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ENERGY CONSUMPTION AND STRUCTURE OF THE U.S. RESIDENTIAL SECTOR: CHANGES BETWEEN 1970 AND 1984

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S. Meyers

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Energy Consumption and Structure of the U.S. Residential Sector: Changes Between 1970 and 1984

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March, 1986

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EXECUTIVE SUMMARY

This report presents a quantitative description of the trends in U.S. residential energy consumption in the 1970-1984 period and the chief structural and behavioral changes shaping those trends. We look both at the sector as a whole and at the particular markets for natural gas, electricity, oil, and other fuels. Although the focus is presentation of data, there is also some interpretation and analysis.

Sector Overview

The amount of energy consumed in the U.S. for residential use (primary energy) was roughly the same in 1983 as in 1973. Consumption rose in 1984, but use per household was still 15% lower than in 1973. Direct consumption by households was 9% lower in total and 26% lower on a per household basis in 1984 than in 1973.[1]

The changes in energy consumption result from considerable changes in both the physical setting for U.S. residential energy use and the interaction of people with that setting. Most of the main changes have acted to **depress** consumption. The most important are: (1) Retrofit improvements of buildings (primarily single-family houses); (2) Introduction of new homes (relatively better insulated and sealed) to the stock (over one-quarter of the homes in 1984 were built after 1970); (3) Introduction of new heating and air conditioning equipment (relatively more efficient) to the stock;[2] (4) Retrofit improvements to old (installed before 1970) heating equipment; (5) Introduction of new non-heating appliances (relatively more efficient) to the stock; (6) Decline in the average number of persons per household (from 3.06 in 1970 to 2.72 in 1983, meaning lower demand per household for certain uses), along with increase in the percentage of 1- and 2-person households (meaning greater likelihood of the home being unoccupied for more of the day); (7) Migration of the average household to a warmer climate; and (8) Decline in the share of single-family housing.

Some structural changes have acted to **increase** energy consumption. These include: (1) Growth in use of central heating; (2) Growth in saturation of air conditioning; (3) Growth in saturation of other electric appliances. The counterbalancing effect of these forces (to those pushing downward on energy consumption) is probably partially responsible for the stabilization of energy consumption in the 1975-77 period.

The way people used their equipment contributed significantly to reduced energy consumption. Most important was the decline in wintertime thermostat settings. The percentage of households keeping the thermostat at 70 °F or higher when someone was at home during the daytime fell from around 85% in 1973 to around 46% in 1981 The percentage of households keeping the thermostat at 70 °F or higher during sleeping hours fell from around 51% in 1973 to around 22% in 1981. Use of secondary heating equipment (especially wood stoves) became more popular,

[1] This was partly due to growing penetration of electric heating, which transferred combustion losses from the home to the power plant. When this factor is removed, the decline in per household consumption is 23%. Consumption values have been normalized for weather.

[2] The increased share of electric heating (from 8% to 19% of all homes) has depressed direct energy consumption, but increased primary energy consumption.

as did heating less than the whole house.

Many of the changes in the structural setting took effect (and continue to be felt) in a gradual way. Others occurred more quickly in response to sharply rising energy costs. The fact that the sharpest decline in average consumption per household occurred in 1974 and 1980 corraborates this. The decline in 1980 and the continued decline through 1983 both reflect the upsurge in retrofit activity in 1979 and 1980 (and lowering of winter indoor temperatures). Retrofit activity slowed in 1981 and slowed further in 1982, but was by no means negligible. Part of the slowing of activity may have been due to some saturation of the market. In addition, the decline and stagnation of disposable income in the 1980-82 period probably acted to inhibit household spending on retrofit. The combination of the recession and the strong growth in the price of natural gas, electricity, and (through 1981) oil was a strong encouragement for a "belt-tightening" response on the part of households. It appears that winter indoor temperatures crept upward in 1982, however. The rise of consumption in 1984 -- not quite back to the 1982 level, however -- probably reflects relaxing of energy-conserving behavior allowed by growth in income and stabilizing of natural gas prices.

Changes for Natural Gas, Electricity, and Oil

The shares of the fuels and electricity in total residential delivered energy consumption have changed as follows:

	1970	*1977*	*1984*
		(percent)	
Gas	52	49	49
Electricity*	17	21	28
Oil	24	23	13
LPG	4	4	4
Wood	2	3	5

* The share of losses in electricity generation rose from 29% of total primary energy consumption in 1980 to 40% in 1984.

Sales of natural gas to residences were below the 1970 level despite growth in customers. Consumption per customer declined steadily after 1973. By 1983, average consumption was about 24% less than in the peak year of 1973. The main factors behind this decline were retrofit improvements, lower winter indoor temperatures, and the entry of new homes into the gas-heated stock of homes. Average consumption rose in 1984 back to the 1982 level, perhaps reflecting higher winter indoor temperatures.

Electricity sales to residences rose faster than the number of customers in the 1970s. This primarily reflected growing penetration of electric heating and air conditioning. Consumption per customer levelled off in the early 1980s as improved efficiency of appliances, retrofit of electric-heated homes, and changed behavior with respect to heating and air conditioning acted to depress usage. As with natural gas, average consumption rose in 1984.

Residential use of oil fell to half its 1973 level by 1983, and rebounded only slightly in 1984. This was due to both decline in the number of households using oil (from nearly 17 million in 1970 to around 13 million in 1983) and greatly reduced use per customer (over 35% less in the 1981/82 winter than in 1972/73). Average consumption increased in the 1982/83 winter as oil prices stabilized, but was still well below the level of 1979/80. An estimated 1-1.5 million households switched from oil to wood as main heating fuel; these could return to greater use of oil.

Chapter 1
Introduction

The primary purpose of this report is to facilitate clearer understanding of both the trends in U.S. residential energy consumption in the 1970-1984 period and the chief structural factors shaping those trends. The residential sector is an evolving, changing collection of households, homes, and energy-using equipment. **The basis of our approach is the belief that changes in energy consumption must be looked at in the context of changes in the structural setting for that consumption.** Looking at consumption data alone is only part of the story. It does not illuminate the underlying forces at work. This is what we have sought to do.

Another term for *structural setting* could be *physical setting*. What we refer to here are all of the physical factors that affect energy consumption. These include climate, household characteristics, and the state of buildings and their energy-using equipment. These factors, along with the behavior of people in their homes, shape energy consumption.[1] The structural features and behavior are in turn shaped by the economic setting, the institutional setting (i.e. -- the orientation of governments, energy suppliers, and equipment manufacturers), demographic changes, and the social psychological setting that influences households' energy-related decisions and behavior. Basic data on the economic setting are discussed briefly in this introduction.

The first main section of the report presents an overview of trends for the residential sector as a whole. Some readers may wish to stop there, though we strongly believe that it is necessary to look at the trends concerning each fuel separately to properly understand the dynamics of change. This is in part because there are so many factors to consider when looking at the sector as a whole. Accordingly, the report has separate chapters on natural gas, electricity, oil (fuel oil and kerosene), and other fuels (LPG, wood, and coal).

In each chapter, we present the information in a similar format.[2] The first section presents information on changes in the structural setting for each fuel. This includes information on the number of households using the fuel for various purposes, other features of households, the role of housing built after 1969, the type and efficiency of equipment, and conservation measures (structural and behavioral) undertaken by households. The second section presents information on trends in consumption, highlighting total consumption and average consumption per household. It contains a brief discussion linking changes in average consumption with changes in the structural setting, including a closer look at the 1980-84 period. The text describes the most important conclusions, but the accompanying tables contain considerably more information.

The report aims at clear exposition of the main trends concerning energy consumption in the U.S. residential sector. Our focus is changes at the national level. We do not speak to differences among the fuels and electricity with respect to consumption and structure. We do present some discussion of the link between changes in energy consumption and changes in the structural setting, but the report is not primarily intended as an explanatory analysis.

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[1] We present some data on household behavior in the sections on structural setting. Although not part of the structural setting *per se,* behavior is very much affected by its characteristics.

[2] The sector overview is somewhat different in format. The chapter on other fuels is shorter than the others.

In terms of content, we work the middle ground between the general and the particular. We have tried to present enough information to properly understand the evolution of U.S. residential energy use, but not so much as to overwhelm the reader with detail.

1. Relationship to Other Work on the U.S. Residential Sector

This report expands upon earlier work by Meyers and Schipper.[3] Its main distinctive features are:

1. Presentation of a comprehensive overview of trends in energy consumption (weather-adjusted) and trends in the structural setting for that consumption for the 1970-84 period;
2. Coverage of individual fuels and electricity separately;
3. Discussion of the link between changes in energy consumption and changes in the structural setting for the sector as a whole and for individual fuels.
4. Close examination of trends after 1979.

This report stands between two valuable works by Pacific Northwest Laboratory (PNL). It presents considerably more information and analysis (particularly on the structural setting for consumption) than the PNL work on energy conservation indicators.[4] It contains less data than the *Residential and Commercial Buildings Data Book* produced by PNL, which presents a great deal of information but does not attempt to place the data within an expository context. (The present report also presents some data not in the *Data Book*, and is more up to date.) The PNL *Data Book* is an excellent complement to this report for the reader who desires more data.

This report focuses on description of trends. An example of an approach for estimating the end-use structure of energy consumption in a given year can be found in the work of Latta[5] and Johnson[6] of the DOE Energy Information Administration. Results from these analyses are incorporated in this report.

2. The Economic Setting

Changes in the structural setting for residential energy consumption are strongly affected by economic parameters. Some of the changes are conditioned by general economic trends. The migration of households to warmer regions is an example of this. The demand for new homes and equipment are others. The particular economic parameters that most strongly affect many of the actions that we are concerned with (retrofits, behavioral changes, appliance purchases) are the prices of fuels and electricity and household income. A rising price of energy may prod households to some action such as retrofit or reduction of thermostat setting. Household income may either constrain or allow household choice of responses to changes in energy prices. Household income also affects appliance purchase decisions. Rising income allows capital investment in energy conservation, but it also allows households to more readily absorb growth in energy prices.

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[3] Energy in American Homes: Changes and Prospects, *Energy*, Vol. 9, No. 6 (1984).

[4] *Energy Conservation Indicators*, 1982, 1983.

[5] *Regression Analysis of Energy Consumption by End Use*, 1983.

[6] *Residential Energy Consumption and Expenditures by End Use for 1978, 1980, and 1981*, 1984.

The decision to invest in energy conservation is also conditioned by expectations of future energy prices as well as by current and historical prices (which in turn condition expectations).

2.1. Energy Prices

The average consumption-weighted price (actual prices) of residential fuels and electricity rose over four-fold between 1970 and 1982 (see Table 1-1). Relative to 1970, the average price in 1984 was 3.4 times higher for electricity, 5.6 times higher for natural gas, and 6.2 times higher for distillate fuel.

The price of natural gas increased steadily between 1973 and 1979, then climbed strongly in the 1980-83 period before stabilizing in 1984. The price of electricity also rose steadily after 1973, with the rate increasing in the 1980-82 period. The price of oil jumped upward in 1974, increased gradually, and then rose sharply in the 1979-81 period before declining in 1982 and 1983.

Prices for all consumer items also rose in the 1970-84 period: the Consumer Price Index saw a two-and-one-half-fold increase. After adjusting for general price inflation, we find much less increase in all cases (see Table 1-1). The adjusted price of distillate fuel declined steadily after 1981, and that of electricity rose little after 1982.

