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Stephen Meyers
(Masters Paper)

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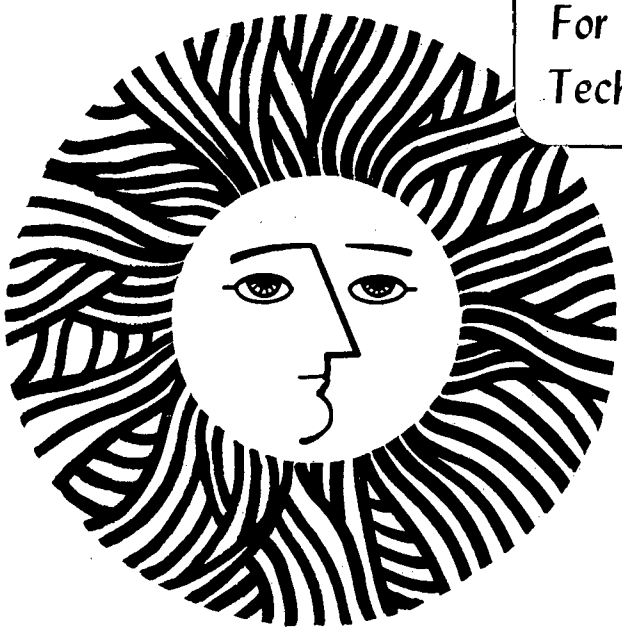

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Residential Energy Use and Conservation in the United States

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ABSTRACT

A portrait is presented of residential energy use in the United States disaggregated by fuel and end-use for the period March 1978 - April 1979. The results are based on analysis of the National Interim Energy Consumption Survey, a major national survey of residential energy use. It is estimated that space heating accounted for 63% of total residential energy use, water heating 15%, cooking 5%, and other electric appliances 16%. It is also shown that, after accounting for climate and dwelling size, the average oil-heated dwelling uses 1.24 times as much energy for space heating as the average gas-heated dwelling and 2.91 times as much as the average electrically-heated dwelling, and the average gas-heated dwelling uses 2.34 times as much as the average electrically-heated dwelling. These differences are attributable to relative heating system efficiencies, differences in weatherization levels, and other factors. An assessment is made of the extent of energy conservation that occurred between 1970 and the period studied. The indicator for which the most reliable data are available, gas space heating per degree-day, showed a drop of 16.4%.

PREFACE

This study began as a contribution to a project investigating the nature of residential energy demand in industrialized nations. In the process of assembling a data base for the United States similar to those already compiled for other countries,[1] it became evident that a reliable, detailed portrait of residential energy use in the U.S. did not exist. This study was undertaken as an attempt to provide such a portrait for interested researchers and policymakers both in the U.S. and abroad.

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[1] - See L. Schipper, A. Ketoff, and S. Meyers, "International Comparison of Residential Energy Use," Lawrence Berkeley Laboratory, May 1981.

CONTENTS

NOTE ON UNITS

Energy consumption data in this report are presented in the International System of Units (SI).

kJ = Kilojoule = 10^3 Joule = 0.948 Btu.

MJ = Megajoule = 10^6 Joule = 0.948 thousand Btu.

GJ = Gigajoule = 10^9 Joule = 0.948 million Btu.

PJ = Petajoule = 10^{15} Joule = 0.948 trillion Btu.
1000 PJ are approximately equal to 1 quad (10^{15} Btu).

All energy consumption data refer to consumption within the dwelling boundary. Conversion or transmission losses that occur outside the building boundary are not counted (thus, 1 kWh = 3.6 MJ).

Area is given in square meters (m^2); 1 m^2 = 10.76 ft^2.

Heating degree-days are given in Celsius values (base 18^o).

Chapter 1
Introduction

In the eight years since the first "oil crisis" Americans have gradually learned to live with higher energy prices. Exhorted by government and utilities and spurred to action by soaring fuel bills, they have bought caulking, weatherstripping, and insulation, turned down thermostats, closed off rooms, put on sweaters, and like Third World villagers, even gathered firewood.

Although this activity has attracted much attention, the fact remains that we know very little about the effect of these actions at either the household or the national level. To be sure, there are signs of apparent energy conservation. Average residential electricity use per customer as reported by the electric utility industry rose hardly at all between 1978 and 1979 after increasing by an average annual rate of almost three percent in the four years prior to 1978. Average natural gas consumption per customer decreased by two percent from 1978 to 1979, and fell a whopping six percent between 1979 and 1980. It is not altogether clear what these aggregate changes mean, however. The drop in gas consumption from 1978 to 1979 could be due to the fact that winter was a good bit colder in 1978 than in 1979. Electricity use is less sensitive to anuual fluctuations in weather conditions (since heating and cooling make up a smaller fraction of total electricity consumption than is the case with gas), but the fact that average consumption per customer rose in 1980 could be due to the unusually warm summer of that year.

The ambiguity of these aggregate statistics points out the need for a more detailed analysis of residential energy use. To understand changes in energy consumption patterns, it is necessary to break up total residential energy consumption into its constituent pieces: the uses to which energy is put in the home.

Past efforts to estimate how much electricity, gas, oil, or other fuel is used to perform services like space heating and cooling, water heating, and cooking have been hampered by a lack of measured energy consumption data. It is only recently, in fact, with the Department of Energy's Residential Energy Consumption Surveys (RECS), that a data base containing information on measured energy consumption of households throughout the United States has been available. The present study is the product of an exercise designed to use data gathered in the first of the RECS surveys, the National Interim Energy Consumption Survey (NIECS), to piece together a picture of residential energy consumption by fuel and end-use for the April 1978 - March 1979 period.[1] Although neither the NIECS survey nor the methods employed in this study are without problems, the result is believed to be a more complete and accurate description of residential energy use in the United States than has existed to date.

This report is divided into two parts. The main body presents and discusses the results of the study. Following a general description of methods, estimates of average consumption of oil, natural gas, electricity, and liquified petroleum gas (LPG) are presented for the major household end-uses, and differences in consumption levels among the fuels are discussed.[2] Combining these estimates with survey data on the number of households using the various fuels for each end-use, a portrait of energy flows through the U.S. residential sector is drawn. Baseline indicators from which changes in patterns of energy consumption can be detected are developed, and consideration is given to the reliability of historical comparisons in attempting to assess the extent of energy conservation.

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[1] - It was originally intended to perform a similar exercise with data from the second RECS survey, the Household Screener Survey, covering the April 1979 - March 1980 period, but the data tape necessary to do the analysis was not available within the time frame of this study.

[2] - Five end-use categories are considered: space heating, water heating, cooking, air-conditioning, and "other appliances."

The second part of the report consists of a number of technical appendixes which describe in detail the sources and methods used to derive the results upon which the previous discussion is based. The reliability of these methods is considered, and the results are compared with those of other studies. As this section strives for clarity and completeness of documentation more than expository style, parts of it may be somewhat dense for the general reader.

Chapter 2

Disaggregating Residential Energy Consumption[1]

The National Interim Energy Consumption Survey (NIECS) was the first large survey to collect data on household consumption of all commercial energy forms (except wood and coal). For most of the 4081 households in the NIECS sample, utilities and fuel suppliers serving the selected households were contacted to determine the household's consumption of electricity, natural gas, fuel oil and kerosine, and LPG during the period April 1978 - March 1979.[2] This information is useful for certain analytical purposes, but it reveals neither how the therms, kilowatt-hours, and gallons was used, nor how much was used in the performance of each household task.

Although the amount of energy used for the various household purposes was not directly measured in the NIECS survey, it is possible to estimate the average energy consumed by a group of surveyed households for the major end-uses. This can be done in either of two ways. One method makes use of a recently developed regression technique known as conditional demand analysis (Parti and Parti, 1980; George, 1981). The other method, less robust from a statistical standpoint but also more readily fathomable by non-econometricians, involves the careful selection and comparison of similar groups of households, or cohorts, in an effort to isolate energy consumption for a particular end-use. The latter method was used in this study. Although it lacks the statistical precision of conditional demand analysis, it also does not leave the reader having to trust that the analyst dealt properly with the several econometric problems that can result in biased (incorrect) estimates of average energy consumption.

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[1] - For complete discussion of the sources and methods to derive end-use energy consumption, see Appendix A.

[2] Energy consumption records were not received for some of the NIECS households. In cases where data were missing or incomplete, consumption over the entire period was imputed using a regression model. See Appendix A for discussion.

With the "cohort comparison" method, the derivation of each estimate is subject to a "test of reasonableness" that even the non-technical reader can perform.

The Cohort Comparison Method

The method used in this study is actually a two-stage procedure. In the first stage, the object is to estimate the average energy consumption for a particular end-use by a selected sub-group of sampled households. To estimate average consumption of gas for space heating, for example, two groups of households (cohorts) are expected to have similar patterns of gas consumption in all respects save one: use of gas for space heating. Thus, in the first stage of the procedure, average gas consumption for space heating is estimated as:

> Average total gas consumption by households using gas for space heating, water heating, and other purposes
>
> minus
>
> Average total gas consumption by households using gas for water heating and other purposes, but not for space heating.

Assuming that the average total gas consumption of the second cohort is equal to the non-space-heating gas consumption of the first cohort, the difference between the averages is the consumption of gas for space heating by the first cohort. Of course, we do not know the non-space-heating gas consumption of the first cohort by direct measure. We can, however, compare the two cohorts to test the hypothesis that their non-space-heating gas consumption is similar. In the above example, we help ensure the similarity of the cohorts by selecting only those households that use gas for water heating. We also check whether other uses of gas (cooking, clothes drying, air conditioning) are present in similar proportions in the two cohorts.

To properly isolate the average gas consumption for space heating by the first cohort, we not only want the presence of other gas-using appliances to be comparable in the two cohorts; we also want to know whether the cohorts used the same average amount of gas for water heating, cooking, etc. To check this, we take certain household characteristics as proxies for gas consumption for water heating and cooking. In the case of water heating, if two cohorts average about the same number of persons per household, have a similar proportion of households with hot-water-using appliances (clothes washers, dishwashers), have a roughly comparable distribution among climatic regions, and average about the same family income, it is assumed that their consumption of gas for water heating is similar. In the case of gas consumption for cooking, which is believed to have a smaller magnitude of variation among households than water heating, we look at the average number of household members. If the two cohorts differ substantially with respect to these characteristics, it is necessary to perform a balancing to estimate the extent to which the average gas consumption of the second cohort is indeed likely to be similar to the non-space-heating gas consumption of the first cohort (see Appendix A).

When the average gas consumption for space heating of the first cohort has been estimated as accurately as possible, we are ready to move on to the second stage of the estimation procedure, in which we project the estimated gas consumption for space heating of the NIECS cohort to the national population of households using gas for space heating.[1] In so doing, we hypothesize that the gas consumption for space heating of the selected cohort is similar to that of the national population. To test this hypothesis, we compare the two groups with respect

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[1] - Since there exists no recent detailed census of all households in the United States, the national population of households using a fuel for a particular end-use must be characterized using survey data. Because the necessary data from the 1978 Annual Housing Survey (a sample of some 60,000 households) were not available, it was necessary to use NIECS data to characterize the national population in each case. The national estimates made from the NIECS survey are subject to sampling variability; the, so-called national population used in this study may be somewhat different from the actual national population that it represents.

to characteristics that are likely to affect their gas consumption for space heating: the distribution of dwelling and heating system types, the extent of weatherization, average income, the price paid for the heating fuel, and the regional distribution within the two groups. Since energy consumption for space heating is strongly affected by the climate in which the household finds itself, this latter characteristic is quite important. In these cases where the regional distribution within the NIECS cohort is significantly different from that of the national population, a weighting technique is applied to make the effective distribution of the NIECS cohort the same as that of the national population. In the majority of cases the selected NIECS cohort represents a substantial fraction of the national population; the comparison then is fairly simple. Where there are significant differences between the selected cohort and the national population, appropriate adjustment is made to the average consumption of the NIECS cohort.

Reliability of Unit Consumption Estimates

The extent to which the energy consumption estimates accurately reflect the actual average consumption of millions of U.S. households depends on factors related to both the NIECS survey and the methods used in this study to derive the estimates. The accuracy of the survey is obviously important. The cohort of households using oil for space heating, for example, should not have any households that actually did not use oil for space heating, nor should the cohort of households using gas only for water heating and cooking have some households that actually used gas for space heating as well. Nevertheless, in a survey like NIECS incorrect responses are inevitable.

Although efforts have been made in this study to "weed out" households that obviously do not belong in the selected cohorts, a certain amount of error no doubt still remains.[1]

With respect to the method employed in this study to derive unit consumption estimates, two factors are particularly important:

1) Whether the cohorts used to make the estimates had similar energy consumption for purposes other than the end-use that is being determined (e.g., all non-space-heating uses);

2) Whether the estimated average energy consumption for a particular end-use by the NIECS cohort is similar to that of the respective national population of households.

