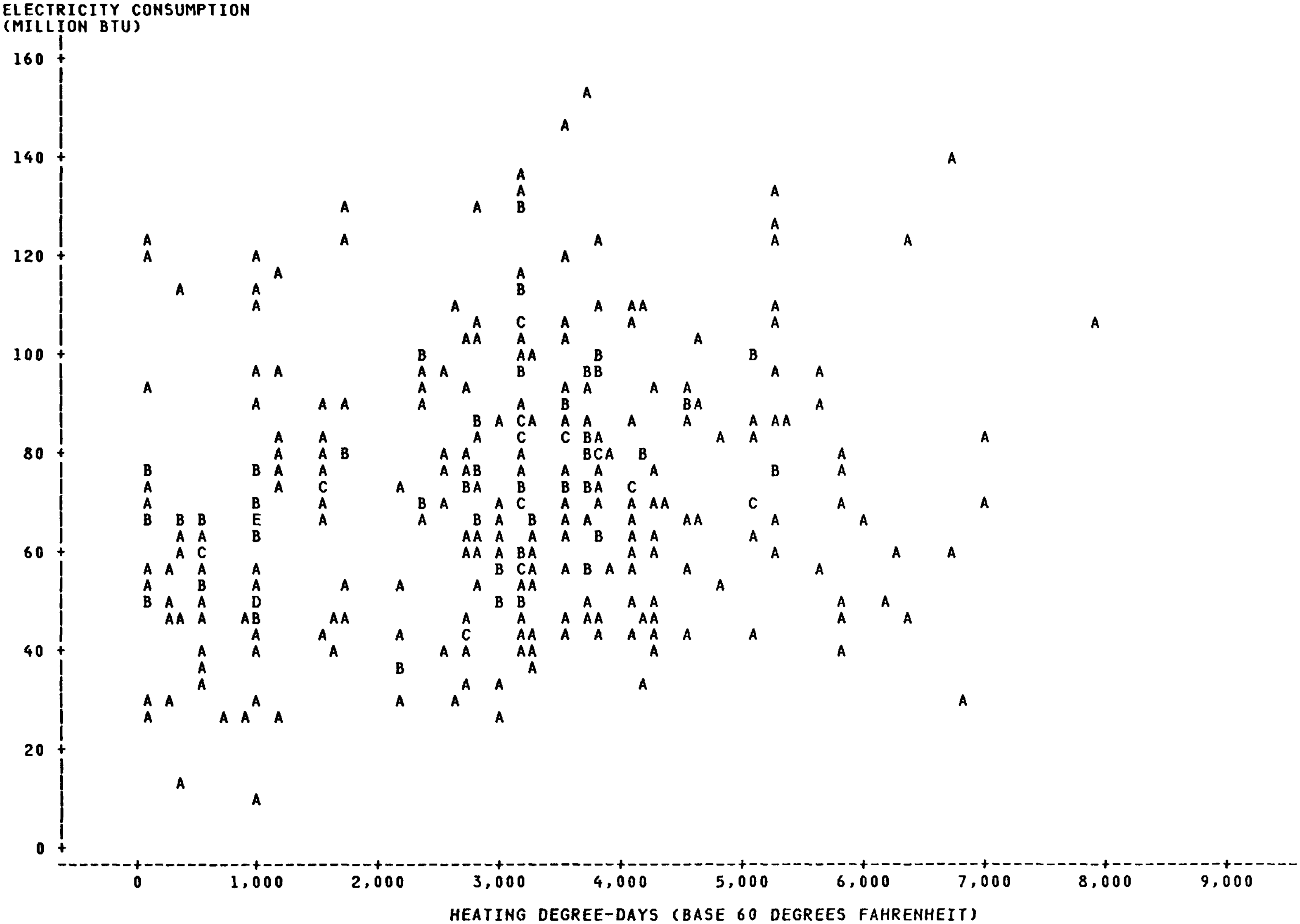


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FIGURE 3. NATURAL GAS CONSUMPTION BY HEATING DEGREE-DAYS FOR HOUSEHOLDS WHOSE MAIN SPACE-HEATING FUEL IS NATURAL GAS (MILLION BTU)

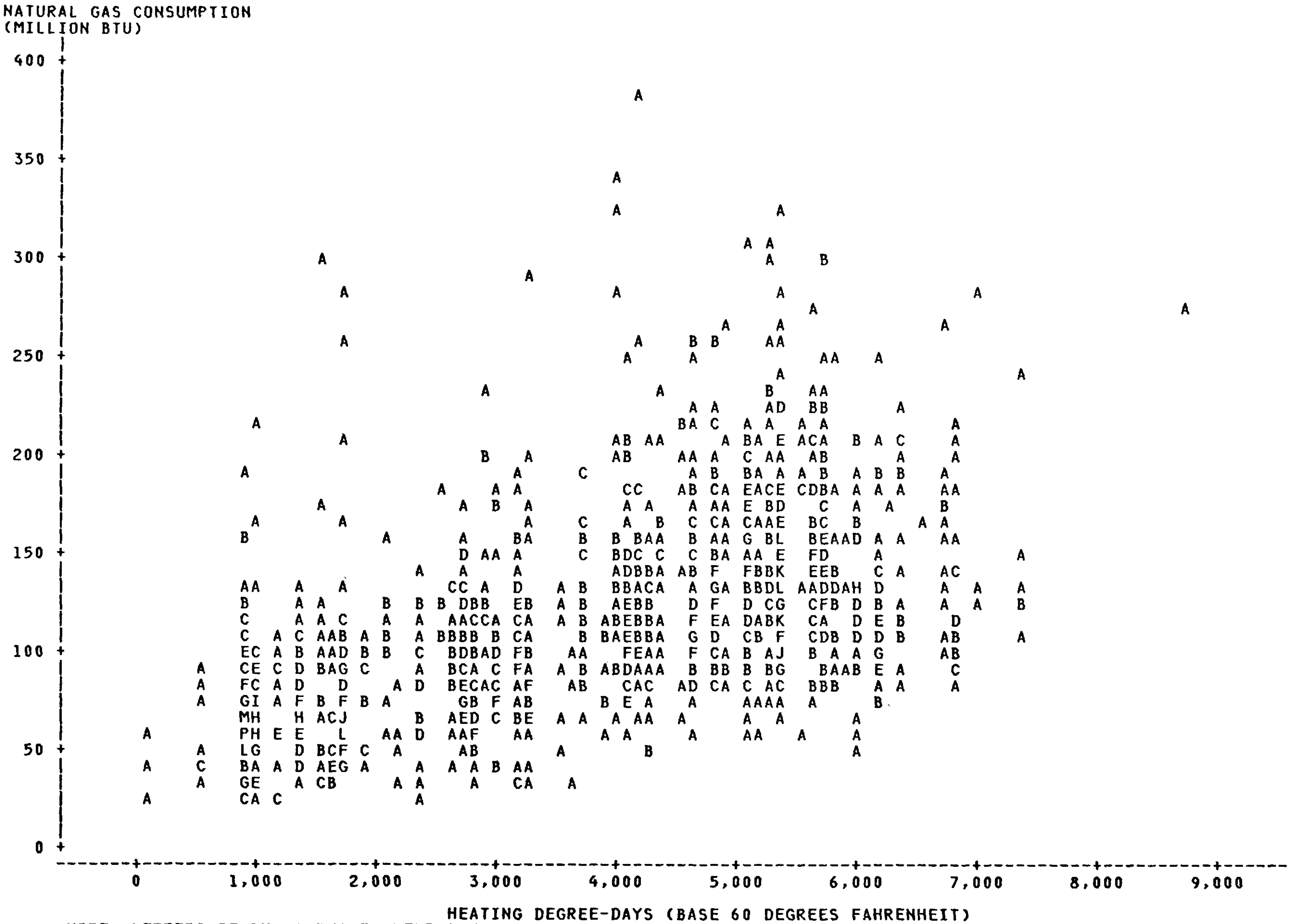

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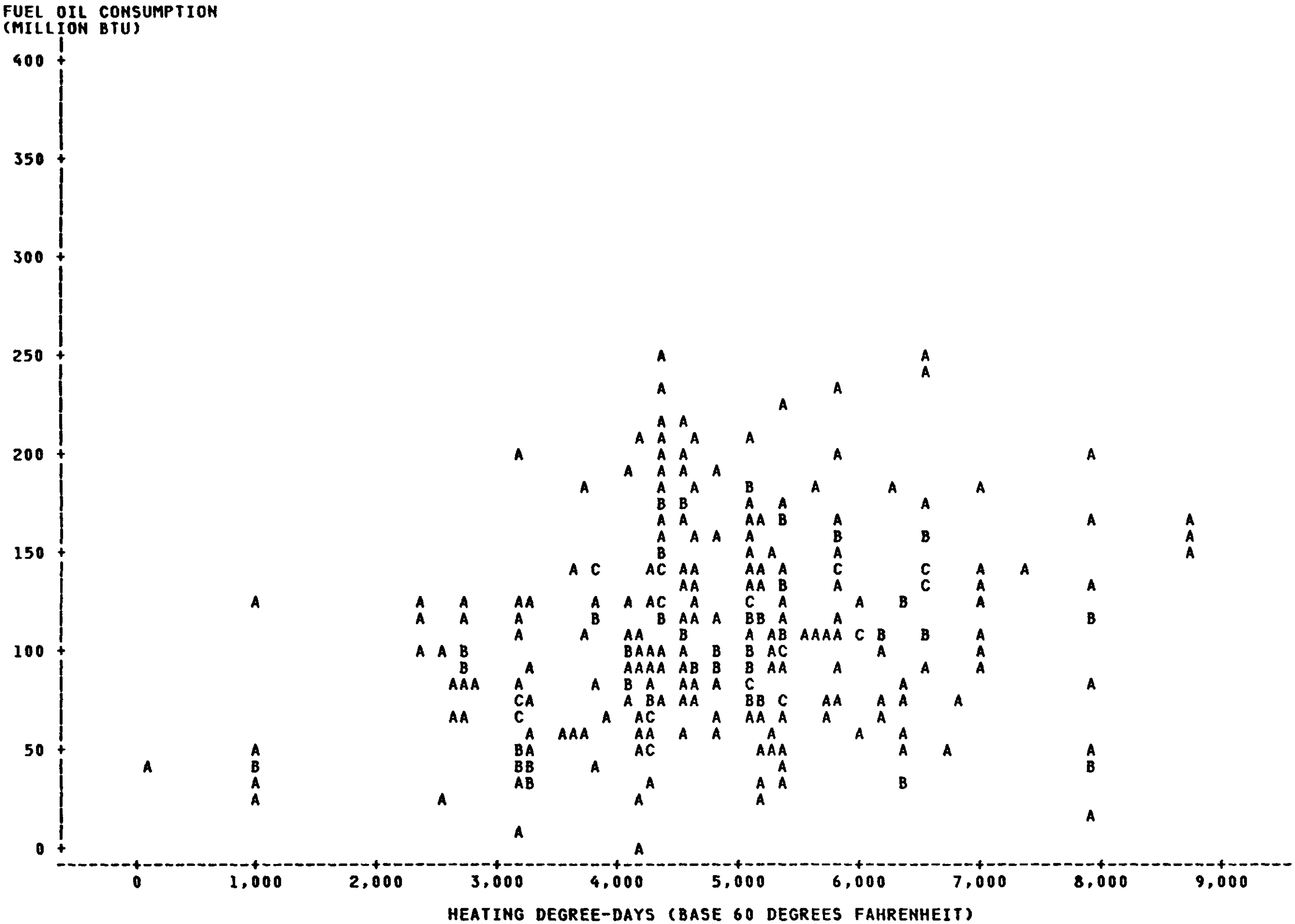
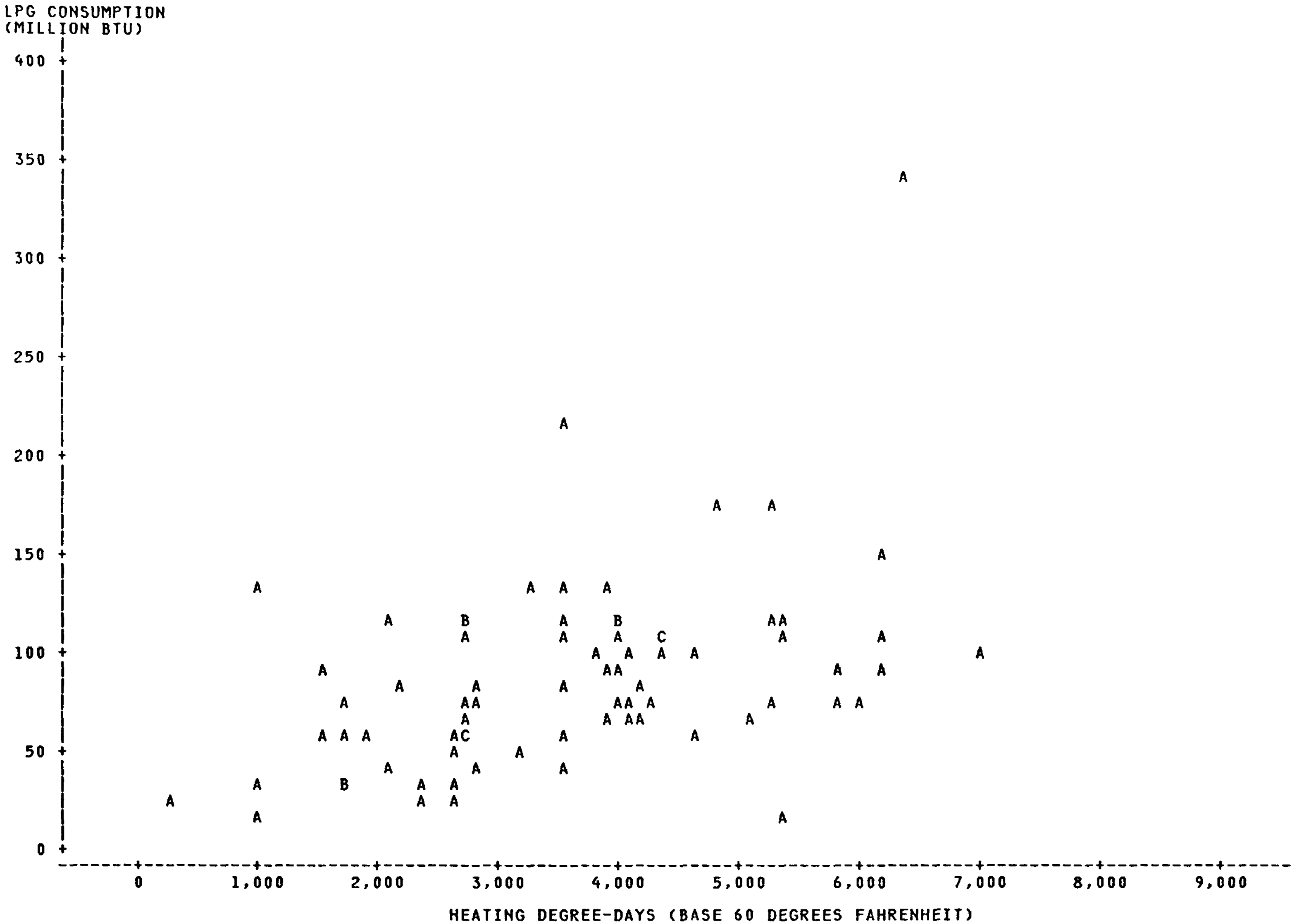
FIGURE 4. FUEL OIL CONSUMPTION BY HEATING DEGREE-DAYS FOR HOUSEHOLDS WHOSE MAIN SPACE-HEATING FUEL IS FUEL OIL (MILLION BTU)



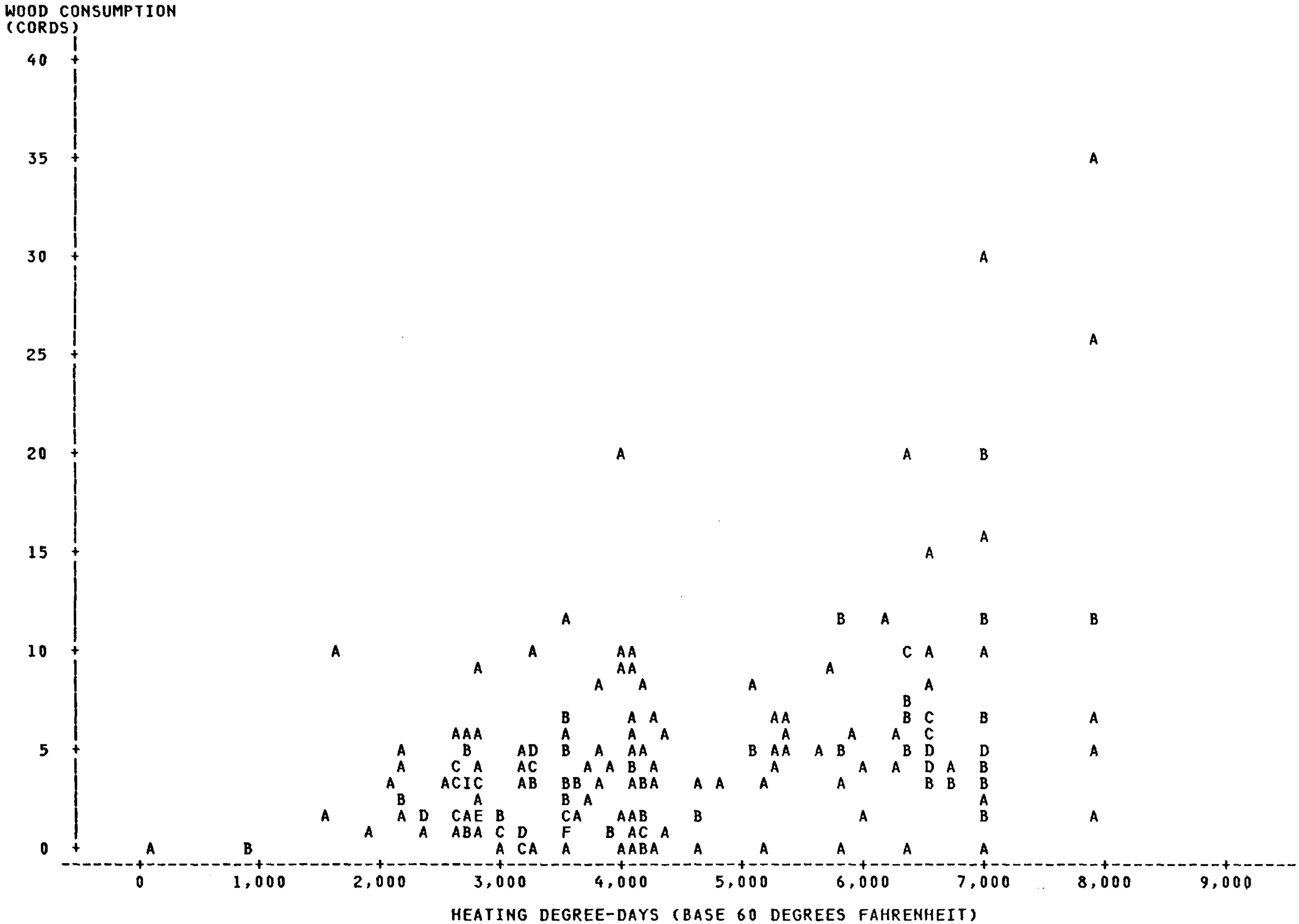
NOTE: LETTERS OF THE ALPHABET REPRESENT THE NUMBER OF OBSERVATIONS: A = ONE OBSERVATION, B = TWO OBSERVATIONS, ETC.

FIGURE 5. LPG CONSUMPTION BY HEATING DEGREE-DAYS FOR HOUSEHOLDS WHOSE MAIN SPACE-HEATING FUEL IS LPG (MILLION BTU)



NOTE: LETTERS OF THE ALPHABET REPRESENT THE NUMBER OF OBSERVATIONS: A = ONE OBSERVATION, B = TWO OBSERVATIONS, ETC.

FIGURE 6. WOOD CONSUMPTION BY HEATING DEGREE-DAYS FOR HOUSEHOLDS WHOSE MAIN SPACE-HEATING FUEL IS WOOD (CORDS)



NOTE: LETTERS OF THE ALPHABET REPRESENT THE NUMBER OF OBSERVATIONS: A = ONE OBSERVATION, B = TWO OBSERVATIONS, ETC.

model. Hence, adding central air conditioning to a previously non-air-conditioned home will multiply the previous electricity consumption estimate by a factor greater than 1, say 1.20. Hence, the increase in the estimated electricity consumption resulting from adding central air conditioning will vary. The increase will depend upon for what other end uses the household uses electricity. For instance, if the household uses electricity for space heating and water heating, the consumption estimate may be 60 million Btu per year. With the log-linear model, adding air conditioning may increase this by 12 million Btu. If the household does not use electricity for space heating or water heating, the consumption estimate may be 20 million Btu per year. Here the log-linear model will increase the consumption estimate by 4 million Btu when air conditioning is added. This difference in the increase for adding any end use is not a desirable trait.

On the other hand, the NIECS model requires the use of an error term, the variance of which is not a constant. Transforming F_h might result in a model in which the error term can reasonably be assumed to have a constant variance across all household and energy characteristics.

The problem with a nonconstant variance in the error term can sometimes be alleviated by normalizing the dependent variable. For residential energy consumption, possible normalizing procedures are dividing the energy consumption by the number of household members, dividing by the square footage of the dwelling or dividing by the degree-days. None of these normalizing procedures will alleviate the problem in this case. The reason they fail is that the data set contains households with various space-heating and water-heating fuels. If the regression procedure was preformed only over a set of households with a given space-heating and water-heating fuel, then a normalizing procedure might work.

It was decided that the nonadditivity of the transformed model was a more serious problem than the nonconstant variance of the error term in the NIECS model. With the NIECS model, the consumption can be expressed as

$$F_h = \text{(Appliance Terms)} + \text{(Water-Heating Terms)} + \text{(Space-Heating Terms)} + \text{(Air-Conditioning Terms)}.$$

This breakdown can be used as a basis for partitioning each household's energy consumption into the four major end uses. With a multiplicative model this partitioning would not be so easy. Section 8 presents a way to partition energy consumption using the NIECS (additive) model.

Regression Procedures with Nonconstant Variance of Error Term

There are various ways to adapt regression procedures to account for a nonconstant variance of the error term. These techniques include the use of weighted least squares regression and the use of nonlinear least squares regression.

Three factors were taken into account in choosing the regression procedure used:

1. How the procedure adapts to nonconstant variance of the error terms,

2. How the procedure adapts to outliers, and

3. How fast and convenient the procedure is.

To describe various regression techniques, the following terminology is needed: Set $F_h = G_h + E_h$, where F_h is the consumption, G_h is the regression estimate, and E_h is the error term.

In preliminary runs, it was noticed that

$$E_h^a = F_h^{1/2} - G_h^{1/2}$$

was more normally distributed than E_h and had approximately a constant variance as G_h varied from small to large values. This fact held for natural gas, fuel oil, and LPG consumption. For electricity, it appeared that

$$E_h^b = F_h^{1/4} - G_h^{1/4}$$

was even better. The model $F_h = G_h + E_h$ could then be fit by using a nonlinear regression procedure that minimizes

$$(E_h^a)^2.$$

For electricity, this could be minimized:

$$(E_h^b)^2.$$

When this nonlinear procedure is used, the effect of outliers with very large consumption is reduced, but the effect of outliers with very small consumption is increased. The distribution of E_h tends to be skewed to the right. Hence, more outliers can be found on the high side. Therefore, the nonlinear procedure does reduce some of the problems of outliers. The use of higher order roots makes the effect of outliers on the low side more pronounced. One drawback of nonlinear regression is that the number of steps it takes to converge can be large and depends heavily on the starting estimates.