The price ratios between electricity and oil and gas in terms of dollars per million Btu (heat content) have decreased considerably since 1970, while that between oil and gas has increased slightly.

	1970	*1984*
Electricity/Gas	6.2	3.7
Electricity/Oil	4.9	2.7
Oil/Gas	1.3	1.4

2.2. Household Income

Disposable personal income per household in **constant 1982 dollars** was 12% higher in 1984 than in 1970.[7] With the exception of 1974 and 1975, this indicator rose continuously through 1979. The period between 1979 and 1982, however, saw decline in real income. This came as energy prices were rising significantly, and probably had an important effect in shaping household response to those rising prices.

[7] Disposable personal income per capita is from the U.S. Dept. of Commerce. DPI per household was estimated from our estimated series of persons per household.

Disposable Income per Household

Year	*1982 $*	*Year*	*1982 $*
1970	25700	1978	28040
1971	26130	1979	28110
1972	26460	1980	27320
1973	27580	1981	27270
1974	26690	1982	27050
1975	26650	1983	27670
1976	26970	1984	28880
1977	27390		

3. Notes to Readers

3.1. Weather Adjustment

Adjustment of annual consumption data to "normal" weather is important, but difficult to do with precision. The method of weather adjustment that we have used at LBL (described in Appendix A) involves separating the estimated space heating component of total consumption, and dividing this by the ratio of heating degree-days in year n to the long-run average degree-day total. The heating degree-day total reflects the average weather experienced by homes heated by the fuel in question, not all homes.

3.2. Standard Errors

The data describing the structural setting for energy consumption come mostly from surveys of some portion of the total households and are thus subject to sampling (and other) errors. Sampling errors are minor for the Annual Housing Surveys, which have large samples, but are often important for the Residential Energy Consumption Surveys, which have relatively small samples. We have presented standard errors for the latter where they seemed especially important. It should be kept in mind that sampling errors exist for all of the estimates from the RECS, and represent a sizable fraction of the estimate in those cases where the estimate is a small number of households.

3.3. Residential Energy Consumption Surveys

A considerable amount of the information presented in this report comes from the Residential Energy Consumption Surveys of the Energy Information Administration of the U.S. Dept. of Energy. These are interview surveys of a representative national sample of households. RECS-1 covered consumption in the period April 1980 through March 1981; RECS-2 covered the same months in 1981-82; RECS-3 covered the same months in 1982-83. Precursors to the RECS were the NIECS (National Interim Energy Consumption Survey, 1978-79) and the HSS (Household

Screener Survey, 1979-80). Some of the data presented here is from the published reports, while some is from our own work with the public use data tapes.

3.4. LPG

Although LPG is a petroleum product refined from crude oil, we have treated it separately from fuel oil and kerosene. LPG is used by a very different set of households; grouping it together with fuel oil and kerosene would detract from understanding the trends for those fuels.

3.5. Abbreviations

AGA: American Gas Association

AHS: Annual Housing Survey (by U.S. Bureau of the Census)

EEI: Edison Electric Institute

EIA: Energy Information Administration (U.S. Dept. of Energy)

RECS: Residential Energy Consumption Survey(s) (by the Energy Information Administration).

WCMS: Washington Center for Metropolitan Studies (conducted surveys of a representative national sample of households in 1973 and 1975)

Table 1-1
Prices of Residential Fuels and Electricity
U.S. Average

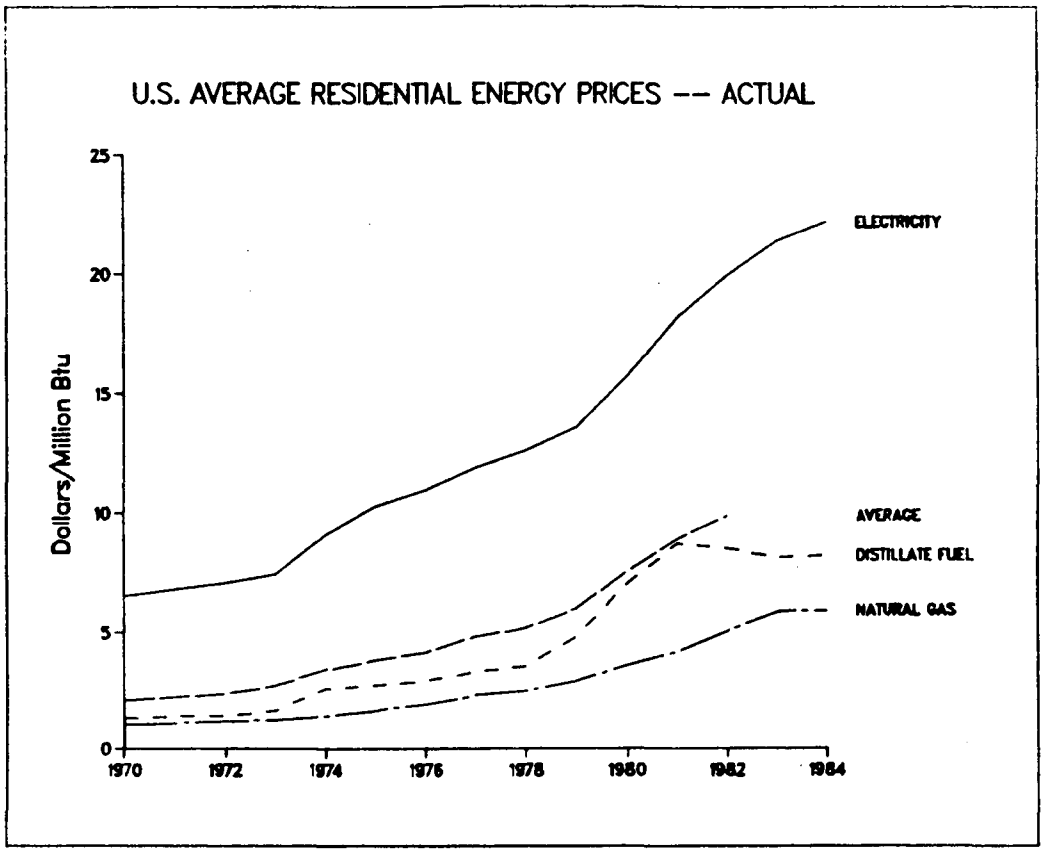
(Dollars per Million Btu)

	Natural Gas	Distillate Fuel	Electricity	Average*
		Actual Prices		
1970	1.06	1.33	6.54	2.10
1971	1.12	1.41	6.82	2.24
1972	1.19	1.41	7.12	2.38
1973	1.25	1.64	7.45	2.73
1974	1.42	2.61	9.08	3.40
1975	1.67	2.74	10.30	3.83
1976	1.94	2.94	10.97	4.16
1977	2.31	3.32	11.91	4.82
1978	2.50	3.56	12.66	5.19
1979	2.91	4.83	13.62	6.01
1980	3.60	7.04	15.73	7.55
1981	4.19	8.72	18.18	8.93
1982	5.05	8.53	19.93	9.88
1983	5.88	8.16	(21.38)**	-
1984	5.94	8.24	(22.15)**	-
		CPI-Adjusted Prices		
1970	0.91	1.14	5.62	1.81
1971	0.92	1.16	5.62	1.85
1972	0.95	1.13	5.68	1.90
1973	0.94	1.23	5.60	2.05
1974	0.96	1.77	6.15	2.30
1975	1.04	1.70	6.39	2.38
1976	1.14	1.72	6.43	2.44
1977	1.27	1.83	6.56	2.66
1978	1.28	1.82	6.48	2.66
1979	1.34	2.22	6.26	2.76
1980	1.46	2.85	6.37	3.06
1981	1.54	3.20	6.67	3.28
1982	1.75	2.95	6.89	3.42
1983	1.97	2.73	(7.16)**	-
1984	1.91	2.65	(7.12)**	-

Sources: EIA, *State Energy Price and Expenditure Report 1970-1982* (1985); EIA, *Monthly Energy Review* (for 1983-84)

* Weighted by consumption. Includes expenditures on LPG, kerosene, and coal.

** Based on percentage increase in average revenues per kWh sold for total electric utilities as reported by Edison Electric Institute.


U.S. AVERAGE RESIDENTIAL ENERGY PRICES -- ACTUAL
Dollars/Million Btu
25
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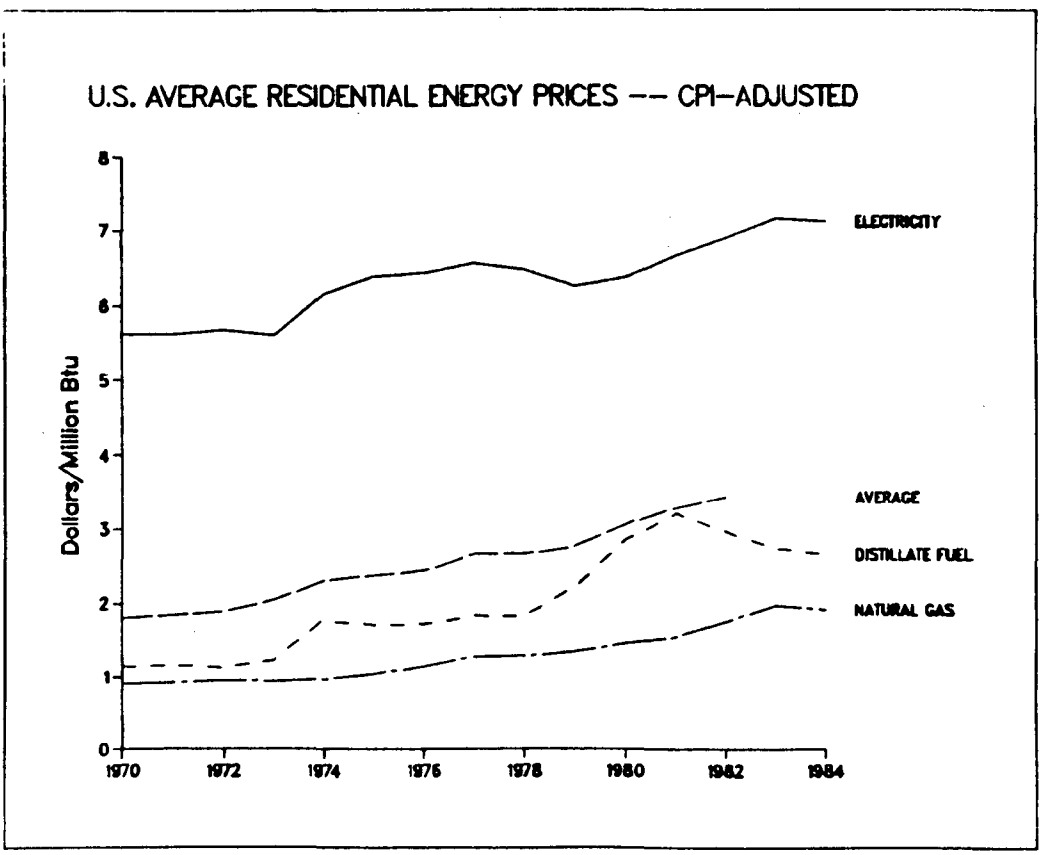
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AVERAGE
DISTILLATE FUEL
NATURAL GAS

Chapter 2
U.S. Residential Energy Use 1970-84: Sector Overview
A. The Structural Setting[1]

The structural setting for U.S. residential energy use has changed considerably since 1970. The behavior of people within that setting has changed as well. In the following sections we present the quantitative picture of the key changes.