It is important to remember that these questions cannot be answered directly. Rather, it is necessary to examine the groups of households with respect to factors that indicate whether their energy consumption for a particular end-use is in fact likely to be similar. The details of the comparisons and the assumptions used in assessing the accuracy of each estimate are described in Appendix A. For each estimate, a statement is made as to the likely direction of error. Although it is not possible to attach a confidence interval to each estimate, it is believed that they are probably accurate to within 5% or less.

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[1] - The discarding of households that obviously did not belong in a particular cohort is described for each unit consumption estimate. These households were identified by listing the energy consumption of each household in a cohort, and then examining those households that appeared to be erroneously placed for features that might explain their too high (or low) consumption. Discretion was exercised in discarding households such that the probability of a household having been wrongly discarded is very low.

Chapter 3

End-Use Energy Demand in American Homes

The end-use approach to energy accounting has become increasingly accepted as the most accurate way to characterize energy consumption patterns. The reason for this is evident: energy is not used for its own sake, but rather for the services it delivers. Thus, it is logical to keep track of energy consumption by associating it with the tasks for which energy is used. In the residential sector of industrialized countries the most commonly demanded services of energy are space conditioning, water heating, cooking, and lighting. In addition, a number of appliances perform various other services that have become increasingly demanded by households: refrigeration and freezing of food, washing and drying of clothes (and dishes), television, and miscellaneous others.

Households in the United States use a variety of fuels to perform the major energy-demanding tasks in the home. Virtually all households use electricity for one purpose or another. The vast majority also use some other fuel; natural gas, fuel oil and kerosene, LPG, wood, and coal are all found (in descending order of popularity) in U.S. households. To capture the differences in usage patterns from one fuel to the next, an end-use energy breakdown must include the average consumption of each fuel by households using it for the various tasks. Analysis of consumption data from the NIECS survey (covering the April 1978 - March 1979 period) by the method described in the previous section has allowed estimation of average consumption of the main household fuels for space heating, water heating, cooking, air-conditioning, and "other appliances," as shown in Table 1.[1]

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[1] - An average electricity consumption for "other appliances" has been estimated by selecting households not using electricity for space heating or cooling, water heating, or cooking. The category includes lighting and refrigeration.

Table 1
Average Household Energy Consumption
by End-Use and Fuel, April 1978 - March 1979.
(Gigajoules)

	Gas	Oil	Electricity	LPG
Space heating	95	127	35	65
Water heating	26	38	14	17
Cooking	10	-	a	9
Air-conditioning	-	-	9	-
Other appliances	-	-	16	-

[a] - Average electricity consumption for cooking cannot be derived by the method used in this study.

Several things stand out among the values in Table 1: that oil consumption is much higher than gas for space heating and water heating, and that electricity consumption for space heating is so much lower than gas or oil. These differences are expected. The seasonal efficiency of gas furnaces is thought to be higher than that of oil furnaces, and with electric heating, of course, there are no conversion losses within the building boundary.

Space Heating

A closer look at the consumption data from which each average was derived sheds further light on the differences between the space heating fuels (Table 2). A high percentage of the population of households heating with oil is located in the Northeast, and faces a colder average climate (10% more heating degree-days) than the population of gas-heating households, which is distributed fairly evenly around the country. The oil-heating housing stock is also found more heavily in older buildings than the gas-heating stock, a factor that could be a sign of older, less-efficient heating systems. The modest percentage of homes built since 1979 in the oil-heating population indicates a smaller presence of newer, better-insulated homes, as well. On the other hand, the oil-heating stock also has a higher percentage of households in multi-family dwellings; we would expect them to exert a downward influence on the population's average energy consumption for space heating.

Table 2
Characteristics of Housing Stocks by Space Heating Fuel 1978
(percentages)

	Oil	Gas	Electricity	LPG	All homes
Dwelling type					
single-family	63	71	58	75	68
multi-family	33	26	37	3	27
mobile home	4	3	5	22	5
Vintage (year built)					
before 1940	47	32	8	29	32
1940-1959	28	31	13	24	27
1960-1969	16	22	27	22	22
1970-1978	8	15	52	24	20
Location					
Northeast	58	15	8	3	22
North Central	18	33	14	32	26
South	20	28	54	56	33
West	5	24	25	10	19
Heating degree-day total (C)[a]	3061	2785	2253	-	2784
Estimated average floor area (m^2)	125.0	127.6	135.7	103	129.3
Weatherization[b]					
storm windows,[c] all	50	37	38	26	38
storm windows, some	27	18	12	14	19
attic insulation	69	65	85	77	68
(6+ inches)[d]	58	53	67	44	56
wall insulation	50	45	72	62	50
Annual income					
< $15,000	57	53	51	67	55
> $35,000	7	9	8	4	8
Number of dwellings (10^3)	16071	42521	12258	4130	77167
(%)	21	55	16	5	100

See following page for notes.

NOTES TO TABLE 2

a - Weighted according to the regional distribution of households heating with each fuel; refers to the April 1978 - March 1979 period.

b - Percentages for weatherization features refer to the stock of households in single-family dwellings, mobile homes, and buildings with 2-4 units (i.e., dwellings in buildings with five or more units are excluded).

c - Storm windows or insulating glass.

d - Percentage refers to dwellings with attic insulation.

Columns may not sum to 100% due to independent rounding.

Sources: Annual Housing Survey for dwelling type, vintage, location, income, and number of dwellings. National Interim Energy Consumption Survey for weatherization and floor area.

Households heating with electricity are on the average much newer than either oil or gas-heating households, with half of the stock (as of late 1978) having been built during the 1970s. Given this, it is not so surprising that electrically-heated homes are on the average better insulated than oil or gas-heated homes, despite the fact that they are located in considerably warmer climates (almost 80% in the South and West) where one would expect to find less insulation. A higher proportion of electric-heating households are found in multi-family buildings than is the case for the other heating fuels. Despite this, the estimated average floor area of electrically-heated homes is a good bit higher than similar averages for oil and gas-heated homes, indicating the presence of many large single-family dwellings.

To account for the effect of differences in climate and dwelling size, one can divide the average space heating energy consumption of each population of households by the average heating degree-day total and the average floor area specific to each group (see Appendixes D and E for a description of how these values were calculated). The results of this exercises are shown in Table 3. As can be seen by comparing these numbers with those in Table 1, the ratio of oil-to-gas energy consumption falls somewhat from 1.34:1 to 1.24:1 after accounting for climate and dwelling size. Several factors could explain the higher energy intensity of oil-heated homes, the most likely being lower heating system efficiency (due either to the furnace or the distribution system) and poorer weatherization of the oil-heated housing stock (which contains a higher proportion of older dwellings than the gas-heated housing stock).

Table 3

Energy Consumption for Space Heating, April 1978-march 1979

	Oil	Gas	Electricity
Space heating (GJ)	127	95	35
per C-degree-day (MJ)	41.5	34.1	15.5
per C-degree-day and per square meter (KJ)[a]	332	267	114

[a] - An approximate conversion from GJ per C-degree-day per square meter to Btu per F-degree-day per square foot can be found by dividing by a factor of 21.

The ratio of gas-to-electricity consumption drops by a greater proportion after correcting for climate and dwelling size: from 2.71:1 to 2.34:1. This ratio is still higher than one would expect, but several factors could explain the outcome:

1) the greater presence of attic and wall insulation in electrically-heated homes;

2) the higher proportion of households in multi-family buildings in the electric-heating group;[1]

3) the use of heat pumps, which have an effective efficiency of greater than 100%, in the electric-heating stock (9% of electric-heating households had heat pumps as of late 1978);

4) the presence of baseboard electric heating (46% of the electric-heating stock), which both eliminates duct losses associated with warm-air systems and allows the occupant to practice room heating (i.e., heating only rooms in use) more effectively;

[1] - The shared walls in multi-family structures tend to reduce energy consumption for space heating. This effect is in addition to the smaller size of multi-family units, which has already been accounted for in the group's average floor area.

5) the higher cost of electricity ($8.35/GJ vs. $2.55/GJ for gas)[2], which might encourage more frugal behavior on the part of electric-heating households; and

6) the likely possibility that the seasonal furnace efficiency in gas-heated homes is less than 60%.

It should be evident that because of the differences in composition, it is difficult to fairly compare the space heating fuels by reference to the full national population of households using each fuel. A better comparison can be gained by looking separately at households in single and multi-family buildings. A lack of adequate data precludes analysis of space heating energy consumption by NIECS multi-family households using oil or electricity for heating, but estimation of average consumption by single-family households is possible. The results, shown before and after accounting for climate and dwelling size, are given in Table 4. The derivation of these values is discussed in Appendix B.

Table 4
Average Energy Consumption for Space Heating
in Single[a] and Multi-family Dwellings

	Oil	Gas	Electricity
Single-family (GJ)	124	109	46
per C-degree-day (MJ)	43.0	39.1	20.6
per C-degree-day and per square meter (KJ)	270	268	129
Multi-family (GJ)	-	70	-

[a] Single refers to households in detached and attached structures.

It is interesting to note that oil and gas have virtually the same intensity of use in single-family dwellings, after accounting for climate and dwelling size. If gas furnaces are indeed more efficient than

[2] - These are the average prices paid by NIECS households using electricity and gas for space heating. Since electricity is used more efficiently within the building boundary, the difference in the cost of delivered heat (to the distribution system) between electricity and gas is smaller.

oil furnaces, this is a surprising result. It could be explained in part by the higher proportion of storm windows found on oil-heated homes (see Table 2), or by a more frugal use of energy on the part of oil-heating households. (It should be remembered that the estimates of energy use and floor area -- particularly the latter - are subject to some uncertainty.)

Another surprising result is that the average space heating energy consumption in oil-heated single-family dwellings is lower than the average for all oil-heating households (127 GJ). This seems to be surely in error -- until one considers the composition of each average. It turns out that the stock of oil-heated single-family dwellings is located on the average in warmer climates than the stock of all oil-heating households (2886 degree-days vs. 3061 degree-days). After dividing by the number of heating degree-days, the single-family average is in fact slightly higher than that of the entire stock. Accounting for the difference in floor area brings the single-family average well below that of the entire stock, however. Part of this difference may be explained by errors in the estimation of average floor area, but the result nonetheless suggests a more efficient use of energy -- due to either behavior or better weatherization - by households in single-family structures. The stock of oil-heated multi-family dwellings consists heavily of units in older structures in cold climates -- the cities of the Northeast. The evidence of the NIECS survey, although subject to some uncertainty, seems to suggest that these buildings are rather poorly weatherized relative to oil-heated single-family dwellings.

A closer comparison between gas and electric heating also results from looking only at single-family dwellings. Whereas the gas-to-electric ratio (after accounting for climate and dwelling size) was 2.34:1 for the entire stocks, it is only 2.08:1 for single-family dwellings. This result suggests that the higher proportion of multi-family dwellings in the electric-heating stock (37% vs. 26% for gas) did indeed bias the average consumption of the stock downward.

Water Heating

The difference between average household energy consumption for oil and gas water heating is surprisingly great (38 GJ for oil vs. 26 GJ for gas). The size of the difference falls a bit when we look at average energy consumption per person, as households with oil water heating have slightly more persons per household. (More households members generally means higher hot water use: more showers and baths, more clothes and dishes to wash.) But the difference is still significant enough to warrant explanation. Two factors are likely responsible. First, households with oil water heating are located in colder climates than those with gas. This means lower average groundwater temperatures and greater losses from hot water pipes. Second, oil water heating is usually part of the space heating system. During the non-heating season the load on the furnace is quite small relative to its capacity, resulting in low efficiency.

Average consumption for electric water heating is just more than half that of gas. This finding supports the observation that electric water heaters generally have lower losses of heat from the tank due to better insulation, and that gas water heaters in use are about 55-60% efficient.

More difficult to explain is the low value found for LPG water heating. Several factors could account for its being so much less than the similar value for gas. Households using LPG for water heating average fewer members (2.56 vs. 2.88). They are located more frequently in warm climates, and as a group have a somewhat lower saturation of clothes washers. And perhaps being more conscious of the possibility of running down their LPG tank, people with LPG water heating take shorter showers!

Chapter 4

A Portrait of the Residential Sector

The U.S. residential sector, consisting of nearly 80 million households, is a dynamic, ever-changing entity.[1] New households are constantly forming, some occupying existing dwellings, others moving into new ones. The size of households changes, as do the kinds of dwellings they occupy. The spatial distribution of households changes gradually over time, as do the types of fuels that are used to perform energy services in the the house.