Another way of fitting the model $F_h = G_h + E_h$ is to use an iterative weighted least squares procedure where the weights depend on $1/G_h$ and/or on $1/E_h$. Weighting on $1/G_h$ that is obtained from a previous step is equivalent to assuming that the variance of E_h is proportional to G_h. Weighting on $1/E_h$ gives least absolute value regression. It is also possible to weight on $1/G_h \times E_h$, which would be weighted least absolute value regression.

Least absolute value regression is much less affected by outliers than least squares regression. Unfortunately, the procedure takes many steps to converge with the models the author tried to fit.

With either nonlinear regression or iterative weighted regression, one can systematically delete outliers and rerun the procedure. This would remove the effect of outliers on the procedure, but would take longer. The cut-off point of what is and is not an outlier would be subjective.

All these procedures were investigated. For the cases examined, all the resulting regression equations were very similar, probably because of the large number of observations.

For convenience, it was decided to use one of the simpler procedures, iterative weighting on G_h alone. The final procedure chosen involved four computations of regression estimates. The first step used unweighted least squares regression. The second step used weighted least squares regression where the weight equaled $1/G_h$, with G_h obtained by using the regression estimates from the first step. Steps 3 and 4 are weighted least squares regression where the weights equal $1/G_h$. Here G_h was determined by the regression estimate obtained in the previous step.

It is not clear how long it would take for the estimates to converge, using the procedure chosen. The changes that take place in the estimates between two weighted regression runs are small compared with changes between the unweighted least squares estimates and the first weighted least squares estimates. For convenience, it was arbitrarily decided to use three weighted regression iterations, which gives a total of four steps. The entire procedure was performed by one program that makes use of the General Linear Model procedure in the Statistical Analysis System (SAS) programming package.

The procedure was used to fit the regression equations for four cases: the electricity consumption, the natural gas consumption, the fuel oil consumption, and the LPG consumption for households living in single-family detached homes.

The regression equations for the other housing types were obtained by constructing consumption indexes based on regression results for households living in single-family detached houses. This was done because there were fewer observations for these housing types and the researchers wanted to maintain comparability across housing types.

6. RESULTS OF REGRESSION ANALYSIS

The final regression equations for consumption of electricity, natural gas, fuel oil, and LPG in single-family detached homes are consolidated into end-use components. For electricity, there are four components; for natural gas, three components; for fuel oil, two components; and for LPG, three components. For each fuel, the sum of the components yields the estimated consumption according to the regression equations. The definitions of the terms used in the equations are contained in Appendix A. The standard errors and levels of significance of the estimated coefficients are contained in Appendix B.

In all the regression analyses, the dependent variable is the energy consumption from April 1980 through March 1981 in thousand Btu (MBtu). The following list contains the conversion factors for this unit of measure used in the RECS data set.

1 MBtu	=	1,000 Btu
	=	0.2931 kilowatt-hours of electricity
	=	0.9794 cubic feet of natural gas
	=	0.007407 gallons of No. 1 fuel oil
	=	0.007407 gallons of kerosene
	=	0.007210 gallons of No. 2 fuel oil
	=	0.04643 pounds of LPG
	=	0.01095 gallons of LPG
	=	0.3984 cubic feet of LPG.

Electricity

The total electricity regression estimate for households living in single-family detached homes is represented by ELCONSFD. The four components of ELCONSFD are represented by ELCONBS, ELCONWT, ELCONHT, and ELCONCL. The terms associated with appliances, lighting, and miscellaneous electricity consumption are consolidated into ELCONBS. Similarly, the water-heating, space-heating, and air-conditioning terms are consolidated into the components ELCONWT, ELCONHT, and ELCONCL, respectively. The discussion of the final set of independent variables used in the electricity regression analysis for households living in single-family detached homes will be divided into four parts. These parts correspond to the four components. A full description of the variables is given in Appendix A.

The intercept term was placed in the miscellaneous or appliance components. The electricity regression analysis was the only place that the intercept term was not constrained to be zero. For electricity the intercept term can be thought of as representing the baseline electricity consumption.

The appliance component also contains variables that describe the household members and the dwelling unit. These variables are the number of adults (NUMADULTS), the square footage of heated living space (HEATED), the percentage of storm windows (PCTSTORM), and a variable that scales the dwelling according to the year it was built (BUILTYEAR). Higher values of BUILTYEAR correspond to newer homes. These variables can be thought of as life-style variables that affect the baseline electricity consumption.

The rest of the variables used in the electricity appliance component describe the stock of appliances or the amount of use they receive. The variables describing the stock of appliances are the number of electric refrigerators (NELFRIG), the number of frost-free or automatic defrost electric refrigerators (NFFELFRIG), the number of electric freezers (NELFREZ), the number of electric ovens or ranges (NELOVARG), the use of a wringer washing machine (HWRNGWSH), the use of an automatic washing machine (HAUTOWSH), the use of an electric clothes dryer (HELCLSDY), the number of black-and-white televisions (TVBLACK), the number of color televisions (TVCOLOR), the use of a central warm air furnace (CFAEQUIP), the presence of a swimming pool (HPOOL), and the presence of a heated swimming pool (HTPOOL). The variables CFAEQUIP and HTPOOL are not dependent upon which fuel is used to heat either the dwelling or the pool. They signify the equipment exists and not that electricity is the fuel that is used.

The only variable that reflects the amount of appliance usage is the interaction term HAUTOWSH x NHSLDMEM, where NHSLDMEM is the number of household members.

The independent variables used in the electric water-heating component are either the indicator variable for electric water heating (ELWTHT) or interactions of ELWTHT with other variables. These other variables are NHSLDMEM, an indicator variable for an electric dishwasher (HELDISHW), and the number of teenage household members (TEENS). The interaction of HELDISHW and ELWTHT will be discussed in Section 7.

The independent variables used in the electric space-heating component are all interaction terms. The only term involving the use of electricity for secondary space heating is the interaction term consisting of the product of the indicator variable for secondary electric space heating (ELSHEAT) and heating degree-days base 60°F (HDD). Note that HDD is in units of 100 degree-days. The terms for main electric space heating are all interaction terms that involve the indicator variable for main electric space heating (ELMHEAT) and HDD. For all except two of these interaction terms, the amount of heated square footage in the dwelling (HEATED) is also part of the term. Other variables used in these interaction terms are the percentage of doors and windows that are covered by storm doors and windows (PCTSTORM), number of bathrooms (NBATHRMS), and BUILTYEAR. In addition, the indicator variable for secondary wood space heating (SWOODHT) times the amount of wood burned (TRUNCORD) is used in one of the interaction terms. TRUNCORD is in units of one-tenth cord and has a maximum value of 60, which represents six cords.

Some of the terms in the space-heating component appear to be complex interaction terms that are hard to justify. The amount of electricity used for space heating will intuitively involve the heating degree-days and the size of the dwelling. The interaction terms that use additional variables represent adjustments to the effect of degree-days and dwelling size on energy consumption for space heating.

The cooling component is composed of six terms. All these terms involve one of two variables that describe the amount of living space that can be air conditioned. RACRMS is the number of rooms that can be air conditioned by electric window units, and CACRMS is the number of rooms that can be air conditioned by electric central air-conditioning systems. Five of the terms are interaction terms involving the cooling degree-days base 75°F (CDD). In addition, in two of the terms, a categorical variable describing the household income (INCOME79) is used.

Care must be taken in interpreting any of the terms in any of the components. This also applies to the other fuels. There is much colinearity in the data. Hence the variables in the terms may actually represent the effect of other factors. This is especially true for the space-heating component. This fact will be discussed more fully in Section 7.

The equations for the four components and the total estimate are as follows:

```
ELCONBS =   2,614.8
          + 1,088.6 x NUMADULTS
          +  399.60 x BUILTYEAR
          -  19.280 x PCTSTORM
          +  1.0980 x HEATED
          + 3,842.0 x HPOOL
          +  10,216 x HTPOOL
          + 2,455.6 x NELFRIG
          + 2,863.3 x NFFELFRIG
          + 3,953.5 x NELFREZ
          +  929.71 x NELOVARG
          - 2,312.1 x HWRNGWSH
          - 4,330.5 x HAUTOWSH
          + 1,734.7 x HAUTOWSH x NHSLDMEM
          + 3,409.5 x HELCLSDY
          +  836.17 x TVBLACK
          + 2,055.4 x TVCOLOR
          + 1,155.6 x CFAEQUIP.

ELCONWT =   3,966.7 x ELWTHT
          + 2,156.9 x ELWTHT x NHSLDMEM
          + 3,337.8 x ELWTHT x TEENS
          + 4,903.6 x ELWTHT x HELDISHW.
```

$$\begin{aligned}
ELCONHT = {} & 56.946 \times ELSHEAT \times HDD \\
& + 990.07 \times ELMHEAT \times HDD \\
& - 7.9569 \times ELMHEAT \times HDD \times HDD \\
& + 0.27790 \times ELMHEAT \times HDD \times HEATED \\
& - 0.0032083 \times ELMHEAT \times HDD \times HEATED \times SWOODHT \times TRUNCORD \\
& - 0.037273 \times ELMHEAT \times HDD \times HEATED \times BUILTYEAR \\
& + 0.075640 \times ELMHEAT \times HDD \times HEATED \times NBATHRMS \\
& - 0.0014999 \times ELMHEAT \times HDD \times HEATED \times PCTSTORM.
\end{aligned}$$

$$\begin{aligned}
ELCONCL = {} & 186.63 \times RACRMS \times CDD \\
& + 10.657 \times RACRMS \times CDD \times INCOME79 \\
& + 409.40 \times CACRMS \\
& + 341.03 \times CACRMS \times CDD \\
& + 9.9592 \times CACRMS \times CDD \times INCOME79 \\
& - 17.884 \times CACRMS \times CDD \times CDD.
\end{aligned}$$

$$ELCONSFD = ELCONBS + ELCONWT + ELCONHT + ELCONCL.$$

Natural Gas

The total natural gas regression estimate for households living in single-family detached homes is represented by NGCONSFD. The three components of NGCONSFD are represented by NGCONBS, NGCONWT, and NGCONHT. The terms associated with appliances, outdoor gas lights, pool heating, and central gas air conditioning are consolidated into the component NGCONBS. Similarly, the water-heating and space-heating terms are consolidated into the components NGCONWT and NGCONHT. The discussion of the final set of independent variables used in the natural gas regression analysis for households living in single-family detached homes will be divided into three parts. These parts correspond to the three components. A full description of the variables is given in Appendix A.

No intercept term was used in the natural gas regression analysis. Many households use natural gas only for space heating and water heating. For these households, there is no baseline natural gas consumption that cannot be attributed to either space heating or water heating.

Four independent variables are used in the miscellaneous or appliance components. One of the variables is an index (NGAPLIDX) representing the natural gas consumption of appliances by the household. The relatively small number of households using some of the appliances and the noise in the consumption for space heating and water heating prevented accurate estimation of the individual coefficients for the natural gas appliance terms. Consequently, the appliance index was created. This index is based on a preliminary regression analysis of the electricity consumption. The coefficients in the index follow closely the coefficients of the corresponding terms in the ELCONBS component. The equation for NGAPLIDX is

$$\begin{aligned}
NGAPLIDX = {} & 2{,}400 \times NNGFRIG \\
& + 2{,}900 \times NFFNGFRIG \\
& + 930 \times NNGOVARG \\
& + 3{,}400 \times HNGCLSDY,
\end{aligned}$$

where NNGFRIG is the number of natural gas refrigerators, NFFNGFRIG is the number of frost-free or automatic defrost natural gas refrigerators, NNGOVARG is the number of natural gas ovens and ranges, and HNGCLSDY is an indicator variable for the use of a natural gas clothes dryer. A few households did report the presence of gas refrigerators, but all of these may actually be electric refrigerators. The households may have interpreted gas to mean Freon, which is used in refrigerators. The author assumed the households' reports were correct in this case.

The natural gas miscellaneous component also uses the variables HODGASLT, NGPOOLHT, and NGCACRMS x CDD. HODGASLT is an indicator variable for outdoor gas lights. NGPOOLHT is an indicator variable for natural gas pool heating. In the interaction term, NGCACRMS is the number of rooms that can be air conditioned with central natural gas systems.

The majority of the households claiming to have natural gas central air conditioning may actually have electric systems. This error may be caused by two things. Households may have confused Freon with the fuel running the compressor. In addition, households with central gas heating systems and electric air-conditioning systems may have thought they were both natural gas systems. The author assumed the households' reports on the air-conditioning fuels were correct.

The water-heating component uses two independent variables. These are NGWTHT, an indicator variable for natural gas water heating, and the interaction term NGWTHT x NHSLDMEM.

The space-heating component for natural gas is similar to that for electricity. It uses indicator variables for natural gas secondary (NGSHEAT) and main (NGMHEAT) space heating. All terms except one are interaction terms that use HDD. Many of the terms also involve HEATED. The following variables were also used in the interaction terms: BUILTYEAR, NBATHRMS, SWOODHT, TRUNCORD, PCTSTORM, CFAEQUIP, indicator variable for radiators (RADEQUIP), age of householder (HEADAGE), indicator variable for presence of small children (CHILDPRE), number of rooms (NROOMS), indicator variable for secondary heating fuel other than natural gas (SOTHHTNG), indicator variable for basement (BASESFU), unheated floorspace (UNHEATED), indicator variable for no upper insulation (NOUPPIN), and number of doors and windows (NDRSAWS).

The equations for the three natural gas components and the total estimate are as follows:

```
NGCONBS =      2.2728 x NGAPLIDX
          +   13,280  x HODGASLT
          +   47,255  x NGPOOLHT
          +  1,531.5  x NGCACRMS x CDD.

NGCONWT =     13,938  x NGWTHT
          +  5,670.3  x NGWTHT   x NHSLDMEM.
```

$$
\begin{aligned}
\text{NGCONHT} = {} & 775.54 \times \text{NGSHEAT} \times \text{HDD} \\
& + 11{,}734 \times \text{NGMHEAT} \\
& + 1{,}154.8 \times \text{NGMHEAT} \times \text{HDD} \\
& + 525.35 \times \text{NGMHEAT} \times \text{HDD} \times \text{RADEQUIP} \\
& + 215.23 \times \text{NGMHEAT} \times \text{HDD} \times \text{CFAEQUIP} \\
& - 0.045498 \times \text{NGMHEAT} \times \text{HDD} \times \text{HEATED} \times \text{BUILTYEAR} \\
& + 0.0032722 \times \text{NGMHEAT} \times \text{HDD} \times \text{HEATED} \times \text{HEADAGE} \\
& + 0.11042 \times \text{NGMHEAT} \times \text{HDD} \times \text{HEATED} \times \text{CHILDPRE} \\
& + 0.036130 \times \text{NGMHEAT} \times \text{HDD} \times \text{HEATED} \times \text{NROOMS} \\
& + 0.17794 \times \text{NGMHEAT} \times \text{HDD} \times \text{HEATED} \times \text{NOUPPIN} \\
& + 0.088873 \times \text{NGMHEAT} \times \text{HDD} \times \text{HEATED} \times \text{NBATHRMS} \\
& - 0.12413 \times \text{NGMHEAT} \times \text{HDD} \times \text{HEATED} \times \text{SOTHHTNG} \\
& - 14.600 \times \text{NGMHEAT} \times \text{HDD} \times \text{SWOODHT} \times \text{TRUNCORD} \\
& - 0.16714 \times \text{NGMHEAT} \times \text{HDD} \times \text{HEATED} \times \text{BASESFU} \\
& + 0.20638 \times \text{NGMHEAT} \times \text{HDD} \times \text{UNHEATED} \\
& + 12.216 \times \text{NGMHEAT} \times \text{HDD} \times \text{NDRSAWS} \\
& - 0.078175 \times \text{NGMHEAT} \times \text{HDD} \times \text{HDD} \times \text{PCTSTORM}.
\end{aligned}
$$

$$\text{NGCONSFD} = \text{NGCONBS} + \text{NGCONWT} + \text{NGCONHT}.$$

Fuel Oil

The total fuel oil regression estimate for households living in single-family detached homes is represented by FOCONSFD. The two components of FOCONSFD are water heating and space heating, represented by FOCONWT and FOCONHT, respectively. One household in the sample used fuel oil for pool heating. As a result, that household was dropped from the set of households used in the regression. No household used fuel oil as the main cooking fuel. The use of fuel oil as a secondary cooking fuel was not collected. Hence the only components used in the fuel oil regression were space heating and water heating.

The independent variables used in the fuel oil regression analysis are similar to those used in the space-heating and water-heating components of the natural gas analysis. The main differences are that the fuel oil analysis uses fewer variables, HDD is dropped from some of the interaction terms in the space-heating component, and indicator variables for fuel oil usage are used instead of indicator variables for natural gas usage. In particular, the fuel oil analysis uses indicator variables for fuel oil water heating (FOWTHT), secondary space heating (FOSHEAT), and main space heating (FOMHEAT). In addition, an indicator variable for secondary heating fuel other than fuel oil (SOTHHTFO) is used.

The equations for the two fuel oil components and the total estimate are as follows:

```
FOCONWT  =  30,999 x FOWTHT.

FOCONHT  =       22,180 x FOSHEAT
              +  42,938 x FOMHEAT
              +  20,531 x FOMHEAT x RADEQUIP
              - 4,589.4 x FOMHEAT x BUILTYEAR
              + 0.59636 x FOMHEAT x HDD x HEATED
              - 0.011390 x FOMHEAT x HDD x HEATED x SWOODHT x TRUNCORD
              - 0.28183 x FOMHEAT x HDD x HEATED  x BASESFU
              +  487.09 x FOMHEAT x HDD x NOUPPIN
              - 0.14023 x FOMHEAT x HDD x HEATED  x SOTHHTFO
              +  9.6239 x FOMHEAT x UNHEATED
              +  27.078 x FOMHEAT x HDD x NDRSAWS.

FOCONSFD = FOCONWT + FOCONHT.
```

Liquid Petroleum Gas

The total LPG regression estimate for households living in single-family detached homes is denoted by LPCONSFD. The three components of LPCONSFD are represented by LPCONBS, LPCONWT, and LPCONHT. The terms associated with LPG appliances and LPG central air conditioning are consolidated into the component LPCONBS. Similarly, the water-heating and space-heating terms are consolidated into the components LPCONWT and LPCONHT. The independent variables used in the LPG regression analysis are similar to those used in the natural gas analysis. The main differences are that the LPG analysis uses fewer variables, the air-conditioning term is included in the appliance index, HEATED is dropped from some of the interaction terms in the space-heating component, and variables describing LPG usage are used instead of variables describing natural gas usage. In particular, the LPG analysis uses indicator variables for LPG water heating (LPWTHT), secondary space heating (LPSHEAT), and main space heating (LPMHEAT).

The LPG appliance index is denoted by LPAPLIDX. The LPG index includes terms for central LPG air-conditioning systems. It was based on a preliminary electricity regression analysis. The equation for LPAPLIDX is given by:

```
LPAPLIDX  =    2,400 x NLPFRIG
             + 2,900 x NFFLPFRIG
             +   930 x NLPOVARG
             + 3,400 x HLPCLSDY
             +   420 x LPCACRMS
             +   340 x CDD x LPCACRMS
             +   9.8 x CDD x LPCACRMS x INCOME79
                  17 x CDD x CDD x LPCACRMS,
```

where NLPFRIG is the number of LPG refrigerators, NFFLPFRIG is the number of frost-free LPG refrigerators, NLPOVARG is the number of LPG ovens and ranges, HLPCLSDY is an indicator variable for using an LPG clothes dryer, and LPCACRMS is the number of rooms that can be air conditioned by an LPG central air-conditioning system.

The few households that consumed LPG and reported that gas was the fuel used in a refrigerator or a central air-conditioning system may have reported the wrong fuel. It is possible that these households actually used electricity. The author assumed that the households accurately reported the fuels that were used in refrigerators and in air-conditioning units.

The equations for the three components and the total estimate are as follows:

LPCONBS = 3.0014 x LPAPLIDX

LPCONWT = 6,916.6 x LPWTHT x NHSLDMEM

LPCONHT = 781.51 x LPSHEAT x HDD
+ 1,917.6 x LPMHEAT x HDD
+ 0.12887 x LPMHEAT x HDD x HEATED x NBATHRMS
- 741.27 x LPMHEAT x HDD x BASESFU.

LPCONSFD = LPCONBS + LPCONWT + LPCONHT.

Measures of Fit

Table 6 lists three measures of fit for the four regression equations. The first measure of fit is the usual measure of fit for unweighted least squares regression. The other two measures of fit take into account the nonconstant variance of the error term and the nonnormality of the error term.

The measures used are

$$R^2 = 100 \times [\sum (y_h - G_h)^2 / \sum (y_h - \bar{y})^2]$$

$$R_a^2 = 100 \times [\sum (y_h^{1/2} - G_h^{1/2})^2 / \sum (y_h^{1/2} - M_1)^2]$$

$$R_b^2 = 100 \times [\sum (y_h^{1/4} - G_h^{1/4})^2 / \sum (y_h^{1/4} - M_2)^2],$$

where

y_h = observed consumption,

G_h = expected consumption calculated from the regression equation,

$\bar{y} = (\sum y_h)/H,$

$M_1 = (\sum y_h^{1/2})/H,$

and

$M_2 = (\sum y_h^{1/4})/H.$

In the last three equations, H is the number of households used in the regression procedures.

The measures of fit were not obtained from the printout produced by the SAS general linear model procedure. Instead they were calculated from the actual consumption values and the predicted consumption values produced by the general linear model procedure.

Table 7 gives the standard deviation of the error term for the models, that is, the standard deviation of E_h, E_h^a, and E_h^b corrected for the number of parameters that were estimated. See Section 5 for a definition and discussion of E_h^a and E_h^b. These estimates of the standard deviations are denoted by s, s_a, and s_b, respectively. The value of s is included for comparison only. It should not be used to calculate confidence intervals because the error term E_h does not have a constant variance and is skewed toward the positive direction. The second two terms can be used to compute confidence intervals around the estimate of the predicted consumption of a particular household with given characteristics. For natural gas, fuel oil, and LPG, use s_a to calculate confidence intervals. For electricity, use s_b to calculate confidence intervals.

Table 6. Measures of Goodness of Fit of Regression Equations

Fuel	R^2	R_a^2	R_b^2
Electricity	74.39	76.06	75.93
Natural Gas	64.38	67.85	69.39
Fuel Oil	63.12	65.35	55.06
LPG	70.02	75.43	70.92

Table 7. Standard Deviations of Error Terms

Fuel	s	s_a	s_b
Electricity	12,151	28.60	1.053
Natural Gas	36,037	51.22	1.453
Fuel Oil	37,281	64.32	2.854
LPG	26,449	52.36	2.183

Assume the regression estimate of the mean consumption over all households with a specified set of characteristics is correct. Let G be this regression estimate. Let F be the actual consumption for a particular household with this set of characteristics. Then s_a or s_b can be used to compute a confidence interval for F around G.