1. Households and Housing

The number of households in the U.S. grew from around 64.5 million in 1970 to around 85.4 million in 1984 (see Table 2-1). Approximately 27 million new residential housing units were completed between 1970 and 1983 (inclusive) (this includes mobile homes placed for residential use).[2] The result of the additions and losses is that nearly 26% of the 1983 occupied housing stock was built after March 1970.

The population in households grew from around 198 million in 1970 to around 230 million in 1983. Thus, **the average number of persons per household fell** from 3.06 in 1970 to 2.72 in 1983. (The median number fell from 2.74 to 2.32.) This means that there is lower demand per household for certain purposes (especially water heating and clothes washing/drying).

The percentage of 1-person households rose from 18% in 1970 to 22% in 1983, while the percentage of 2-person households rose from 30% to 32%. Along with the increased participation of women in the labor force, this has probably resulted in **more homes being left empty (and at lower indoor winter temperature) today than in the early 1970s.** (We are not aware of data to confirm this.)

The average U.S. household is located in a slightly warmer climate today than in 1970. Because of migration, the same winter in 1980 would have imposed 2.7% less overall heating requirements than in 1970. The trend also means that the same summer would impose greater overall cooling requirements today than in 1970.

A lower percentage of households live in single-family houses today than in 1970.

	1970 Census	*1983 AHS*
	(percent of households)	
Type of Structure:		
Single-family*	71.4	68.1

[1] This section covers key factors that have shaped the overall level of residential energy consumption. Other factors that have affected consumption of particular fuels are discussed in the appropriate chapters. The last part of this section describes the sources of data. The most recent year for which Annual Housing Survey data are available is 1983. The most recent year for which Residential Energy Consumption Survey data are available is 1982 (data for 1984 will be available in mid-1986).

[2] Bureau of the Census, *Characteristics of New Housing.*

Multi-family	25.3	27.2
Mobile home	3.3	4.7

* Includes townhouses.

This trend means that a lower percentage of homes have all walls and ceiling exposed to the weather.

Change in the average size of U.S. homes is difficult to determine. Measurements from the 1980 RECS give an average enclosed area of 1757 square feet for homes built before 1970.[3] Measurements from the 1982 RECS give an average enclosed area of 1698 square feet for all homes. The lower average size in 1982 could be a product of the increased share of multi-family housing and mobile homes.[4] The median number of rooms per dwelling increased slightly from 5.0 in 1970 to 5.1 in 1983.

2. Improved Thermal Integrity of Residential Buildings

The average home today is both better insulated and has lower air infiltration than in 1970. This statement is based on data on improvements to older homes ("retrofitting") and the addition of new, better-insulated and sealed homes to the stock. Both of these trends are well-substantiated (see below). Unfortunately, the existing data that describe in general terms the thermal characteristics of U.S. homes are not terribly revealing of the changes that seem to have occurred.

Statistics from the AHS for the 1974-80 period (see Table 2-2) show an increase in the percentage of single-family homes with storm windows (from 45% to 52%), and in the percentage of homes with attic/roof insulation (from 71% to 78%). Slight increase is evident in the percentage of homes with storm doors.

Data from the RECS for the 1978-82 period (see Table 2-3) show some increase in the percentage of homes with storm windows, but no increase for storm doors. The percentage of single-family houses with attic/roof insulation shows slight increase, but the data on the average number of inches of insulation present show little evidence of significant change between 1980 and 1982.[5] The percentage of homes with wall insulation shows considerable increase between 1978 and 1980, but not in 1981 or 1982.

2.1. Retrofit Activity

Data from the 1975 WCMS household survey indicate that there was some retrofit activity in the period after the 1973 oil price rise. Eight percent of the households reported adding new or additional insulation in the May 1973-May 1975 period, and a similar percentage reported adding storm windows and/or doors.[6]

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[3] This estimate does not take into account the homes that were removed from the stock between 1970 and 1980. If, on the average, the removed units were smaller than the units not removed, then the average of 1757 would overestimate the average area of homes in 1970.

[4] Our efforts to determine the average area for different housing types turned up as yet unresolved problems with the data on the RECS tapes.

[5] Since data on inches of insulation come from respondents' estimates and not from measurements, their reliability is probably not high.

[6] Personal communication from The Grier Partnership, Bethesda, MD.

Data from the AHS (for the 1978-80 period) and from the RECS (for the 1978-82 period) both show evidence of **considerable retrofit activity on single-family houses and mobile homes** (see Table 2-4). (Some data are also available from RECS for multi-family housing.) The AHS consistently show more activity than the RECS. The RECS show addition of ceiling and wall insulation peaking in 1980; the AHS do not show this. The RECS also show addition of caulking and weatherstripping peaking sharply in 1980; again, the AHS do not show this. The RECS show addition of ceiling and wall insulation falling off in 1982.

2.2. Thermal Characteristics of Housing Built After 1970[7]

The introduction of new housing into the stock has resulted in improvement in the average thermal integrity of U.S. homes. Data from surveys conducted by the National Association of Home Builders (NAHB) provide evidence of **considerable increase since 1973 in the average level of ceiling and floor insulation and in the installation of double and triple window glazing in newly-constructed single-family houses** (see Table 2-5). Data for **low-rise multi-family housing,** which accounts for 60-85% of all new multi-family housing, **show little increase in insulation levels and some increase in the use of double and triple glazing since 1976** (see Table 2-5).

For single-family houses, the average installed level of ceiling insulation increased from around R-14 in 1973 to around R-25 in 1979, remained at that level in 1980-81, increased in 1982 to around R-28, and then declined from this peak in 1983 and 1984. The average level of floor insulation has steadily increased, while the average level of wall insulation has seen only slight increase. The use of single-glazing fell from 60% of new single-family houses in 1973 to 37% in 1979, remained at about this level through 1983, and then fell to 26% in 1984. The incidence of triple glazing has increased from nil to 9% in 1984.[8]

Measurements of air infiltration rates suggest that recently-constructed homes have lower values than older homes. The mean seasonal infiltration value from a sample of 312 houses recently constructed in the U.S. and Canada was 0.63 air changes per hour (ach). The mean value for 266 older, low-income houses throughout the U.S. was 0.9 ach.[9]

3. Energy-Using Equipment

The three main trends with respect to energy-using equipment that have affected the level of total energy consumption **are the increased electrification of space heating, water heating, and cooking; growth in saturation of certain appliances; and improved energy efficiency of new appliances.**

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[7] Homes built after 1969 accounted for 23% of the 1982 stock of single-family houses, 31% of the 1982 stock of multi-family units, and 73% of the 1982 stock of mobile homes, according to RECS.

[8] A factor to consider in interpreting these values is that the average new single-family house has steadily been located in a warmer climate. This trend would tend to depress the average insulation level and the penetration of double and triple glazing.

[9] *Manual on Indoor Air Quality,* Electric Power Research Institute, 1984.

3.1. Increased Electrification of Space Heating, Water Heating, and Cooking

The use of electricity as main space heating, water heating, and cooking fuel has become more common since 1970.

	Electricity	*Gas*	*Oil*	*Other*
	(percent of households)			
Space Heating				
1970*	8	55	26	10
1983**	19	55	15	10
Water Heating				
1970*	26	57	10	3
1982***	32	56	7	5
Cooking				
1970*	41	49	-	10
1982***	54	40	-	6

* 1970 Census ** Annual Housing Survey *** RECS

This change mostly reflects the popularity of electric heating in homes built since 1970. There has also been a modest amount of switching to electric heating from other fuels.

In the case of space heating and water heating, the increased penetration of electricity means that less energy needs to be consumed in the home to meet the same need (because electric heating systems convert a higher percentage of the energy input into usable heat). This depresses site (delivered) energy consumption. Increased electrification also means an increase in primary energy consumption, since fossil-fuel generation of one unit of electricity[10] requires the consumption of around three units of some fuel.

3.2. Increased Appliance Saturation

The average household has more energy-using equipment now than in 1970. Some of these appliances are devices with minor energy use, but the prevalence of some major energy-using appliances has increased as well.

Foremost among these are **air-conditioners, whose saturation has grown substantially since 1970:**

	1970 Census	*1983 AHS*
	(percent of households)	
Have A/C	37	59
Have Central A/C	11	29

[10] Fossil fuels accounted for 73% of U.S. electricity generation in 1984.

Other major appliances whose saturation has increased include the following:

	1973 WCMS	*1981/82 RECS*
	(percent of households with)	
Frost-Free Fridge	51	60/63
Freezer	34	41/37
Clothes dryer*	38	45/45
Dishwasher	25	37/36
Color television	53	82/85
Microwave oven	3	17/21

* Electric

With the exception of microwave ovens, higher saturation of these appliances has exerted upward pressure on electricity consumption.

3.3. Improved Appliance Efficiency

The major appliances in the average U.S. home today are more energy-efficient than in 1970. The percent improvement in efficiency over 1972 levels of each year's shipments of major residential appliances is shown in Figure 2-1.[11] New refrigerators and freezers in 1984 were on average 60-70% more efficient than in 1972. Central air conditioners were 30% more efficient, while room air conditioners were 25% more efficient. Gas space and water heaters were around 15% more efficient.

These appliances have entered the stock in new homes and as replacements in existing homes. Changes in the resulting equipment energy use, averaged over all homes, are estimated by the LBL Residential Energy Model[12] (see Table 2-6). The values shown are estimated consumption before accounting for the effects of changing usage by households in response to higher energy prices and other factors.

4. Energy-Conserving Behavior

Survey data on energy-conserving behavior by U.S. households provide evidence of considerable change in heating practices. The most important change has been a **major reduction in winter indoor temperatures** (see Table 2-7). The percentage of households keeping the thermostat at 70 °F or higher when someone was at home during the daytime fell from around 85% in 1973 to around 46% in 1981 (the first year RECS collected such information). The percentage of households keeping the thermostat at 70 °F or higher during sleeping hours fell from around 51% in 1973 to around 22% in 1981.

[11] Source: Levine, *et al.*, Economics of Efficiency Improvements in Residential Appliances and Space Conditioning Equipment, Lawrence Berkeley Laboratory, 1985.

[12] McMahon, *et al.*, The LBL Residential Energy Model (LBL-18622), Lawrence Berkeley Laboratory, 1986.

Data from the 1975 WCMS survey indicate that the 1973 "energy crisis" brought on a major response by the winter of 1974/75. The percentage of households reporting their typical daytime temperature as 70°F or above fell from 85% in 1973 to 52% in 1975. This is about the same as the RECS found in November 1981. Whether temperatures crept upward after 1975 and then fell again in 1980 is uncertain. The RECS data do indicate that daytime temperatures crept upward from 1981 to 1982, however.

One type of behavior associated with the lowering of thermostats is the use of small room heaters (electric and kerosene) and wood stoves. The percentage of households using such equipment increased between 1978 and 1982 (see Table 2-8).

Another change in heating practices that parallels the reduction in thermostat settings is closing off and not heating some rooms. We are not aware of national data on this practice.