The portrait of residential energy use presented here is a snapshot. It focuses on the average manner in which households used the various fuels for space conditioning, water heating, and other purposes over a distinct period: April 1978 through March 1979. Combining this information with the number of households using each fuel for each end-use as of the mid-point in this period (November 1978), we gain a picture of how much of what kind of energy was used for what purpose over the considered period. The details are presented in Table 5. Two things are immediately evident:

1) Gas is the dominant residential fuel, accounting for half of total household energy consumption.[2] Gas was used by 55% of all households at their main space heating fuel, by 54% as water heating fuel, and by 42% as main cooking fuel.

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[1] - The residential sector as typically defined excludes group residences such as dormitories, hospitals, and military barracks.

[2] - The picture changes significantly if we consider the energy that went into electricity production. According to the Department of Energy, 71 PJ of energy were lost for every 29 PJ of electricity sold to residential customers in 1978 (EIA, 1981). From this perspective, electricity accounted for 50% of residential energy use, and the share of gas drops to 32%.

2) More energy is used for space heating than for all other purposes combined. This is partly due to the fact that electricity, which is very efficient at the point of end-use relative to oil and gas, has not penetrated the space heating market to the extent it has in water heating and cooking. It is also true that the April 1978 - March 1979 period was much colder than the 50-year average. However, a "normal" winter would have reduced the share of space heating only slightly.

Some comment is germane on the use of wood as the oldest of fuels is now enjoying a renaissance of sorts. The value given for total residential wood consumption in Table 5 is considerably less than other estimates, particularly that of the Wood Energy Institute, which estimated residential consumption of wood in 1979 at about 50 million cords; around 1000 PJ. This figure was based on a nation-wide Gallup Survey that estimated the number of homes with wood stoves at five million, and the number with fireplaces at 18 million. The 1978 Annual Housing Survey, however, yielded a total of only one million households who used wood as main heating fuel. Results from the NIECS survey suggest that another 11 million households used wood as a secondary heating fuel. Thus, there appears to be some discrepancy between the government and the Gallup surveys. Presumably survey respondents were uncertain whether wood was their main heating fuel, or whether their fireplace was used for heating or just for sitting around. (The Gallup survey indicated that 2.2 million of the 18 million households with fireplaces didn't use it at all, and another 5.2 million used it infrequently.) The estimate of wood energy consumption given in Table 5 does not account for wood consumption in households not reporting its use for primary or secondary heating, and thus is likely conservative.

Table 5
Residential Energy Use in the United States, April 1978 - March 1979

Households: 77.167x10^6 Population: 215.2x10^6 Climate Index: 1.08

	Heat	Hot Water	Cooking	Appliances(AC)	Total
Oil (PJ)	2041	267	1	-	2309
-Stock,(10^3)	16071	7039	107	-	-
-Unit Cons,(GJ)	127	38	10		
Gas (PJ)	4039	1078	326	~225	5668
-Stock,(10^3)	42521	41468	32576	-	-
-Unit Cons,(GJ)	95	26	10	-	-
LPG (PJ)	268	53	47	-	368
-Stock,(10^3)	4130	3129	5225	-	-
-Unit Cons,(GJ)	65	17	9	-	-
Electricity (PJ)	451	340	167	1235(372)	2565
-Stock,(10^3)	12258	24295	38779	77167	-
-Unit Cons,(GJ)	35	14	4.3	16(9)	-
Wood (PJ)	300	1	3	-	304
-Stock,(10^3)	1066	46	191	-	
-Unit Cons,(GJ)	80	30	15	-	
Coal & Other (PJ)	52	7	1	-	60
-Stock,(10^3)	523	223	54	-	
-Unit Cons,(GJ)	100	30	15		
TOTAL,(PJ)	7151	1746	545	1832	11274
	(63%)	(15%)	(5%)	(16%)	(100%)

See following page for notes.

Notes to Table 5

Note: AC= air conditioning; Unit cons = unit consumption

The end-use category "Appliances" refers to all usages of electrical city or gas other than space heating, water heating, and cooking; it includes lighting.

Electricity consumption refers to purchases by the household and does not include production and distribution losses.

The Climate Index is the ratio of the population-weighted national heating degree-day total for the April 1978 - March 1979 period to the national average over the 1931-1980 period, 2579 degree-day (4778 degree-days, base 65°F). The source for climate data is the National Climatic Center publication, "State Regional and National Monthly and Seasonal Degree Days Weighted by Population".

Stock refers to the number of households using a particular fuel for a particular end-use.

Unit Consumption (Unit Cons) is the average consumption of energy per household.

Population refers to the population in housing units. Source is the Annual Housing Survey.

Oil includes distillate fuel and kerosene. Coal includes coke.

The value given in the table for total energy consumption of each fuel for each major end-use is calculated as the product of the average consumption per household (or unit energy consumption) times the number of households using the fuel for the particular end-use. (In the case of space heating, energy consumption for secondary space heating is added to the above product).

The Changing Residential Sector

In considering the current (or recent) state of the residential sector, it is useful to look at how it has evolved over time. Table 6 presents a series of portraits in which we can see how the residential sector has grown and changed in the past 20 years.

In 1960 some 53 million households were home to 177 million Americans, an average of 3.35 persons per household. By 1979 there were over 78 million households with 217 million people, an average of 2.76 per household. This trend toward smaller households, which demographers expect to continue, (though at a slower rate) has important implications for energy use. With fewer persons in each household, we would expect average energy consumption per household for water heating and cooking to be less. This is also true of space heating, but here the effect is more a function of smaller dwelling size ior the mix of dwelling types rather than the number of persons per dwelling. (Of course, changes in dwelling size and type ar largely brought on by changing household demographics.) When looked at on a per-person basis, on the other hand, we would expect some increase in average energy use, as the services of water heating and cooking can be provided more efficiently for a 3 or 4 person household than for a 1 or 2 person household (however, the latter probably eat out more often).

Table 6
Selected Data on the U.S. Housing Stock

	1960	1970	1979
No. of households (10^3)	53024	63445	78572
Persons per household	3.35	3.16	2.76
Households:			
in 1 family structures	75%	66%	68%
with central heating	68%	78%	87%
with air-conditioning	12%	37%	53%a
Households located in:			
Northeast	26%	24%	22%
North Central	29%	28%	26%
South	29%	30%	33%
West	16%	18%	19%
Main heating fuel:			
gas	43%	55%	55%
oil	32%	26%	20%
electricity	2%	8%	17%
LPG	5%	6%	5%
wood & coal	16%	4%	2%
Water heating fuel:			
gas	48%	55%	54%a
electricity	20%	25%	31%a
oil	12%	10%	9%a
none	11%	4%	1%a

a - 1978 data

See following page for notes.

Notes for Table 6

Number of households is total as of April for 1960 and 1970, as of November for 1979 (or 1978).

Single-family-structure includes single-family detached (64% of all households in 1979) and attached dwellings (4%). Households in 2-unit buildings constituted 12% of the occupied stock; those in buildings with 5 or more units 14%; mobile homes 5%. A structure is considered a separate building if it has either open space on all sides (detached) or is separated from other structures by dividing walls that extend from ground to roof (attached -- row houses, townhouses, etc.).

Central heating includes dwellings with a warm air furnace with ducts (52% in 1978); an electric heat pump (1.5%); a steam or hot water system (18%); a floor, wall, or pipeless furnace (8%); or built-in electric units (7%).

Location: Northeast consists of New England and Middle Atlantic states; North Central of East and West Central states; South of South Atlantic, East and West South Central States; West of Mountain and Pacific States.

Household disposable income equals annual personal income minus contributions for social insurance minus tax and payments. It is deflated to 1970 $ using the consumer price index for all items. Source: Statistical Abstract

Sources: 1979 and 1978 Annual Housing Survey, 1970 and 1960 Census of Housing

Another trend with important implications for residential energy consumption is the movement of households away from the Northern regions toward the South and West. In 1960, 55% of U.S. households were located in the Northeast and North Central region; by 1979 this percentage had dropped to 48%. The presumed effect of this migration is that the share of total residential energy use devoted to space heating has fallen from what it otherwise would have been while the share for air-conditioning has increased. (The latter is true in any case, since the percentage of households with air-conditioning has risen from only 12% in 1960 to 53% in 1978.) In terms of end-use energy, the result would be a decrease in total residential consumption, since households in the North use considerably more energy for space heating than those in the South and West use for air-conditioning. The net effect of this shift from oil and gas to electricity on resource energy (i.e., taking into consideration fuel burned to produce electricity) is a more complicated issue, and depends in part on the fuel mix of electric utilities in the South and West. It is reasonable to posit that resource energy consumption has in fact decreased from what it otherwise would have been due to the migration from the North. On the other hand, the peak demand for electric power has grown as a result. Thus, total expenditures for energy are less than they would have been, but capital outlays (for new power plants) are greater.

The fuels used by households for the main residential services -- space heating and water heating -- have also shifted over time. Wood and coal were once important heating fuels, used in 1960 by 16% of all households as their primary space heating fuel. y 1979 the combined share of wood and coal had fallen to only 2%. This drop was due largely to the decreasing popularity of coal (12% share in 1960 vs. less than 1% in 1979); the share of wood in the house heating market has actually increased slightly since 1970.[1]

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[1] - Given the number of wood stoves sold in the last few years, it seems likely that the actual share of wood is greater than that found in the Annual Housing Survey. As indicated earlier, many households using wood for a substantial part of their heating needs were probably uncertain whether it was the main heating fuel.

The use of oil as a space heating fuel has also decreased steadily. In 1979 only one-fifth of all households had oil heating, compared with a share of 32% in 1960. This decline was occurring even before the 1973 oil shock, as oil lost ground to both gas and electricity between 1960 and 1970. Since 1970, most of oil's continued losses in the househeating market have been picked up by electricity, whose share grew rapidly in the early 1970s with the popularity of electric heating in new construction. The use of gas, on the other hand, was about the same in 1979 as it was in 1970 for both space and water heating.

The Residential Section in Perspective

It is commonly stated that the residential sector accounts for about one-fifth of total U.S. energy consumption. While true, this description does not tell the whole story of how households contribute to the American energy picture.

The residential share of U.S. energy use varies among the different fuels, as shown in Table 7. Households account for only a small fraction of total oil consumption, but for over a third of electricity use. Thus, even if all households in the U.S. were to stop using oil for heating, the effect on total oil demand would be modest.

Table 7
The Residential Share of U.S. Energy Use

	Residential use 1978[a] (PJ)	Total U.S. use, 1978 (PJ)	Residential share
Oil	2,360	40,047	6%
Gas	5,769	21,097	27%
Electricity	2,576	7,216	36%
Total[b]	15,168	82,740	18%

[a] Totals for 1978 were estimated from data covering the April 1978 - March 1979 period. Energy consumption for space heating during the latter period was multiplied by the ratio of national heating degree-days. (population weighted) in 1978 to the similar total for the 1978/79 period (1.025).

[b] Resource energy; using an electricity sales-to-resource energy ratio of 0.29.

Source: This study; Monthly Energy Review (DOE, 1981).

Chapter 5

Indicators of Conservation

To most people conservation simply means using less energy. The specialist seeks to define energy conservation more precisely by introducing the concept of service. He or she looks at the processes in which energy is used: Making a ton of steel, heating a house, traveling to Philadelphia. Energy is connected with the particular service it provides, and energy conservation is regarded as using less energy to provide the same level of service. The relationship between energy and service can be examined at the macroscopic level -- total energy use in an economy per unit of gross national product, for example -- but conservation specialists prefer to look at the actual processes in which energy is used.

Delivering the same level of service would logically include the quality of service provided, and it is here that some complications arise. In the case of steel-making things are relatively clear, but for other services provided by energy there is ambiguity. With respect to space heating, what is actually the desired service? A warm space in which to live, or simply a comfortable body temperature? If the latter is sufficient, turning down the thermostat and wearing warmer clothing would be an act of energy conservation. Simply turning the thermostat down and experiencing a lower quality home environment would not, by the above definition, be considered energy conservation, despite the fact that the same amount of energy would be saved.

"Quality of service" can be assessed with reference to objective criteria (e.g., indoor temperature), but it is often a matter of personal perception and tolerance. One person might perceive no reduction in comfort as the result of a lowered indoor temperature, while another might be unpleasant. Thus, in those cases where the result of using energy is an actual service or amenity, rather than a tangible good, assessing energy conservation in abstraction from the person who enjoys the service is bound to be somewhat arbitrary.

Difficulties in Selecting Indicators

Having pointed out some of the conceptual difficulties in identifying energy conservation, we will now attempt to do just that in the area where conservation is perhaps most difficult to pin down: the residential sector. In principle, it is easy to see that a better-insulated, tightly-constructed house will require less energy to keep the interior space at a given temperature, all other things being equal. In practice, however, other things are usually not equal. In attempting to assess the extent of energy conservation in a large number of households, it is important to try to make things as equal as possible, while remaining aware of the things that are not equal.