For example, if the predicted electricity consumption is G = 83,000 MBtu, then $G^{1/4} = 17.0$, and a 95-percent confidence interval for $F^{1/4}$ is (14.9, 19.1). Hence, a 95-percent confidence interval for F is (49,000, 133,000). As another example, assume that the predicted natural gas consumption is 4,200 MBtu, then $G^{1/2} = 65$, and a 95-percent confidence interval for $F^{1/2}$ is (-35, 165) or (0, 165), because negative values of $F^{1/2}$ are not valid. Hence, a 95-percent confidence interval for F is (0, 27,000). Finally, assume that the predicted natural gas consumption is 100,000 MBtu, then $G^{1/2} = 316$, and a 95-percent confidence interval for $F^{1/2}$ is (216, 416). Hence, in this case, a 95-percent confidence interval for F is (47,000, 173,000). Notice that the range of the confidence interval is larger where G is large. Notice also that the confidence intervals are very wide. This reflects the large amount of variance in energy consumption among households living in similar dwellings and having similar characteristics.

Regression Equations for Non-Single-Family Detached Households

It was decided to use the results of the regression analysis of electricity, natural gas, fuel oil, and LPG consumption for households living in single-family detached (SFD) units in analyzing the energy consumption for households living in other housing types. In addition, the results of the regression analysis of fuel oil consumption were used in analyzing the kerosene consumption for all housing types.

The equations for the components that were developed for households living in SFD homes were used as indexes for energy consumption for the other housing types. For example, the space-heating component equation developed for SFD units was used as an index for the potential use of energy for space heating for households living in other housing types.

An overall index that equals the sum of the component indexes was also used. The indexes were multiplied by indicator variables for housing types and used as independent variables in the regression analyses. The individual terms in the indexes were not used in the regression analyses of energy consumption for non-SFD households. The intercept terms in these analyses were set equal to zero.

The indexes were used to preserve similarity and comparability between the regression equations for the different housing types. For each housing type and each fuel, it would also be possible to use the exact same set of independent variables that was used for the SFD analysis for the corresponding fuel. Unfortunately, there are fewer observations available for use in a regression analysis for the other housing types. (See Tables 1 to 4.) Hence, the coefficients would have a larger standard deviation, and many of the coefficients would no longer be significantly different from zero. Therefore, it would be deceptive to compare the resulting coefficients in the regression equations for the different housing types term by term, even if they correspond to the same fuel. Using the indexes decreases the number of independent variables and allows the coefficients of those that are used to be more easily interpreted.

For electricity and natural gas, some of the non-SFD housing types have more observations available for regression analysis than for the analysis of LPG consumption for households living in SFD units. A set of independent variables could have been established for use in these cases. It would be a smaller set than was used for the SFD analysis for the same fuel. In addition, some variables in the new set would not be in the set used for the SFD analysis. The desire to preserve comparability between regression equations for different housing types but with the same fuel dictated that the indexes be used.

The author did try using the natural gas space-heating component equation and the electricity water-heating component equation as indexes for space heating and water heating for all fuels in the SFD analysis. The natural gas space-heating component was chosen because more households used natural gas for space heating than any other fuel. As a result of the larger number of observations with natural gas space heating, the equation for the space-heating component with natural gas had more terms in it than the space-heating component for other fuels. With water heating, the use of a fuel for both space heating and water heating tends to add noise when one attempts to fit a regression equation for the water-heating component. The electricity water-heating component was chosen because more households used electricity for water heating but not for space heating than any other fuel.

When one uses the indexes based on the natural gas space-heating component and the electricity water-heating component, the resulting fits to the data are not so good as with the set of independent variables that were finally used. This may indicate that the dynamics of space heating and water heating differ among the fuels. There is not enough information available to resolve these differences.

The regression analysis for energy consumption in non-SFD units was done separately for each fuel. The analysis for the different housing types was combined for each fuel. Only those households with type I overall data, with type I consumption data for the fuel in question, and not living in single-family detached homes were used in the regression procedure.

For each fuel, one of the indexes for the components was dropped; otherwise, the data matrix would be singular. The remaining component indexes and the overall index were multiplied by indicator variables for the different housing types to form interaction terms. These terms were used as the independent variables in the regression analysis. In all cases the intercept term was set equal to zero.

The regression analysis used the same iterative procedure that was used in the SFD analysis. This involves an initial unweighted least squares followed by three weighted least squares fits.

The interaction terms for indexes other than the overall index were dropped if they were not significant at the 0.01 level. If one of the overall index interaction terms was not significant, then one of the component index interaction terms was dropped.

For the electricity analysis, the water-heating index, the space-heating index, the cooling index, and the overall index were used. The appliance index was dropped to avoid singularity problems. Hence the appliance component is always contained in the overall index. The coefficient for the overall index gives the estimated proportion of energy used in non-SFD households relative to the regression estimate based upon SFD households. The coefficients for the individual indexes estimate the difference between the proportions for the individual indexes and that for the overall index. Four indicator variables for housing types were used. The indicator variable for mobile homes is MOBILEHM; for single-family attached units, SFATTACH; for units in small apartment buildings, SMLAPTBD; and for units in large apartment buildings, LRGAPTBD. Initially, the regression procedure used 16 independent variables, the interactions between the four indexes, and the four indicator variables. After some terms were removed because of nonsignificances, there were only six terms remaining.

The resulting equation is

$$
\begin{aligned}
\text{ELCON} = \; & 1.1491 \times \text{ELCONSFD} \times \text{MOBILEHM} \\
& + 0.83612 \times \text{ELCONSFD} \times \text{SFATTACH} \\
& + 0.84548 \times \text{ELCONSFD} \times \text{SMLAPTBD} \\
& + 0.82659 \times \text{ELCONSFD} \times \text{LRGAPTBD} \\
& - 0.55746 \times \text{ELCONWT} \times \text{MOBILEHM} \\
& - 0.39426 \times \text{ELCONHT} \times \text{LRGAPTBD}.
\end{aligned}
$$

For the natural gas analysis, the appliance index, water-heating index, and the overall index were used. The space-heating index was dropped to avoid singularity problems. The space-heating index was included in the overall index and in most cases represents the largest proportion of it. The same four indicator variables for housing types were used as were used in the electricity analysis. Initially, the regression procedure used 12 independent variables, the interactions between the three indexes, and the four indicator variables. Initially, all the interaction terms involving NGCONBS were positive, but only one was significant. The lack of significance for some housing types may have been due to the small sample sizes for these housing types. The author decided to consolidate all these terms by using NGCONBS alone as an independent variable. The resulting equation involving NGCONBS will be discussed further in Section 7.

The resulting equation is

$$
\begin{aligned}
\text{NGCON} = \; & 0.87748 \times \text{NGCONSFD} \times \text{MOBILEHM} \\
& + 0.82201 \times \text{NGCONSFD} \times \text{SFATTACH} \\
& + 0.87284 \times \text{NGCONSFD} \times \text{SMLAPTBD} \\
& + 0.61270 \times \text{NGCONSFD} \times \text{LRGAPTBD} \\
& + 1.20153 \times \text{NGCONBS}.
\end{aligned}
$$

For the fuel oil analysis, only two indexes were used, the overall index and the water-heating index. The number of housing types was reduced. The categories for units in small and large apartment buildings were combined. The indicator variable for units in large or small apartment buildings is APTBLDG. For all housing types, the water-heating index was removed because it was not significant. In addition, for all housing types, the coefficient for the overall index was not significantly different from 1.0 at the 0.05 level.

The final equation is

$$\begin{aligned} \text{FOCON} = {} & 1.12327 \times \text{FOCONSFD} \times \text{MOBILEHM} \\ & + 0.91895 \times \text{FOCONSFD} \times \text{SFATTACH} \\ & + 0.97387 \times \text{FOCONSFD} \times \text{APTBLDG}. \end{aligned}$$

For the LPG analysis, three indexes were initially used, the overall index, the water-heating index, and the appliance index. The number of housing types was reduced. The categories for single-family attached units, units in small apartment buildings, and units in large apartment buildings were combined into a category for units in multiunit buildings. The indicator variable for units in multiunit buildings is MULTIUNIT . This leaves only two housing types other than SFD. For these two housing types, the water-heating index and the appliance index were removed from the final equation. In addition, the overall index for units in multiunit buildings was not significantly different from one.

The final equation is

$$\begin{aligned} \text{LPCON} = {} & 0.72418 \times \text{LPCONSFD} \times \text{MOBILEHM} \\ & + 1.22596 \times \text{LPCONSFD} \times \text{MULTIUNIT}. \end{aligned}$$

For kerosene, the same procedure was used except for one change. One household, which listed kerosene as its main heating fuel and LPG as its secondary heating fuel, purchased no kerosene during the interview year, but did purchase a large amount of LPG. The consumption of kerosene was set at zero since there were no purchases. Hence, this household was an extreme outlier in the set of 23 households with type I kerosene data. To moderate its effect on the kerosene regression procedure, the main space-heating fuel for this household was changed to LPG, and kerosene was demoted to the secondary heating fuel. This was done only for the kerosene regression procedure.

In the kerosene regression procedure, the fuel oil indexes were used. All the housing types were combined because of the small sample size. The only coefficient that was significantly different from zero was the one for the overall index. Here again, the coefficient was not significantly different from 1.0 at the 0.05 level.

The final equation is

$$\text{KRCON} = 0.92448 \times \text{FOCONSFD}.$$

Appendix B contains the standard deviation and levels of significance for all the coefficients in the regression equations.

Measures of Fit for Non-SFD Analysis

Table 8 gives the measures of fit for the non-single-family detached regressions, and Table 9 gives the standard deviation of the error terms. Individual measures of fit and standard deviations are not given for each housing type. They are given for the different fuels. For kerosene, the measures of fit and standard deviations also apply to households living in single-family detached homes. The standard deviations listed in Table 9 can be used in the same way as those for households living in the single-family detached homes. Use s_a with consumption statistics other than electricity. Use s_b with electricity consumption statistics.

Table 8. Measures of Fit for Secondary Regression Equations for Non-Single-Family Detached Homes

Fuel	R^2	R_a^2	R_b^2
Electricity	74.73	74.50	72.94
Natural Gas	62.73	69.64	70.01
Fuel Oil	45.90	51.03	50.18
LPG	67.32	75.15	75.85
Kerosene	10.91	26.53	29.82

Table 9. Standard Deviations for Secondary Regression Equations for Non-Single-Family Detached Homes

Fuel	s	s_a	s_b
Electricity	9,207	27.95	1.188
Natural Gas	34,504	56.92	1.903
Fuel Oil	45,122	70.20	2.380
LPG	24,809	50.20	1.843
Kerosene	31,592	72.43	3.326

7. DISCUSSION OF REGRESSION RESULTS

The independent variables used in the final regressions for the SFD analysis were chosen on the basis of intuition, experience gained by the NIECS analysis, and trial and error. Many terms and interactions were tried. Only those significant at the 0.01 level after the final weighted least squares regression were left in the equation. Clearly, there was not enough time to investigate all possible terms. This is particularly true of the interaction terms involved in the space-heating component. Hence, some terms that would have been significant were not tried and, as a result, were left out.

Many of the potential interaction terms were highly colinear. For instance, one could use degree-days squared instead of degree-days in the term. If two highly colinear terms were such that neither was significant when the other one was included, then the one that was less significant was dropped.

Because of the nature of this regression analysis, one cannot use the coefficients of an individual term to accurately assess the effect of an individual variable. There is much colinearity in the response variables and interaction terms. Some of the terms that are significant are in some ways surrogates for other variables such as income, fuel cost, and life-style. For example, in the electricity regression equation for households living in SFD homes, the coefficient for the indicator variable for a wringer washing machine is negative. This negative coefficient may represent the life-style of households that have wringer washing machines, and it does not signify that the machines are energy-saving devices.

The size of the coefficient in the electricity and natural gas regression equations related to swimming pools may partially reflect the life-style of households that have swimming pools.

The individual terms that make up the heating components in the regression equations are not comparable across fuels. Some terms were used for one fuel and not for another. The terms that were chosen were selected on the basis of which were the most significant. Changing the terms by adding or deleting a variable from the interaction may still result in significant coefficients. Using the new terms may result in fits that are almost as good as the fit with the final set of terms. Not all possible interactions were tried. Hence, some changes may result in improved fits.

To force comparability, the heating part of the natural gas equation was tried as a heating index for the other fuels. The resulting fits were not so good as the fits in which the data were allowed to influence the choice of the interaction heating terms. In future analysis, it may be better to agree on a common index to use from year to year. This index may vary across fuels.

The coefficient corresponding to the independent variable that is the indicator variable for fuel oil main space heating is large. The one for electricity is not significantly different from zero; hence, the corresponding independent variable was not used. The coefficient for the indicator variable for natural gas main space heating was significant but much smaller than that for fuel oil. The difference in these coefficients is one reason the heating components are not comparable term by term.

The reason that the coefficient for the indicator variable for fuel oil main space heating is large is not clear. One reason may be that few households in the warmer regions heat with fuel oil. Hence, it is harder to get a reasonable fit for warmer regions.

Similar to the space-heating terms, the water-heating terms are also inconsistent. With electricity and natural gas, there is an increase as the number of household members increases. In addition, with electricity, it was found that the number of teenagers in the household indicates a larger increase in the water-heating term than the number for any other age group. This increase does not necessarily mean that teenagers use more hot water than other household members. It only suggests that households with teenagers use more hot water than households with an equal number of household members where none of them are teenagers. Clearly one possible reason for the difference is that teenagers do use more hot water, but it is not the only possible reason.

With fuel oil, the indicator variable for fuel oil water heat is by itself highly significant. The interaction term with the number of household members is not significant if the indicator variable is also used as an independent variable. These results are similar to those found in the NIECS analysis. The difference between the water-heating term for fuel oil and that for electricity or natural gas may be related to the different types of water-heating equipment.

With electricity, the interaction term between electric water heating and the indicated variable for an electric dishwasher was significant. It is not clear what the positive coefficient for this term indicates. It could be a life-style response or an indication that households with electric dishwashers do use more energy for water heating. The interaction terms between electric dishwasher and natural gas water heating, fuel oil water heating, or LPG water heating were not significant. The NIECS analysis yielded similar results for these interaction terms. The lack of significance for all but the electricity case may be due to noise in the natural gas consumption about the space-heating term and the small number of observations in the other cases. It may also indicate that the interaction term for the electric water-heating case is really a life-style variable.

An index based on the electric water-heating component was tried with the other fuels. The fit was not so good as the fit when actual variables chosen were used.

The effect of secondary heating is accounted for in two ways. If the main heating fuel is the fuel in question, then the existence of a secondary heating fuel lowers the heating component of the main heating fuel. If the main heating fuel is not the fuel in question and the secondary heating fuel is, then the heating component is composed of the secondary contribution.

Information was not collected on the amount of secondary heat provided, only on the existence of secondary heating fuels and equipment. There is some information contained in the total consumption amounts given for the secondary heating fuel when the fuel in question is the main heating fuel. The only case in which this information was used involved the use of wood as a secondary space-heating fuel. Hence, the positive secondary heating term consists only of an indicator variable or an indicator variable interacted with heating degree-days. The negative term consists only of one term, except in the case of wood secondary heating, for which the secondary heating term is an interaction term that includes an indicator variable for wood secondary heating and the amount of wood burned. If the amount of wood burned exceeds six cords, the actual amount was not used. Instead, the amount was set at six cords.

Many variables that considerably affect energy consumption were not used. These variables either were not available, were only partly available, or were available in unreliable forms. These include marginal prices for fuels, thermostat settings, measures of air-conditioning use, measures of appliance use, measures of insulation, and measures of air infiltration. Marginal prices for electricity are available, but only for some households. The effect of marginal electricity will be discussed at the end of Section 10. Thermostat settings and some measures of air-conditioning use may be obtained in subsequent surveys.

The income variable is a categorical variable that is treated in the analysis as a numerical variable. (See Appendix A for definition of the categories.) For incomes between $3,000 and $15,000, the variable is approximately equivalent to rounding the income off to the nearest thousand dollars.

The income variable was tried in many places, in particular in the space-heating components. When the other terms were added, the only place it remained significant was in the air-conditioning terms. This does not mean that income does not affect the other components, but instead it indicates that income is taken into account by the other terms used in the equation, in particular, by the size of the house in the space-heating component and the number of appliances in the miscellaneous component.

The relatively large value for NGCONBS obtained in the non-SFD natural gas regression analysis is troubling. On the surface it appears to indicate that non-SFD households use natural gas appliances more intensely than households living in SFD houses. What may actually be happening may be related to the problem of people claiming to have gas refrigerators and central air-conditioning units when these appliances really use electricity.

8. DISAGGREGATION OF ANNUAL UTILITY BILLS

End-Use Estimates

One aspect of residential energy consumption that is not listed directly on the RECS data tape is energy consumption by end use. The end-use categories discussed here are space heating, water heating, air conditioning, and miscellaneous. In this section, two basic methods of obtaining estimates of end-use consumption are presented. There are two variations of the second method. The different methods of estimating end-use consumption are illustrated by describing how to estimate the amount of electricity used for air conditioning. The advantages and disadvantages of each method are also discussed.

Method 1: Estimation Using Differences in Strata Means

An obvious method of estimating the amount of electricity consumed for residential air conditioning would be to stratify the households in the country and estimate the amount used in each stratum. The households in each stratum should be similar in all major characteristics that affect electricity consumption, except that some households use electricity for air conditioning and some do not. Within each stratum, calculate the difference between the mean electricity consumption for users of electric air conditioning and the mean electricity consumption for nonusers of electric air conditioning. The difference is an estimate of the mean amount of electricity used for air conditioning among households represented by the stratum. Weighted sums of the differences can be used to estimate regional and national totals.

Two advantages of this method are that it is simple to estimate the end-use components once the strata are selected and the idea behind the method is easy to understand.

The main disadvantage of this procedure is that many factors influence electricity consumption. This makes selection of the strata difficult. In estimating air-conditioning use, it would be desirable to stratify according to use and nonuse of electricity for space heating and for water heating. In addition, it would be desirable to stratify according to weather zones and size of dwelling. If one does these two things, the number of observations in some strata becomes too small. The differences between users and nonusers of air conditioners within strata may still be substantial. For example, consider the stratum consisting of households living in the South that use electricity for water heating and space heating. Households in this stratum that have air conditioning tend to have higher incomes, larger homes, and more electrical appliances than those households that do not have air conditioning. This means that the estimate of the amount of electricity used for air conditioning in this stratum will be biased upward. For other strata it may be biased downward. The total national estimate of electricity used for air conditioning may depend heavily on the stratification procedure used.

One possible stratification scheme that may result in a national estimate with a small bias would be to stratify according to ELCONBS + ELCONHT + ELCONWT. This scheme would result in strata that contain households from all parts of the country. On the other hand, the households in the strata would theoretically use similar amounts of electricity for noncooling purposes.

Even if a stratification scheme that yields a reliable national estimate exists, it may not be usable for obtaining regional estimates, estimates by income categories, and estimates for other categories. To obtain these estimates, one may need to seek different stratification schemes. In addition, separate stratification schemes may be needed for each end use.

Method 2: Estimation Using End-Use Consumption Amounts for Each Household

One procedure that could be used to yield national, regional, and special category estimates would be to estimate the energy consumed for the major end uses by fuel for each household in the RECS data set. Given these numbers, one would then use the household weights to estimate the amount of energy used by end use for any category defined by variables in the RECS data set.

Variation 1: Regression Estimates. One way of estimating the energy consumed for the major end uses would be to use the estimated components ELCONBS, ELCONCL, ELCONHT, ELCONWT, FOCONHT, FOCONWT, LPCONBS, LPCONHT, LPCONWT, NGCONBS, NGCONHT, and NGCONWT as end-use consumption estimates. This would apply for households living in single-family detached homes. The variables for fuels not used by a particular household will be set equal to zero. For households not living in single-family detached homes, the variables would be multiplied by the appropriate coefficients in the regression equations for ELCON, FOCON, LPCON, and NGCON. The only adjustment in the equations is to change the fuel oil components so that they reflect both fuel oil and kerosene consumption. This was done by setting the indicator function for water heating, main space heating, and secondary space heating equal to one if either fuel oil or kerosene was used for these purposes. This was done because the consumption amounts for fuel oil and kerosene were combined on the RECS data set.

Using that scheme, one can estimate the amount of electricity used for air conditioning for any category. Unfortunately, the estimates depend heavily on the results of the regression analysis. Also, many households consume much more or much less than the regression equation predicts. In addition, not all factors that possibly affect energy consumption were examined during the regression analysis. If one of these factors happens to be used in the definition of the category over which one desires an estimate of the amount of electricity used for air conditioning, then the resulting estimates may be seriously biased. This will happen when the regression equations consistently overestimate or consistently underestimate the amount of electricity used for air conditioning by households falling in the category.

<u>Variation 2: Normalized Regression Estimates</u>. The possibility of serious bias can be reduced by normalizing the end-use estimates for each household in the data set so that the sum of the end-use estimates for each fuel equals the actual (or imputed) yearly consumption. For example, set p_1 = ELCONBS/ELCON, p_2 = ELCONWT/ELCON, p_3 = ELCONHT/ELCON, and p_4 = ELCONCL/ELCON. Then p_1, p_2, p_3, and p_4 are estimates of the proportion of the yearly electricity consumption that is used for miscellaneous uses, water heating, space heating, and air conditioning, respectively. The actual (or imputed) yearly electricity consumption is denoted by BTUEL. Set BTUELBS = p_1 x BTUEL, BTUELWT = p_2 x BTUEL, BTUELHT = p_3 x BTUEL, and BTUELCL = p_4 x BTUEL. Then BTUELBS, BTUELWT, BTUELHT, and BTUELCL are estimates of the end-use consumption normalized so that BTUELBS + BTUELWT + BTUELHT + BTUELCL = BTUEL.

The same procedure can be used to produce normalized end-use consumption estimates for all fuels and for all households. The end-use estimates for fuel oil and kerosene are combined. To obtain the estimated proportions for fuel oil and kerosene, the fuel oil regression equation is used but the indicator functions reflect both fuel oil and kerosene use.

When working with households living in dwellings other than single-family detached homes, one needs to take into account the coefficients in the equations defining ELCON and NGCON. For example, when estimating end-use electricity consumption for households living in mobile homes, set p_1 = 1.1491 x ELCONBS/ELCON, p_2 = 0.5916 x ELCONWT/ELCON, p_3 = 1.1491 x ELCONHT/ELCON, and p_4 = 1.1491 x ELCONCL/ELCON. Note in the equation for p_2 the coefficient, 0.5916, comes from the sum of the coefficients for ELCONSFD and ELCONWT in the equation for ELCON. Using the values of p_1, p_2, p_3, and p_4, proceed as before. With fuel oil and LPG, the proportions obtained from FOCON and LPCON will be the same as those obtained from FOCONSFD and LPCONSFD.

As mentioned previously, the coefficients for some of the terms in the regression equations may be changed dramatically by adding new independent variables or by removing other independent variables. This was one of the reasons the author was hesitant to interpret the values of the individual coefficients. On the other hand, any reasonable set of independent variables should produce normalized end-use consumption estimates similar to the ones produced by the set of independent variables that were used. The biggest changes would occur in components composed of only one or two independent variables or components affected by response errors. These included the water-heating component for fuel oil, the appliance component for natural gas, the water-heating component for LPG, and the appliance component for LPG.

Using the normalized regression estimates, the regression results are used only to estimate the proportion of the energy consumption that goes for each end use. In addition, the normalized end-use estimates are easier to interpret than the coefficients of the individual terms in the regression equations. They represent broad end-use consumption classes, there are far fewer terms to interpret, and the estimates have been normalized so that they sum to the actual consumption.