It is widely believed that household practices have also changed with respect to other residential energy uses, particularly air conditioning, hot water (for clothes washing), and lighting, but we are not aware of data on this. Data are available on air conditioning practices, but only for 1981 and 1982 (from RECS).

5. Data Sources

The two main sources of national-level data on energy-related structural characteristics of housing are the Annual Housing Surveys (AHS) conducted since 1973 by the Bureau of the Census and the Residential Energy Consumption Surveys (RECS) conducted since 1978 by the Energy Information Administration. The AHS has a very large sample (around 70,000 households), but asks few questions related to energy use. The RECS asks many questions, but has a small sample size (4700-6400 households) and therefore higher standard errors around its estimates.

One problem with the AHS is that it relies on the information provided by households, which may sometimes be erroneous (particularly in apartment buildings). In RECS, telephone interviews to check information on heating fuels were conducted with rental agents and landlords of households living in multi-unit buildings.

Both surveys have problems with respect to comparability of longitudinal data. The AHS series exhibits a large jump in the total household population between 1980 and 1981 because the survey frame was adjusted after the 1980 census. RECS estimates (actually pre-RECS) before 1980 do not include Alaska and Hawaii, and there is an unaccountably large jump in the estimate of the total household population between 1979 and 1980. These problems should be kept in mind when looking at longitudinal data.

The latest RECS for which data are available is the 1982 survey. There was no RECS in 1983. Results from the 1984 RECS will be available summer 1986. The latest AHS for which data are available is the 1983 survey. There was no AHS in 1984.

Table 2-1
Estimates of the Number of U.S. Households and Residents

(thousands)

	Ann Housing Survey (October)	RECS (November)	Current Pop Survey (March)	Census (April)	Resident Population (July)
1970	-	-	63401	63445*	203984
1971	-	-	64778	-	206827
1972	-	-	66676	-	209284
1973	69337	-	68251	-	211357
1974	70831	-	69859	-	213342
1975	72523	-	71120	-	215465
1976	74005	-	72867	-	217563
1977	75280	-	74142	-	219760
1978	77167	76608**	76030	-	222095
1979	78572	77500**	77330	-	224567
1980	80072	81600	80776	80390	227255
1981	83175***	83100	82368	-	229637
1982	-	83800	83527	-	231996
1983	84638	-	83918	-	234284
1984	-	86300	85407	-	236495

Sources: Annual Housing Survey, Bureau of the Census and the Dept. of Housing and Urban Development. Current Population Survey, Bureau of the Census. Bureau of the Census, *Preliminary Estimates of the Population of the U.S. by Age,* Sex, and Race: 1970-1981; and personal communication.

* 64527 when estimated missing units are added. The 1980 census is believed to have much more complete coverage.

** Does not include Alaska and Hawaii (425,000 households in 1980).

*** Reflects change in survey frame after 1980 census. Does not match with pre-1981 values. The AHS became bi-annual after 1981.

Table 2-2
Thermal Characteristics of U.S. Single-Family and Mobile Homes

(percent of homes)

	1974	1975	1976	1977	1978	1979	1980
Storm windows*							
All covered	45	46	46	-	48.6	51.7	52.3
None covered	44	43	42	-	39.5	37.0	35.6
Storm doors							
All covered	47	48	47	-	46.5	48.9	47.4
None covered	41	39	39	-	38.7	37.2	38.0
Attic/roof insulation							
Have	71	74	76	-	74.6	77.0	77.5

Source: Annual Housing Surveys

* Or other protective window covering.

Table 2-3
Thermal Characteristics of U.S. Homes*

(percent of households)

	1978	1980	1981	1982
With storm windows on 100% of windows				
Single-family	42	41	44	46
Multi-family	-	32	42	36
No storm windows				
Single-family	37	37	37	36
Multi-family	-	56	51	56
With storm doors on 100% of doors				
Single-family	40	38	38	40
Multi-family	-	19	22	21
No storm doors				
Single-family	33	32	32	31
Multi-family	-	70	69	70
Single-Family Houses:				
Have roof/ceiling insulation	76	77	78	79
All insulated	-	68	67	66
Batts only	36	38	39	38
Avg. number of inches	-	5.3	5.5	5.1
Loose fill only	25	21	19	23
Avg. number of inches	-	6.5	6.2	6.8
Batts and loose fill	5	8	8	9
Avg. number of inches	-	10.3	10.4	10.3
Have wall insulation	53	64	61	61
All walls	-	53	51	51

Source: Residential Energy Consumption Surveys

* As of around November.

Table 2-4
Conservation Improvements by U.S. Households:
Single-Family Houses and Mobile Homes

(million households)

	1978	1979	1980	1981	1982
Storm windows					
RECS*	2.7	2.9	2.8	2.5	2.3
Storm doors					
AHS	3.0	3.2	2.6	-	-
RECS*	2.7	3.2	3.6	2.9	3.2
Roof/ceiling insulation					
AHS	4.2	4.2	4.1	-	-
RECS	2.7	3.1**	3.4**	2.7	2.1
Wall insulation					
AHS	3.0	3.2	2.9	-	-
RECS	1.4	1.8**	2.0**	1.6	1.2
Floor insulation					
RECS	1.2	0.9**	0.9**	0.7	0.9
Caulking or weatherstripping (AHS)	11.4	12.1	10.6	-	-
Caulking (RECS)	10.1	5.3	11.2	8.8	7.8
Weatherstripping (RECS)	4.2	4.9	8.3	5.8	5.5
Shutters, etc.*** (RECS)	4.9	2.9	6.1	4.0	6.0
Plastic sheets	-	-	-	-	4.0
Water heater ins. (RECS)	0.5	0.9	1.6	1.9	1.8
Heating ducts ins. (RECS)	-	0.6	0.7	0.8	0.8
Elec. or mechanical furnace ignition (RECS)	-	0.5	0.5	0.5	0.5
Smaller burner nozzle (RECS)	-	0.3	0.6	0.5	0.2
Heating equipment maintenance or modification (AHS)****	9.9	10.4	-	-	-

Source: Annual Housing Surveys; Residential Energy Consumption Surveys. Based on reported activity.

* Includes multi-family housing.

** Single-family units only.

*** Shutters, insulating drapes, reflective film, or plastic sheets.

**** Owner-occupied units only.

Conservation Improvements by U.S. Households*

(million households)

	1978	1979	1980
Single-Family Units and Mobile Homes:			
Storm windows or other covering	4.4	4.5	4.4
Storm doors	3.0	3.2	2.6
Roof/ceiling insulation	4.2	4.2	4.1
<3 inches	0.3	0.3	-
3-6 inches	1.7	1.7	-
>6 inches	1.6	1.5	-
Wall insulation	3.0	3.2	2.9
Caulking or Weatherstripping	11.4	12.1	10.6
Other insulation	2.4	2.9	4.2
Heating equipment maintenance or modification**	9.9	10.4	-

Source: Annual Housing Surveys

* During 12-month period before the survey (conducted during the last third of the year).

** Owner-occupied units only.

Note: These questions were not asked in the 1981 and 1983 surveys.

Table 2-5
Construction Practices for New Homes
U.S. Totals

	Single-Family Detached Homes									
	1973	1974	1976	1978	1979	1980	1981	1982	1983	1984
Average R-values of Insulation*										
Ceiling	14.4	15.8	18	22.3	24.8	24.7	24.9	28.3	24.8	26.1
Exterior Walls	10.0	9.2	12	10.9	11.2	11.6	11.4	11.9	11.8	12.3
Floor	4.0	4.3	-	5.2	6.6	6.1	6.9	7.8	8.3	9.7
Window Glazing (% of homes)										
Single	60	52	50	42	37	36	38	38	38	26
Double	40	48	49	56	60	58	54	54	55	65
Single w/storm	16	24	18	-	24	-	-	-		
Double	24	24	31	-	31	-	-	-		
Triple**	-	-	1	2	3	6	8	8	7	9
Number of houses completed ('000)	-	-	-	1353	1100	776	643	577	899	877

	Multi-Family Low-Rise Housing***									
	1973	1974	1976	1978	1979	1980	1981	1982	1983	1984
Average R-values of Insulation										
Ceiling	-	-	21.2	20.2	21.3	23.5	22.8	22.7	23.5	22.7
Exterior walls	-	-	11.0	11.1	11.0	10.7	10.2	11.5	12.1	11.7
Floor****	-	-	n.a.	4.8	9.4	8.8	10.2	3.3	5.4	4.4
Window Glazing (% of homes)										
Single	-	-	54	54	48	49	46	58	51	48
Double	-	-	45	45	50	47	48	38	41	46
Triple	-	-	1	1	2	4	6	4	8	6
Number of units completed ('000)	-	-	-	326	295	214	186	223	405	444

Source: NAHB Research Foundation

* Excluding siding and sheathing. For floor insulation, the values appear to be an average for all units, not just those units that had floor insulation.

** Includes double-with-storm.

*** Low-rise housing accounts for 60-85% of all new multi-family units.

**** In some years the values appear to be an average for all units, in other years for only those units that had floor insulation.

Table 2-6
Equipment Energy Use in the Average U.S. Home:
Model Estimates*

(Million Btu)**

	1977	1978	1979	1980	1981	1982	1983	1984
Central Space Heaters***								
Gas	82.50	82.63	82.65	82.51	82.26	81.97	81.64	81.21
Heat Pump	89.82	89.65	89.28	88.76	88.26	87.79	87.35	86.88
Air Conditioners								
Room	13.24	13.21	13.15	13.06	12.94	12.81	12.67	12.52
Central	36.33	36.21	36.01	35.76	35.49	35.18	34.85	34.49
Heat Pump	36.33	35.67	35.10	34.67	34.39	34.11	33.90	33.69
Water Heaters								
Electric	51.14	51.11	51.10	51.07	50.99	50.89	50.79	50.69
Gas	21.82	21.81	21.76	21.65	21.51	21.29	21.02	20.77
Refrigerators	16.11	15.96	15.76	15.52	15.25	14.98	14.72	14.44
Freezers	16.04	15.86	15.64	15.40	15.17	14.94	144.72	14.50
Stoves/Ovens								
Electric	14.33	14.20	14.03	13.85	13.69	13.53	13.38	13.23
Gas	9.60	9.50	9.33	9.13	8.94	8.72	8.51	8.28
Dryers								
Electric	12.82	12.76	12.70	12.63	12.56	12.50	12.44	12.38
Gas	7.02	6.98	6.93	6.87	6.82	6.77	6.72	6.66

Source: LBL Residential Energy Model, July 1985. Penetration of new equipment in the model depends on fuel prices and equipment costs. Energy consumption of new equipment is based on test data. Estimates of average consumption in the base year (1977) are derived from a combination of sources.

* These values reflect estimated consumption before the application of usage elasticities, which account for changes in usage of the equipment as a result of higher energy prices or other factors, and before application of thermal integrity factors, which account for modifications on building envelopes.