The first rule of thumb is to avoid (or at least use with care) "something happened" indicators. These are indicators that suggest that something may have happened, but don't reveal any information that allows one to assess exactly what did in fact occur. In the absence of such knowledge, they can lead one to erroneous conclusions. An example is average residential energy consumption per household. The growth seen during the 1960s is not necessarily a sign of increasing energy profligacy. Most if not all of the change can probably be attributed to the rising saturation of central heating, air conditioning and other large electrical appliances seen during those years. By the same token, the dramatic drop in average household consumption in 1973 and 1974 need not be the result of energy conservation alone. As Table 8 shows, warmer weather and the rapid penetration of electricity into the househeating market both contributed to the observed drop in energy consumption. This seems especially true for 1973, a year in which substantial conservation would not have been expected. The fact that average household energy consumption fell again in 1974 despite slightly colder weather, however, is a fairly unmistakable sign of consumer response to the "energy crisis" of late 1973 and early 1974. Since 1974, average household energy consumption has fallen still further, but as the penetration of electric heating has continued to increase, it is uncertain as to how much of the drop is attributable to conservation rather than the shift in heating fuels.

Table 8
Household Energy Consumption in the 1970sa

	1970	1973	1974	1975	1976	1977	1978
Avg. consumption per household (GJ)	165	157	148	145	149	144	142
Heating degree-daysb	2669	2447	2525	2546	2714	2638	2854
Electric heat market share (%)	7.7	10.4	11.9	12.6	13.7	14.8	15.9

[a] The energy consumption data shown here are probably somewhat inaccurate; the errors are consistent throughout the series, however.

[b] population-weighted national total

Sources: Energy Information Administration (EIA, 1981), Annual Housing Surveys, National Climatic Center.

To gain a better assessment of progress in energy conservation it is necessary to account for changes in weather patterns and in the energy forms used to meet household needs. Such corrections are not feasible with aggregate indicators like average energy consumption per household. Hence the need for a disaggregation by fuel and end-use, as presented in Chapter 3. If a similar breakdown existed for a year in the early 1970s, one could assess the extent of energy conservation between then and the period covered in this study with a reasonable degree of certainty (subject to caveats discussed below). Such is unfortunately not the case.

Conservation in Gas Space Heating

The one exception to the general dearth of reliable end-use data is consumption of gas for space heating. Using 1970 data on quarterly gas consumption by region, Dole (1975) estimated gas consumption for non-space heating and then subtracted this figure from total residential gas consumption. To account for gas consumption in mass-metered apartment buildings, he added 22% of commercial gas sales in each quarter to the residential total. Subsequent investigation by Cohn strongly suggested that this 22% figure should have been closer to 13% (Cohn, 1978). Making this correction reduces Dole's estimate of average gas use for space

heating slightly from 109 GJ to 107 GJ.

The comparable estimate from this study for the April 1978 - March 1979 period is 95 GJ, 11% less than the 1970 average. Dividing by the appropriate heating degree-day total for gas-heated homes provides a reasonable measure of the change in consumption not attributable to weather. As Table 9 shows, the drop from 1970 is now a good bit larger.

Table 9
Gas Consumption for Space Heating

	1970	1978/79
Avg. consumption per household (GJ)	107	95
Heating degree-days	2632	2783
Consumption per degree-day (MJ)	40.8	34.1
% change		-16.4

Sources: Based on data from American Gas Association and National Climatic Center; this study.

Before we label the 16% drop in gas consumption seen in Table 9 as the result of energy conservation, however, there are several things to consider. One is the average size of dwellings composing the gas-heating stocks in the two years. If the average size (measured as floor area) of the stock grew from 1970 to 1978, as is plausible, there would be more area to heat. Thus, a better comparative indicator of space heating energy consumption is energy use per degree-day and unit of floor area. Unfortunately, reliable stock-wide estimates of average floor area do not exist for years prior to 1978.

The mix of dwelling types within a particular housing stock should also be considered when making comparisons between groups of particular households. The composition of the stock of gas-heating households changed little between 1970 and 1978, with the proportion of households in single-family structures remaining at 71%. For electricity and oil, however, there has been a trend toward a smaller share of single-family

units, however. Such a trend would probably be reflected in the average floor area of each heating stock, which one can account for. The move toward more or less multi-family units may have an effect on energy consumption over and above that due simply to the smaller relative size of such units. Because of the presence of shared walls and (often) a large thermal mass, households in apartment buildings may require less energy than one would expect from knowing its size alone. To remove this potential source of uncertainty, it is preferable to develop separate consumption estimates for single and multi-family units. This has been done where possible for the 1978/79 period (see Appendix B); the data necessary to do the same for earlier years is unfortunately not available.

In summary, it appears reasonable to conclude that there was a "real" drop (independent of weather) in average gas consumption for space heating between 1970 and 1978/79 of at least 16%. The causes of this reduction are less clear. Many new dwellings -- presumably better insulated than the average gas-heated house in 1970 -- were added to the stock during the 1970s, and a number of older dwellings were removed from the stock. As for those dwellings that were in use in both years, we can surmise that many occupants lowered their thermostats, installed storm windows, caulked and weatherstripped, and added insulation - in varying combinations. The relative importance of behavioral and physical modifications is and will probably remain unknown. What is clear is that, relative to the increase in the residential price of gas (140% in nominal terms from 1973 to 1978), the observed drop in gas consumption for space heating is fairly modest.

Other Indicators of Conservation

The American Gas Association (AGA) has estimated average residential gas consumption per customer per heating degree-day for the years 1967-78 (AGA, 1980). By their estimate, consumption in the 1978/79 winter season (October-March) was 14% less than in the similar period in 1970/71. Correction of a small error in the AGA's degree-day accounting increases the size of the reduction to 15%, quite close to the number

derived in this study.

The AGA data show that a major drop in consumption per degree-day occurred in the winter of the Arab oil embargo. This was followed by a levelling, with further reductions in the winters of 1976/77 and 1977/78, followed by a slight rise in 1978/79. The path of this trend is interesting, as the average residential price of gas has undergone a fairly steady rise throughout the post-embargo period. In fact, the increase from 1973 to 1974 ($1.08 per thousand cubic feet to $1.25/mcf) was smaller than the subsequent increases from 1975 through 1977 (DOE, 1981). It seems that gas-heating households may have responded to the general furor about energy even though their own cost of energy did not rise greatly.

The AGA data also show regional differences with respect to the magnitude of conservation. Consumption per degree-day in 1978 was 20% below the average pre-embargo (1967-72) level in the West South Central region, but only 2.6% less in New England. Possible changes in the mix of dwelling types during this period (perhaps more apartments in the West South Central region, fewer in New England) complicate the interpretation of such regional data however. Households in New England also began from a lower base. Their average gas consumption per degree-day (F) in the pre-embargo period was 16.7 MJ, the lowest in the country. The comparable average in the West South Central region was 25.1 MJ, second highest in the country. (The three Southern regions had the highest average consumption per degree-day in the U.S. during the pre-embargo period, an apparent sign of the lack of insulation in Southern homes).

Increases in the price of oil received great attention during the 1970s, and thus one would expect to find a substantial degree of energy conservation in oil heating. The suprising fact is, however, that the average retail price of heating oil rose by a smaller percentage from 1973 to 1978 (from $0.22 per gallon to $0.49 per gallon) than did the average price of gas. The key difference is that heating oil experienced a sharp increase (58%) from 1973to 1974 and then rose very modestly (hardly at all in real terms) until 1979, when the next big jump

occurred. Survey data from heating oil suppliers suggest that this single large increase had a greater effect than the more gradual rise in gas prices. Average residential consumption of No. 2 fuel oil during the 1978/79 heating season (as reported in Fuel Oil and Oil Heat, Sept. 1979) was 1,198 gallons per household (176 GJ)[1]. (The total is for space and water heating. It is not known how many households in the survey used oil for water heating; nationally about 44% of oil-space-heating households has oil water heating in 1978.) In 1972/73 the average was 1,463 gallons (214 GJ). Accounting for the colder weather of the 1978/79 winter results in a drop of 23.5% in average consumption from the 1972/73 level.

It is difficult to make any statements about conservation with respect to electric space heating. The stock of households using electricity for heating has grown and changed so much during the 1970s (there were two-and-a-half times as many households using electricity for space heating in 1978 as in 1970) that, even if adequate data existed, assessment would be problematic. Residential electricity prices rose much more slowly (a nominal increase of 70% from 1973 to 1978) than either oil or gas prices, suggesting that electric-heating households may have responded with less conservation fervor.

The situation is similarly uncertain with respect to energy conservation in water heating, cooking, and other end-uses. Estimates of average consumption at the national level prior to this study have almost all been based on engineering calculations or scattered submetering. The American Gas Association gave a value of 34 GJ for average consumption by water heaters in 1975 (AGA, 1979). This is considerably higher than the value estimated in this study (26 GJ); perhaps some of the difference is due to conservation. For electricity, values of 4000-4500 kWh (14-16 GJ) are frequently cited for water heater consumption -- close to the 14 GJ derived in this study. In other areas the data do not permit an assessment of conservation.

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[1] - This value is much higher than that derived in this study. It may be that most of the households in the oil dealer survey used oil for water heating, or were located in the Northeast.

Chapter 6

Conclusion

In the years since energy became a major political concern, the residential sector has been the primary target of federal and state effort to encourage energy conservation. The analyses used to evaluate the potential effect of proposed policy actions have been based on woefully inadequate knowledge of actual patterns of energy consumption and levels of energy efficiency in the household sector. The endeavor in this study to piece together a national portrait of U.S. residential energy use sheds some light on the situation, but the picture presented suffers in two respects:

1) It is dated; the April, 1978 - March, 1979 period from which data are drawn -- although the most recent year for which a complete picture can reliably be assembled -- is hardly representative of the present situation; and,

2) It is a portrait of averages, and as such, does not give a feel for the wide range of differences among households in their patterns of energy consumption.

The usefulness of this study is not so much that it describes where we are, but that it establishes a reasonably reliable base case against which changes in energy consumption can be compared as they become known. It has shown that it is possible to construct a picture of residential energy consumption by end-use from data in which such information is lacking. Such a format is essential in developing indicators that shed light on changes in patterns of household energy use. The problem is that our quantitative understanding of these changes is likely to always lag considerably behind the changes themselves. This presents a difficulty for the formulation of effective energy policy, as the policy targeted for the household sector of the near future may be based on an understanding of the residential sector that does not reflect the present.

The lag time for developing indicators of energy use like those presented in this report can be reduced. Combined with better information on the physical state of the housing stock with respect to energy-conserving features, such indicators can assist in the design of intelligent energy policy.

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TECHNICAL APPENDICES

Appendix A
Sources and Methods: A Closer Look

Appendix A presents a more complete discussion of the sources and methods used in constructing the picture of U.S. residential energy use described in the earlier sections of this report. The introductory remarks below are followed by notes on the stock of energy-using equipment and by a detailed account of how each end-use estimate was derived.

DATA SOURCES

Two kind of data were used in the course of this study. Data on households and the fuels they used for the various end-uses were taken from the published results of the 1978 Annual Housing Survey.[1] Conducted in the Fall of 1978 by the Bureau of the Census, the survey consisted of personal interviews with some 68,000 sample households. Although this is less than 1/10 of 1 percent of the entire housing stock, the standard errors associated with such a large sample are very small.

Estimates of average household energy use for most fuels and end-uses were derived from data gathered in the National Interim Energy Consumption Survey (NIECS), conducted by the Energy Information Administration of the U.S. Department of Energy (EIA, 1980). The NIECS used personal interviews to obtain data on energy-related features of housing units, characteristics of appliances, and information on the conservation activities and demographic characteristics of household members.[2] In addition, data on energy consumption and expenditures during the April 1978 - March 1979 period were obtained from the utilities and fuel suppliers serving the sampled households.

The selection technique used in the NIECS was roughly equivalent to dividing the continental United States into small geographic segments -- each consisting of a cluster of about 10 households -- and making a systematic random selection of such clusters for the survey. Probability methods were used at each stage of sample selection. Altogether, 4,849 housing units were selected for the national sample. Of these, 342 were vacant or seasonal (i.e., vacation homes) at the time of the first interviewer contact. Personal interviews were completed at 3,8422 households, and mailed questionaires were completed by an additional 239 households for a total of 4,071 households.

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[1] Similar data exist in the NIECS data base, but the much smaller sample size of the NIECS makes the national estimates less reliable than those resulting from the Annual Housing Survey.

[2] The description of the NIECS closely follows the discussion in (EIA, 1981), and (EIA, 1980).

The data used in this study were taken from the NIECS public use data tape issued by the Energy Information Administration.

PROBLEMS WITH THE DATA

Because of its large sample, the level of uncertainty associated with the Annual Housing Survey estimates is quite small. Thus, the values given for the number of households using the fuels for the various end-uses are quite reliable. National estimates made from the NIECS data are more subject to sampling variability. This does not affect the estimated average energy consumption for each end-use of the selected NIECS cohort, as the cohorts used to make these estimates are compared against each other. They need not be exactly like the national household populations that they represent.