A possible source of colinearity that may adversely affect the normalized end-use estimates is the fact that households that use natural gas, fuel oil, or LPG for the main water-heating fuel tend to use the same fuel as the main space-heating fuel. Any miscellaneous use of natural gas tends also to imply natural gas space heating.

A greater problem involves one of the assumptions behind the normalization procedure. Here, one assumes that if a household conserves or overuses energy for one end use, it will do so on all end uses for that fuel by the same proportion. For instance, if BTUEL/ELCON = 1.34, then BTUELBS = 1.34 x ELCONBS, BTUELWT = 1.34 x ELCONWT, BTUELHT = 1.34 x ELCONHT, and BTUELCL = 1.34 x ELCONCL. It is clear that some households may conserve electricity by setting the thermostat low in the winter, but they may also use more electricity than comparable households with comparable air-conditioning equipment for cooling in the summer. Other households may do the opposite.

For individual households, the normalized end-use estimates may not accurately reflect the true breakdown of the energy consumption for the household. If one averages the normalized end-use estimates over categories with a "reasonable" number of sample households in the category, then the average estimates should approximate the actual averages for the sample households in the category. In addition, when one computes the average estimates, one uses these numbers to represent the energy consumption of all households in the country that fall in the category. Hence, the sampling errors and the nonsampling errors involved in producing the reported (or imputed) yearly energy consumption for the households also affect the use of the author's estimates.

The desire to keep the errors in the end-use averages caused by either the normalized estimation procedure, sampling error, or nonsampling error points to estimating averages only over categories with a "reasonable" number of sample households. It is not obvious how large a number needs to be before it is considered to be "reasonable." In addition, the idea of a "reasonable" number may vary. For instance, if one wants to estimate the amount of fuel oil used for space heating by households that used fuel oil only for space heating, then the normalized end-use estimate equals the actual (or imputed) consumption. On the other hand, the normalized estimate of the amount of natural gas used for non-water-heating and non-space-heating purposes may be subject to large errors caused by the noise in the space-heating and water-heating components.

Recommended Disaggregation Technique

It was decided that variation 2 of method 2, the normalized end-use estimate, was the best of the three proposed techniques. It allows one to produce estimates for subpopulations. In addition, the resulting end-use estimates will sum to the overall consumption estimate.

An additional criticism of the normalized end-use estimates is that they do not use the additional information contained in the billing-period data. They use only the annual consumption data. For that matter, none of the proposed procedures uses this additional information. Major problems that are encountered in using the billing-period information are that it is available for only some households, the lengths of the billing periods vary considerably, and the quality of the billing-period data varies considerably.

One would probably need to divide the sample into several subsets according to the amount of useful billing-period data. The disaggregation technique could then vary between subsets. In some subsets, one may be able to use the billing-period data, while in others, one may have only the annual consumption amounts to use.

It is not clear how much using the billing-period data would improve the disaggregation procedure. The extra work needed to use the data means that it may be some time before a procedure can be developed that produces end-use estimates for all households and uses the billing-period data, when available, to calculate these estimates.

Indexes for Residential Energy Consumption

The national or regional averages for the normalized end-use estimates can be used as indexes for residential energy consumption. In addition, one can compute the averages for other ways of categorizing households.

It might be interesting to sum the normalized space-heating consumption estimates across fuels. In this way, one could estimate the total or average amount of energy used for space heating. This average value could be used as an index for residential space-heating consumption. It remains to be determined if a straight sum or a weighted sum should be used. The weights could reflect the efficiency with which the different fuels can be used. In particular, a Btu of electricity can be used more efficiently than a Btu of other fuels. On the other hand, more than a Btu of oil or coal is consumed in a power plant to produce a Btu of electricity. Additional energy is lost when electricity is transmitted a long distance over power lines. A general rule of thumb is that it takes approximately 3.0 Btu of fuel at the power plant to produce 1.0 Btu of electricity. The additional amount of energy lost in transmission depends on the distance and the climate.

For each fuel, one could correct the normalized space-heating consumption estimate for weather by dividing by the average number of heating degree-days. This would give one the heating component in thousands of Btu per degree-day. In addition, if one also divides by the average number of square feet heated per household, the heating component is given in Btu per degree-day per square foot. This final index will reflect not only the thermal integrity of the housing stock and the efficiency of the residential heating equipment but also the life-style of the household members. In particular, a trend toward lower thermostat settings should result in a lower value of the Btu per degree-day per square foot index.

Tables of Results

The average normalized end-use consumption estimates for electricity, natural gas, fuel oil, and LPG are summarized in Tables 10 to 19. These tables give the national averages, regional averages, and averages for various categories. The averages are weighted averages where the weights equal the number of households in the population that the sample household represents. In all tables, the values in parentheses are the estimated standard deviations of the corresponding statistic.

The estimates for the standard deviations were obtained by using a balanced half-sample replication technique.[1] The listed standard deviations reflect only the sampling variation. They do not take into account errors made in disaggregating the annual energy consumption for individual households. Hence, the listed standard deviations are biased toward the low side. In the author's opinion, the sampling error should be greater than the disaggregation error in most cases. Hence, one expects that the bias should be small in most cases. The cases where the half-sample estimates may be substantially too small involve components that contain only one independent variable or components with independent variables subject to considerable response error. The components with only one independent variable are the fuel oil water-heating component, LPG appliance component, and the LPG water-heating component. The components subject to possible large amounts of response error are the natural gas appliance component and the LPG appliance component. The response errors involved are the possible incorrect fuels for refrigerators and central air-conditioning systems.

Table 10 lists the weighted averages for the electricity end-use components by Census division, by income group, by amount of heated floorspace, and by heating degree-days. The averages are over all households, including the relatively few households that do not use electricity.

Tables 11, 12, and 13 list the weighted averages for the natural gas, fuel oil, and LPG end-use components by Census division, by income group, by amount of heated floorspace, and by heating degree-days. The averages are over only those households that use the fuel in question.

The heating component averages listed in Tables 10 through 13 depend heavily on the percentage of the households that use each fuel for heating. To study trends in space-heating consumption, it is necessary to study the averages over only those households that heat with the fuel that is being studied. The same applies to the water-heating components.

Table 14 applies only to households where the main space-heating fuel is electricity. Table 14 lists the average degree-days, average heated square footage, and average amount of electricity consumed for space heating in Btu, Btu per degree-day, and Btu per degree-day per square foot. Tables 15, 16, and 17 are the corresponding tables for natural gas, fuel oil, and LPG.

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[1]For a description of how the balanced half-sample replication technique is applied to RECS data, see Energy Information Administration, Residential Energy Consumption Survey: Housing Characteristics, 1980 (Washington, D.C., June 1982).

In Tables 14 through 17, the averages for Btu per degree-day do not equal the results given by dividing the average Btu consumed for space heating by the average amount of heating degree-days. Instead the tabled values are the average values of the indexes. The difference between the average values of the indexes and the indexes computed from the average values reflects the skewness in the distribution of the indexes among the sample households. The same applies to the averages for Btu per degree-day per square foot.

The water-heating component for each fuel is isolated and displayed in Tables 18 and 19. Table 18 lists the average values of the electricity water-heating component over only those households whose main water-heating fuel is electricity. Table 18 also lists the corresponding average values for natural gas. Table 19 lists the corresponding average values for fuel oil and LPG.

The heating degree-day base used in Tables 10 through 19 to classify households by weather is 65°F. In addition, the heating degree-day base used to calculate the indexes given in Tables 14 through 17 is also 65°F. The tables could have been constructed using any degree-day base. The base does not have to be the same as was used in the regression analysis. The author chose 65°F because it is the most commonly used base for calculating heating degree-days. Changing the base used in the computation of the space-heating indexes may alter some of the trends that appear when using a base of 65°F.

Table 10. Average Household Electricity Consumption by End Use for All Households

Location and Income	Number of Households (Millions)	Average Household Electricity Consumption (Million Btu) for: Space Heating	Water Heating	Air Conditioning	Miscellaneous Uses
National	81.6 (0.0)	3.4 (0.3)	3.8 (0.2)	3.9 (0.1)	19.0 (0.2)
Census Divisions					
New England	4.3 (0.3)	1.9 (0.4)	2.9 (0.3)	0.4 (0.1)	17.1 (0.6)
Middle Atlantic	13.4 (0.3)	2.6 (0.5)	2.4 (0.5)	1.0 (0.2)	16.1 (0.5)
East North Central	14.8 (0.4)	3.2 (0.8)	3.2 (0.5)	1.4 (0.4)	19.5 (0.5)
West North Central	6.3 (0.4)	2.1 (0.5)	2.9 (0.5)	5.3 (0.6)	20.8 (0.5)
South Atlantic	14.0 (0.5)	3.7 (0.8)	7.0 (0.5)	6.4 (0.7)	19.9 (0.6)
East South Central	5.2 (0.3)	9.1 (1.2)	7.5 (0.8)	8.2 (0.7)	21.9 (0.8)
West South Central	7.7 (0.3)	2.5 (0.5)	2.3 (0.5)	12.6 (1.2)	20.8 (1.0)
Mountain	4.1 (0.1)	2.1 (0.6)	2.4 (0.8)	3.0 (0.5)	19.3 (0.5)
Pacific	11.8 (0.1)	3.8 (0.7)	3.1 (0.4)	0.8 (0.2)	17.9 (0.5)
Income Group (Estimated 1979 Income)					
Less than $5,000	10.4 (0.5)	3.1 (0.4)	2.4 (0.2)	1.6 (0.2)	13.1 (0.4)
$5,000 to $9,999	13.9 (0.6)	2.7 (0.3)	3.1 (0.3)	2.2 (0.2)	15.3 (0.3)
$10,000 to $14,999	13.8 (0.5)	3.1 (0.4)	3.7 (0.4)	3.1 (0.2)	16.4 (0.5)
$15,000 to $19,999	11.9 (0.4)	3.2 (0.4)	4.1 (0.3)	3.9 (0.3)	19.8 (0.4)
$20,000 to $24,999	9.9 (0.5)	3.8 (0.5)	4.3 (0.3)	4.7 (0.4)	22.1 (0.5)
$25,000 to $34,999	12.4 (0.5)	3.8 (0.6)	4.5 (0.4)	5.2 (0.3)	22.3 (0.5)
$35,000 or More	9.4 (0.6)	4.4 (0.6)	4.8 (0.4)	7.7 (0.6)	26.3 (0.6)

Table 10. Average Household Electricity Consumption by End Use for All Households (Continued)

Space Heated and Heating Degree-Days	Number of Households (Millions)	Average Household Electricity Consumption (Million Btu) for: Space Heating	Water Heating	Air Conditioning	Miscellaneous Uses
Heated Square Footage					
0	0.5 (0.1)	0.0 (0.0)	2.4 (0.7)	0.6 (0.4)	14.4 (1.0)
1 to 799	17.0 (0.7)	2.6 (0.3)	2.3 (0.2)	2.0 (0.1)	11.9 (0.3)
800 to 999	11.1 (0.5)	3.0 (0.3)	3.2 (0.2)	2.9 (0.3)	14.9 (0.4)
1,000 to 1,199	9.3 (0.4)	3.2 (0.4)	3.7 (0.3)	3.5 (0.2)	17.5 (0.5)
1,200 to 1,399	7.7 (0.3)	3.6 (0.5)	4.4 (0.3)	4.4 (0.4)	19.7 (0.4)
1,400 to 1,799	12.5 (0.4)	3.4 (0.5)	4.4 (0.4)	4.9 (0.5)	21.4 (0.4)
1,800 to 2,399	12.2 (0.5)	4.7 (0.6)	4.8 (0.4)	5.2 (0.4)	23.9 (0.4)
2,400 or More	11.4 (0.5)	3.7 (0.5)	4.7 (0.4)	5.4 (0.3)	26.8 (0.6)
Heating Degree-Days for April 1980 Through March 1981 (Base 65°F)					
0 to 1,999	11.7 (1.9)	1.6 (0.3)	3.7 (0.6)	7.9 (1.0)	18.5 (0.7)
2,000 to 2,999	7.2 (1.6)	2.1 (0.5)	2.3 (0.8)	8.8 (1.1)	19.4 (0.8)
3,000 to 3,999	9.8 (1.4)	3.4 (0.6)	4.8 (0.6)	5.7 (0.5)	19.6 (0.7)
4,000 to 4,999	8.6 (1.4)	8.8 (1.4)	7.3 (0.8)	4.8 (0.7)	22.1 (0.6)
5,000 to 5,999	17.5 (2.1)	3.3 (0.7)	3.1 (0.6)	2.7 (0.3)	17.1 (0.4)
6,000 to 6,999	15.7 (1.6)	3.2 (0.8)	2.8 (0.4)	1.1 (0.2)	18.7 (0.5)
7,000 to 7,999	7.3 (0.8)	1.8 (0.5)	3.1 (0.6)	0.2 (0.1)	18.9 (0.6)
8,000 or More	3.9 (1.3)	3.2 (0.6)	5.2 (1.0)	0.2 (0.1)	21.8 (0.9)

Table 11. Average Household Natural Gas Consumption by End Use for Households Using Natural Gas

Location and Income	Number of Households That Use Natural Gas (Millions)	Average Household Natural Gas Consumption (Million Btu) for Space Heating	Water Heating	Miscellaneous Uses
National	51.6 (1.4)	64.4 (1.3)	24.1 (0.4)	7.3 (0.3)
Census Divisions				
New England	1.9 (0.3)	52.0 (7.0)	17.5 (0.9)	6.8 (0.5)
Middle Atlantic	9.0 (0.9)	59.6 (5.4)	17.9 (1.2)	9.0 (0.5)
East North Central	10.9 (0.4)	99.3 (2.8)	27.8 (0.5)	7.7 (0.6)
West North Central	4.6 (0.5)	87.9 (4.1)	24.3 (1.2)	5.6 (0.5)
South Atlantic	4.9 (0.6)	57.0 (5.2)	22.7 (2.1)	5.7 (0.5)
East South Central	2.3 (0.3)	58.9 (4.5)	20.9 (2.5)	4.8 (0.9)
West South Central	6.1 (0.3)	44.5 (3.4)	28.0 (1.2)	9.5 (1.0)
Mountain	3.0 (0.3)	70.0 (1.8)	24.7 (1.2)	3.5 (0.6)
Pacific	8.9 (0.4)	34.1 (1.3)	25.6 (1.0)	7.1 (1.0)
Income Group (Estimated 1979 Income)				
Less than $5,000	6.6 (0.4)	55.5 (3.4)	19.9 (0.7)	6.2 (0.3)
$5,000 to $9,999	8.9 (0.5)	56.6 (2.4)	20.8 (0.7)	7.2 (0.7)
$10,000 to $14,999	8.4 (0.5)	56.6 (2.6)	21.2 (0.8)	6.6 (0.5)
$15,000 to $19,999	7.6 (0.4)	61.8 (2.4)	24.7 (0.9)	6.9 (0.4)
$20,000 to $24,999	6.4 (0.5)	74.1 (3.3)	28.6 (0.9)	7.4 (0.5)
$25,000 to $34,999	7.5 (0.5)	70.7 (2.4)	27.0 (1.0)	8.0 (0.7)
$35,000 or More	6.1 (0.4)	81.1 (4.9)	28.3 (1.0)	9.0 (1.3)

Table 11. Average Household Natural Gas Consumption by End Use for Households Using Natural Gas (Continued)

Space Heated and Heating Degree-Days	Number of Households That Use Natural Gas (Millions)		Average Household Natural Gas Consumption (Million Btu) for					
			Space Heating		Water Heating		Miscellaneous Uses	
Heated Square Footage								
0	0.1	(0.0)	0.0	(0.0)	47.8	(10.4)	4.4	(1.6)
1 to 799	10.8	(0.6)	37.8	(1.8)	15.3	(0.7)	6.2	(0.3)
800 to 999	7.5	(0.5)	49.2	(2.0)	20.7	(0.8)	6.5	(0.4)
1,000 to 1,199	5.6	(0.4)	61.8	(3.2)	25.4	(0.7)	6.6	(0.4)
1,200 to 1,399	4.9	(0.3)	59.9	(3.0)	25.8	(1.1)	9.0	(1.1)
1,400 to 1,799	7.9	(0.4)	69.0	(2.1)	26.9	(0.9)	7.3	(0.5)
1,800 to 2,399	7.7	(0.4)	81.3	(3.2)	29.2	(1.3)	7.4	(0.6)
2,400 or More	7.0	(0.4)	103.4	(4.1)	29.8	(1.0)	8.9	(1.1)
Heating Degree-Days for April 1980 Through March 1981 (Base 65°F)								
0 to 1,999	7.4	(1.2)	24.8	(1.2)	26.8	(1.2)	9.1	(1.0)
2,000 to 2,999	5.7	(1.3)	40.7	(2.5)	25.3	(1.6)	6.4	(1.0)
3,000 to 3,999	5.5	(0.8)	54.6	(3.5)	25.0	(1.4)	6.2	(0.7)
4,000 to 4,999	3.5	(0.8)	63.9	(3.5)	23.2	(1.8)	5.2	(0.7)
5,000 to 5,999	11.7	(1.1)	61.8	(3.3)	20.1	(1.2)	8.4	(0.6)
6,000 to 6,999	11.4	(1.1)	89.4	(2.5)	25.6	(0.4)	7.5	(0.4)
7,000 to 7,999	4.8	(0.6)	98.9	(2.6)	24.7	(0.8)	5.7	(0.4)
8,000 or More	1.6	(0.6)	102.2	(9.5)	22.4	(2.1)	5.5	(1.2)

Table 12. Average Household Fuel Oil and Kerosene Consumption by End Use for Households Using Fuel Oil or Kerosene

Location and Income	Number of Households That Use Fuel Oil or Kerosene (Millions)	Average Household Fuel Oil and Kerosene Consumption (Million Btu) for Space Heating	Water Heating
National	15.4 (0.9)	85.5 (1.9)	15.3 (0.7)
Census Divisions			
New England	2.7 (0.2)	98.0 (3.6)	20.2 (1.1)
Middle Atlantic	6.5 (0.5)	95.8 (2.8)	23.1 (1.4)
East North Central	1.5 (0.3)	73.9 (4.8)	3.2 (1.5)
West North Central	0.5 (0.1)	76.0 (9.5)	1.0 (0.7)
South Atlantic	3.5 (0.5)	69.2 (5.1)	7.1 (2.6)
East South Central	-	-	-
West South Central	-	-	-
Mountain	-	-	-
Pacific	0.5 (0.1)	61.7 (4.2)	1.5 (0.7)
Income Group (Estimated 1979 Income)			
Less than $5,000	2.2 (0.3)	86.0 (6.8)	16.2 (2.4)
$5,000 to $9,999	2.8 (0.2)	84.4 (4.1)	18.1 (1.9)
$10,000 to $14,999	2.9 (0.3)	77.7 (2.8)	13.8 (1.3)
$15,000 to $19,999	2.2 (0.3)	82.1 (4.5)	12.9 (1.3)
$20,000 to $24,999	1.5 (0.1)	91.1 (7.5)	12.0 (2.4)
$25,000 to $34,999	2.3 (0.2)	85.0 (3.2)	14.1 (1.9)
$35,000 or More	1.5 (0.2)	101.6 (3.9)	19.9 (1.6)

Table 12. Average Household Fuel Oil and Kerosene Consumption by End Use for Households Using Fuel Oil or Kerosene (Continued)

Space Heated and Heating Degree-Days	Number of Households That Use Fuel Oil or Kerosene (Millions)	Average Household Fuel Oil and Kerosene Consumption (Million Btu) for: Space Heating	Water Heating
Heated Square Footage			
0	-	-	-
1 to 799	3.4 (0.4)	73.1 (3.9)	21.1 (2.1)
800 to 999	1.8 (0.2)	73.4 (4.2)	16.4 (1.3)
1,000 to 1,199	1.7 (0.2)	78.1 (5.8)	15.7 (2.7)
1,200 to 1,399	1.3 (0.2)	79.9 (4.7)	12.1 (1.6)
1,400 to 1,799	2.2 (0.2)	87.2 (3.1)	11.7 (1.3)
1,800 to 2,399	2.1 (0.2)	92.1 (6.0)	12.8 (1.6)
2,400 or More	2.8 (0.3)	109.9 (4.6)	13.4 (1.7)
Heating Degree-Days for April 1980 Through March 1981 (Base 65°F)			
0 to 1,999	0.4 (0.2)	45.8 (4.0)	2.5 (1.3)
2,000 to 2,999	-	-	-
3,000 to 3,999	1.1 (0.3)	68.6 (6.3)	1.6 (1.2)
4,000 to 4,999	1.3 (0.4)	75.5 (9.2)	10.5 (3.6)
5,000 to 5,999	6.2 (0.8)	88.7 (3.8)	21.4 (2.2)
6,000 to 6,999	3.2 (0.5)	96.5 (4.0)	16.1 (1.3)
7,000 to 7,999	1.7 (0.3)	96.3 (6.4)	13.7 (1.7)
8,000 or More	1.4 (0.7)	69.7 (7.3)	7.3 (1.8)

Note: A dash "-" represents data withheld because there were not enough sample households in this category to produce accurate estimates.