** Electricity is counted as primary energy (1 kWh = 11500 Btu)

*** Electric (non-heat pump) and Oil show little change.

Table 2-7
Average Reported Winter Indoor Temperatures in U.S. Homes

(% of households with heating controls)*

	Temperature in degrees F as of:			
	Winter 1972/73	Winter 1974/75	November 1981	November 1982
Daytime temperature when someone is at home				
70 or above	85**	52**	46	51
71+	-	-	20	25
73+	33	13	-	-
Under 70	12**	39**	50	46
Under 67	-	-	20	18
Heat off	-	-	2	2
Daytime temperature when no one is at home				
70 or above	-	-	17	22
71+	-	-	8	10
73+	-	-	-	-
Under 70	-	-	62	62
Under 67	-	-	45	47
Heat off	-	-	18	15
Nightime (sleeping hours) temperature				
70 or above	51	29	22	23
Under 70	45	62	75***	76***
Under 64	-	20	25***	34***

Sources: Washington Center for Metropolitan Studies surveys (1973, 1975); EIA, RECS-2 and RECS-3

* 81% of households had heating controls in both 1973 and 1981, 80% in 1982.

** The data do not distinguish between the temperature when someone is at home or not. Given the increased entry of women into the labor force and the higher proportion of 1 and 2-person households, it was probably more common for someone to be at home in 1973 than in 1981-82.

*** Includes households with heat off.

Totals are less than 100% due to households who did not know.

Table 2-8
U.S. Households Using Secondary Heating Equipment*

(% of all households)

	1978	1980	1981	1982
Wood	14.0	16.4	18.8	19.7
Fireplace	-	12.3	14.7	15.8
Stove	-	4.1	4.1	4.8
Electricity**	8.3	11.3	10.8	12.5
Portable heater	-	7.1	7.0	8.3
Kerosene	-	-	1.4	3.2
Portable heater	-	-	0.7	3.1

Source: Residential Energy Consumption Surveys

* There were also households using natural gas and fuel oil systems as secondary heat source. Many of these had installed and used wood stoves as primary heat source.

** In a number of homes, the built-in electric units were used as secondary heating equipment.

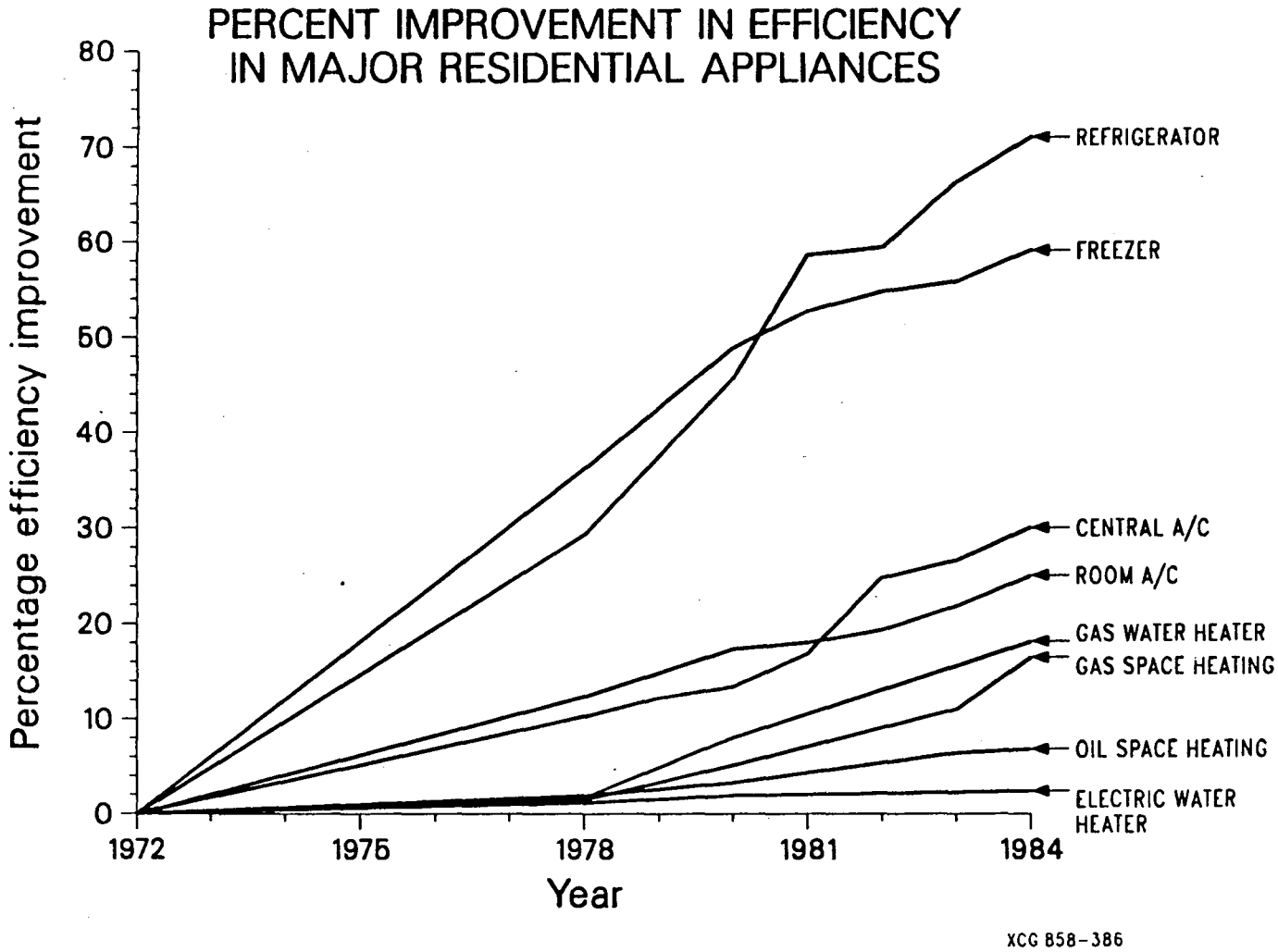
PERCENT IMPROVEMENT IN EFFICIENCY
IN MAJOR RESIDENTIAL APPLIANCES
Percentage efficiency improvement
80
70
60
50
40
30
20
10
0
1972
1975
1978
1981
1984
Year
REFRIGERATOR
FREEZER
CENTRAL A/C
ROOM A/C
GAS WATER HEATER
GAS SPACE HEATING
OIL SPACE HEATING
ELECTRIC WATER HEATER
XCG 858-386

FIGURE 2-1

B. Trends in U.S. Residential Energy Consumption: 1970-1984

1. State of the Data

The energy consumption numbers presented in this section are drawn from the chapters on the individual fuels. The sources are the EIA, the American Gas Association, and the Edison Electric Institute. This chapter presents our weather-adjusted values. The actual values can be found in the chapters on the individual fuels. The later chapters discuss data problems -- uncertainties about oil consumption in the 1970-78 period, about inclusion of master-metered apartment buildings, and disagreements among sources. These problems are not so significant as to cast doubt on the general conclusions presented below.

There are three main ways of looking at the trend in total sectoral energy consumption. One is to count **primary energy,** which includes all energy consumption accounted for by the residential sector. The disadvantage here is that, because losses in electricity generation are so large, changes in consumption of electricity overshadow changes in consumption of gas and oil. Counting **delivered energy,** which reflects the energy actually purchased by households, has the disadvantage that the increasing share of the heating market captured by electricity acts to depress total consumption, since electricity does not have combustion losses at the building site. A way of removing this bias is to remove the approximate combustion losses of fuels.[1] This leaves a quantity that is called **useful energy.** This quanitity reflects changes independent of the increasing electricity share of the heating market.

Another accounting issue is presented by wood consumption. Wood is generally not included in residential energy consumption statistics, but since wood consumption is in gross calorific terms nearly as great as oil, this seems unsatisfactory. But counting wood at full calorific value also seems unsatisfactory: because it is used relatively inefficiently, the increased use of wood inflates total consumption beyond where it would have been if wood consumption had not increased. To place wood on a similar footing with the other fossil fuels (which in effect are counted at around 1.5 times their conversion efficiency), we use our estimate of the overall average conversion efficiency for wood heating for 1982 of 35% (see Note below). Thus, in calculating total delivered and primary energy consumption, we count half of total wood consumption. This is a somewhat arbitrary but reasonable approach.

2. Total Residential Energy Consumption

Primary energy consumption accounted for by the U.S. residential sector, adjusted to approximate normal weather, was 5% higher in 1984 than in 1973 (see Table 2-9). **Delivered** energy consumption, adjusted to approximate normal weather, was 9% lower in 1984 than in 1973. **Useful** energy consumption, adjusted to approximate normal weather, was 5% lower in 1984 than in the peak year of 1973.

---

[1] We approximate combustion losses as 35% of delivered energy for gas, oil, LPG, and coal, as 65% of delivered energy for wood.

The time-series for primary energy shows a drop in 1974 followed by a period of increase up until 1979, and some decline through 1983 (see Figure 2-2). 1984 saw a substantial increase due largely to growth in electricity consumption. The time-series for delivered energy shows a larger drop in 1974 followed by several years of very modest increase, gradual decline in 1978-79 followed by a large decline in 1980, modest decline in 1981-82, followed by a large drop in 1983. 1984 saw the first increase since 1977. The time-series for useful energy shows a trend similar to that of delivered energy, except that the decline is slightly less after 1977. This smaller decline is due to the fact that part of the decline in delivered energy is attributable to the increased penetration of electricity in the heating market.

3. Average Energy Consumption per Household

Average energy consumption per household, counted as **primary** energy, adjusted to approximate normal weather, was 15% lower in 1984 than in 1973 (see Table 2-10). Counted as **delivered** energy, adjusted to approximate normal weather, it was 26% lower in 1984 than in the peak year of 1973. Counted as **useful** energy, adjusted to approximate normal weather, it was 23% lower in 1984 than in the peak year of 1973.

The time-series for primary energy shows a drop in 1974 followed by a period of stability up until 1978, gradual decline in 1978-79 followed by a large drop in 1980, and gradual decline in 1981-82 (see Figure 2-3). 1984 saw the first increase since 1973. The time-series for delivered energy shows a drop in 1974 followed by several years of slight decline, declines in 1978-79 followed by a large decline in 1980, and steady decline in the 1981-83 period. Here too, 1984 saw the first increase since 1973. The time-series for useful energy shows a trend similar to that of delivered energy, except that the decline is slightly less after 1973.

4. Average Energy Consumption per Capita

Average energy consumption per capita (see Table 2-11 and Figure 2-4) **has declined less than average energy consumption per household** (see table below). This shows that the decline in size of the average household (from 3.06 in 1970 to 2.72 in 1983), was an important factor in reducing consumption per household. The decline in household size may have pushed slightly upwards on consumption per capita. This is because for some end-uses, energy consumption probably does not decrease as fast as household size. Refrigeration is a good example; the principle applies to other end-uses that a smaller household uses as much as a larger one. To a certain extent, this may include space heating and air conditioning, since the decline in household size has apparently not been matched by an equivalent decline in average living area. That is, today's average (and smaller) household may have as much space to condition as the average (and larger) household in 1970. On the other hand, the smaller household is more likely to be unoccupied (and not conditioned to normal comfort level) than the larger household. This is especially true given that today's household is more likely to have a working wife.

5. Summary of Changes

Percentage changes in U.S. residential energy consumption (weather-adjusted) between 1973 (the peak year) and 1984[2] vary according to the method of accounting:

	Total	*Per Household*	*Per Capita*
Primary energy	+5%	-15%	-7%
Delivered energy	-9%	-26%	-18%
Useful energy	-5%	-23%	-15%

Note that when we move from delivered energy per household to useful energy per capita -- thereby accounting for the effect of the increased share of electric heating and the effect of the decline in household size -- the story changes considerably.