The uncertainty comes into play when the unit consumption estimates for the NIECS cohorts are extrapolated to each particular national population of households. This is because national estimates made from the NIECS housing data, which have standard errors of 5-15%, are used to characterize each national population. Thus, when we ask whether the estimated gas consumption for space heating of the selected NIECS cohort is comparable to that of the national population of households using gas for space heating (as given by NIECS), we must properly also inquire as to whether the characteristics of the national population as given by NIECS are the same as the characteristics of the actual national population of gas-heating households. Of course, they are not exactly the same, and thus, the comparison between the NIECS cohort used to make the unit consumption estimate and the national population of households using gas for space heating (for example) is imperfect.

Of greater concern than the sampling variability is the fact that data on energy consumption are missing for many households. This problem is particularly serious for oil and LPG and for multi-family dwellings. Energy consumption records for 11 months or more were received from energy suppliers for 74% of surveyed households using electricity, 68% of households using utility gas, 54% of households using fuel oil, and 57% of households using LPG. Partial records (5-10 months) were received for an additional 8% of households using electricity and 5% of households using gas. Energy consumption of households that refused to sign an authorization form, whose fuel company refused to cooperate or could not locate the household's records, or whose energy use was included in rent was imputed using a regression model. Although it appears that the regression techniques used to impute missing energy consumption data are reasonable (Blumstein, et al., 1981), this must be regarded as a weak link in the data set.

THE STOCK OF ENERGY-USING EQUIPMENT

These notes are particularly useful with reference to Table 5 in Chapter 4. The source for all data on the stock of energy-using systems unless otherwise indicated is the 1978 Annual Housing Survey.

Space heating: "House heating fuel". The breakdown between Coal and Other fuel is Coal: 402,000 households, Other: 121,000 households. ("Other fuel" includes any other fuel such as solar heat, briquettes made of pitch and sawdust, or purchased steam.) 597,000 households (0.8% of the occupied stock) used no heating fuel.

Secondary space heating (defined as use of heating equipment in addition to the household's main equipment): 30% of NIECS households reported use of secondary space heating equipment with the following fuels: wood - 14% (10.8 million households); electricity - 8% (6.4 million); piped gas - 5% (3.9 million); LPG, oil, and other - 1% or less each. All secondary space heating with wood was done with a fireplace or stove. With electricity, 59% of the secondary heating was done with portable heaters, the rest with an electric wall unit. For gas, 50% of the secondary heating was done with room heaters, 26% with a fireplace or stove, and 12% with portable heaters. A secondary space heating fuel was used by 26% of households using gas for primary heating, 30% of households using oil, and 36% of households using electricity for primary heating.

Water heating: "Most used water heating fuel." The breakdown between Coal and Other fuel is Coal: 68,000 households; Other: 138,000 households. In addition, 17,000 households used solar water heating. 926,000 households (1% of the occupied stock) had no hot water facilities.

Cooking: "Most used cooking fuel." The breakdown between Coal and Other fuel is Coal: 26,000 households; Other: 28,000 households. 226,000 households reported using no cooking fuel.

Electric Appliances: Stock is assumed equal to all households, as less than 0.1% of the occupied stock has no electricity. There were 41.284 million households with air-conditioning (53% of the occupied stock); 45% of these had central air-conditioning.

Gas Appliances: The best available data are from NIECS: air-conditioning -- 1.5 million households (3% of all air-conditioned households); clothes dryers -- 11.5 million households (15% of stock); outdoor gas-lighting -- 1.3 million households (1.7% of stock); refrigerator -- 0.3 million households. (Note:

The number of households with each device is calculated by multiplying saturation percentages from NIECS by the total dwelling stock as given by the Annual Housing Survey.) The best estimate of the number of heated swimming pools, most of which are heated with gas, is 0.5 million (1/3 of the 1.6 million pools in 1978; source: National Swimming Pool Institute). Other uses of gas include outdoor gas grills (used occasionally by 6% of NIECS households).

ESTIMATING END-USE ENERGY CONSUMPTION

The following section presents a detailed account of the procedure used to estimate average consumption of the various fuels for each end-use. (These estimates are given in Table 5 in Chapter 4. A general description of the estimation procedure can be found in Chapter 2.) The selected NIECS cohorts used to isolate each end-use are described and compared (question 1), and the lead cohort (the one whose energy consumption for the end-use in question is estimated) is compared to the appropriate national population of households (question 2). In those cases where an estimate is not derivable from NIECS data (wood, coal, other gas appliances, oil and electric cooking), the reasoning behind the chosen value is given.

Note: The EIA calculated weights for each of the 4,081 households in the final NIECS sample. These weights were used to compensate for differences in probability of selection, adjust for differences in interview completion rate in individual sampling locations, and to expand data for sample households to estimates for the total population of households. Estimates for the national population using the various fuels for the various end-uses were made using the weighted data. Estimates for the selected cohorts were made using unweighted data because it is the households themselves, and not the national population that they represent, with which we are concerned. As a rule of thumb for reference, each sample household represents 18-19,000 households in the national population.

Oil

Unit consumption for space heating = average total consumption by households using oil for space heating but not for water heating (127 GJ). Households in the cohort were weighted to make the regional distribution within the

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[1] Weighting of oil heating households was done using data from the Annual Housing Survey. Unless noted otherwise, all other housing stock data presented in the subsequent discussion come from the NIECS data base because equivalent data from the Annual Housing Survey were not availably for this study.

cohort equal to that of the national population of all oil-heated houses.[1] (Households in NIECS and the Annual Housing Survey are grouped into four regions: Northeast, North Central, South, and West).

The selected cohort consists of 605 households. Three households with zero oil consumption were discarded from the cohort.

1) The question of cohort comparability is not applicable in this case, as only one cohort is required to estimate energy use for space heating. Very few households use oil for cooking; we can safely presume that oil consumption in households not using oil for water heating was all for space heating only.

2) Is the energy consumption for space heating of the selected cohort comparable to that of the national population of oil heating households?

The selected cohort represents two-thirds of the total population of oil-heating households. Households in cold climates (Northeast and North Central) are however under-represented, as the majority of the oil-space-heating households that use oil for water heating are located in the Northeast. Because this bias would make the average heating consumption of the selected cohort lower than that of the national population all oil-space-heating households, it is desirable to weight the households in the selected cohort to make their regional distribution equal to that of the national population of all oil-space-heating households. After this weighting, the most important difference between the selected cohort (as weighted) and the national population of oil-space-heating households is the relative under-representation of multi-family dwellings in the selected cohort (14% of households in the selected cohort vs. 25% in the national population), and over-representation of single-family dwellings (77% vs. 68%). As expected from these statistics, the selected cohort also a higher percentage of dwellings heated with warm-air furnaces than the national population (61% vs. 46%). Aside from these differences, the two groups are fairly similar with respect to other factors that are likely to affect space heating demand: the presence of storm windows and attic and wall insulation, persons per dwelling, household income, and the price paid for oil (~$3.90/GJ). Because of the differences in dwelling and heating system type, however, the unit consumption value of the selected cohort may be <u>slightly higher</u> than the proper value for the national population of oil-space-heating households.

Unit consumption for <u>water heating</u> = average total oil consumption by households by the Northeast using oil for space heating and water heating (176 GJ) minus average total oil consumption in Northeast households using oil for water heating but not for space heating (138 GJ). Only the Northeast was considered because 90 percent of all households with oil water heating are located there.

The selected cohorts consist of 238 and 191 households, respectively. Two households with zero oil consumption were discarded from first the cohorts, one from the second.

1) Do the two cohorts have similar consumption of oil for space heating?

To isolate oil consumption for water heating of the first cohort, the average oil consumption for space heating of the two cohorts must be similar. Both cohorts are in the Northeast, so climate differences should not be a major factor. The non-oil space heating cohort has a higher percentage of single-family dwellings, (68% vs. 43%), warm-air-furnace heating systems, however. (The reported levels of attic and wall insulation were about the same.) Thus, the energy consumption for space heating of the non-oil space heating cohort was probably higher than that of the oil space heating cohort, with the result that the estimate given for the latter's oil water heating energy consumption is likely somewhat too low.

2) Is the oil consumption for water heating of the selected cohort comparable to that of the national population of households using oil for water heating?

The selected cohort represents 90% of the national population and therefore is quite comparable to it with respect to features that would affect water heating energy consumption.

Unit consumption for cooking is not derivable from NIECS data. It was assumed to be the same as unit consumption for gas cooking.

Piped gas

Unit consumption for space heating = average total gas consumption by households using gas for space heating, water heating, and other purposes (130 GJ) minus average total gas consumption by households using gas for water heating and other purposes, but not for space heating (35 GJ). Households in the gas space heating cohort were weighted to make the regional distribution within the cohort equal to that of the national population of households using gas for space heating (as given by the Annual Housing Survey).

[1] Many of the households with inconsistent responses were located in buildings with five or more units, and were obviously uncertain of their water heating fuel.

Participants in the NIECS survey were asked whether they used piped gas for water heating in two separate places; the discrepancy in their responses was suprisingly large.[1] Of the non-gas space heating households who said that piped gas was their most-used fuel for water heating, 18% said that they did not use piped gas for hot water when asked again at the end of the survey interview. Conversely, some respondents who replied affirm that atively to the question at the end of the invertiew not say gas was their most-usedddd fuel for water heating. To ensure that the households selected actually did use gas for water heating, only those households whose responses agreed were included in the selected cohorts. The effect of this is to increase the average total gas consumption of the cohorts from what their consumption would have been if households claiming use of gas for water heating in only one of the two questions had been selected. The result is not surprising, as the cohorts with lower average consumption probably had some households that did not actually use gas for water heating.

The selected cohorts consist of 1784 and 97 households, respectively. Five households whose given gas consumption seemed implausibly high considering their location, dwelling type, and income, were discarded from the first cohort. Households with total gas consumption of less than 5 million Btu were also excluded in the cohort selection process. In the second cohort, eleven households with total gas consumption of greater than 80 million Btu or less than 5 million Btu were discarded.[1]

1) Is the average total gas consumption of the other-fuel space heating cohort similar to the non-space-heating gas consumption of the gas space heating cohort?

To help ensure comparability, only households that also use gas for water heating were included. The small number of households with gas air-conditioning were excluded, as were households using gas for secondary heating. The presence of gas cooking is similar in the two cohorts (60-65%) The gas space heating cohort averages slightly more persons per dwelling (2.84 vs. 2.76). The average income of the two groups is the same. The non-gas space heating cohort comprised heavily of households located in the Northeast (40%), but both cohorts comprised in roughly similar proportions of households located in "cold" regions (Northeast and North Central), thus evening out the possible effect of weather on energy consumption for water heating. Both cohorts have about the same saturation of washing machines (70% vs. 63%), dishwashers (34% vs. 29%), and gas clothes dryers (23%). The percentage of

[1] It is apparent that many of the households in the Other-fuel Space Heating cohort actually did use gas for space heating (or swimming pool heating). It is believed that these households have been identified and discarded from the final cohort.

households in each cohort using gas for swimming pool heating is not known, as the survey unfortunately did not inquire about this. The total gas consumption of the gas space heating cohort was adjusted slightly to delete possible use of gas for pool heating. The exclusion of households using more than 80 MMBtu from the non-gas space heating cohort probably removed any households that might have had gas pool heating. On balance, it appears that the two cohorts are fairly similar with respect to features that would affect their non-space-heating gas consumption. The likely direction of possible error is that the non-space-heating gas consumption of the gas space heating cohort may be slightly higher than the consumption of the non-gas space heating cohort, which would make the unit consumption estimate for space heating slightly high.

2) Is the gas consumption for space heating of the selected cohort comparable to that of the national population of all gas-space-heating households?

The selected cohort represents 80% of all gas-space-heating households, as very few households that use gas for space heating do not also use it for water heating. Both groups have a similar regional and dwelling type distribution, and both paid the same price for gas ($2.55/GJ).

Unit consumption for secondary space heating cannot be reliably derived from NIECS data. It was estimated as 10 GJ.

Unit consumption for water heating = average total gas consumption by households using gas for water heating and cooking but not for space heating (36 GJ) minus average total gas consumption by households using gas for cooking but not for water heating or space heating (10 GJ).

The selected cohorts consist of 52 and 129 households, respectively. Four households for which it was obvious that gas had been used for space heating or pool heating (total gas consumption greater than 80 million Btu) were excluded from the first cohort; five households where gas had obviously been used for those purposes or water heating were excluded from the second cohort.

1) Is the average total gas consumption of the non-gas water heating cohort similar to the non-water heating gas consumption of the Gas Water Heating cohort?