Table 13. Average Household LPG Consumption by End Use for Households Using LPG

Location and Income	Number of Households That Use LPG (Millions)	Average Household LPG Consumption (Million Btu) for		
		Space Heating	Water Heating	Miscel-laneous Uses
National	7.7 (0.7)	32.3 (2.8)	9.6 (0.8)	5.7 (0.4)
Census Division				
New England	0.5 (0.1)	8.0 (7.1)	4.8 (0.8)	6.5 (0.7)
Middle Atlantic	0.7 (0.3)	12.8 (9.3)	4.6 (1.2)	5.5 (0.7)
East North Central	1.2 (0.2)	56.4 (5.4)	12.7 (0.8)	5.6 (0.5)
West North Central	0.9 (0.2)	54.8 (8.4)	11.9 (0.9)	4.8 (0.6)
South Atlantic	2.4 (0.5)	23.2 (3.8)	7.3 (1.8)	6.4 (0.9)
East South Central	0.5 (0.1)	40.3 (6.4)	6.2 (1.1)	4.0 (1.1)
West South Central	0.6 (0.2)	31.1 (5.1)	14.7 (5.4)	5.9 (0.5)
Mountain	0.4 (0.1)	51.9 (7.3)	12.0 (3.2)	3.5 (0.5)
Pacific	0.4 (0.1)	8.8 (2.7)	18.4 (1.8)	6.9 (2.3)
Income Group (Estimated 1979 Income)				
Less than $5,000	1.2 (0.2)	24.7 (3.5)	7.4 (2.0)	5.9 (0.8)
$5,000 to $9,999	1.6 (0.2)	30.9 (3.2)	5.8 (1.1)	5.0 (0.6)
$10,000 to $14,999	1.6 (0.2)	34.2 (3.3)	9.7 (1.2)	5.0 (0.7)
$15,000 to $19,999	1.0 (0.2)	27.6 (6.0)	9.4 (1.9)	5.6 (0.7)
$20,000 to $24,999	0.5 (0.1)	46.2 (8.9)	18.5 (6.2)	5.7 (0.9)
$25,000 to $34,999	1.0 (0.1)	34.2 (5.5)	11.2 (2.2)	6.7 (1.1)
$35,000 or More	0.6 (0.1)	39.6 (7.5)	13.6 (2.3)	7.4 (1.4)

Table 13. Average Household LPG Consumption by End Use for Households Using LPG (Continued)

Space Heated and Heating Degree-Days	Number of Households That Use LPG (Millions)	Average Household LPG Consumption (Million Btu) for: Space Heating	Water Heating	Miscel-laneous Uses
Heated Square Footage				
0	0.2 (0.0)	0.0 (0.0)	22.5 (2.7)	4.3 (1.1)
1 to 799	2.3 (0.3)	31.1 (4.6)	7.7 (1.4)	6.2 (0.7)
800 to 999	0.9 (0.1)	25.4 (4.4)	7.7 (2.0)	5.5 (0.9)
1,000 to 1,199	0.9 (0.2)	41.9 (4.8)	8.2 (2.0)	5.6 (0.6)
1,200 to 1,399	0.6 (0.1)	28.7 (4.1)	6.1 (1.5)	4.7 (0.6)
1,400 to 1,799	0.9 (0.1)	30.7 (3.9)	7.1 (1.3)	4.5 (1.1)
1,800 to 2,399	0.9 (0.2)	32.0 (5.8)	10.8 (1.9)	6.5 (1.3)
2,400 or More	0.9 (0.2)	42.8 (9.2)	19.0 (4.0)	5.8 (0.8)
Heating Degree-Days for April 1980 Through March 1981 (Base 65°F)				
0 to 1,999	1.0 (0.3)	12.3 (3.9)	13.3 (4.5)	8.8 (0.8)
2,000 to 2,999	0.5 (0.2)	32.6 (6.6)	17.2 (4.3)	5.7 (1.7)
3,000 to 3,999	1.7 (0.5)	33.1 (4.0)	7.8 (1.8)	3.2 (1.0)
4,000 to 4,999	0.9 (0.4)	33.6 (9.1)	7.3 (1.6)	4.3 (1.0)
5,000 to 5,999	1.2 (0.3)	45.3 (8.1)	9.8 (1.9)	4.7 (0.6)
6,000 to 6,999	0.9 (0.2)	28.4 (11.2)	8.0 (1.7)	5.7 (0.5)
7,000 to 7,999	0.8 (0.3)	44.3 (8.6)	10.0 (1.4)	5.4 (0.8)
8,000 or More	0.7 (0.3)	25.8 (12.7)	7.3 (2.4)	6.3 (1.1)

Table 14. Average Household Electricity Consumption for Space Heating for Households Whose Main Space-Heating Fuel Is Electricity

Location and Income	Number of Households (Millions)	Average Heating Degree-Days (Base 65°F)	Average Heated Square Footage	Average Electricity Consumption for Space Heating: Million Btu	Thousand Btu per Degree-Days	Btu per Degree-Day per Square Foot
National	14.3 (1.0)	3,956 (278)	1,366 (32)	18.2 (1.5)	4.6 (0.2)	3.9 (0.2)
Census Divisions						
New England	0.3 (0.1)	6,774 (275)	1,350 (201)	20.1 (3.4)	3.1 (0.6)	2.6 (0.3)
Middle Atlantic	1.3 (0.4)	6,441 (393)	1,552 (172)	25.3 (3.4)	4.0 (0.6)	2.9 (0.4)
East North Central	1.7 (0.4)	6,634 (249)	1,415 (172)	26.1 (3.3)	4.0 (0.5)	3.1 (0.2)
West North Central	0.4 (0.1)	5,713 (332)	1,889 (231)	28.0 (2.2)	5.1 (0.4)	3.2 (0.4)
South Atlantic	4.3 (0.8)	2,290 (663)	1,387 (79)	11.6 (3.9)	4.6 (0.6)	3.7 (0.4)
East South Central	1.8 (0.3)	4,173 (184)	1,497 (121)	24.9 (1.3)	6.0 (0.2)	4.9 (0.4)
West South Central	1.6 (0.3)	2,393 (193)	1,289 (101)	12.3 (0.9)	5.3 (0.6)	4.2 (0.3)
Mountain	0.7 (0.2)	3,120 (467)	1,216 (97)	11.6 (2.3)	3.7 (0.2)	3.4 (0.3)
Pacific	2.2 (0.3)	4,176 (209)	1,075 (64)	19.7 (1.8)	4.4 (0.4)	4.9 (0.2)
Income Group (Estimated 1979 Income)						
Less than $5,000	1.8 (0.3)	4,313 (201)	904 (64)	17.4 (1.4)	4.0 (0.2)	5.2 (0.3)
$5,000 to $9,999	2.1 (0.3)	3,842 (434)	1,032 (46)	16.4 (2.2)	4.3 (0.3)	4.7 (0.3)
$10,000 to $14,999	2.5 (0.2)	3,930 (282)	1,220 (41)	16.3 (1.6)	4.2 (0.3)	3.6 (0.2)
$15,000 to $19,999	2.0 (0.3)	4,085 (456)	1,222 (69)	17.4 (2.2)	4.3 (0.3)	3.9 (0.2)
$20,000 to $24,999	1.7 (0.2)	3,851 (336)	1,589 (78)	20.5 (2.0)	5.2 (0.3)	3.7 (0.3)
$25,000 to $34,999	2.4 (0.3)	3,907 (305)	1,626 (71)	18.8 (2.2)	4.8 (0.5)	3.3 (0.3)
$35,000 or More	1.8 (0.3)	3,789 (483)	2,029 (78)	21.9 (3.1)	5.9 (0.4)	3.2 (0.2)

Table 14. Average Household Electricity Consumption for Space Heating for Households Whose Main Space-Heating Fuel Is Electricity (Continued)

Space Heated and Heating Degree-Days	Number of Households (Millions)	Average Heating Degree-Days (Base 65°F)	Average Heated Square Footage	Average Electricity Consumption for Space Heating: Million Btu	Average Electricity Consumption for Space Heating: Thousand Btu per Degree-Days	Average Electricity Consumption for Space Heating: Btu per Degree-Day per Square Foot
Heated Square Footage						
1 to 799	3.6 (0.4)	4,063 (334)	611 (10)	11.8 (1.0)	2.9 (0.2)	5.1 (0.3)
800 to 999	2.2 (0.2)	3,839 (214)	891 (5)	14.5 (1.1)	3.8 (0.2)	4.2 (0.2)
1,000 to 1,199	1.7 (0.2)	3,777 (406)	1,079 (6)	16.0 (2.0)	4.3 (0.4)	4.0 (0.3)
1,200 to 1,399	1.4 (0.2)	3,535 (535)	1,288 (5)	19.4 (3.1)	5.1 (0.4)	3.9 (0.3)
1,400 to 1,799	2.0 (0.2)	3,543 (357)	1,581 (9)	19.9 (2.4)	5.6 (0.3)	3.5 (0.2)
1,800 to 2,399	2.0 (0.3)	4,394 (326)	2,073 (18)	26.6 (2.1)	6.3 (0.3)	3.0 (0.1)
2,400 or More	1.4 (0.2)	4,446 (314)	3,152 (86)	27.6 (2.5)	6.6 (0.4)	2.1 (0.1)
Heating Degree-Days for April 1980 Through March 1981 (Base 65°F)						
0 to 1,999	3.8 (1.1)	1,094 (319)	1,258 (72)	4.9 (1.8)	4.1 (0.5)	3.6 (0.5)
2,000 to 2,999	1.2 (0.3)	2,447 (78)	1,324 (88)	11.9 (1.1)	4.9 (0.6)	3.9 (0.4)
3,000 to 3,999	1.7 (0.4)	3,565 (83)	1,244 (93)	18.0 (1.6)	5.1 (0.5)	4.8 (0.2)
4,000 to 4,999	2.8 (0.5)	4,658 (58)	1,379 (99)	26.2 (0.7)	5.6 (0.2)	4.9 (0.3)
5,000 to 5,999	2.0 (0.5)	5,414 (43)	1,608 (98)	27.2 (1.5)	5.0 (0.3)	3.8 (0.3)
6,000 to 6,999	2.0 (0.5)	6,556 (92)	1,368 (140)	23.5 (4.1)	3.6 (0.6)	2.8 (0.3)
7,000 to 7,999	0.4 (0.1)	7,475 (59)	1,555 (322)	24.4 (3.9)	3.3 (0.5)	3.0 (0.6)
8,000 or More	0.3 (0.1)	8,925 (407)	1,562 (285)	32.6 (7.2)	3.8 (0.9)	2.6 (0.4)

Table 15. Average Household Natural Gas Consumption for Space Heating for Households Whose Main Space-Heating Fuel Is Natural Gas

Location and Income	Number of Households (Millions)	Average Heating Degree-Days (Base 65°F)	Average Heated Square Footage	Average Natural Gas Consumption for Space Heating		
				Million Btu	Thousand Btu per Degree-Days	Btu per Degree-Day per Square Foot
National	44.6 (1.5)	4,847 (66)	1,533 (22)	74.1 (1.2)	15.6 (0.2)	12.4 (0.2)
Census Divisions						
New England	1.1 (0.2)	6,823 (86)	1,388 (115)	87.6 (6.9)	12.8 (0.9)	10.8 (0.4)
Middle Atlantic	5.5 (0.9)	6,239 (163)	1,663 (60)	96.4 (2.8)	15.6 (0.6)	11.9 (0.3)
East North Central	10.4 (0.5)	6,736 (112)	1,587 (42)	103.6 (2.3)	15.4 (0.3)	11.4 (0.2)
West North Central	4.5 (0.5)	6,236 (156)	1,735 (99)	88.9 (4.2)	14.7 (0.7)	10.6 (0.8)
South Atlantic	4.0 (0.6)	4,117 (282)	1,459 (52)	68.4 (4.8)	17.2 (0.7)	14.0 (0.8)
East South Central	2.2 (0.3)	3,804 (164)	1,418 (94)	62.4 (3.5)	16.7 (0.8)	14.2 (0.6)
West South Central	5.6 (0.3)	2,601 (136)	1,387 (57)	47.8 (3.7)	18.6 (1.2)	15.8 (0.7)
Mountain	2.9 (0.3)	5,031 (165)	1,459 (92)	72.2 (2.7)	14.3 (0.4)	11.8 (0.5)
Pacific	8.3 (0.5)	2,602 (115)	1,477 (75)	36.3 (1.2)	14.2 (0.4)	11.6 (0.5)
Income Group (Estimated 1979 Income)						
Less than $5,000	5.5 (0.3)	4,633 (169)	1,066 (39)	66.9 (3.1)	15.0 (0.5)	16.4 (0.6)
$5,000 to $9,999	7.3 (0.4)	4,826 (129)	1,193 (32)	68.7 (1.9)	14.5 (0.4)	14.4 (0.5)
$10,000 to $14,999	6.9 (0.5)	4,932 (162)	1,250 (29)	68.4 (2.6)	14.1 (0.3)	13.3 (0.4)
$15,000 to $19,999	6.6 (0.4)	4,822 (121)	1,426 (36)	70.1 (2.2)	15.0 (0.3)	11.9 (0.3)
$20,000 to $24,999	6.0 (0.4)	5,090 (133)	1,664 (50)	79.5 (3.4)	15.9 (0.5)	10.9 (0.4)
$25,000 to $34,999	6.7 (0.4)	4,993 (122)	1,854 (48)	79.1 (2.3)	16.1 (0.3)	9.9 (0.2)
$35,000 or More	5.6 (0.4)	4,574 (182)	2,379 (74)	87.9 (5.0)	19.6 (0.6)	9.6 (0.4)

Table 15. Average Household Natural Gas Consumption for Space Heating for Households Whose Main Space-Heating Fuel Is Natural Gas (Continued)

				Average Natural Gas Consumption for Space Heating		
Space Heated and Heating Degree-Days	Number of Households (Millions)	Average Heating Degree-Days (Base 65°F)	Average Heated Square Footage	Million Btu	Thousand Btu per Degree-Days	Btu per Degree-Day per Square Foot
Heated Sqaure Footage						
1 to 799	8.3 (0.5)	4,636 (139)	602 (9)	48.3 (1.5)	10.9 (0.3)	19.1 (0.6)
800 to 999	6.3 (0.5)	4,697 (157)	890 (3)	57.7 (2.3)	13.0 (0.4)	14.6 (0.4)
1,000 to 1,199	5.1 (0.3)	4,768 (152)	1,094 (3)	68.5 (2.9)	14.8 (0.3)	13.5 (0.3)
1,200 to 1,399	4.4 (0.3)	4,336 (153)	1,290 (4)	67.3 (2.9)	15.7 (0.5)	12.2 (0.4)
1,400 to 1,799	7.2 (0.4)	4,776 (106)	1,584 (7)	75.8 (2.5)	16.3 (0.3)	10.3 (0.2)
1,800 to 2,399	7.0 (0.4)	5,187 (116)	2,073 (10)	89.2 (3.3)	17.9 (0.5)	8.6 (0.2)
2,400 or More	6.3 (0.4)	5,400 (114)	3,279 (68)	115.1 (4.8)	22.0 (0.8)	6.9 (0.2)
Heating Degree-Days for April 1980 Through March 1981 (Base 65°F)						
0 to 1,999	6.5 (1.1)	1,707 (30)	1,390 (85)	27.8 (0.9)	16.5 (0.5)	14.2 (0.6)
2,000 to 2,999	5.5 (1.2)	2,576 (56)	1,441 (86)	42.4 (2.5)	16.6 (1.0)	13.8 (0.9)
3,000 to 3,999	5.0 (0.7)	3,579 (92)	1,347 (48)	58.6 (3.7)	16.3 (0.8)	13.9 (0.5)
4,000 to 4,999	3.3 (0.7)	4,496 (75)	1,463 (76)	68.3 (2.9)	15.2 (0.5)	12.7 (0.7)
5,000 to 5,999	8.1 (0.9)	5,552 (43)	1,647 (59)	88.4 (2.2)	16.0 (0.5)	12.3 (0.3)
6,000 to 6,999	10.1 (1.0)	6,620 (32)	1,629 (48)	100.4 (2.0)	15.2 (0.3)	11.2 (0.2)
7,000 to 7,999	4.6 (0.6)	7,343 (25)	1,634 (68)	104.3 (3.5)	14.3 (0.5)	10.1 (0.4)
8,000 or More	1.5 (0.6)	8,349 (110)	1,686 (201)	107.1 (8.7)	12.8 (1.2)	8.7 (0.9)

Table 16. Average Household Fuel Oil and Kerosene Consumption for Space Heating for Households Whose Main Space-Heating Fuel Is Fuel Oil or Kerosene

Location and Income	Number of Households (Millions)	Average Heating Degree-Days (Base 65°F)	Average Heated Square Footage	Average Fuel Oil and Kerosene Consumption for Space Heating		
				Million Btu	Thousand Btu per Degree-Days	Btu per Degree-Day per Square Foot
National	13.4 (0.7)	5,827 (143)	1,571 (48)	96.0 (2.0)	17.6 (0.5)	15.6 (0.8)
Census Division						
New England	2.3 (0.2)	6,960 (90)	1,800 (137)	112.5 (3.7)	16.2 (0.4)	13.5 (1.5)
Middle Atlantic	5.9 (0.4)	5,987 (232)	1,516 (70)	104.2 (3.1)	17.7 (0.7)	16.5 (1.4)
East North Central	1.2 (0.2)	7,179 (209)	1,751 (145)	88.8 (3.3)	12.6 (0.7)	8.8 (0.6)
West North Central	0.4 (0.1)	7,284 (216)	1,640 (177)	88.8 (8.6)	12.5 (1.1)	8.9 (1.0)
South Atlantic	3.0 (0.4)	4,121 (225)	1,407 (96)	76.7 (3.9)	21.6 (1.7)	20.0 (2.8)
East South Central	-	-	-	-	-	-
West South Central	-	-	-	-	-	-
Mountain	-	-	-	-	-	-
Pacific	0.4 (0.1)	4,939 (343)	1,779 (134)	67.1 (4.3)	14.5 (1.7)	9.3 (0.6)
Income Group (Estimated 1979 Income)						
Less than $5,000	2.0 (0.2)	5,552 (154)	1,192 (94)	94.0 (6.9)	17.3 (1.2)	20.2 (1.9)
$5,000 to $9,999	2.5 (0.2)	5,953 (183)	1,158 (64)	95.2 (4.5)	17.6 (1.3)	21.1 (2.2)
$10,000 to $14,999	2.4 (0.2)	5,797 (208)	1,307 (91)	88.8 (3.7)	17.0 (1.1)	17.3 (2.5)
$15,000 to $19,999	1.8 (0.2)	5,912 (241)	1,619 (108)	95.0 (3.9)	16.6 (0.9)	13.1 (0.9)
$20,000 to $24,999	1.4 (0.1)	5,887 (207)	1,940 (148)	98.7 (7.7)	17.1 (1.2)	10.2 (0.7)
$25,000 to $34,999	2.0 (0.2)	5,874 (169)	1,933 (97)	96.7 (3.2)	18.2 (0.9)	12.0 (0.9)
$35,000 or More	1.4 (0.2)	5,810 (192)	2,357 (91)	110.8 (3.8)	19.8 (0.9)	10.3 (0.5)

Table 16. Average Household Fuel Oil and Kerosene Consumption for Space Heating for Households Whose Main Space-Heating Fuel Is Fuel Oil or Kerosene (Continued)

Space Heated and Heating Degree-Days	Number of Households (Millions)	Average Heating Degree-Days (Base 65°F)	Average Heated Square Footage	Average Fuel Oil and Kerosene Consumption for Space Heating: Million Btu	Thousand Btu per Degree-Days	Btu per Degree-Day per Square Foot
Heated Square Footage						
1 to 799	3.1 (0.4)	5,662 (157)	578 (10)	80.8 (3.9)	15.7 (1.1)	29.6 (2.3)
800 to 999	1.6 (0.2)	5,555 (138)	911 (13)	81.5 (4.5)	15.8 (1.6)	17.3 (1.7)
1,000 to 1,199	1.4 (0.2)	5,876 (237)	1,103 (9)	90.1 (4.9)	15.9 (0.9)	14.4 (0.8)
1,200 to 1,399	1.2 (0.2)	5,450 (174)	1,295 (6)	85.9 (4.4)	18.0 (1.5)	14.0 (1.2)
1,400 to 1,799	1.9 (0.2)	5,873 (344)	1,607 (9)	98.7 (3.6)	17.8 (1.1)	11.2 (0.7)
1,800 to 2,399	1.7 (0.2)	6,286 (212)	2,105 (16)	107.3 (4.3)	18.0 (1.0)	8.5 (0.5)
2,400 or More	2.5 (0.2)	6,012 (176)	3,241 (83)	122.9 (3.9)	21.3 (0.8)	6.8 (0.2)
Heating Degree-Days for April 1980 Through March 1981 (Base 65°F)						
0 to 1,999	0.4 (0.1)	1,396 (376)	1,296 (183)	48.5 (3.7)	43.8 (17.4)	47.4 (29.0)
2,000 to 2,999	-	-	-	-	-	-
3,000 to 3,999	1.0 (0.3)	3,571 (92)	1,396 (217)	73.5 (4.4)	20.7 (1.5)	18.7 (3.2)
4,000 to 4,999	1.2 (0.4)	4,764 (106)	1,624 (90)	85.0 (5.0)	17.9 (1.3)	12.8 (1.3)
5,000 to 5,999	5.6 (0.7)	5,534 (25)	1,411 (71)	96.9 (4.2)	17.5 (0.7)	17.3 (1.7)
6,000 to 6,999	2.9 (0.5)	6,477 (39)	1,778 (121)	105.0 (3.9)	16.3 (0.6)	12.1 (1.2)
7,000 to 7,999	1.4 (0.2)	7,484 (39)	1,954 (148)	109.4 (3.8)	14.6 (0.5)	10.8 (1.6)
8,000 or More	0.9 (0.5)	8,709 (333)	1,540 (189)	100.6 (9.5)	11.6 (1.1)	10.0 (1.0)

Note: A dash "-" represents data withheld because there were not enough sample households in this category to produce accurate estimates.

Table 17. Average Household LPG Consumption for Space Heating for Households Whose Main Space-Heating Fuel Is LPG

Location and Income	Number of Households (Millions)	Average Heating Degree-Days (Base 65°F)	Average Heated Square Footage	Average LPG Consumption for Space Heating		
				Million Btu	Thousand Btu per Degree-Days	Btu per Degree-Day per Square Foot
National	3.7 (0.4)	4,386 (210)	1,234 (64)	60.7 (2.8)	14.9 (0.7)	16.7 (1.6)
Census Division						
New England	-	-	-	-	-	-
Middle Atlantic	-	-	-	-	-	-
East North Central	0.7 (0.1)	6,788 (622)	1,571 (155)	92.3 (5.6)	13.8 (1.0)	10.6 (0.7)
West North Central	0.5 (0.1)	5,575 (253)	1,788 (264)	85.4 (8.6)	15.7 (1.7)	11.9 (2.0)
South Atlantic	1.1 (0.2)	2,708 (338)	1,051 (79)	41.6 (4.2)	17.1 (2.3)	22.3 (4.4)
East South Central	0.4 (0.1)	3,622 (128)	1,177 (119)	53.5 (5.6)	15.1 (1.5)	17.6 (4.3)
West South Central	0.5 (0.1)	2,532 (265)	967 (145)	37.5 (4.9)	14.9 (0.6)	18.4 (2.2)
Mountain	0.3 (0.1)	5,846 (446)	893 (133)	61.7 (6.3)	11.0 (1.2)	16.8 (3.7)
Pacific	0.1 (0.0)	3,751 (841)	1,487 (477)	38.1 (5.7)	10.3 (0.7)	8.4 (2.8)
Income Group (Estimated 1979 Income)						
Less than $5,000	0.5 (0.1)	3,725 (355)	908 (89)	54.6 (4.2)	15.3 (1.5)	23.8 (5.3)
$5,000 to $9,999	0.9 (0.1)	4,191 (319)	1,090 (104)	55.0 (4.6)	15.5 (2.3)	18.2 (4.2)
$10,000 to $14,999	0.9 (0.1)	4,427 (354)	1,106 (74)	60.3 (4.0)	14.6 (0.7)	15.4 (1.3)
$15,000 to $19,999	0.4 (0.1)	4,597 (522)	1,132 (163)	61.8 (8.4)	14.5 (1.0)	19.4 (3.4)
$20,000 to $24,999	0.3 (0.1)	5,008 (390)	1,467 (190)	71.0 (12.0)	13.8 (1.9)	12.1 (2.3)
$25,000 to $34,999	0.5 (0.1)	4,706 (411)	1,498 (174)	60.8 (8.6)	12.8 (1.2)	11.2 (1.1)
$35,000 or More	0.3 (0.1)	4,404 (567)	2,046 (388)	77.2 (10.6)	19.7 (3.5)	16.0 (4.3)

Table 17. Average Household LPG Consumption for Space Heating for Households Whose Main Space-Heating Fuel Is LPG (Continued)

Space Heated and Heating Degree-Days	Number of Households (Millions)	Average Heating Degree-Days (Base 65°F)	Average Heated Square Footage	Average LPG Consumption for Space Heating: Million Btu	Average LPG Consumption for Space Heating: Thousand Btu per Degree-Days	Average LPG Consumption for Space Heating: Btu per Degree-Day per Square Foot
Heated Square Footage						
1 to 799	1.4 (0.2)	3,954 (346)	627 (18)	51.6 (3.6)	15.8 (1.7)	27.7 (3.1)
800 to 999	0.5 (0.1)	4,497 (335)	893 (11)	44.4 (3.7)	9.9 (1.1)	11.2 (1.2)
1,000 to 1,199	0.6 (0.1)	4,444 (376)	1,088 (6)	66.1 (7.9)	15.3 (1.4)	14.1 (1.3)
1,200 to 1,399	0.3 (0.1)	4,531 (417)	1,287 (14)	56.5 (5.9)	13.0 (1.1)	10.1 (0.9)
1,400 to 1,799	0.4 (0.1)	4,688 (442)	1,566 (26)	61.1 (5.3)	13.9 (1.2)	9.0 (0.8)
1,800 to 2,399	0.3 (0.1)	4,170 (347)	2,092 (37)	73.4 (10.5)	17.1 (2.4)	8.4 (1.3)
2,400 or More	0.3 (0.1)	5,736 (617)	3,230 (279)	103.8 (13.2)	18.8 (1.5)	6.1 (0.6)
Heating Degree-Days for April 1980 Through March 1981 (Base 65°F)						
0 to 1,999	0.5 (0.1)	1,171 (340)	978 (117)	22.5 (5.1)	20.4 (5.6)	27.0 (10.0)
2,000 to 2,999	0.4 (0.2)	2,488 (94)	1,053 (125)	36.7 (5.4)	14.6 (1.6)	19.3 (5.5)
3,000 to 3,999	0.9 (0.3)	3,504 (59)	1,098 (110)	53.9 (4.4)	15.4 (1.1)	19.4 (3.0)
4,000 to 4,999	0.4 (0.1)	4,698 (85)	1,116 (38)	67.8 (9.7)	14.5 (2.3)	15.1 (1.8)
5,000 to 5,999	0.6 (0.2)	5,418 (76)	1,616 (323)	80.7 (7.3)	14.9 (1.3)	12.2 (1.1)
6,000 to 6,999	0.3 (0.1)	6,610 (35)	1,504 (254)	79.2 (12.2)	12.0 (1.8)	9.7 (1.1)
7,000 to 7,999	0.4 (0.2)	7,529 (92)	1,251 (237)	82.6 (9.5)	10.9 (1.1)	11.2 (2.5)
8,000 or More	-	-	-	-	-	-

Note: A dash "-" represents data withheld because there were not enough sample households in this category to produce accurate estimates.