6. Changing Fuel Shares

The shares of the fuels in total residential **delivered** energy consumption have changed as follows (based on Table 2-9):

	1970	*1977*	*1984*
		(percent)	
Gas	52	49	49
Electricity	17	21	28
Oil	24	23	13
LPG	4	4	4
Wood	2	3	5

The changes in consumption of the different fuels are depicted in Figure 2-5.

7. Linking Changes in Consumption and the Structural Setting

The structural setting for residential energy use has changed in many ways. Most of the changes have acted to depress energy consumption, but some have worked in the opposite direction. To attempt to quantify the contributions of the various factors is not impossible. King *et al.* estimated the size of total energy savings attributable to changes in shell efficiency, appliance efficiency, and to household migration for the 1973-80 period.[3] Given the limitations of the available data, however, such estimates are in our opinion subject to considerable uncertainty. While acknowledging the uncertainty, we can nonetheless give the direction, permanence, and (in some cases) relative importance of the effect of the different structural changes on residential energy use.

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[2] Consumption in 1984 was higher than in 1983.

[3] King, M.J., *et al., An Analysis of Changes in Residential Energy Consumption, 1973-1980,* Pacific Northwest Laboratory, 1982.

Most of the main changes in the structural setting have acted to depress average consumption. These include:

- Retrofit improvements of buildings;
- Introduction of new homes (relatively better insulated and sealed) to the stock;
- Introduction of new heating equipment (relatively more efficient) to the stock;[4]
- Retrofit improvements to old (installed before 1970) heating equipment;
- Introduction of new non-heating appliances (relatively more efficient) to the stock;
- Decline in the average number of persons per household (and increase in the percentage of 1- and 2-person households);
- Migration of the average household to a warmer climate; and
- Growth in the share of multi-family housing.

The factors that have acted to **increase** energy consumption per household all fall into the permanent category. All of the three below have had a significant effect:

- Growth in use of central heating;
- Growth in saturation of air conditioning;
- Growth in saturation of other electric appliances.

The counterbalancing effect of these forces (to those pushing downward on energy consumption) is probably partially responsible for the stabilization of energy consumption in the 1975-77 period.

The **behavioral** changes include:

- Decline in wintertime indoor temperatures;
- Increase in summertime indoor temperatures in air-conditioned homes;
- Other aspects of household behavior that affect energy use.

We believe the decrease in wintertime indoor temperatures to be the single most important factor behind the decline in residential energy consumption. Retrofit improvements probably rank second in importance, followed by the introduction of new homes. After that it becomes difficult to judge. Note that many changes have occurred in combination with one another (a fact that makes multivariate analysis problematic).

7.1. The 1980-84 Period: A Closer Look

Energy consumption per household began to decline in 1978 after several years of stability (see Figure 2-3). This decline accelerated considerably in 1980, the year when the full effect of the jump in the world price of oil combined with rising natural gas and electricity prices to once more make energy a focus of consumer attention. After 1980, consumption continued to fall gradually in 1981 and 1982, declined more strongly in 1983, and rose in 1984.

---

[4] The increased share of electric heating has depressed delivered energy consumption, but increased primary energy consumption.

Energy consumption in the 1980s was, of course, affected by the structural changes that had taken place during the 1970s. Retrofit activity was stimulated by the introduction of the conservation tax credit (beginning in 1977) and the growth of utility conservation programs. The effect of the improved energy efficiency of new home appliances and new homes was being felt by the end of the 1970s. Unfortunately, we do not know the path taken by wintertime indoor temperatures after 1973. Data are also not available for 1980, but the large drop in 1980 suggests a strong decline.[5] There is also evidence of increase in low-cost weatherization in 1980.[6]

The decline in 1980 and the continued decline through 1983 both reflect the upsurge in retrofit activity in 1979 and 1980 (and lowering of winter indoor temperatures). Retrofit activity slowed in 1981 and slowed further in 1982, but was by no means negligible. Part of the slowing of activity may have been due to some saturation of the market. In addition, the decline and stagnation of disposable income in the 1980-82 period probably acted to inhibit household spending on retrofit. The combination of the recession and the considerable growth in the price of natural gas, electricity, and (through 1981) oil was strong encouragement for a "belt-tightening" response on the part of households. It appears that winter indoor temperatures crept upward in 1982, however. The rise of consumption in 1984 -- not quite back to the 1982 level, however -- probably reflects relaxing of energy-conserving behavior allowed by growth in income and stabilizing of natural gas prices.

Note on Residential Wood Consumption

According to RECS-3 (1982-83), households using wood as main heating fuel accounted for 58% of total wood consumption. Among these households, those with stoves or furnaces as main heating equipment accounted for 95% of total wood consumption. Among the households using wood as a secondary heating fuel, 80% relied on a fireplace. Let us assume that fireplaces accounted for 60% of secondary wood consumption. If we assume a conversion efficiency of 45% for wood stoves and 10% for fireplaces, this yields an average conversion efficiency for total wood consumption of 35%.[7]

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[5] Data on indoor temperatures are unfortunately only available for 1973, 1981 and 1982.

[6] Data on the structural factors mentioned in this section were presented in Section A.

[7] 58% of the total wood consumed was burned at an average efficiency of 43%, while 42% was burned at an average efficiency of 24%.

Table 2-9
U.S. Residential Energy Consumption
Adjusted to Approximate Normal Weather*

(quadrillion Btu)

	Gas	Oil	LPG	Elec	Coal	Wood	Total Delivered**	Elec Losses	Total Primary**	Total Useful***
1970	4.98	2.35	0.34	1.59	0.15	0.40	9.61	3.86	13.47	6.81
1971	5.20	2.42	0.35	1.71	0.14	0.38	10.01	4.14	14.15	7.11
1972	5.19	2.41	0.36	1.86	0.11	0.38	10.12	4.47	14.59	7.24
1973	5.22	2.56	0.37	1.99	0.11	0.35	10.43	4.77	15.20	7.48
1974	5.07	2.30	0.38	2.02	0.11	0.37	10.07	4.93	15.00	7.26
1975	5.16	2.26	0.38	2.02	0.09	0.43	10.13	4.88	15.01	7.30
1976	5.12	2.30	0.38	2.12	0.08	0.48	10.24	5.11	15.35	7.41
1977	5.01	2.35	0.38	2.21	0.09	0.54	10.31	5.34	15.65	7.49
1978	4.90	2.18	0.38	2.28	0.09	0.62	10.14	5.58	15.72	7.40
1979	4.96	1.95	0.36	2.38	0.07	0.73	10.09	5.75	15.84	7.41
1980	4.82	1.58	0.33	2.43	0.06	0.86	9.65	5.91	15.56	7.14
1981	4.78	1.43	0.31	2.51	0.07	0.87	9.54	5.98	15.52	7.10
1982	4.75	1.35	0.30	2.52	0.08	0.94	9.47	6.05	15.51	7.06
1983	4.50	1.23	0.35	2.54	0.08	0.93	9.17	6.09	15.26	6.87
1984	4.70	1.25	0.35e	2.66	0.08e	0.93e	9.51	6.38e	15.89	7.13

Source: Report tables

* No adjustment has been made to LPG, coal, and wood due to the somewhat uncertain accuracy of the data. See Appendix A for discussion of weather adjustment.

** Includes 50% of wood consumption (see text for discussion).

*** Excludes estimated combustion losses: 35% of delivered energy for gas, oil, LPG, and coal, 65% of delivered energy for wood.

Table 2-10
U.S. Residential Energy Consumption per Household
Adjusted to Approximate Normal Weather

(million Btu)

	Primary Energy	Delivered Energy	Useful Energy
1970	209	149	106
1971	215	152	108
1972	215	149	107
1973	219	150	108
1974	211	142	102
1975	208	140	101
1976	208	138	100
1977	208	137	100
1978	204	131	96
1979	202	129	94
1980	193	119	88
1981	188	116	86
1982	186	113	85
1983*	182	109	82
1984	186	111	83

Sources: Table 2-9; Current Population Survey (for household numbers)**

* The CPS number of households for 1983 seems low, given the known additions to the stock. This means that the values given for consumption per household may be slightly overstated.

** Published data on households from the CPS for the 1970-79 period reflect the undercounting of the 1970 census (estimated at about 1.1 million households). To correct for this, 1.1 million households have been added to the CPS estimate for each year in this period.

Table 2-11
U.S. Residential Energy Consumption per Capita*
Adjusted to Approximate Normal Weather

(million Btu)

	Primary Energy	Delivered Energy	Useful Energy
1970	66.0	47.1	33.4
1971	68.4	48.4	34.4
1972	69.7	48.4	34.6
1973	71.9	49.3	35.4
1974	70.3	47.2	34.0
1975	69.7	47.0	33.9
1976	70.6	47.1	34.1
1977	71.2	46.9	34.1
1978	70.8	45.7	33.3
1979	70.5	44.9	33.0
1980	68.5	42.5	31.4
1981	67.6	41.5	30.9
1982	66.9	40.8	30.4
1983	65.1	39.1	29.3
1984	67.2	40.2	30.1

Sources: Table 2-9; Current Population Survey

* Based on resident population as of July 1 (see Table 2-1).
The resident population is slightly higher than the population in households.

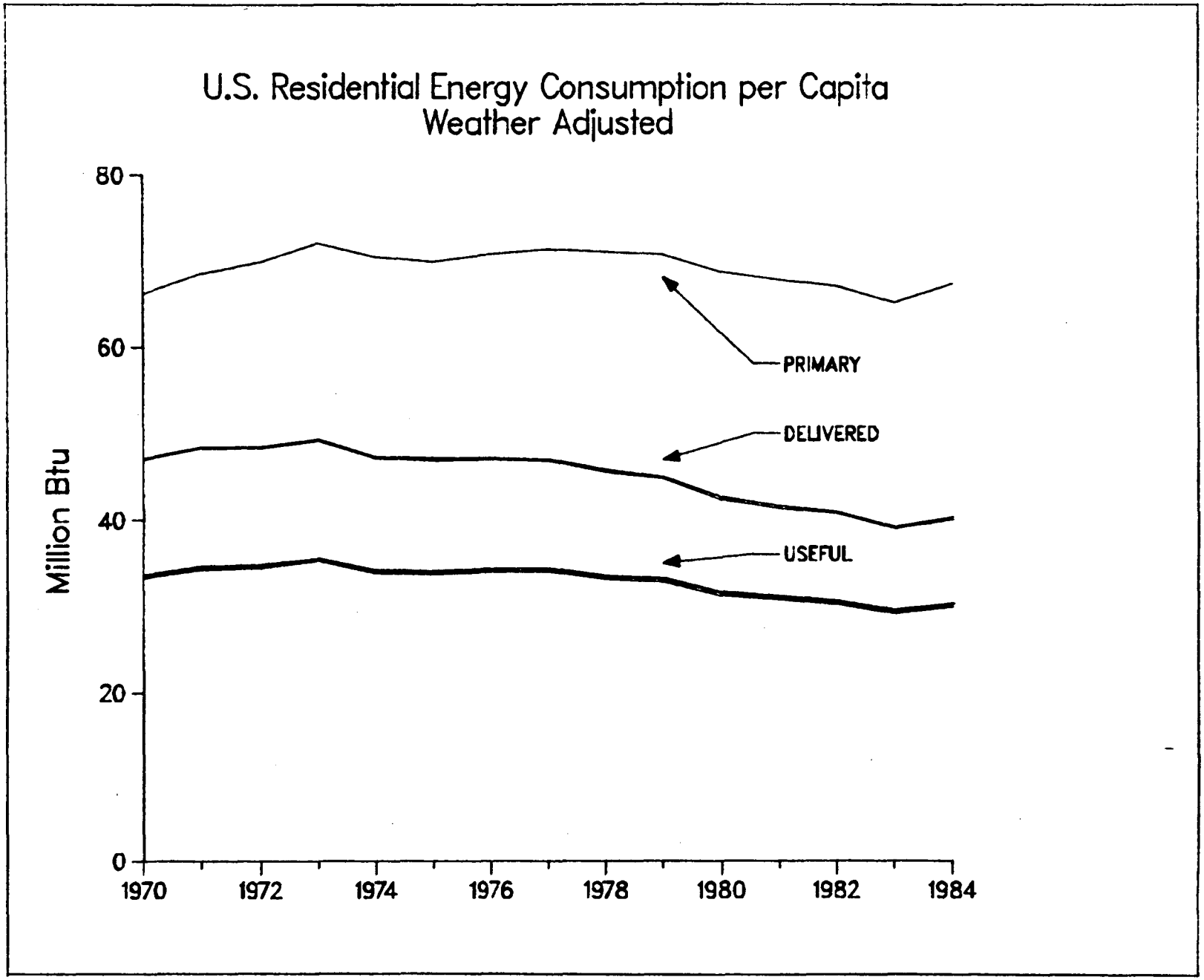
U.S. Residential Energy Consumption per Capita
Weather Adjusted
Million Btu
80
60
40
20
0
1970
1972
1974
1976
1978
1980
1982
1984
PRIMARY
DELIVERED
USEFUL