Households using gas for clothes drying and secondary heating were excluded from both cohorts. None of the households used gas for air-conditioning. The gas water heating cohort averages more persons per dwelling (2.88 vs. 2.69) which could indicate that its gas consumption for cooking was slightly higher than that of the other cohort. If so, this would make the unit consumption value given slightly too high.

2) Is the gas consumption for water heating of the selected cohort comparable to that of the national population of households using gas for water heating?

The selected cohort averages about the same number of persons per dwelling as the national population (2.88 vs. 2.84). It is located more heavily in cold climates (71% vs. 56%). Both groups have about the same saturation of clothes washers (63% vs. 69%), although the national population has a higher saturation of dishwashers (34% vs. 7%). The national population also has a higher average income. On balance, it appears that the gas consumption for water heating of the selected cohort may be slightly lower than that of the national population.

Unit consumption by cooking = average total gas consumption for households using gas for cooking but not for space heating, water heating, or other purposes (10 GJ).

The selected cohort consists of 129 households. Five households where gas was obviously used for purposes other than cooking were excluded from the cohort.

1) Does the average total gas consumption of this cohort reflect use for cooking only?

The small percentage of households using gas for clothes dryers, secondary space heating, or gas air-conditioning were excluded; thus, the remaining households almost surely use gas only for cooking.

2) Is the gas consumption for cooking of the selected cohort comparable to that of the national population of households using gas for cooking?

The national population has somewhat more persons per dwelling (2.83 vs. 2.69), and thus may have slightly higher cooking energy use than the selected cohort.

Gas appliances. Other residential uses of gas include air-conditioning, clothes drying, and swimming pool heating. The consumption estimate given for these other uses of gas is not derived from NIECS data, but is based upon the following considerations. Air-conditioning: the AGA gives an average annual consumption of 273 therms (29 GJ) per ton of cooling capacity; assuming a load of 2 tons per household, total consumption is about 80 PJ. Gas clothes dryers: unit consumption (gas only) was estimated by Oak Ridge National Laboratory as 6 GJ (assuming 370 loads per year); total gas consumption by clothes dryers can thus be estimated as about 70 PJ. Swimming pool heating: unit consumption was estimated by LBL's 1981 Solar/Conservation study as 93 GJ; thus, total gas

consumption by swimming pool heaters can be estimated to be about 50 PJ. For outdoor gas lighting, the AGA in 1975 gave average annual consumption for gas lights as 184 therms (19 GJ), which would bring national consumption to about 25 PJ. (The AGA estimate and may be too high for 1978, by which time the level of public awareness of energy conservation and gas prices had increased.) For outdoor outdoor grills, average annual consumption is given by the AGA as 27 therms; as some of the grills are fueled by bottled gas, national consumption of gas by gas grills is probably less than 10 PJ.

Liquid Petroleum Gas (LPG)

Unit consumption for space heating = average total LPG consumption by households using LPG for space heating, water heating, and other purposes (94 GJ) minus average total LPG consumption by households using LPG for water heating and other purposes but not for space heating (29 GJ).

The selected cohorts each consist of 77 households. One household where LPG was obviously not used for space heating was discarded from the first cohort. One household where gas was obviously used for space heating was discarded from the second cohort.

1) Is the average total LPG consumption of the non-LPG space heating cohort comparable to the non-space-heating LPG consumption of the LPG space heating cohort?

Both cohorts have about the same saturation of LPG cooking (72% vs. 79%). The LPG space heating cohort has a somewhat greater saturation of clothes washers (77% vs. 65%) and dishwashers (22% vs. 15%). The non-LPG space heating cohort has fewer persons per dwelling (2.79 vs. 2.94), but is located in colder climates. It also has a higher percentage of households using LPG for secondary heating (15% vs. 9%). On balance, it appears that the average non-space-heating LPG consumption of the LPG space heat cohort may be slightly higher than that of the other cohort, which would lead to a small overestimation of unit consumption for space heating.

2) Is the LPG consumption for space heating of the selected cohort comparable to that of the national population of LPG-space-heating households?

The selected cohort represents half of the national population of LPG-space-heating households. It has a somewhat higher proportion of single-family dwellings (74% vs. 62%) and a lower proportion of mobile homes (22% vs. 30%). It also has a higher percentage of households located in cold climates (37% vs. 28%). Thus, the unit consumption value given is probably somewhat higher than the proper value for the national population of LPG-space-heating

households.

Unit consumption for water heating = average total LPG consumption by households using LPG for water heating and cooking but not for space heating (24 GJ) minus average total LPG consumption by households using LPG for cooking but not for space heating or water heating (9 GJ). (Unit consumption given in table has been adjusted as described below.)

The selected cohorts consist of 46 and 78 households, respectively. Two households where LPG was obviously not used year-round for water heating were discarded from the first cohort. Four households where LPG was obviously used for purposes other than cooking were discarded from the second cohort.

1) Is the average total LPG consumption of the non-LPG water heating cohort comparable to the non-water-heating LPG consumption of the LPG Water Heating cohort?

Households using LPG for secondary space heating were excluded from both cohorts. The non-LPG cohort averages more persons per dwelling (2.87 vs. 2.56). Thus, its LPG consumption for cooking may be higher than that of the LPG water heating cohort, which would mean that the derived unit consumption is slightly low.

2) Is the LPG consumption for water heating of the selected cohort comparable to that of the national population of households using LPG for water heating?

The selected cohort is located somewhat more heavily in cold climates than the national population, but the latter has more persons per dwelling (2.86 vs. 2.56). The national population has a higher saturation of clothes washers (72% vs. 54%) and dishwashers (20% vs. 8%). Thus, it appears fairly certain that the consumption of the selected cohort is too low. To more accurately reflect the characteristics of the national population of LPG-water-heating households, the unit consumption estimate for LPG water heating has been adjusted from 15 GJ to 17 GJ.

Unit consumption for cooking = average total LPG consumption households using LPG for cooking but not for space heating or water heating (9 GJ).

The selected cohort consists of 78 households. Four households where LPG was obviously used for purposes other than cooking were discarded from the cohort.

1) Does the average total LPG consumption of the selected cohort represent cooking use only?

The small number of households using LPG for secondary space heating were excluded. It is not known if LPG was put to any other uses in the selected cohort, but the value of the average (9 GJ) suggests that any other were probably small.

2) Is the LPG consumption for cooking of the selected cohort comparable to that of the national population of households using LPG for cooking?

The two groups average about the same number of persons per dwelling (2.83 vs. 2.87). Thus, the unit consumption for cooking of the selected cohort is likely comparable to that of the national population.

Electricity

Unit consumption for space heating = average total electricity consumption by households using electricity for space heating, water heating, cooking, and other appliances (79 GJ) minus average electricity consumption of households using electricity for water heating, cooking, and other appliances but not for space heating. (Unit consumption given in table has been adjusted as described below.) Households that also have electric air-conditioning were not selected out because the cohort of air-conditioned households that also use electricity for space heating is heavily biased toward the South makes the resulting comparison somewhat problematic differences in the presencee of air-conditioning.

The selected cohorts consist of 537 and 514 households, respectively. One household where electricity was obviously not used for space heating was discarded from the first cohort. Three households where electricity was almost certainly used for space heating were discarded from the second cohort.[1]

[1] - It is difficult to detect households that obviously used electricity for space heating since their high electricity consumption could be due to heavy use of air-conditioning or other electric appliances rather than the presence of electric space heating. Only those households whose size, location, and income made it most implausible that factors other than the presence of space heating could have accounted for their high level of electricity consumption were discarded from the cohort.

1) Is the average total electricity consumption of the non-electric space heating cohort comparable to the non-space-heating consumption of the electric space heating cohort?

Households using electricity for secondary space heating were excluded from both cohorts. The most important difference between the two groups is that the electric space heating cohort has a higher percentage of households with central air-conditioning than the other cohort (37% vs. 21%). Partially ofsetting this is the fact that the latter cohort has more room air-conditioning (32% vs. 24%). The electric space heat cohort is also somewhat wealthier, and faced a lower average price for electricity ($0.03/kWh vs. $0.04/kWh). Water heating energy consumption was perhaps somewhat higher in the non-electric cohort, as it located more heavily in colder climates (34% vs. 19%), and average more persons per dwelling (2.95 vs. 2.80). Both cohorts have the same saturation of clothes washers (~80%); the electric space heating cohort has a higher saturation of dishwashers (52% vs. 32%) and clothes dryers (75% vs. 69%); and the non-electric space heating cohort has a higher saturation of food freezers (50% vs. 41%). Although it is difficult to judge the overall effect of these differences, the greater proportion of central air-conditioning in the electric space heating cohort suggests that its non-space-heating electricity consumption was perhaps somewhat higher than that of the other cohort, which would lead to a small overestimation of electricity consumption for space heating. To compensate for this, the estimated electricity consumption for electric space heating of the selected cohort has been adjusted from 37 GJ to 35 GJ.

2) Is the electricity consumption for space heating of the selected cohort comparable to that of the national population of households using electricity for space heating?

The selected cohort is reasonably comparable to the national population of electric-heating households, as it represents 84% of that population.

Secondary space heating: Unit consumption = average total electricity consumption by households using electricity for secondary heating and other appliances but not for primary space heating, water heating, air-conditioning, or cooking minus average total electricity consumption by households using electricity for other appliances only.

1) Is the average total electricity consumption of the second cohort comparable to the non-secondary heating consumption of the Secondary Heating cohort?

Both cohorts have similar saturations of dishwashers, food freezers, and washing machines. Thus, the difference between the consumption of the two cohorts is probably a good approximation of electricity consumption for secondary heating.

2) Is the electricity consumption for secondary heating of the selected cohort comparable to that of the national population of households using electricity for secondary heating?

The selected cohort represents 19% of the national population of 6.4 million households using electricity for secondary space heating. Both groups have a roughly similar proportion of single-family dwellings (67% vs. 76%) and both have about 60% of their households located in the South or West. Thus, the consumption of the selected cohort is probably fairly representative of that of the national population.

Unit consumption for water heating = average total electricity consumption by households using electricity for water heating and cooking, but not for space heating or air-conditioning (36 GJ) minus average total electricity consumption by households using electricity for cooking but not for water heating, space heating or air-conditioning (22 GJ).

The selected cohorts consist of 244 and 340 households, respectively. Two households where electricity was obviously used for space heating or air-conditioning were discarded from the first cohort. One household where electricity was obviously used for those purposes or water heating was discarded from the second cohort.

1) Is the average total electricity consumption of the non-electric water heatin onort o parable to the non-water heating electricity consumption of the electric water heating cohort?

Households using electricity for secondary heating were excluded from both cohorts. Both have about the same saturation of clothes dryers (61% vs. 55%) and washing machines (74% vs. 82%). The Other-fuel cohort has a higher saturation of dishwashers (43% vs. 20%), but the electric water heating cohort has more food freezers (50% vs. 37%). Both average about the same number of persons per dwelling (~2.95). On balance, then, it appears that the electricity consumption of the non-electric cohort is reasonably comparable to the non-water heating consumption of the electric water heating cohort.

2) Is the electricity consumption for water heating of the selected cohort comparable to that of the national population of households using electricity for water heating?

Both groups average about the same number of persons per dwelling (2.91 vs. 2.85), have about the same saturation of clothes washers (74% vs. 77%), and have a reasonably similar regional distribution. The national population has a higher saturation of dishwashers (40% vs. 20%). On balance, then, it appears that the consumption for water heating of the selected cohort may be slightly lower than that of the national population of households using electricity for water heating.

Unit consumption for cooking is estimated as 4.3 GJ (1200). It is not feasible to estimate electricity consumption for cooking by comparing NIECS cohorts due to the differing saturation of other electric appliances within the cohorts. The value used is the average of a number of estimates, including that of the Edison Electric Institute. The Midwest Research Institute metered electricity consumption of 13 cooktops and ovens in 1976/77 and found an average consumption of 950 kWh. The small sample size (13) makes the reliability of the estimate open to question, however.

Unit consumption for air-conditioning = average total electricity consumption by households using electricity for air-conditioning, water heating, and other purposes but not for space heating (45 GJ) minus average total electricity consumption by households using electricity for water heating and other purposes but not for space heating or air-conditioning (34 GJ). (Unit consumption given in table has been adjusted; as described below.)

The selected cohorts consist of 346 and 302 households, respectively. One household where electricity was obviously used for space heating was excluded from each cohort.

1) Is the average total electricity consumption of the non-air-conditioning cohort comparable to the non-air-conditioning electricity consumption of the air-conditioning cohort?