Table 18. Average Household Electricity Consumption and Natural Gas Consumption for Water Heating for Households Whose Main Water-Heating Fuel Is Electricity or Natural Gas

Location and Income	Households Whose Main Water Heating Fuel Is Electricity: Number of Households (Millions)	Households Whose Main Water Heating Fuel Is Electricity: Average Household Electricity Consumption for Water Heating (Million Btu)	Households Whose Main Water Heating Fuel Is Natural Gas: Number of Households (Millions)	Households Whose Main Water Heating Fuel Is Natural Gas: Average Household Natural Gas Consumption for Water Heating (Million Btu)
National	26.1 (1.2)	11.9 (0.2)	44.1 (1.3)	28.2 (0.4)
Census Division				
New England	1.0 (0.1)	12.7 (0.5)	1.4 (0.2)	22.8 (0.9)
Middle Atlantic	2.9 (0.5)	11.1 (0.8)	5.8 (0.8)	27.9 (1.1)
East North Central	3.7 (0.4)	12.8 (0.8)	10.2 (0.4)	29.8 (0.6)
West North Central	1.5 (0.3)	12.0 (0.9)	4.2 (0.4)	26.9 (1.0)
South Atlantic	8.5 (0.7)	11.5 (0.5)	3.8 (0.5)	29.1 (1.3)
East South Central	3.1 (0.4)	12.7 (0.6)	1.8 (0.2)	27.1 (2.0)
West South Central	1.6 (0.4)	11.0 (0.9)	5.7 (0.4)	30.1 (1.7)
Mountain	0.9 (0.3)	11.0 (0.9)	2.8 (0.3)	25.9 (0.8)
Pacific	2.9 (0.4)	12.5 (0.6)	8.4 (0.4)	27.2 (1.1)
Income Group (Estimated 1979 Income)				
Less than $5,000	3.1 (0.3)	8.1 (0.4)	5.4 (0.3)	24.3 (0.8)
$5,000 to $9,999	4.5 (0.4)	9.7 (0.4)	7.1 (0.4)	26.1 (0.7)
$10,000 to $14,999	4.6 (0.3)	11.0 (0.6)	7.0 (0.5)	25.3 (0.8)
$15,000 to $19,999	3.8 (0.3)	12.6 (0.5)	6.6 (0.3)	28.5 (0.8)
$20,000 to $24,999	3.1 (0.2)	13.5 (0.4)	5.9 (0.4)	31.0 (0.9)
$25,000 to $34,999	4.1 (0.4)	13.5 (0.6)	6.7 (0.4)	30.4 (0.9)
$35,000 or More	2.8 (0.3)	16.0 (0.5)	5.3 (0.4)	32.3 (0.9)

Table 18. Average Household Electricity Consumption and Natural Gas Consumption for Water Heating for Households Whose Main Water-Heating Fuel Is Electricity or Natural Gas (Continued)

	Households Whose Main Water Heating Fuel Is Electricity		Households Whose Main Water Heating Fuel Is Natural Gas	
Space Heated and Heating Degree-Days	Number of Households (Millions)	Average Household Electricity Consumption for Water Heating (Million Btu)	Number of Households (Millions)	Average Household Natural Gas Consumption for Water Heating (Million Btu)
Heated Square Footage				
0	0.2 (0.1)	7.4 (1.3)	0.1 (0.0)	47.8 (10.4)
1 to 799	5.5 (0.5)	7.1 (0.3)	8.1 (0.4)	20.4 (0.7)
800 to 999	3.5 (0.3)	10.1 (0.4)	6.2 (0.4)	25.1 (0.8)
1,000 to 1,199	3.2 (0.3)	10.7 (0.5)	4.9 (0.3)	29.2 (0.6)
1,200 to 1,399	2.6 (0.2)	13.2 (0.5)	4.4 (0.3)	29.2 (1.2)
1,400 to 1,799	4.0 (0.3)	13.9 (0.5)	7.2 (0.4)	29.6 (0.9)
1,800 to 2,399	3.9 (0.3)	14.8 (0.5)	7.0 (0.3)	32.2 (1.1)
2,400 or More	3.2 (0.3)	16.4 (0.6)	6.3 (0.4)	33.3 (0.7)
Heating Degree-Days for April 1980 Through March 1981 (Base 65°F)				
0 to 1,999	4.1 (1.2)	10.7 (0.4)	7.1 (1.1)	27.8 (1.4)
2,000 to 2,999	1.5 (0.6)	11.2 (0.9)	5.3 (1.3)	27.5 (1.5)
3,000 to 3,999	4.0 (0.8)	11.7 (0.5)	4.7 (0.7)	29.2 (1.4)
4,000 to 4,999	4.8 (0.9)	13.3 (0.5)	2.9 (0.7)	28.4 (1.3)
5,000 to 5,999	4.6 (1.3)	11.5 (0.5)	8.2 (0.9)	28.7 (1.0)
6,000 to 6,999	3.5 (0.7)	12.5 (0.6)	10.2 (0.9)	28.4 (0.5)
7,000 to 7,999	1.9 (0.5)	11.9 (0.6)	4.3 (0.6)	27.8 (0.7)
8,000 or More	1.6 (0.7)	12.3 (0.6)	1.5 (0.5)	24.7 (1.8)

Note: A dash "-" represents data withheld because there were not enough sample households in this category to produce accurate estimates.

Table 19. Average Household Fuel Oil and Kerosene Consumption and LPG Consumption for Water Heating for Households Whose Main Water-Heating Fuel Is Fuel Oil, Kerosene, or LPG

Location and Income	Households Whose Main Water Heating Fuel Is Fuel Oil or Kerosene		Households Whose Main Water Heating Fuel Is LPG	
	Number of Households (Millions)	Average Household Fuel Oil and Kerosene Consumption for Water Heating (Million Btu)	Number of Households (Millions)	Average Household LPG Consumption for Water Heating (Million Btu)
National	7.1 (0.5)	32.8 (0.8)	3.6 (0.3)	20.6 (1.1)
Census Division				
New England	1.6 (0.1)	33.0 (1.4)	0.1 (0.1)	19.8 (3.7)
Middle Atlantic	4.5 (0.3)	33.4 (1.1)	0.2 (0.1)	16.7 (1.6)
East North Central	0.2 (0.1)	28.2 (3.3)	0.7 (0.1)	20.7 (0.7)
West North Central	-	-	0.5 (0.1)	20.7 (1.4)
South Atlantic	0.8 (0.3)	31.0 (2.8)	0.7 (0.2)	23.5 (5.6)
East South Central	-	-	0.2 (0.0)	18.1 (2.0)
West South Central	-	-	0.4 (0.2)	21.8 (3.1)
Mountain	-	-	0.3 (0.1)	14.2 (3.6)
Pacific	-	-	0.4 (0.1)	22.7 (1.4)
Income Group (Estimated 1979 Income)				
Less than $5,000	1.0 (0.2)	33.4 (2.3)	0.5 (0.1)	18.5 (3.7)
$5,000 to $9,999	1.4 (0.1)	35.7 (1.8)	0.7 (0.2)	14.2 (1.6)
$10,000 to $14,999	1.3 (0.1)	30.8 (2.5)	0.9 (0.2)	18.3 (1.4)
$15,000 to $19,999	0.9 (0.1)	30.9 (1.6)	0.5 (0.1)	18.1 (2.4)
$20,000 to $24,999	0.6 (0.1)	30.1 (2.9)	0.2 (0.1)	42.6 (14.5)
$25,000 to $34,999	1.0 (0.1)	33.3 (2.2)	0.5 (0.1)	24.7 (2.2)
$35,000 or More	0.9 (0.1)	33.9 (1.9)	0.3 (0.1)	25.6 (1.7)

Table 19. Average Household Fuel Oil and Kerosene Consumption and LPG Consumption for Water Heating for Households Whose Main Water-Heating Fuel Is Fuel Oil, Kerosene, or LPG (Continued)

Space Heated and Heating Degree-Days	Households Whose Main Water Heating Fuel Is Fuel Oil or Kerosene		Households Whose Main Water Heating Fuel Is LPG	
	Number of Households (Millions)	Average Household Fuel Oil and Kerosene Consumption for Water Heating (Million Btu)	Number of Households (Millions)	Average Household LPG Consumption for Water Heating (Million Btu)
Heated Square Footage				
0	-	-	0.2 (0.0)	22.5 (2.7)
1 to 799	2.0 (0.3)	35.1 (1.9)	1.1 (0.2)	15.8 (1.3)
800 to 999	0.9 (0.1)	32.3 (2.1)	0.4 (0.1)	17.5 (2.6)
1,000 to 1,199	0.7 (0.2)	34.4 (1.7)	0.3 (0.1)	23.4 (4.1)
1,200 to 1,399	0.5 (0.1)	31.0 (1.7)	0.2 (0.1)	17.1 (2.8)
1,400 to 1,799	0.8 (0.1)	31.0 (1.8)	0.3 (0.1)	17.7 (2.1)
1,800 to 2,399	0.8 (0.1)	34.0 (2.7)	0.5 (0.1)	21.5 (2.4)
2,400 or More	1.2 (0.2)	30.0 (0.9)	0.5 (0.1)	34.2 (7.4)
Heating Degree-Days for April 1980 Through March 1981 (Base 65°F)				
0 to 1,999	-	-	0.4 (0.1)	35.2 (8.3)
2,000 to 2,999	-	-	0.4 (0.2)	22.9 (3.6)
3,000 to 3,999	-	-	0.7 (0.2)	18.3 (1.2)
4,000 to 4,999	0.5 (0.3)	30.9 (3.2)	0.4 (0.2)	15.6 (1.9)
5,000 to 5,999	3.9 (0.3)	33.9 (1.3)	0.6 (0.2)	19.0 (1.9)
6,000 to 6,999	1.6 (0.3)	32.7 (1.7)	0.4 (0.1)	19.2 (2.8)
7,000 to 7,999	0.7 (0.1)	33.7 (2.5)	0.4 (0.2)	21.0 (3.4)
8,000 or More	0.4 (0.2)	25.9 (2.1)	0.3 (0.1)	-

Note: A dash "-" represents data withheld because there were not enough sample households in this category to produce accurate estimates.

ƷION OF DISAGGREGATION RESULTS

. drawn from the results listed in Tables 10 / end use. The results for the additional are discussed, along with the uncorrected results.

Air Conditioning

icity for air conditioning increases dramatically warm regions, from low-income to high-income seholds living in small units to those living in eases are more pronounced than the trend for sults for household income and dwelling unit size , as is illustrated by Tables 14 through 17, where come households tend to live in larger units.

Miscellaneous Energy Usage

Miscellaneous uses include cooking, lighting, dishwashing, clothes drying, pool heating, and other uses. The consumption of electricity for miscellaneous uses increases as one goes from low-income to high-income households and from households living in small units to those living in large units. As with air-conditioning use, the results for household income and dwelling unit size are somewhat confounded. Also, the trends for miscellaneous use are not so pronounced as the trends for air conditioning. There is no clear trend for miscellaneous electricity consumption according to heating degree-days. The small differences that do occur may be caused by different percentages of households using electricity for cooking and clothes drying in different parts of the country.

The consumption of natural gas for miscellaneous uses exhibits the same trends as that for electricity. The remarks concerning electricity also apply to natural gas. The tables do not show a clear trend for miscellaneous uses of LPG.

Water Heating

The average fuel consumption for water heating depends heavily on the percentage of households that use the particular fuel for water heating. Tables 18 and 19 give the averages over only those households that use the particular fuels for water heating. The results listed in Table 18 show that the average electricity consumption for water heating increases as one goes from low-income to high-income households and from households living in small dwelling units to those living in large units. The same relations hold for natural gas, but the increases are not as pronounced. There does not seem to be any clear trend by weather or Census division for either of these two fuels.

The resulting trends for electricity and natural gas reflect the form of the regression equation for the water-heating components. The number of household members plays an important role in these equations. This suggests that the use of hot water is related to the number of household members. Multimember households tend to have higher incomes and live in larger dwellings than single-member households.

The average fuel oil consumption and the average LPG consumption for water heating do not show any clear trends in Table 19. This may be a result of the fact that the water-heating component for these two fuels is not as accurately estimated as for electricity and natural gas.

Space Heating

The averages in Tables 14 through 17 are averages over only those households whose main heating fuel is electricity, natural gas, fuel oil, and LPG, respectively. Using these tables, one notices that the same trends appear for all fuels.

In all tables, the uncorrected average energy consumption for space heating and the consumption in Btu per degree-day increases as one goes from low-income to high-income households. The increase in average consumption does not match the larger increase in the average amount of heated square footage. As a result, the average value for the Btu per degree-day per square foot index decreases as one goes to the higher income categories. Similar trends appear when one goes from households living in small units to households living in large units, except the increases or decreases are more pronounced. This implies that the trends by income categories may be a result of the tendency of households with higher incomes to live in larger units.

As one goes from households living in warmer climates to those living in cooler climates, the average consumption for space heating in Btu increases but the average consumption in Btu per degree-day and Btu per degree-day per square foot decreases. Part of the trend for Btu per degree-day per square foot may be related to the fact that the average unit size increases as one goes toward the cooler climates.

The overall trends for the index giving Btu per degree-day per square foot are troubling. It would be better if one had an index that was less affected by climate and unit size. Unfortunately, such an index may not have the intuitive appeal that Btu per degree-day per square foot does. A possible change in the index that may give better results would be to use a higher degree-day base for heating degree-day and divide by the square root of the heated floorspace instead of by the heated floorspace itself. The higher base for degree-days would result in a smaller percentage change in degree-days as one goes from warm to cool climates. The square root of the heated floorspace would be roughly proportional to the area of the exterior walls of the dwelling unit. This would increase at a lower rate than the heated floorspace.

Tables 14 through 17 show that households that use electricity as their main space-heating fuel tend to use dramatically less Btu for space heating than those households that use natural gas, fuel oil, kerosene, or LPG as the main space-heating fuel. This does not mean that it is more efficient to use electricity to heat homes. The Btu equivalent of electricity is measured as the heat equivalent of the electricity that is delivered to the household, not the amount of energy required to generate and transmit the electricity to the household. In addition, households that use electricity as the main space-heating fuel tend to live in newer homes and warmer climates than those that heat with other fuels. As a result, this report does not provide an answer to the question as to which fuel is the most efficient for residential space-heating purposes.

Trends According to Income and Heating Degree-Days

The trends according to income shown in the tables reflect differences in a cross section of the population at a particular point in time. The effect of a general increase in the average household income may be different from the cross-sectional differences. In particular, unless the average dwelling size also increases, increases in the average real income may not result in an increase in the average amount of energy used for space heating.

Similarly, the trends according to heating degree-days shown in the tables reflect cross-sectional differences. Hence, one can use the results shown in the tables to predict the effect of changes in the weather on energy consumption only if one assumes that the longitudinal differences caused by weather are the same as the cross-sectional differences. It is intuitively obvious that weather does affect the amount of energy used for heating and cooling. But the type of equipment, amount of insulation, and percentage of storm windows vary by weather zone. Hence, the size of the differences shown in the tables also reflect these facts.

This report is based on data collected from households surveyed during the 1980 RECS. Some of these households are also being surveyed during the 1982 RECS. The resulting longitudinal data will be helpful in studying the longitudinal effect of changes in income, weather, and other variables.

10. EFFECT OF ELECTRICITY PRICES

The price of the various fuels was not used in the regression results presented in Section 6. For each household and each fuel the average price could be computed by dividing the expenditures by the consumption. But these average prices would be affected by the block rate structures. Hence the coefficient of any term involving the average price may reflect the change in average price between large and small consumers caused by the block rate structure as well as the response of consumers to price. It would be more desirable to use a set of marginal prices that are the same for all consumers that are under the same rate structure.

Fuel prices do affect the regression results. The choice of space-heating fuels, water-heating fuels, and appliance stock is affected by prices. The effect of electricity prices on these choices is discussed later in this section. The use of indicator variables that describe these choices in the regression procedure will partially account for fuel prices. If the fuel prices and these variables were simultaneously used in the regression procedures, then the coefficient for the price variables would probably underestimate the true effect of price on cross-sectional differences in energy consumption.

The 1980 RECS data set is a cross-sectional data set. Hence even if the price effect could be accurately estimated, it would be a cross-sectional effect. The cross-sectional effect of price obtained from 1980 data may be substantially different from the longitudinal effect of price. It is the longitudinal effect that should be used in estimating the effect of future fuel prices on energy consumption. The 1982 RECS will contain some households that were also used in the 1980 RECS. The resulting longitudinal data will be helpful in studying the longitudinal effect of changes in price.

For some of the households interviewed during the survey, the marginal prices for the utilities that serviced the households were available. The marginal price data for major investor-owned utilities were estimated from data listed in Typical Residential, Commercial and Industrial Bills--Investor Owned Utilities, published by the Edison Electric Institute (EEI). A convenient source for marginal price data for rural electric cooperatives or municipal (public) electric companies was not available. Six marginal prices were listed when data were available. These were the marginal prices at low, medium, and high consumption levels, for both winter and summer months.

Table 20 lists the percentage of households that use electricity for major appliances and major end uses by the average of the six marginal prices. Table 21 lists the average estimated amount of electricity used for space heating, water heating, air conditioning, and miscellaneous end uses by the average marginal price. Table 21 also lists the average cooling degree-days base 65°F. Table 22 applies only to households where the main space-heating fuel is electricity. Table 22 lists the average degree-days, average heated square footage, and average amount of electricity consumed for space heating in Btu, Btu per degree-day, and Btu per degree-day per square foot. These averages are listed by the marginal prices.

Table 20. Households Using Electricity, by End Use

Price of Electricity	Number of Households (Millions)	Percentage of Households Using Electricity for								
		Main Space-Heating Fuel	Main Water-Heating Fuel	Clothes Drying	Main Cooking Fuel	Central Air Conditioning	Room Air Conditioning	Freezer	Dishwasher
National	81.6 (0)	17.5 (1.3)	31.9 (1.4)	46.9 (1.2)	54.4 (1.7)	25.1 (1.0)	30.4 (0.9)	38.1 (1.0)	37.2 (1.1)
Marginal Price (Cents/kWh)									
Not Available	30.4 (1.4)	21.4 (1.8)	36.7 (2.4)	44.3 (1.8)	55.6 (2.3)	27.3 (1.8)	28.2 (1.3)	36.5 (1.3)	33.1 (1.5)
0 to 2.99	1.3 (0.3)	32.3 (4.4)	67.5 (6.9)	74.6 (2.5)	90.2 (2.8)	6.2 (2.0)	13.0 (6.2)	49.4 (4.9)	54.5 (3.5)
3 to 3.99	5.1 (1.2)	25.5 (4.2)	57.1 (8.7)	59.6 (3.8)	75.2 (5.2)	28.4 (4.2)	28.8 (2.9)	47.7 (4.9)	38.2 (2.5)
4 to 4.99	17.4 (1.7)	13.1 (1.8)	30.9 (4.4)	55.1 (2.6)	55.0 (2.8)	28.3 (2.4)	29.1 (2.5)	47.2 (2.2)	36.1 (2.0)
5 to 5.99	9.6 (1.6)	29.9 (7.2)	41.7 (6.9)	51.1 (3.2)	63.7 (3.6)	31.7 (3.0)	32.5 (3.7)	40.3 (4.4)	45.4 (2.6)
6 to 6.99	7.1 (0.9)	8.4 (1.8)	16.5 (3.3)	47.5 (4.5)	56.6 (4.7)	16.0 (3.0)	30.1 (2.2)	35.9 (3.3)	46.1 (5.6)
7 to 7.99	6.5 (0.8)	4.6 (1.1)	8.3 (1.3)	30.3 (3.0)	26.7 (3.1)	20.2 (3.7)	37.6 (2.9)	24.9 (3.2)	35.5 (4.1)
8 or more	4.3 (0.2)	0.4 (0.4)	0.8 (0.5)	23.9 (3.9)	25.4 (3.0)	5.7 (1.8)	43.3 (2.4)	16.7 (2.0)	34.7 (3.6)

Table 21. Average Household Electricity Consumption by End Use

Price of Electricity	Number of Households (Millions)	Cooling Degree-Days (Base 65°F)	Average Household Electricity Consumption (Million Btu) for: Space Heating	Water Heating	Air Condi-tioning	Miscel-laneous Uses
National	81.6 (0.0)	1,180 (35)	3.4 (0.3)	3.8 (0.2)	3.9 (0.1)	19.0 (0.2)
Marginal Price (Cents/kWh)						
Not Available	30.4 (1.4)	1,317 (47)	4.1 (0.4)	4.4 (0.3)	4.3 (0.3)	18.0 (0.3)
0 to 2.99	1.3 (0.3)	175 (94)	8.5 (1.1)	9.0 (1.0)	0.2 (0.1)	23.2 (1.3)
3 to 3.99	5.1 (1.2)	933 (108)	6.1 (1.0)	7.0 (1.2)	3.4 (0.7)	21.4 (0.7)
4 to 4.99	17.4 (1.7)	1,320 (90)	3.3 (0.5)	3.6 (0.5)	5.5 (0.7)	21.1 (0.4)
5 to 5.99	9.6 (1.6)	1,497 (285)	2.8 (0.6)	4.7 (0.7)	5.5 (1.2)	20.2 (0.6)
6 to 6.99	7.1 (0.9)	675 (65)	2.3 (0.5)	2.2 (0.5)	1.2 (0.2)	18.9 (0.6)
7 to 7.99	6.5 (0.8)	858 (18)	1.1 (0.3)	1.1 (0.2)	1.7 (0.3)	17.0 (0.9)
8 or More	4.3 (0.2)	857 (9)	0.2 (0.0)	0.0 (0.0)	0.8 (0.1)	14.4 (1.1)

Table 22. Average Household Electricity Consumption for Space Heating for Households Whose Main Space-Heating Fuel Is Electricity

Price of Electricity	Number of Households (Millions)	Average Heating Degree-Days (Base 65°F)	Average Heated Square Footage	Average Electricity Consumption for Space Heating		
				Million Btu	Thousand Btu per Degree-Days	Btu per Degree-Day per Square Foot
National	14.3 (1.0)	3,956 (278)	1,366 (32)	18.2 (1.5)	4.6 (0.2)	3.9 (0.2)
Marginal Price (Cents/kWh)						
Not Available	6.5 (0.7)	3,862 (180)	1,305 (61)	18.3 (1.3)	4.7 (0.2)	4.2 (0.1)
0 to 2.99	0.4 (0.1)	5,208 (157)	1,190 (138)	25.8 (1.2)	4.9 (0.2)	4.7 (0.3)
3 to 3.99	1.3 (0.4)	5,218 (382)	1,409 (86)	23.2 (1.0)	4.8 (0.5)	4.0 (0.5)
4 to 4.99	2.3 (0.4)	4,645 (281)	1,521 (94)	23.6 (1.6)	5.5 (0.4)	4.1 (0.2)
5 to 5.99	2.9 (1.0)	2,372 (1074)	1,346 (57)	8.9 (4.0)	3.7 (0.4)	3.2 (0.4)
6 to 6.99	0.6 (0.2)	5,659 (298)	1,649 (218)	24.6 (2.1)	4.5 (0.5)	3.1 (0.4)
7 to 7.99	0.3 (0.1)	5,490 (317)	1,229 (220)	21.1 (3.9)	3.8 (0.7)	3.4 (0.6)
8 or More	-	-	-	-	-	-

Note: A dash "-" represents data withheld because there were not enough sample households in this category to produce accurate estimates.