FIGURE 2-4

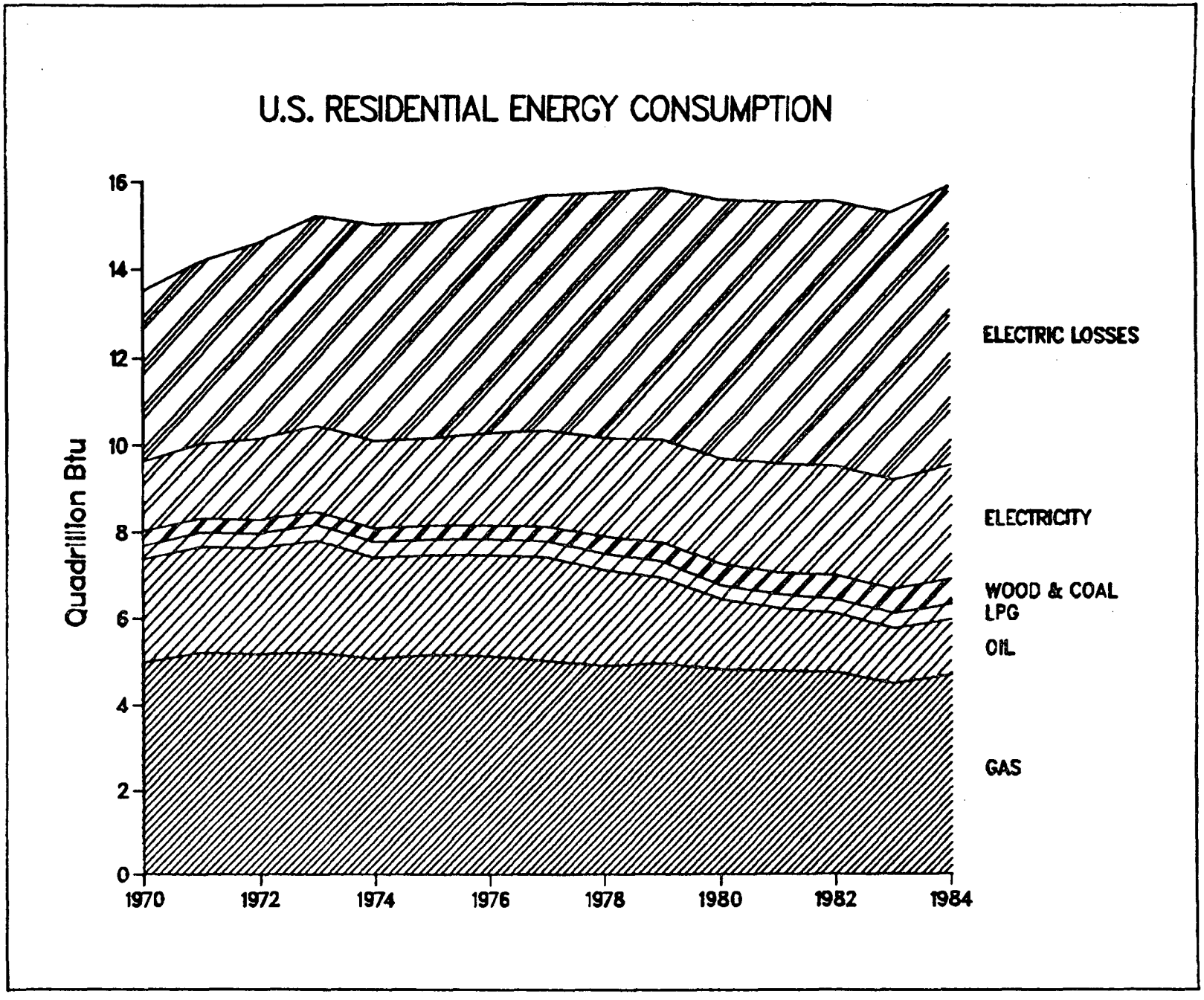
U.S. RESIDENTIAL ENERGY CONSUMPTION
Quadrillion Btu
16
14
12
10
8
6
4
2
0
1970
1972
1974
1976
1978
1980
1982
1984
ELECTRIC LOSSES
ELECTRICITY
WOOD & COAL
LPG
OIL
GAS

FIGURE 2-5

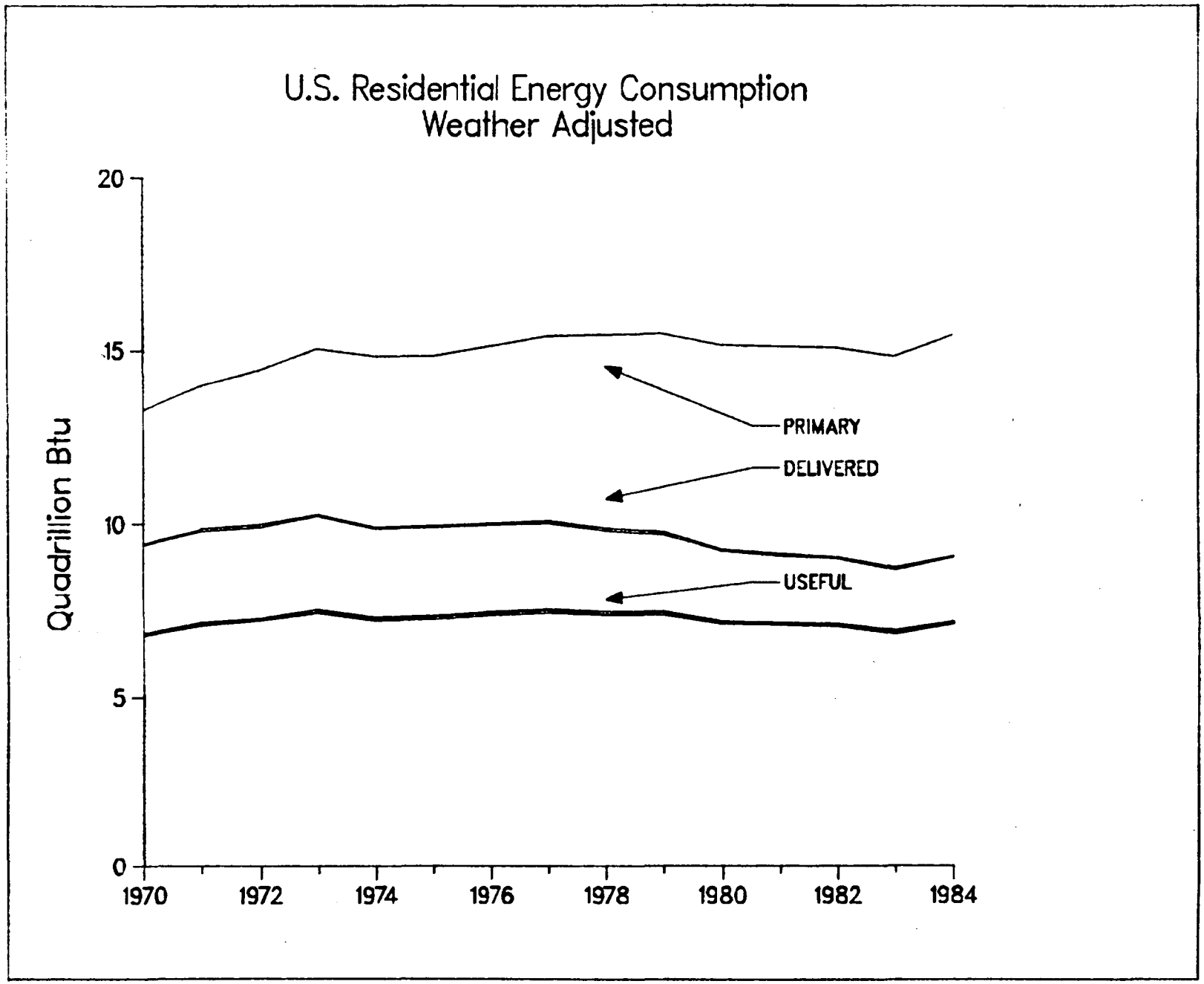
U.S. Residential Energy Consumption
Weather Adjusted
Quadrillion Btu
20
15
10
5
0
1970
1972
1974
1976
1978
1980
1982
1984
PRIMARY
DELIVERED
USEFUL