The small number of households using electricity for secondary heating were excluded from both cohorts. It appears that electricity consumption for water heating may be slightly higher in the Air-Conditioning cohort, as it averages more persons per dwelling (3.00 vs. 2.85), and has a higher saturation of dishwashers (38% vs. 19%) and clothes washers (86% vs. 71%). It also has a higher saturation of clothes dryers (71% vs. 56%). Both cohorts have about the same saturation of electric cooking (72% vs. 79%) and food freezers (46%). On balance, then, it appears that the electricity consumption of the non-air-conditioning cohort may be somewhat less than the non-air-conditioning electricity consumption of the air-conditioning cohort, which would lead to overestimation of unit consumption for air-conditioning. The estimate of electricity consumption for air-conditioning by the selected cohort has thus been adjusted from 11 GJ to 10 GJ.

2) Is the (adjusted) air-conditioning electricity consumption of the selected cohort comparable to that of the national population of households with air-conditioning?

The selected cohort has a higher proportion of single-family dwellings (79% vs. 65%), and of course, a much lower proportion of multi-family dwellings (3% vs. 25%). It is also located somewhat more heavily in warm climates (66% vs. 53%), and paid slightly more for electricity (4.3 cents/kWh vs. 4.0 cents/kWh). Both groups have about the same proportion of central air-conditioning (37% vs. 39%), attic insulation (83% vs. 85%), and wall insulation (65% vs. 68%). On balance, it appears that the air-conditioning electricity consumption of the selected cohort is probably higher than that of the national population. To arrive at a more accurate estimate for the national population, the unit consumption value of the selected cohort (10 GJ) has been adjusted to 9 GJ.

Wood

Unit consumption for space heating was estimated as 80 GJ. This assumes an average consumption of four cords of wood with an average heating value of 20 GJ/cord. According to NIECS, 90% of all households using wood as primary heating fuel are in single-family dwellings, and almost all of them heat with a stove or fireplace. In the NIECS sample, most of the households using wood as primary heating fuel are located in the South (65%) and West (21%). The wood-heating cohort has a much higher proportion of households using some fuel for secondary space heating (57%) than households using other fuels for primary heating.

Unit consumption for secondary space heating was estimated as 20 GJ (one cord).

Unit consumption for water heating was estimated as 30 GJ. It was assumed that the inconvenience of using wood for water heating limits its use somewhat, thus balancing out the lower relative efficiency of burning wood.

Unit consumption for cooking was estimated as 15 GJ.

Coal & Other

Unit consumption for space heating was estimated as 100 GJ. Most NIECS households using coal as primary heating fuel are single-family dwellings, but many more of them heat with a central warm air system (43%) than is the case with wood. A high proportion of coal-heating households are located in cold

climates (32% vs. 14% for wood), although the majority are found in the South (59%).

Unit consumption for water heating was estimated as 40 GJ.

Unit consumption for cooking was estimated as 15 GJ.

Appendix B

Energy Consumption by Households in Single and Multi-Family Structures

The unit consumption estimates presented in the main table of 1978 residential energy consumption in Chapter 4 are averages over the entire stock of households using each fuel for a particular end-use. It is possible in some cases to apply the same procedure used in making those estimates to derive separate estimates of average energy consumption for households in single and multi-family structures. This has been done for households in both kinds of structures for gas space heating, and for households in single-family structures for oil and electric space heating. (Measured consumption data were available for less than 25% of oil-heating households in multi-family buildings and for less than half of electric-heating households in multi-family buildings. In the latter case the two cohorts were also too dissimilar to allow for comparison. Unit consumption estimates for water heating and cooking and other end-uses were not made for both reasons of time and because it is believed that the differences between average consumption of households in single and multi-family structures are not as significant as is the case with space heating.

The derived unit energy consumption (UEC) estimates are presented in the table below along with the number of households in each category. A description of the cohorts and method used to make the estimates follows the table. For a discussion of the cohort comparison method see Chapter 2.

Space Heating in Single and Multi-family Dwellings -- 1978/79

	Single-family	Multi-family
Oil (PJ)	1250	-
Stock(10^3)	10166	5222
Unit Cons(GJ)	123	-
Gas(PJ)	3290	767
Stock(10^3)	30181	10964
Unit Cons(GJ)	109	70
Electricity(PJ)	330	-
Stock(10^3)	7170	4457
Unit Cons(GJ)	46	-

Oil space heating, single-family: UEC = average total oil consumption of households using oil for space heating but not for water heating, weighted to make the regional distribution within this cohort equal to that of the national population of single-family oil-heated households.[1]

The selected cohort consists of 458 households. Two households with zero oil consumption were discarded from the cohort.

1) Is the energy consumption for space heating of the selected cohort comparable to that of the national population of single-family oil-heating households?

The selected cohort represents 75% of the national population of single-family oil-heating households. Both paid the same average price for oil and had the same average income. The extent of weatherization in the two groups is also about the same. The selected cohort has a somewhat higher percentage of dwellings heated with warm-air furnaces than the national population (65% vs. 54%). Although this latter factor could have some effect, it appears that the oil consumption for space heating of the selected cohort is probably

[1] - The regional distribution of the national population of single-family oil-heating households was approximated by adjusting the distribution as given by NIECS with data on the distribution of all oil-heating households from the Annual Housing Survey. It should be noted that single-family oil-heating households are on the average located in warmer climates than the population of all oil-heating households.

comparable to that of the national population.

Piped gas space heating, single-family: UEC = average total gas consumption by households using gas for space heating, water heating, and other purposes [the Gas Space Heating cohort] minus average total gas consumption by households using gas for water heating and other purposes, but not for space heating [the Other-fuel Space Heating cohort]. Households in the Gas Space Heating cohort were weighted to make the regional distribution within the cohort equal to the estimated regional distribution of the national population of single-family gas-heated households.[1]

The selected cohorts consist of 1290 and 68 households, respectively. Two households whose given gas consumption seemed implausibly high considering their location, dwelling type, and income were discarded from the first cohort. In the second cohort, thirteen households with total gas consumption of greater than 80 million Btu (12) or less than 5 million Btu (1) were discarded.[2]

1) Is the average total gas consumption of the Other-fuel Space Heating cohort similar to the non-space-heating gas consumption of the Gas Space Heating cohort?

To help ensure comparability, only households that also used gas for water heating were included. The small number of households with gas air-conditioning were excluded, as were households using gas for secondary heating. The presence of gas cooking is similar in the two cohorts (61% in the Gas Space Heating cohort vs. 69% in the Other-fuel Space Heating cohort) and the two cohorts average about the same number persons per dwelling. The average income of the two groups is the same. The Other-fuel Space Heating cohort is comprised heavily of households located in the Northeast, but both cohorts are comprised in roughly similar proportions of households located in "cold" regions (Northeast and North Central), thus evening out the possible effect of weather on energy consumption for water heating. Both cohorts have about the same saturation of washing machines (85% vs. 80%) and gas clothes dryers (29% vs. 32%); the Gas Space Heating cohort has a higher saturation of dishwashers

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[1] - The regional distribution of the national population of single-family gas-heating households was approximated by adjusting the distribution as given by NIECS with data on the distribution of all gas-heating households from the Annual Housing Survey.

[2] - It is apparent that many of the households in the Other-fuel Space Heating cohort actually did use gas for space heating (or for swimming pool heating). It is believed that these households have been identified and discarded from the final cohort.

(39% vs. 26%). The percentage of households in each cohort using gas for swimming pool heating is not known, as the survey unfortunately did not inquire about this. An effort was made to remove gas consumption for pool heating from the Gas Space Heating cohort by assuming that 20 households (based on national percaentage of households with a heated swimming pool) each used 90 GJ for pool heating, and then subtracting this amount of gas from the cohort's total gas consumption. It is assumed that the exclusion of households using more than 80 million Btu from the Other-fuel Space Heating cohort removed any households that might have used gas for pool heating. On balance, it appears that the two cohorts are fairly similar with respect to features that would affect their non-space-heating gas consumption.

2) Is the gas consumption for space heating of the selected cohort comparable to that of the national population of all single-family gas-space-heating households?

The selected cohort represents 79% of the national population. Both groups paid the same price for gas ($2.63) and have similar weatherization features. Thus, the consumption of the selected cohort is probably reasonably comparable to that of the national population.

Piped gas space heating, multi-family: UEC = average total gas consumption by households using gas for space heating, water heating, and other purposes [the Gas Space Heating cohort] minus average total gas consumption by households using gas for water heating and other purposes, but not for space heating [the Other-fuel Space Heating cohort].[1]

The selected cohorts consist of 476 and 29 households, respectively. Three households whose given gas consumption seemed implausibly high considering their location and income were discarded from the first cohort, as were two households whose gas consumption was so low (<2 million Btu) that it is very unlikely that they did in fact use gas for space heating and water heating. In the second cohort, ten households with total gas consumption of greater than 60 million Btu were discarded.

1) Is the average total gas consumption of the Other-fuel Space Heating cohort similar to the non-space-heating gas consumption of the Gas Space Heating cohort?

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[1] - Regional weighting was not employed because the regional distribution within the selected cohort was quite close to the regional distribution of the national population of multi-family gas-space-heating households.

To help ensure comparability, only households that also used gas for water heating were included. The small number of households with gas air-conditioning were excluded, as were households using gas for secondary heating. The Gas Space Heating cohort has a much higher saturation of gas cooking (73% vs. 45% in the Other-fuel Space Heating cohort). The two cohorts average about the same number of persons per dwelling; the Other-fuel cohort is somewhat wealthier. Both cohorts are comprised in roughly similar proportions of households located in "cold" regions (Northeast and North Central), thus evening out the possible effect of weather on energy consumption for water heating. The Other-fuel cohort has a higher saturation of washing machines (45% vs. 33%) and dishwashers (28% vs. 23%); both cohorts have about the same saturation of gas clothes dryers (8%). Since the households are in multi-family structures, it is assumed that gas was not used for swimming pool heating. On balance, it appears that the non-heating gas consumption of the Gas Space Heating cohort is probably higher than that of the Other-fuel cohort (due to the higher saturation of gas cooking). The non-heating gas consumption of the Other-fuel cohort is 31 GJ; in estimating the gas consumption for space heating of the Gas Space Heating cohort a value of 33 GJ is used to represent its non-heating gas consumption.

2) Is the gas consumption for space heating of the selected cohort comparable to that of the national population of all multi-family gas-space-heating households?

The selected cohort represents 90% of all gas-space-heating multi-family households, and thus is quite comparable to the national population with respect to features that would affect space heating energy consumption.

Electric space heating, single-family: UEC = average total electricity consumption by households using electricity for space heating, water heating, cooking, and other appliances [the Electric Space Heating cohort] minus average electricity consumption of households using electricity for water heating, cooking, and other appliances but not for space heating [the Other-fuel Space Heating cohort].

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[1] - It is difficult to detect households that obviously use electricity for space heating since their high electricity consumption could be due to heavy use of air-conditioning or other electric appliances rather than the presence of electric space heating. Only those households whose size, location, and income made it most implausible that factors other than the presence of space heating could have accounted for their high level of electricity consumption were discarded from the cohort.

The selected cohorts consist of 357 and 528 households, respectively. One household where electricity was obviously not used for space heating was discarded from the first cohort. Three households where electricity was almost certainly used for space heating were discarded from the second cohort.[1]

1) Is the average total electricity consumption of the Other-fuel Space Heating cohort comparable to the non-space-heating consumption of the Electric Space Heating cohort?

The most important difference between the two groups is that the Electric Space Heating cohort has a higher percentage of households with central air-conditioning than the Other-fuel Space Heating cohort (38% vs. 21%). The Electric Space Heat cohort is also somewhat wealthier, and faced a lower average price for electricity ($0.03/kWh vs. $0.04/kWh). Water heating energy consumption was probably similar in the two groups: the Other-fuel cohort is located more heavily in colder climates (35% vs. 19%), but the Electric Space Heating cohort averages more persons per dwelling (3.17 vs. 2.93). Both cohorts have similar saturations of clothes washers (91% vs. 83%) and food freezers (~54%); the Electric Space Heating cohort has a higher saturation of dishwashers (54% vs. 34%) and clothes dryers (86% vs. 71%). Although it is difficult to judge the overall effect of these differences, the greater proportion of central air-conditioning in the Electric Space Heating cohort suggests that its non-space-heating electricity consumption may be somewhat higher than that of the Other-fuel cohort, which would lead to a small overestimation of electricity consumption for space heating. To compensate for this, the estimated electricity consumption for electric space heating of the selected cohort has been adjusted from 49 GJ to 46 GJ.

2) Is the electricity consumption for space heating of the selected cohort comparable to that of the national population of households using electricity for space heating?

The selected cohort represents 92% of the national population, and is thus quite comparable to the national population with respect to features that would affect space heating energy consumption.

Appendix C
Other Estimates of Residential Energy Use

Total Consumption by Fuel

The American Gas Association (AGA) and the Edison Electric Institute (EEI) collect data on residential energy use from their member utilities. Thus, it is possible to check the estimates of residential gas and electricity consumption made in this study with the "known" residential consumption of those fuels.[1] The Energy Information Administration (EIA) also tabulates consumption of the various fuels in the residential sector as part of its State Energy Data System (SEDS). In the case of oil, LPG, and coal, however, there are no truly reliable records of their total consumption in the residential sector; existing estimates (as in SEDS) are based on a survey of fuel suppliers and/or on guesses as to the split between residential and commercial sector consumption.