The author did not use the marginal electricity prices in the initial regression procedure because these marginal prices were not available for many of the households. The marginal prices were used in a supplemental regression procedure. The only households used in this regression procedure were those households for which all six marginal prices were available and for which Type I electricity consumption data were available. The electricity consumption was used as the dependent variable. Eight independent variables were used. Four of these were ESTELBS, ESTELWT, ESTELHT, and ESTELCL. Where

$$\begin{aligned} ESTELBS = ELCONBS\ (1 &+ 0.1491 \times MOBILEHM \\ &- 0.1639 \times SFATTACH \\ &- 0.1545 \times SMLAPTBD \\ &- 0.1734 \times LRGAPTBD), \end{aligned}$$

$$\begin{aligned} ESTELWT = ELCONWT\ (1 &- 0.4084 \times MOBILEHM \\ &- 0.1639 \times SFATTACH \\ &- 0.1545 \times SMLAPTBD \\ &- 0.1734 \times LRGAPTBD), \end{aligned}$$

$$\begin{aligned} ESTELHT = ELCONHT\ (1 &+ 0.1491 \times MOBILEHM \\ &- 0.1639 \times SFATTACH \\ &- 0.1545 \times SMLAPTBD \\ &- 0.5677 \times LRGAPTBD), \end{aligned}$$

and

$$\begin{aligned} ESTELCL = ELCONCL\ (1 &+ 0.1491 \times MOBILEHM \\ &- 0.1639 \times SFATTACH \\ &- 0.1545 \times SMLAPTBD \\ &- 0.1734 \times LRGAPTBD). \end{aligned}$$

Here ESTELBS, ESTELWT, ESTELHT, and ESTELCL are the non normalized regression estimates of the miscellaneous, water-heating, space-heating, and air-conditioning components of electricity consumption. For households living in single-family detached dwellings, these estimates will equal ELCONBS, ELCONWT, ELCONHT, and ELCONCL, respectively. For households living in other housing types, the estimates are adjusted to reflect the non-SFD regression results.

The other four independent variables were the interactions of these four terms with one of the marginal prices. These interaction terms will represent the effect of electricity prices beyond the effect on the choice of fuels, equipment, and other variables used in the initial regression analysis. The marginal price depended on the consumption component. The same robust procedure was used as was used for the initial regressions.

Table 23 lists the resulting estimates, their standard deviations, and their level of significance. The estimates of the coefficients for ELCONHT x RATE3W and ELCONCL x RATE3S are not significantly different from zero. These two terms were then dropped. Table 24 lists the results when only six independent variables are used.

Table 23. Estimates of Coefficients for Regression Using Marginal Electricity Rates with All Components

Independent Variable	Estimate of Coefficient	Standard Error of Estimates	Two-Sided Level of Significance
ESTELBS	1.12186	0.03020	Less than 0.0001
ESTELBS x RATE2S	-0.00024	0.00005	Less than 0.0001
ESTELWT	1.14175	0.11163	Less than 0.0001
ESTELWT x RATE2S	-0.00050	0.00023	0.03
ESTELCL	1.32160	0.15097	Less than 0.0001
ESTELCL x RATE3S	-0.00039	0.00030	0.19
ESTELHT	0.96489	0.08784	Less than 0.0001
ESTELHT x RATE3W	-0.00005	0.00020	0.81

Table 24. Estimates of Coefficients for Regression Using Marginal Electricity Rates Only When They Are Significant

Independent Variable	Estimate of Coefficient	Standard Error of Estimates	Two-Sided Level of Significance
ESTELBS	1.13528	0.02849	Less than 0.0001
ESTELBS x RATE2S	-0.00027	0.00005	Less than 0.0001
ESTELWT	1.15063	0.10604	Less than 0.0001
ESTELWT x RATE2S	-0.00053	0.00022	0.015
ESTELCL	1.13000	0.03328	Less than 0.0001
ESTELHT	0.94410	0.03198	Less than 0.0001

Conclusions Concerning Effect of Electricity Prices

The results shown in Tables 20 through 24 reflect cross-sectional differences. They should not be used to estimate the effect of a sudden increase in electricity prices without careful consideration of the relationship between cross-sectional differences and longitudinal differences. The results in Table 20 show that in areas with low electricity prices the prevalence of electric appliances is greater than in areas with high electricity prices. This is especially true for electric main space heating and electric water heating. The results in Tables 23 and 24 indicate that electricity prices result in cross-sectional differences in electricity consumption that cannot be fully explained by all the independent variables used in the original regression procedure.

The effect of marginal electricity prices on the air-conditioning component is masked by the changes in the cooling degree-days when one goes from one part of the country to another. Table 21 reveals that both the average electricity consumption for air conditioning and the average cooling degree-days go up and then down as one goes from low-price areas to high-price areas. The drop in consumption is faster than the drop in cooling degree-days. This can be partially explained by examining the ratio between the percentage of households with electric window units to the percentage of households with electric central systems. Table 20 reveals that in high-price areas, room air-conditioning units are much more prevalent than central systems. In areas with low electricity prices but not extremely low values of cooling degree-days, the ratio is approximately one to one.

11. CALENDAR YEAR CONSUMPTION ESTIMATES

The energy consumption estimates that have been presented are for the period from April 1980 through March 1981. There is some interest in presenting energy consumption estimates covering the period from January 1980 through December 1980, that is, calendar year estimates. It is possible to produce calendar year estimates using the April through March consumption estimates and the regression results. The procedure used was to produce calendar year estimates for each household by fuel. National and regional calendar year estimates can be obtained by using the household calendar year consumption estimates and the household sampling weights.

In estimating the calendar year consumption, the author adjusted the components separately for each household and each fuel. The author assumed that there was no need to adjust the air-conditioning component for electricity. This decision was made because there was at most a small change in the cooling degree-days between the calendar year and the interview year. The water-heating and appliance components for all fuels were increased by 0.274 percent because 1980 was a leap year. The space-heating components were adjusted to account for changes in the heating degree-days and the main space-heating fuel. The adjusted components were then added together by fuel and by household to obtain calendar year consumption estimates by fuel and by household.

In adjusting the space-heating component, the author made the following assumptions:

Assumption 1: Any change in the main space-heating fuel takes place on April 1, 1980.

Assumption 2: There is no change in the secondary space-heating fuel.

Assumption 3: The changes in a household's energy consumption for space heating due to changes in heating degree-days are proportional to the changes in the heating degree-days base 60°F.

Assumption 1 is approximately equivalent to assuming that the change in the main space-heating fuel occurred during the summer months. This happens because the majority of the heating degree-days occur during the winter months. Assumption 2 is necessary because the author has data only on changes in the main space-heating fuel. One could replace assumption 3 with another assumption on how changes in the heating degree-days affect energy consumption. It is not clear if assumption 3 is the best assumption to use.

The details of the space-heating adjustments are given in Appendix C. The resulting calendar year estimates for national and regional energy consumption are given in Table 25. Table 26 gives the corresponding estimates for the period covering April 1980 through March 1981.

Table 25. Residential Energy Consumption for Calendar Year 1980 by Census Division and Fuel Type (Trillion Btu)

	Energy Consumption			
Census Division	Electricity	Natural Gas	Fuel Oil/ Kerosene	LPG
New England	96 (7)	137 (23)	330 (26)	11 (5)
Middle Atlantic	296 (14)	770 (122)	804 (52)	17 (9)
East North Central	406 (29)	1,521 (84)	139 (28)	93 (18)
West North Central	197 (12)	590 (65)	49 (16)	69 (12)
South Atlantic	520 (25)	416 (72)	264 (49)	85 (22)
East South Central	243 (22)	201 (30)	7 (3)	28 (5)
West South Central	297 (27)	504 (31)	2 (2)	32 (13)
Mountain	111 (7)	306 (30)	7 (6)	26 (6)
Pacific	308 (14)	604 (42)	33 (6)	15 (5)
Total	2,473 (48)	5,050 (192)	1,636 (89)	377 (34)

Table 26. Residential Energy Consumption for April 1980 Through March 1981 by Census Division and Fuel Type (Trillion Btu)

	Energy Consumption			
Census Division	Electricity	Natural Gas	Fuel Oil/ Kerosene	LPG
New England	95 (7)	141 (24)	318 (26)	10 (5)
Middle Atlantic	296 (14)	782 (122)	772 (50)	17 (9)
East North Central	404 (29)	1,474 (80)	117 (23)	89 (17)
West North Central	195 (12)	543 (59)	39 (13)	63 (12)
South Atlantic	519 (24)	417 (71)	263 (48)	87 (22)
East South Central	242 (21)	199 (29)	6 (3)	28 (5)
West South Central	296 (28)	499 (32)	1 (1)	31 (13)
Mountain	110 (7)	291 (28)	6 (6)	25 (5)
Pacific	303 (14)	598 (42)	30 (6)	15 (5)
Total	2,460 (47)	4,943 (190)	1,552 (85)	365 (33)

The differences between the calendar year estimates and the April 1980 through March 1981 estimates are small. The biggest change occurs with fuel oil consumption. Most of the change with fuel oil is caused by households switching from fuel oil to some other source of main heating fuel.

The results shown in Table 25 differ slightly from the corresponding results given in previous reports.[1] The difference is caused by a change in assumption 3 and the adjustment for the leap year.

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[1]Energy Information Administration, Energy Price and Expenditure Data Report, 1970-1980 (State and U.S. Total), DOE/EIA-0376 (Washington, D.C., July 1983); Energy Information Administration, Residential Energy Consumption Survey: Consumption and Expenditures April 1980 Through March 1981, Part 1: National Data, DOE/EIA-0321/1 (Washington, D.C., September 1982); Energy Information Administration, Residential Energy Consumption Survey: Consumption and Expenditures April 1980 Through March 1981, Part 2: Regional Data, DOE/EIA-0321/2 (Washington, D.C., June 1983).

Appendix A

DEFINITION OF VARIABLES USED IN REGRESSION ANALYSIS

Table A1. Variables Used in Regression Equations

Variables	On Public-Use Tape	Page First Used	Description
APTBLDG	No	41	Household lives in an apartment building (Yes = 1, No = 0). Obtainable from the variable TYPEHOME on the public-use tape.
BASESFU	No	33	Household lives in a single-family unit that has a basement (Yes = 1, No = 0). Obtainable from the variable BASEMENT on the public-use tape.
BUILTYEAR	No	30	Year dwelling was built; Before 1940 = 1; 1940-1949 = 2; 1950-1959 = 3; 1960-1964 = 4; 1965-1969 = 5; 1970-1974 = 6; After 1974 = 7. Obtainable from the variable BUILTYEAR on the public-use tape.
CACRMS	No	31	Number of rooms that can be air conditioned with an electric central system. Equals the number of rooms that can be air conditioned if the dwelling unit has an electric central system and no room air-conditioning units. If the dwelling unit has both types of electric systems, then CACRMS equals the number of rooms that can be air conditioned minus one. Obtainable from the variables HCENTAC, HROOMAC, NROOMAC, NROOMS, and KFLCNAC on the public-use tape.
CDD	No	31	Cooling degree-days base 75°F. Equals CDD75 on public-use tape. Units = 100 degree-days.
CFAEQUIP	No	30	Main space-heating equipment is a central forced-air unit (Yes = 1, No = 0). Obtainable from the variable EQUIPM on the public-use tape.

Table A1. Variables Used in Regression Equations (Continued)

Variables	On Public-Use Tape	Page First Used	Description
CHILDPRE	No	33	One of the household members is less than 3 years old (Yes = 1, No = 0). Obtainable from the variables NAGE01 - NAGE12 on the public-use tape.
ELCON	No	40	Regression estimate of total electricity consumption for households not living in single-family detached units.
ELCONBS	No	29	Regression estimate of electricity consumption for lighting, appliances, and miscellaneous use based on households living in single-family detached homes.
ELCONCL	No	29	Regression estimate of electricity consumption for air conditioning based on households living in single-family detached homes.
ELCONHT	No	29	Regression estimate of electricity consumption for space heating based on households living in single-family detached homes.
ELCONSFD	No	29	Regression estimate of total electricity consumption based on households living in single-family detached homes.
ELCONWT	No	29	Regression estimate of electricity consumption for water heating based on households living in single-family detached homes.
ELMHEAT	No	30	Use electricity as the main heating fuel (Yes = 1, No = 0). Obtainable from the variable KFLMHEAT on the public-use tape.
ELSHEAT	No	30	Use electricity as a secondary heating fuel but not as the main heating fuel (Yes = 1, No = 0). Obtainable from variables KFLMHEAT and KFLSHEAT on the public-use tape.
ELWTHT	No	30	Use electricity as the main fuel for water heating (Yes = 1, No = 0). Obtainable from the variable KWHEATFL on the public-use tape.

Table A1. Variables Used in Regression Equations (Continued)

Variables	On Public-Use Tape	Page First Used	Description
ESTELBS	No	83	Nonnormalized regression estimate of the miscellaneous component of electricity consumption. For households living in single-family detached homes this equals ELCONBS. For households living in other housing types the estimate is adjusted to reflect the non-SFD regression results.
ESTELCL	No	83	Nonnormalized regression estimate of the air-conditioning component of electricity consumption. For households living in single-family detached homes this equals ELCONCL. For households living in other housing types the estimate is adjusted to reflect the non-SFD regression results.
ESTELHT	No	83	Nonnormalized regression estimate of the space-heating component of electricity consumption. For households living in single-family detached homes this equals ELCONHT. For households living in other housing types the estimate is adjusted to reflect the non-SFD regression results.
ESTELWT	No	83	Nonnormalized regression estimate of the water-heating component of electricity consumption. For households living in single-family detached homes this equals ELCONWT. For households living in other housing types the estimate is adjusted to reflect the non-SFD regression results.
FOCON	No	41	Regression estimate of total fuel oil consumption for households not living in single-family detached units.
FOCONHT	No	34	Regression estimate of fuel oil consumption for space heating based on households living in single-family detached homes.
FOCONSFD	No	34	Regression estimate of total fuel oil consumption based on households living in single-family detached homes.

Table A1. Variables Used in Regression Equations (Continued)

Variables	On Public-Use Tape	Page First Used	Description
FOCONWT	No	34	Regression estimate of fuel oil consumption for water heating based on households living in single-family detached homes.
FOMHEAT	No	34	Use fuel oil as the main heating fuel (Yes = 1, No = 0). Obtainable from the variable KFLMHEAT on the public-use tape.
FOSHEAT	No	34	Use fuel oil as a secondary heating fuel but not as main heating fuel. (Yes = 1, No = 0). Mathematical definition: FOSHEAT = 1 if KFLMHEAT $\neq$ 3 and (KFLSHEAT = 3 or FOHEAT = 1). The variables KFLMHEAT, KFLSHEAT, and FOHEAT are on the public-use tape.
FOWTHT	No	34	Use fuel oil as a water-heating fuel (Used as main water-heating fuel = 1, Used as secondary water-heating fuel = 0.5, Not used as a water-heating fuel = 0). Mathematical definition: FOWTHT = 1 if KWHEATFL = 3; = 0.5 if KWHEATFL $\neq$ 3, and FOH20 = 1; = 0 otherwise.
HAUTOWSH	Yes	30	Use automatic clothes washer (Yes = 1, No = 0).
HDD	No	30	Heating degree-days base 60°F. Equals HDD60 on public-use tape. Units = 100 degree-days.
HEADAGE	Yes	33	Age of head of household.
HEATED	Yes	29	Total square footage of heated area.
HELCLSDY	Yes	30	Use electric clothes dryer (Yes = 1, No = 0).
HELDISHW	Yes	30	Use electric dishwasher (Yes = 1, No = 0).

Table A1. Variables Used in Regression Equations (Continued)

Variables	On Public-Use Tape	Page First Used	Description
HLPCLSDY	No	35	Use LPG clothes dryer (Yes = 1, No = 0). Obtainable from variables HGSCLSDY and BTULP on the public-use tape.
HNGCLSDY	No	32	Use natural gas clothes dryer (Yes = 1, No = 0). Obtainable from variables HGSCLSDY and BTUNG on the public-use tape.
HODGASLT	Yes	33	Use outdoor gas lights (Yes = 1, No = 0).
HPOOL	No	30	Have swimming pool (Yes = 1, No = 0). Obtainable from variable POOL in public-use tape.
HTPOOL	No	30	Use a pool heater (fuel unspecified) (Yes = 1, No = 0). Obtainable from variable POOLHEAT on public-use tape.
HWRNGWSH	Yes	30	Use electric wringer washing machine (Yes = 1, No = 0).
INCOME79	Yes	31	Self-reported family income for 1979 Loss = 1; $0 - $2,999 = 2; $3,000 - $3,999 = 3; $4,000 - $4,999 = 4; $5,000 - $5,999 = 5; $6,000 - $6,999 = 6; $7,000 - $7,999 = 7; $8,000 - $8,999 = 8; $9,000 - $9,999 = 9; $10,000 - $10,999 = 10; $11,000 - $11,999 = 11; $12,000 - $12,999 = 12; $13,000 - $13,999 = 13; $14,000 - $14,999 = 14; $15,000 - $16,999 = 15; $17,000 - $19,999 = 16; $20,000 - $24,999 = 17; $25,000 - $29,999 = 18; $30,000 - $34,999 = 19; $35,000 - $39,999 = 20; $40,000 - $49,999 = 21; $50,000 - $74,999 = 22; $75,000 or More = 23;

Variables	On Public-Use Tape	Page First Used	Description
KRCON	No	41	Regression estimate of total kerosene consumption.
LPAPLIDX	No	35	Appliance index for LPG appliances.
LPCACRMS	No	35	Number of rooms that can be air conditioned with an LPG central system. Equals the number of rooms that can be air conditioned if the dwelling unit has an LPG central system and no room air-conditioning units. If the dwelling unit has both room units and an LPG central system, then LPCACRMS equals the number of rooms that can be air conditioned minus one. Obtainable from the variables HCENTAC, HROOMAC, NROOMAC, NROOMS, KFLCNAC, and BTULP on the public-use tape.
LPCON	No	41	Regression estimate of total LPG consumption for households not living in single-family detached units.
LPCONBS	No	35	Regression estimate of LPG consumption for appliances, air conditioning, and miscellaneous uses based on households living in single-family detached homes.
LPCONHT	No	35	Regression estimate of LPG consumption for space heating based on households living in single-family detached homes.
LPCONSFD	No	35	Regression estimate of total LPG consumption based on households living in single-family detached units.
LPCONWT	No	35	Regression estimate of LPG consumption for water heating based on households living in single-family detached homes.
LPMHEAT	No	35	Use LPG as the main heating fuel (Yes = 1, No = 0). Obtainable from the variable KFLMHEAT on the public-use tape.
LPSHEAT	No	35	Use LPG as a secondary heating fuel but not as the main heating fuel (Yes = 1, No = 0). Obtainable from variables KFLMHEAT and KFLSHEAT on the public-use tape.

Table A1. Variables Used in Regression Equations (Continued)

Variables	On Public-Use Tape	Page First Used	Description
LPWTHT	No	35	Use LPG as the main fuel for water heating (Yes = 1, No = 0). Obtainable from the variable KWHEATFL on the public-use tape.
LRGAPTBD	No	40	Dwelling unit is in a large apartment building (Yes = 1, No = 0). Obtainable from the variable TYPEHOME on the public-use tape.
MOBILEHM	No	40	Dwelling unit is a mobile home (Yes = 1, No = 0). Obtainable from the variable TYPEHOME on the public-use tape.
MULTIUNIT	No	41	Dwelling unit is either a single-family attached unit or a unit in an apartment building (Yes = 1, No = 0). Obtainable from the variable TYPEHOME on the public-use tape.
NBATHRMS	No	30	Number of bathrooms equals the number of full bathrooms plus half the number of half-bathrooms. Obtainable from the variables NCOMBATH and NHAFBATH on the public-use tape.
NDRSAWS	No	33	Number of windows and doors. Obtainable from the variables DOOR1ALL, DOOR2ALL, DOOR3ALL, WINDOWS, WIND1ALL WIND2ALL, and WIND3ALL on the public-use tape.
NELFRIG	No	30	Number of electric refrigerators. Obtainable from the variables NREFRIG, KREFREL1, and KREFRFL2 on the public-use tape. Any refrigerator for which fuel is not listed is assumed to be an electric refrigerator.
NELFREZ	No	30	Number of electric freezers that are separate from refrigerators. Obtainable from the variables FREEZEN, FREEZE1F, and FREEZE2F on the public-use tape. Any freezer for which fuel is not listed is assumed to be an electric freezer.

Table A1. Variables Used in Regression Equations (Continued)

Variables	On Public-Use Tape	Page First Used	Description
NELOVARG	No	30	Number of conventional electric ovens plus one if the household has an electric range. Obtainable from the variables OVENNUM, OVEN1F, OVEN2F, OVEN1M, OVEN2M, and HELRANGE.
NFFELFRIG	No	30	Number of frost-free or automatic defrost electric refrigerators. Any refrigerator whose type is not specified is assumed to be a manual defrost refrigerator. Obtainable from the variables KREFRFL1, KREFRFL2, REFRIGT1, and REFRIGT2 on the public-use tape.
NFFLPFRIG	No	35	Number of frost-free or automatic defrost LPG refrigerators. Any refrigerator whose type is not specified is assumed to be a manual defrost refrigerator. Obtainable from the variables KREFRFL1, KREFRFL2, REFRIGT1, REFRIGT2, and BTULP on the public-use tape.
NFFNGFRIG	No	32	Number of frost-free or automatic defrost natural gas refrigerators. Any refrigerator whose type is not specified is assumed to be a manual defrost refrigerator. Obtainable from the variables KREFRFL1, KREFRFL2, REFRIGT1, REFRIGT2, and BTUNG on the public-use tape.
NGAPLIDX	No	32	Appliance index for natural gas appliances.
NGCACRMS	No	33	Number of rooms that can be air conditioned with a natural gas central system. Equals the number of rooms that can be air conditioned if the dwelling unit has a natural gas central system and no room air-conditioning units. If the dwelling unit has both room units and a natural gas central system, then NGCACRMS equals the number of rooms that can be air conditioned minus one. Obtainable from the variables NCENTAC, HROOMAC, NROOMAC, NROOMS, KFLCNAC, and BTUNG on the public-use tape.

Table A1. Variables Used in Regression Equations (Continued)

Variables	On Public-Use Tape	Page First Used	Description
NGCON	No	40	Regression estimate of total natural gas consumption for households not living in single-family detached units.
NGCONBS	No	32	Regression estimate of natural gas consumption for appliances and miscellaneous uses based on households living in single-family detached homes.
NGCONHT	No	32	Regression estimate of natural gas consumption for space heating based on households living in single-family detached homes.
NGCONSFD	No	32	Regression estimate of total natural gas consumption based on households living in single-family detached units.
NGCONWT	No	32	Regression estimate of natural gas consumption for water heating based on households living in single-family detached homes.
NGMHEAT	No	33	Use natural gas as the main heating fuel (Yes = 1, No = 0). Obtainable from the variable KFLMHEAT on the public-use tape.
NGPOOLHT	No	33	Use natural gas to heat a swimming pool (Yes = 1, No = 0). Obtainable from the variable POOLFUEL on the public-use tape.
NGSHEAT	No	33	Use natural gas as a secondary space-heating fuel but not as the main space-heating fuel (Yes = 1, No = 0). Obtainable from variables KFLMHEAT and KFLSHEAT on the public-use tape.
NGWTHT	No	33	Use natural gas as the main water-heating fuel (Yes = 1, No = 0). Obtainable from the variable KWHEATFL on the public-use tape.
NHSLDMEM	Yes	30	Number of household members.
NLPFRIG	No	35	Number of LPG refrigerators. Obtainable from variables KREFRFL1, KREFRFL2, and BTULP on the public-use tape.

Table A1. Variables Used in Regression Equations (Continued)

Variables	On Public-Use Tape	Page First Used	Description
NLPOVARG	No	35	Number of LPG ovens and ranges. Obtainable from variables OVEN1F, OVEN2F, HGASRANG, and BTULP on the public-use tape.
NNGFRIG	No	32	Number of natural gas refrigerators. Obtainable from variables KREFRFL1, KREFRFL2, and BTUNG on the public-use tape.
NNGOVARL	No	32	Number of natural gas ovens and ranges. Obtainable from variables OVEN1F, OVEN2F, HGASRANG, and BTUNG.
NOUPPIN	No	33	Presence of insulation in roof for single-family units: No insulation = 1; Some insulation or unknown = 0. Obtainable from variable HINATTIC on the public-use tape.
NROOMS	Yes	33	Number of rooms.
NUMADULTS	No	29	Number of household members who are between 13 and 64 years of age. Obtainable from the variables NAGE01-NAGE12 on the public-use tape.
PCTSTORM	No	29	Percentage of windows and doors that are covered by storm windows or storm doors. Obtainable from the variables DOOR1ALL, DOOR1INS, DOOR2ALL, DOOR2INS, DOOR3ALL, DOOR3INS, WINDOWS, WIND1ALL, WIND1INDS, WIND2ALL, WIND2INS, WIND3ALL, and WIND3INS.

Table A1. Variables Used in Regression Equations (Continued)

Variables	On Public-Use Tape	Page First Used	Description
RACRMS	No	31	Number of rooms that can be air conditioned with electric room units. Equals the number of rooms that can be air conditioned if the dwelling unit does not have a central air-conditioning system. Equals one if the dwelling unit has both room units and a central system. Obtainable from the variables HCENTAC, HROOMAC, NROOMAC, and NROOMS on the public-use tape.
RADEQUIP	No	33	Main space-heating equipment uses radiators or hot-water pipes (Yes = 1, No = 0). Obtainable from the variable EQUIPM on the public-use tape.
SFATTACH	No	40	Dwelling unit is a single-family attached unit (Yes = 1, No = 0). Obtainable from the variable TYPEHOME on the public-use tape.
SMLAPTBD	No	40	Dwelling unit is in a small apartment building (Yes = 1, No = 0). Obtainable from the variable TYPEHOME on the public-use tape.
SOTHHTFO	No	34	Fuel oil is the main space-heating fuel, and the secondary space-heating fuel is not fuel oil or wood (Yes = 1, No = 0). Obtainable from the variables KFLMHEAT and KFLSHEAT on the public-use tape.
SOTHHTNG	No	33	Natural gas is the main space-heating fuel, and the secondary space-heating fuel is not natural gas or wood (Yes = 1, No = 0). Obtainable from the variables KFLMHEAT and KFLSHEAT on the public-use tape.
SWOODHT	No	30	Secondary space-heating fuel is wood (Yes = 1, No = 0). Obtainable from the variables KFLSHEAT on the public-use tape.
TEENS	No	30	Number of household members between the ages of 13 and 19. Obtainable from the variable NAGE01-NAGE12 on the public-use tape.

Table A1. Variables Used in Regression Equations (Continued)

Variables	On Public-Use Tape	Page First Used	Description
TRUNCORD	No	30	Number of cords of wood burned truncated at six cords. Units = one-tenth cord. Obtainable from the variable CORD on the public-use tape.
TVBLACK	Yes	30	Number of black-and-white television sets.
TVCOLOR	Yes	30	Number of color television sets.
UNHEATED	Yes	33	Amount of unheated enclosed floorspace in the dwelling unit.

Appendix B

RESULTS OF REGRESSION ANALYSIS

The standard errors and levels of significance listed in this appendix were obtained from the fourth step in the regression procedure. They are based on the assumption that the variance of the error term is proportional to G, the estimated consumption. For selected coefficients the standard errors were also calculated using the half-sample technique. In this technique the entire four-step robust regression estimation procedure was run for each of 32 half-samples. The variances were computed using the differences between the full-sample estimates and the half-sample estimates. In most cases the results were very close to the values listed in this appendix.

Table B1. Estimates of Coefficients for Regression Using Households Living in Single-Family Detached Homes Where Electricity Consumption Is the Dependent Variable

Independent Variable	Estimate of Coefficient	Standard Error of Estimate	Two-Sided Level of Signif-icance
INTERCEPT	2,614.7530	766.6629	0.0007
NUMADULTS	1,088.5794	189.8177	Less than 0.0001
BUILTYR	339.6044	103.9762	0.0011
PCTSTORM	-19.2800	4.3472	Less than 0.0001
HEATED	1.0980	0.2104	Less than 0.0001
HPOOL	3,842.0099	1,085.3462	0.0004
HTPOOL	10,215.6688	2,886.4758	0.0004
NELFRIG	2,455.6169	451.7848	Less than 0.0001
NFFELFRIG	2,863.3164	362.8396	Less than 0.0001
NELFREZ	3,953.5273	318.0743	Less than 0.0001
NELOVARG	929.7142	181.1381	Less than 0.0001
HWRNGWSH	-2,312.1431	744.0982	0.0019
HAUTOWSH	-4,330.5340	728.4072	Less than 0.0001
HAUTOWSH x NHSLDMEM	1,734.7495	191.0041	Less than 0.0001
HELCLSDY	3,409.5230	411.2129	Less than 0.0001
TVBLACK	836.1728	271.8875	0.0021
TVCOLOR	2,055.3690	316.2878	Less than 0.0001
CFAEQUIP	1,155.5738	374.6923	0.0021
ELWTHT	3,966.6710	954.5912	Less than 0.0001
ELWTHT x NHSLDMEM	2,156.9070	342.4235	Less than 0.0001
ELWTHT x TEENS	3,337.8452	715.5884	Less than 0.0001
ELWTHT x HELDISHW	4,903.5595	827.4341	Less than 0.0001
ELSHEAT x HDD	56.9456	13.0142	Less than 0.0001
ELMHEAT x HDD	990.0705	94.3625	Less than 0.0001
ELMHEAT x HDD x HDD	-7.9569	1.9617	Less than 0.0001
ELMHEAT x HDD x HEATED	0.2779	0.0735	0.0002
ELMHEAT x HDD x HEATED x SWOODHT x TRUNCORD	-0.0032	0.0006	Less than 0.0001
ELMHEAT x HDD x HEATED x BUILTYEAR	-0.0373	0.0063	Less than 0.0001
ELMHEAT x HDD x HEATED x NBATHRMS	0.0756	0.0215	0.0004
ELMHEAT x HDD x HEATED x PCTSTROM	-0.0015	0.0004	0.0007
RACRMS x CDD	186.6288	38.8665	Less than 0.0001
RACRMS x CDD x INCOME79	10.6565	2.8786	0.0002
CACRMS	409.4043	134.2959	0.0023
CACRMS x CDD	341.0278	75.5023	Less than 0.0001
CACRMS x CDD x INCOME79	9.9593	2.7631	0.0003
CACRMS x CDD x CDD	-17.8836	4.6018	Less than 0.0001

Table B2. Estimates of Coefficients for Regression Using Households Living in Single-Family Detached Homes Where Natural Gas Consumption Is the Dependent Variable

Independent Variable	Estimate of Coefficient	Standard Error of Estimate	Two-Sided Level of Signif- icance
NGAPLIDX	2.2728	0.3388	Less than 0.0001
HODGASLT	13,279.5561	4,197.5617	0.0016
NGPOOLHT	47,254.5513	10,946.3122	Less than 0.0001
NGCACRMS x CDD	1,531.4794	190.6077	Less than 0.0001
NGWTHT	13,938.2185	2,417.9503	Less than 0.0001
NGWTHT x NHSLDMEM	5,670.3061	607.8977	Less than 0.0001
NGSHEAT x HDD	775.5358	122.1136	Less than 0.0001
NGMHEAT	11,734.1752	2,592.0192	Less than 0.0001
NGMHEAT x HDD	1,154.7755	114.6721	Less than 0.0001
NGMHEAT x HDD x RADEQUIP	525.3524	103.4086	Less than 0.0001
NGMHEAT x HDD x CFAEQUIP	215.2257	66.0483	0.0011
NGMHEAT x HDD x HEATED x BUILTYR	-0.0455	0.0055	Less than 0.0001
NGMHEAT x HDD x HEATED x HEADAGE	0.0033	0.0007	Less than 0.0001
NGMHEAT x HDD x HEATED x CHILDPRE	0.1104	0.0397	0.0054
NGMHEAT x HDD x HEATED x NROOMS	0.0361	0.0069	Less than 0.0001
NGMHEAT x HDD X HEATED x NOUPPIN	0.1779	0.0449	Less than 0.0001
NGMHEAT x HDD x HEATED x NBATHRMS	0.0889	0.0211	Less than 0.0001
NGMHEAT x HDD x HEATED x SOTHHT	-0.1241	0.0313	Less than 0.0001
NGMHEAT x HDD X HEATED x BASESFU	-0.1671	0.0284	Less than 0.0001
NGMHEAT x HDD x SWOODHT x TRUNCORD	-14.5995	2.8712	Less than 0.0001
NGMHEAT x HDD x UNHEATED	0.2064	0.0476	Less than 0.0001
NGMHEAT x HDD x NDRSAWS	12.2160	4.0052	0.0023
NGMHEAT x HDD x HDD x PCTSTORM	-0.0782	0.0127	Less than 0.0001

Table B3. Estimates of Coefficients for Regression Using Households Living in Single-Family Detached Homes Where Fuel Oil Consumption Is the Dependent Variable

Independent Variable	Estimate of Coefficient	Standard Error of Estimate	Two-Sided Level of Significance
FOWTHT	30,999.0166	5,236.7468	Less than 0.0001
FOSHEAT	22,180.0847	2,705.4357	Less than 0.0001
FOMHEAT	42,938.0614	6,104.5076	Less than 0.0001
FOMHEAT x RADEQUIP	20,530.6213	5,757.5719	0.0004
FOMHEAT x BUILTYR	-4,589.3523	1,209.3584	0.0002
FOMHEAT x HDD x HEATED	0.5964	0.0969	Less than 0.0001
FOMHEAT x HDD x HEATED x SWOODHT x TRUNCORD	-0.0114	0.0012	Less than 0.0001
FOMHEAT x HDD x HEATED x BASESFU	-0.2818	0.0739	0.0002
FOMHEAT x HDD x NOUPPIN	487.0920	152.7990	0.0015
FOMHEAT x HDD x HEATED x SOTHHTFO	-0.1402	0.0480	0.0037
FOMHEAT x UNHEATED	9.6239	3.3383	0.0041
FOMHEAT x HDD x NDRSAWS	27.0782	7.0031	Less than 0.0001

Table B4. Estimates of Coefficients for Regression Using Households Living in Single-Family Detached Homes Where LPG Consumption Is the Dependent Variable

Independent Variable	Estimate of Coefficient	Standard Error of Estimate	Two-Sided Level of Significance
LPAPLIDX	3.0014	0.4258	Less than 0.0001
LPWTHT x NHSLDMEM	6,916.5963	729.6707	Less than 0.0001
LPSHEAT x HDD	781.5050	114.0048	Less than 0.0001
LPMHEAT x HDD	1,917.5892	131.6575	Less than 0.0001
LPMHEAT x HDD x HEATED x NBATHRMS	0.1289	0.0329	Less than 0.0001
LPMHEAT x HDD x BASESFU	-741.2733	170.2643	Less than 0.0001

Table B5. Estimates of Coefficients for Regression Using Households Not Living in Single-Family Detached Homes Where Electricity Consumption Is the Dependent Variable

Independent Variable	Estimate of Coefficient	Standard Error of Estimate	Two-Sided Level of Significance
ELCONSFD x MOBILEHM	1.1491	0.0354	Less than 0.0001
ELCONSFD x SFATTACH	0.8361	0.0245	Less than 0.0001
ELCONSFD x SMLAPTBD	0.8455	0.0173	Less than 0.0001
ELCONSFD x LRGAPTBD	0.8266	0.0281	Less than 0.0001
ELCONWT x MOBILEHM	-0.5575	0.1340	Less than 0.0001
ELCONHT x LRGAPTBD	-0.3943	0.0703	Less than 0.0001

Table B6. Estimates of Coefficients for Regression Using Households Not Living in Single-Family Detached Homes Where Natural Gas Consumption Is the Dependent Variable

Independent Variable	Estimate of Coefficient	Standard Error of Estimate	Two-Sided Level of Significance
NGCONSFD x MOBILEHM	0.8775	0.0522	Less than 0.0001
NGCONSFD x SFATTACH	0.8220	0.0426	Less than 0.0001
NGCONSFD x SMLAPTBD	0.8728	0.0300	Less than 0.0001
NGCONSFD x LRGAPTBD	0.6127	0.0522	Less than 0.0001
NGCONSBS	1.2015	0.2697	Less than 0.0001

Table B7. Estimates of Coefficients for Regression Using Households Not Living in Single-Family Detached Homes Where Fuel Oil Consumption Is the Dependent Variable

Independent Variable	Estimate of Coefficient	Standard Error of Estimate	Two-Sided Level of Significance
FOCONSFD x MOBILEHM	1.1233	0.1557	Less than 0.0001
FOCONSFD x SFATTACH	0.9189	0.0773	Less than 0.0001
FOCONSFD x APTBLDG	0.9739	0.0654	Less than 0.0001

Table B8. Estimates of Coefficients for Regression Using Households Not Living in Single-Family Detached Homes Where LPG Consumption Is the Dependent Variable

Independent Variable	Estimate of Coefficient	Standard Error of Estimate	Two-Sided Level of Significance
LPCONSFD x MOBILEHM	0.7242	0.0466	Less than 0.0001
LPCONSFD x MULTIUNIT	1.2260	0.1572	Less than 0.0001

Table B9. Estimates of Coefficients for Regression Where Kerosene Consumption Is the Dependent Variable Using All Households

Independent Variable	Estimate of Coefficient	Standard Error of Estimate	Two-Sided Level of Significance
FOCONSFD	0.9245	0.1227	Less than 0.0001

Appendix C

ADJUSTMENTS TO SPACE-HEATING COMPONENT TO REFLECT CALENDAR YEAR CONSUMPTION

This appendix contains the details of the procedure used to adjust the space-heating component of energy consumption to reflect consumption from January 1980 through December 1980 (calendar year 1980). The procedure is described in general terms. It can be applied to any of the fuels. In producing the calendar year 1980 estimates, the fuel oil and kerosene consumption amounts are combined. This last convention was also used in producing the consumption estimates for the April 1980 through March 1981 period.

The adjustments that were used can be divided into seven cases. The factors determining the cases are the main space-heating fuel on November 1979, the main space-heating fuel on November 1980, and the secondary space-heating fuels on November 1980. By assumption 1, the main space-heating fuel on November 1980 was also the main space-heating fuel during the period from April 1980 through March 1981. The main space-heating fuel on November 1979 was also the main space-heating fuel during the period from January 1980 through March 1980. By assumption 2, any fuel listed as a secondary space-heating fuel on November 1980 was also a secondary space-heating fuel from January 1980 through March 1981. In the regression procedure, the convention used was that if a fuel was the main space-heating fuel then it was not counted as a secondary space-heating fuel, even if the respondent listed it as one. This convention will be used for estimating calendar year consumption. The seven cases follow:

Case 1: The fuel was not used as a secondary or main space-heating fuel in either November 1979 or November 1980.

Case 2: The fuel was listed as the main space-heating fuel in November 1980. The respondent stated that there was no change in the main space-heating fuel between November 1979 and November 1980.

Case 3: The fuel was listed as a secondary space-heating fuel on November 1980. The fuel was not listed as the main space-heating fuel in either November 1979 or November 1980.

Case 4: The fuel was not listed as the secondary or main space-heating fuel on November 1980 but was listed as the main space-heating fuel in November 1979.

Case 5: The fuel was listed as a secondary space-heating fuel but not the main space-heating fuel in November 1980. The fuel was listed as the main space-heating fuel in November 1979.

Case 6: The fuel was listed as the main space-heating fuel in November 1980, but the respondent stated that a different fuel was used as the main space-heating fuel in November 1979. The fuel was not listed as a secondary space-heating fuel in November 1980.

Case 7: The fuel was listed as the main space-heating fuel in November 1980, but the respondent stated that a different fuel was used as the main space-heating fuel in November 1979. The fuel was also listed as a secondary space-heating fuel in November 1980.

In the adjustment procedure, the following heating degree-day amounts are used: HDDJM80 is the heating degree-days base 60°F for the period from January 1, 1980, through March 31, 1980; HDDAD80 is the total from April 1, 1980, through December 31, 1980; and HDDJM81 is the total from January 1, 1981, through March 31, 1981. These amounts were obtained for each household interviewed in the survey. The sum of HDDAD80 and HDDJM81 equals the heating degree-days used in the regression procedure.

The adjustment made for each case is listed:

Case 1: No adjustments are necessary. The heating component is zero for both the April 1980 through March 1981 period and the 1980 calendar year.

Case 2: The space-heating component needs to be adjusted for changes in heating degree-days. By assumption 3, one needs only to multiply the space-heating component by (HDDJM80 + HDDAD80)/(HDDAD80 + HDDJM81).

Case 3: By assumption 2, it was assumed that the fuel is a secondary heating fuel from January 1980 through March 1981. By assumption 3, one needs only to multiply the space-heating component by (HDDJM80 + HDDAD80)/(HDDAD80 + HDDJM81).

Case 4: By assumption 1, one can assume that the fuel was the main space-heating fuel from January 1980 through March 1980 and was not used as the main or secondary space-heating fuel from April 1980 through March 1981. Hence the space-heating component for the interview year is zero. This needs to be adjusted to reflect calendar year consumption by adding an estimate for the consumption from January 1980 to March 1980. Estimate this by calculating the space-heating regression estimate, assuming the fuel is the main space-heating fuel, and multiply by (HDDJM80)/ (HDDAD80 + HDDJM81).

Case 5: By assumption 1, one can assume the fuel was the main space-heating fuel from January 1980 through March 1980 and was a secondary space-heating fuel from January 1980 through March 1981. The space-heating component must be adjusted by subtracting the secondary space-heating contribution for January 1981 through March 1981 and adding the main space-heating contribution for January 1980 through March 1980. Let BTUSPH be the space-heating component for the period from April 1980 through March 1981. Estimate the secondary space-heating contribution for January 1981 through March 1981 by SSHJM81 = (BTUSPH) x (HDDJM81)/ (HDDAD80 + HDDJM81). Then SSHAD80 = BTUSPH-SSHJM81 is the space-heating consumption for April 1980 through December 1980. Let REGMSH be the regression estimate for the space-heating component for April 1980 through March 1981, assuming the fuel is the main space-heating fuel. Estimate the main space-heating contribution for January 1980 through March 1980 by MSHJM80 = (REGMSH) (HDDJM80)/(HDDAD80 + HDDJM81). Set the space-heating component equal to SSHAD80 plus the maximum of SSHJM80 and MSHJM80, where SSHJM80 = (BTUSPH) x (HDDJM80)/(HDDAD80 + HDDJM81). Note that SSMJM80 is an estimate of the space-heating consumption for secondary space-heating based on the estimate for April 1980 through March 1981. The maximum was used because the author did not want the switch from secondary space heating to main space heating to result in a decrease in the space-heating component.

Case 6: By assumption 1, one can assume the fuel was the main space-heating fuel from April 1980 through March 1981 and was not the main space-heating fuel from January 1980 through March 1980. By assumption 2, one can assume the fuel is not a secondary space-heating fuel from January 1980 through March 1980. One needs to adjust the space-heating component by subtracting the main space-heating consumption for January 1981 through March 1981. By assumption 3, one can accomplish this by multiplying the space-heating component by (HDDAD80)/(HDDAD80 + HDDJM81).

Case 7: By assumption 1, one can assume the fuel was the main space-heating fuel from April 1980 through March 1981 and was not the main space-heating fuel from January 1980 through March 1980. By assumption 2, one can assume the fuel was a secondary space-heating fuel from January 1980 through March 1980. One needs to adjust the space-heating component by subtracting the main space-heating consumption for January 1981 through March 1981 and adding the secondary space-heating consumption for January 1980 through March 1980. Let BTUSPH be the space-heating component for the period from April 1980 through March 1981. Estimate the main space-heating consumption for January 1, 1981, through March 31, 1981, by MSHJM81 = (BTUSPH)(HDDJM81)/(HDDAD80 + HDDJM81). Then MSHAD80 = BTUSPH - MSHJM81 is the estimated space-heating consumption for April 1980 through December 1980. Let REGSSH be the regression estimate for the space-heating component for April 1980 through March 1981, assuming the fuel is the secondary space-heating fuel but not the main space-heating fuel. Estimate the secondary space-heating consumption for January 1980 through March 1980 by SSHJM80 = (REGSSH) x (HDDJM80)/(HDDAD80 + HDDJM81). Set the space-heating component equal to MSHAD80 plus the minimum of MSHJM80 and SSHJM80 where MSHJM80 = (BTUSPH) x (HDDJM80)/(HDDAD80 + HDDJM81). Note that MSHJM80 is an estimate of the space-heating consumption for main space heating based on the estimate for April 1980 through March 1981. The minimum was used because the author did not want the switch from main space heating to secondary space heating to result in an increase in the space-heating component.

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