Before making a comparison for gas and electricity, it is necessary to modify the AGA and EEI data to include energy consumption in mass-metered apartment buildings. The methodology employed is described in Appendix F. The difficulty here is that the extent to which gas and electric utilities have managed to separate residential buildings from their commercial tariff class is not known. The AGA has asked its member utilities to make this adjustment in their data reporting, and increasing compliance is believed to have occurred.[2] It is likely that the AGA and EEI totals do in fact include energy consumption in some mass-metered apartment buildings, which would mean that the best estimate of residential sector consumption probably lies between the unmodified and modified AGA and EEI values.

As can be seen from the table below, the totals arrived at (independently) for residential gas and electricity use in this study are extremely close to the adjusted AGA and EEI totals for residential gas and electricity consumption. Since the AGA and EEI tabulations cover calendar year 1978, we would expect them to be somewhat lower than this study's estimates, which cover a period when there were more consuming households (April 1978 - March 1979).

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[1] - "Known" is placed in quotation marks because the available data on total residential gas and electricity consumption do not include energy consumption in many large mass-metered apartment buildings, which are usually found in a commercial tariff class.

[2] - This gradual adjustment has the effect of artifically increasing residential sector consumption. Part of the apparent growth in consumption seen in the late 1970s is no doubt due to the inclusion of apartment buildings that were previously mis-classified.

It is a matter of speculation whether this effect is larger than that caused by the colder weather of calendar year 1978.

U.S. Residential Energy Use
(Petajoules)

	This study (April 1978 - March 1979)	AGA/EEI (1978)	SEDS (1978)	AGA/EEI* (1978)
Gas	5668	5387	5255	5649
Electricity	2565	2445	2415	2541
Oil	2309	-	2623	-
LPG	368	-	544	-
Coal	60	-	99	-
Wood	304	-	-	-
TOTAL	11274	-	10937	

* - AGA and EEI residential sector totals have been modified to include estimated energy consumption in mass-metered apartment buildings.

With respect to oil, LPG, and coal, the accuracy of the SEDS estimates is not considered to be high enough to warrant comparison with the estimates made in this study. In 1979, the EIA implemented a new system for collecting data on oil consumption, and their estimate of residential sector distillate and kerosene consumption fell to 1942 PJ. Since consumption could hardly have dropped by over 25% in one year, the 1978 value obviously overstates actual consumption. The LPG and coal totals are also clearly too high: given the number of households using LPG and coal for the various end-uses, it is virtually impossible for total consumption to be as high as the EIA value suggests.

Unit Energy Consumption

The fact that this study's estimates of gas and electricity consumption agree rather well with those of the AGA and EEI is encouraging but does not necessarily imply that each of the end-use estimates of average consumption are precisely accurate; a too-high estimate could balance a too-low one.

The most reliable other estimate of average household consumption is that made by the AGA for gas space heating. Based on responses from 65 member utilities[1], the AGA estimated average gas consumption for space heating in 1978 as 101 GJ (AGA, 1979). Dividing by the number of heating degree-days brings the estimate to 35.8 MJ per degree-day, quite close to the 34.1 MJ per degree-day derived in this study.

The only other recent work that presents a set of national-level values for average household energy consumption by fuel and end-use is the data base on which Oak Ridge National Laboratory's Residential Energy Use Model (Version 7.1) is built.[2] These values are based on an end-use breakdown estimated from aggregate 1977 residential consumption of the main fuel by J.A. Tevepaugh of the Lockheed Missiles and Space Corporation.

The basic method used in the Lockheed study involves plotting total consumption of gas or electricity by month for each Federal region. "Baseload" consumption (i.e., for water heating, cooking, etc.) is estimated from consumption in non-heating or non-cooling months. Energy consumption for space heating or cooling is then estimated by subtracting baseload consumption from the winter or summer "hump." It is not clear how other end-uses were disaggregated.

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1 - It is not known if the 65 responding utilities were fully representative of the national population of gas-heating households.

2 - The Department of Energy's residential energy consumption forecasts are based on output from the Oak Ridge model.

Estimates of Average Household Energy Consumption

	This study (April 1978 - March 1979)	Oak Ridge (1977)
	(Gigajoules)	
Space Heating[a]		
- oil	127 (42)	139 (47)
- gas	95 (34)	84 (32)
- electricity	35 (15)	29 (14)
Water Heating		
- oil	38	34
- gas	26	31
- electricity	14	18
Cooking		
- gas	10	10
- electricity	4.3	4.3
Air conditioning	9	7
Other appliances	16	21

[a] - The period used in this study was on the average colder than 1977, the base year for the Oak Ridge estimates. The values in parenthesis are expressed in MJ per heating degree-day, with the latter calculated according to the regional distribution of households using each fuel for heating.

Significant differences exist between the estimates in this study and those used in the Oak Ridge model in many areas, particularly water heating, oil space heating, air-conditioning, and other appliances. (Note how correcting for climate brings the estimates for gas and electric space heating much closer together.) Given the imprecision of estimation technique and, in the case of oil, lack of reliable consumption data, the Oak Ridge estimates should in the author's opinion be considered less accurate than those made in this study.[1]

[1] It should be noted that this study's estimate of average consumption for other appliances is more uncertain than the other unit consumption estimates shown.

Appendix D

The Size of Housing Units in the United States

One of the most important variables to consider when comparing energy consumption for space conditioning among houses or among segments of the housing stock is the size of the homes in question, typically represented by their floor area. Although data on floor area of newly-constructed houses have been collected for a number of years, no data existed on the floor area of the existing housing stock until the NIECS survey.

The NIECS survey asked household respondents if they knew how many square feet of living space were in their residence. Only 43% of the respondents answered yes. Respondents answering no were then asked to guess their floor area; 23% of all respondents did so, with the rest saying that they had no idea. The average floor area of households where the area was known or guessed is 1345 ft^2 (125 m^2). If only those households where the floor area was known are considered, the average is 1437 ft^2 (134 m^2).

Both of these averages have serious flaws. An examination of the NIECS data shows that, households where the area was known had more rooms per dwelling and were more heavily concentrated in single-family dwellings than households where the area was guessed or completely unknown. Thus, it would clearly be wrong to use the average of only those households who knew their floor area. Using those households where the area was either known or guessed also has drawbacks, however. It is obvious that the households where respondents guessed their area are either significantly smaller than those where the area was known, or that those respondents understated the true area of their residence. A post-survey assessment in which trained technicians measured the floor area of 44 NIECS households revealed very large differences between the measurements and the responses to the NIECS survey. (Blumstein et al., 1981). This disagreement was particularly large in the few cases where the respondent guessed the area: in three cases the response differed from the measured value by a factor of three or more! Because of the design of the NIECS data tape, it is not feasible to look at the distribution of dwelling types or the average number of rooms among households where the area was either known or guessed.

A method of estimating average floor area believed to be more reliable than either of the above is to calculate the average floor area for each dwelling type, considering only those households where the area was known, and then use this average value for all households of each dwelling type. Of course, this assumes, for example, that the households in single-family detached dwellings where the area was known are similar in size to all single-family detached dwellings. Once an average for each dwelling type has been calculated, an average for the entire stock can be found by weighting

these values by the total number of households in each dwelling type. This has been done for the stock of households using the major fuels for primary heating as well as for the entire housing stock. The results are shown in the table below.

Estimating Floor Area of the U.S. Housing Stock

	Oil heat	Gas heat	Elec heat	All homes
Households who knew or guessed area:				
Mean (ft^2)	1383	1321	1391	1345
Knew area[a]	38%	39%	52%	43%
Guessed area[a]	20%	26%	22%	23%
Households who knew area:				
Mean (ft^2) for households in:				
- single-family detached	1716	1586	1707	1619
- single-family attached	1710	1261	1864	1377
- 2-4 unit buildings	1032	929	1045	975
- 5+ unit buildings	434	878	1159	935
- mobile home	788	970	884	869
Weighted average[b]	1345	1373	1460	1391

a - these percentages refer to the entire stock of households.

b - weighted by the number of each type of dwelling within each stock of dwellings (from Annual Housing Survey)

Note: analysis of area by dwelling type has not been for homes heated with LPG. The average area for households where the area was either known (49% of LPG-heating households) or guessed (18%) is 1111 ft^2.

Source: Based on data from the National Interim Energy Consumption Survey

Appendix E
Degree-Days and Space Heating

It is commonly recognized that the effect of climate must be accounted for when comparing energy consumption for space heating among houses in different locations. This is usually done by dividing energy consumption by the number of heating degree-days in the period in question. The implicit assumption is that energy consumption for space heating scales linearly with the number of degree-days.

When comparing consumption between large groups of houses it is important that the degree-day value used accurately reflects the weather conditions experienced by the households being examined. Households using the various space heating fuels are located in different parts of the country, and thus, face different climatic conditions. Knowing the population-weighted number of degree-days in each region of the country, and the number of households in each region using a particular fuel, it is possible to construct an approximate degree-day total appropriate for each group of households. The national degree-day total (DD) for a particular fuel (f) is given by:

$$DD_f = \frac{\sum_{r=1}^{n} DD_{fr} * H_{fr}}{\sum_{r=1}^{n} H_{fr}}$$

where r refers to each of the nine regions, n is the number of regions considered, and H is the number of households.

The main assumption made is that the distribution within a region of households using a particular fuel for heating is similar to the population distribution within the region. Although there may be instances where this is not the case, it seems on the whole to be reasonable.

Degree-day totals for the various regions for the April 1978 - March 1979 period (the months covered by the NIECS) are shown below. The source of degree-day information is the National Climatic Center publication, "State, Regional and National Monthly and Seasonal Heating Degree Days Weighted by Population." The number of households in each region was taken from unpublished tables from the 1978 Annual Housing Survey.

Degree-Day Totals for April 1978 - March 1979 (base 18°C)

Region	Degree-days
New England	3640
Mid Atlantic	3290
E.N. Central	3754
W.N. Central	4040
S. Atlantic	1722
E.S. Central	1989
W.S. Central	1403
Mountain	3349
Pacific	1978

Note: The degree-day totals given by the National Climate Center are calculated using 65°F as the base. In keeping with the effort in this report to use SI units, Fahrenheit values were converted to Celsius values with a base of 18°C. A precise way to make this conversion has been formulated by D.W. Boyd of the Canadian Atmospheric Environment Service. This method, which converts degree-day totals month by month, was used for the April 1978 - March 1979 period. Comparison of this method with a simplified technique (multiplying the 65°F total by 5/9 to get to 18.3°C, and then subtracting 75 degree-days*) showed that the simplier technique resulted in only a very small error. This method was used in degree-day conversion for other years.

The calculated degree-day totals for the national population of households heating with the various fuels are shown below:

Heating fuel	Degree-days
Oil	3061
Gas	2785
Electricity	2253
All homes	2784

*The number 75 is derived by multiplying 0.3°C by 250 days, the approximate length of a heating season.

Appendix F

Energy Consumption in Mass-Metered Apartments

A traditional problem with data on energy consumption in the residential sector is that consumption by dwellings in large mass-metered apartment buildings is usually not included or is included to an unknown extent. This is because these buildings generally fall under a commercial tariff class, and thus, energy consumption that is properly residential is counted by utilities as part of the commercial sector.

A previous attempt to separate out residential energy consumption from the commercial class was made for 1970 by S. Cohn of Oak Ridge National Laboratory (Cohn, 1978). Using appliance saturation data from the 1970 Census of Housing and estimates of unit energy consumption, Cohn calculated electricity consumption in mass-metered apartments to be 4% of total residential electricity consumption as reported by the Edison Electric Institute (EEI), and gas consumption in mass-metered apartments to be 4.8% of total residential energy consumption as reported by the American Gas Association (AGA).

To estimate similar consumption for 1978, energy use data from the NIECS are used. Average electricity consumption by households in buildings with five or more units where electricity is included in the rent was 17 GJ.[1] Multiplying this figure by the number of such households as reported by the 1978 Annual Housing Survey (5,562,000) gives a value for total electricity consumption in mass-metered apartments of 96 PJ. For gas, the average consumption per mass-metered household was 54 GJ. There were 4,843,000 households in buildings with five or more units where gas was included in the rent, yielding an estimate of total gas consumption in mass-metered apartments of 262 PJ. These values are 3.9% and 4.9% of total residential electricity and gas consumption as reported for 1978 by the EEI and AGA, respectively -- rather close to the values estimated by Cohn for 1970.

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[1] - The electricity and gas consumption values for mass-metered apartments should be considered as estimates, as the data do not represent actual measured consumption, but rather were imputed with a regression model by the Energy Information Administration.

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