FIGURE 2-2

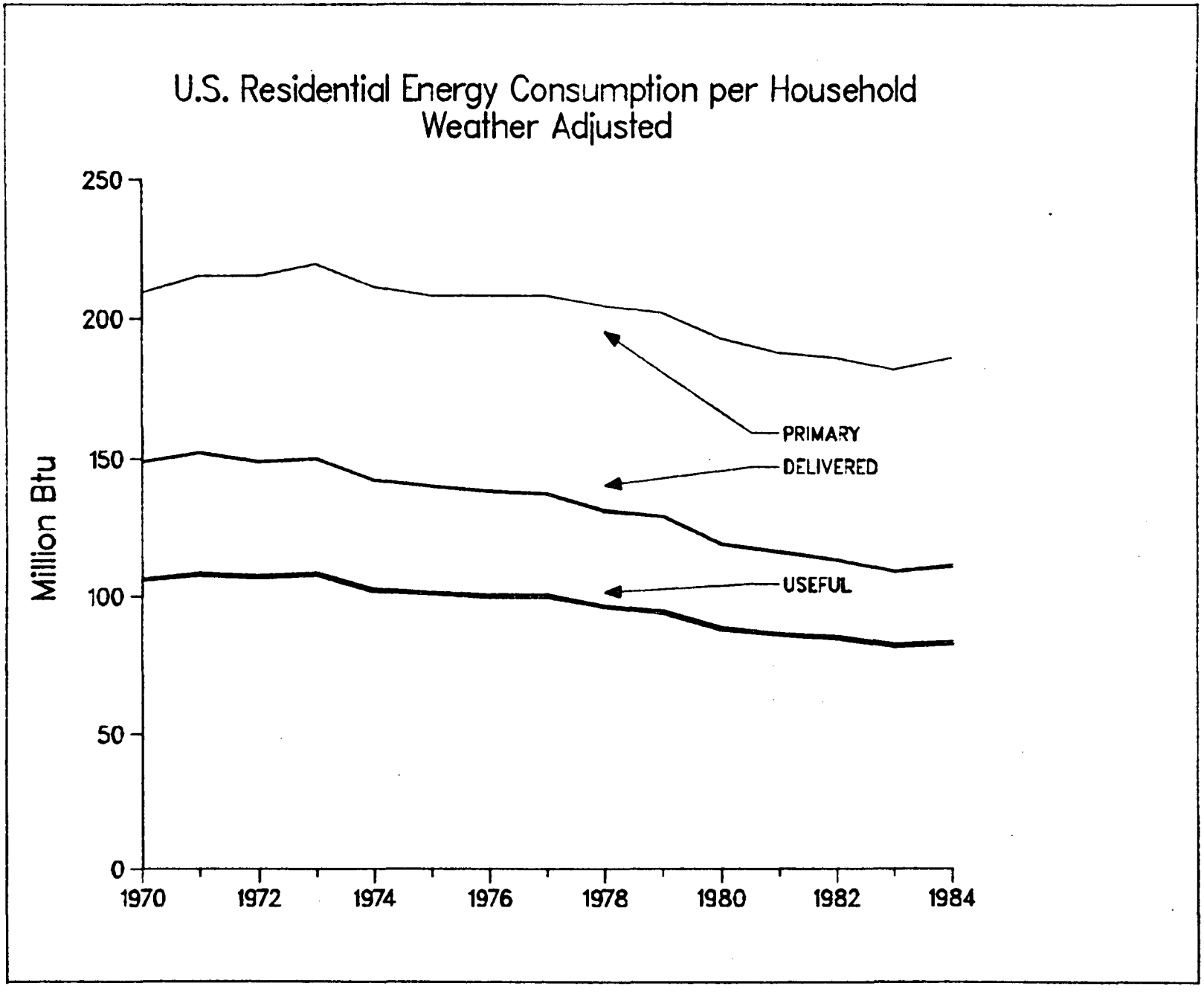
U.S. Residential Energy Consumption per Household
Weather Adjusted
Million Btu
250
200
150
100
50
0
1970
1972
1974
1976
1978
1980
1982
1984
PRIMARY
DELIVERED
USEFUL

FIGURE 2-3

Chapter 3
U.S. Residential Natural Gas Use: 1970-84
A. The Structural Setting

1. Data Sources

The two sources of annual (or nearly annual) national-level data on energy-related structural characteristics of housing are the Annual Housing Survey (AHS) of the Bureau of the Census and the RECS. Unless specified otherwise, statistics refering to 1982 are from the RECS, while statistics refering to 1983 are from the AHS. See Chapter 2A for discussion.

2. Space Heating

The total number of gas-heated homes[1] has risen steadily from about 35.6 million in 1970 -- 55% of all homes -- to around 46.7 million in 1983 -- also 55% (see Table 3-1).

2.1. Switching to Natural Gas as Main Heating Fuel

Around 1.5-2.5 million households switched to gas as main heating fuel -- mostly from oil -- in the 1979-81 period. Conversions declined in 1982 and 1983.

	1978	*1979*	*1980*	*1981*	*1982*	*1983*
	(millions of homes)					
RECS	-	0.7	0.8	0.9	-	-
AGA	0.1	0.4	0.6	0.5	0.2	0.1

2.2. Gas Heating in New Homes

Around 20% of gas-heated homes standing in 1982 had been built after 1969; 10% had been built after 1974. The number of new homes heated with gas (not including mobile homes) has averaged 545,000 per year since 1974. The gas heating share of total completions has remained around 36-38%.

[1] The term "gas-heated" refers to the use of natural gas as *main* heating fuel.

	1972-74	*1975-77*	*1978-80*	*1981-83*	*1984*
	(thousands of units completed)				
Single-family houses	1555	1230	1416	991	460
Gas share (%)	48	39	39	42	45
Multi-family units	-	373	446	378	165
Gas share (%)	-	32	28	29	26
Total	-	1603	1862	1369	625
Gas share (%)	-	37	36	37	38

Source: Bureau of the Census, *Construction Reports.*
Does not include mobile homes.

2.3. Gas Heating Equipment

The share of central heating equipment in gas-heated homes has increased since 1970:

	1970 Census	*1978 NIECS*	*1982 RECS*
	(percent of homes)		
Warm-air furnace	52	59	61
Steam or hot water	15	14	16
Floor, wall, or pipeless furnace	13	11	14
Other	20	15	10

2.4. Type and Location of Gas-Heated Homes

The shares of different housing types in the gas-heated housing stock have not changed since 1970:

	1970 Census	*1978 AHS*	*1983 AHS*
	(percent)		
Single-family	71	71	71
Multi-unit building	27	26	26
2-4 unit building	-	14	14
5+ unit building	-	12	12
Mobile home	2	3	3

The geographical distribution of the gas-heated housing stock is basically unchanged since 1970:

	1970 Census	*1983 AHS*
	(percent of homes)	
Northeast	16	17
North Central	33	34
South	27	26
West	23	23

2.5. Use of Secondary Heating Equipment

Use of fuels other than natural gas for secondary heating in gas-heated homes increased between 1978 and 1982. RECS says that the percentage of gas-heated homes using wood as a secondary heating fuel rose from around 11% in 1978 to around 19% in 1982 (Table 3-2). The percentage reporting use of electricity as a secondary heating fuel rose from around 8% in 1978 to around 12% in 1982, while the percentage reporting use of kerosene as a secondary heating fuel rose from nil to around 2%.

3. Other Uses of Natural Gas

3.1. Water Heating

The number of homes with gas water heating has increased since 1970, though the gas share has remained at about 55%.

1970 Census	*1978 AHS*	*1982 RECS*
	(millions)	
35.5	41.5	47.1

The RECS estimate that the percentage of homes with gas where gas was used for water heating remained about the same between 1978 and 1982 at around 85%. The percentage of gas-heated homes where gas was used for water heating remained about the same at 91-92%.

3.2. Cooking

The number of homes where gas was the most used cooking fuel has increased slightly since 1970. The gas share of the market has fallen from around 49% to around 40%.

1970 Census	*1978 AHS*	*1982 RECS*
	(millions)	
31.7	32.6	33.6

RECS says that the percentage of gas-heated homes where gas was also used for cooking remained about the same between 1978 and 1982 at around 60%.

3.3. Other Gas Appliances

Other uses of natural gas in homes are relatively minor. The percentage of homes with gas clothes dryers has fallen from 16% in 1973 to 12% in 1982. Other uses include outdoor grills (3.0% of homes in 1982), outdoor lights (1.4% of homes in 1982), and swimming pool heaters (0.3% of homes in 1982).

4. Structural Improvements on Gas-Heated Residences

Improvements to the thermal integrity of residences affected many gas-heated homes in the 1979-82 period (see Table 3-3).[2] The major improvements apply mainly to single-family housing. We see that the uptake of certain major improvements -- storm windows and attic insulation -- declined in 1982, perhaps reflecting some saturation of the market.

5. Improved Efficiency of New Gas Appliances

The average (shipment-weighted) annual fuel utilization efficiency of new gas central space heaters has improved since 1975:[3]

Source	*1975*	*1982*	*1984*
		(AFUE%)	
Lennox	65.0	67.0	-
Carrier	63.7	66.5	-
GAMA	-	-	73.0

New gas heaters have entered the stock in new homes and as replacements in other homes. The average overall decrease in equipment energy consumption (independent of changes in household usage) between 1977 and 1984 has been estimated by the LBL Residential Energy Model at 1.6% (see Table 2-6 in Chapter 2A).

No recent data are available on the efficiency of new gas water heaters, but a forecast (based on partial data) from the LBL Residential Energy Model puts the fuel utilization efficiency

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[2] Data for 1978 are available for major measures from the NIECS. Data for the May 1973-May 1975 period are available for major measures from the 1975 WCMS survey.

[3] Source: Levine, *et al.*, Economics of Efficiency Improvements in Residential Appliances and Space Conditioning Equipment, Lawrence Berkeley Laboratory, 1985.

for 1984 at 49.4%. This compares with data for 1972 that give an average of 47.4%.

6. Energy-Conserving Behavior

We do not have data to compare winter indoor temperatures for gas-heated homes in the mid-1970s and the early 1980s.[4] From the data for all households, however (see Ch. 2A), we can infer that they fell considerably.

The RECS provide data on wintertime indoor temperatures for 1981 and 1982. They suggest a slight increase in daytime temperatures and some decrease in nighttime temperatures in 1982 (see Appendix B).

[4] Data on indoor temperatures are available from the data tapes from the 1973 and 1975 WCMS national household surveys.

Table 3-1
Gas-Heated* Homes in the U.S.

(million)

	Census (April)	AHS (October)	RECS (November)
1970	35.0 35.6**	-	-
1971	-	-	-
1972	-	-	-
1973	-	38.5	-
1974	-	39.5	
1975	-	40.9	
1976	-	41.2	
1977	-	41.5	
1978	-	42.5	41.8(1.9)
1979	-	43.3	42.4(1.8)
1980	42.9	44.4	44.6(1.5)
1981	-	46.1	46.2(1.5)
1982	-	***	47.5(1.5)
1983	-	46.7	***

* Used natural gas as *main* heating fuel.

** Includes estimate of units missed by Census (details available)

*** Survey not conducted.

Note: The Annual Housing Survey and RECS are done by interview, while the Census is self-enumeration. The AHS asks "How is this house (apt.) heated?" RECS asks "What is the main fuel used for heating this house (apt.)? In the case of RECS, telephone interviews to check information on heating fuels were conducted with rental agents and landlords of households living in multi-unit buildings.

Values in parentheses are 1 standard error.

Table 3-2
Secondary Heating in Gas-Heated Homes*

(millions)

	NIECS 1978	HSS 1979	RECS-1 1980	RECS-2 1981	RECS-3 1982
Secondary Heating Fuel**					
Wood	4.4(0.7)	3.9(0.7)	7.0(0.9)	9.3(0.5)	9.2(0.6)
Wood Burned***	-	-	-	10.3(0.6)	8.8(0.6)
< 1/3 cord	-	-	-	4.8(0.4)	3.7(0.4)
> 1/3 cord	-	-	4.4(0.5)	5.5(0.5)	5.0(0.5)
Electricity	3.3(0.5)	2.9(0.5)	4.6(0.5)	4.6(0.4)	5.8(0.5)
Kerosene	..	0.1(0.04)	0.3(0.1)	0.3(0.1)	0.8(0.2)
Natural Gas****	3.1(0.5)	-	2.4(0.3)	2.1(0.3)	1.7(0.3)
Total Gas-Heated Homes*	41.8(1.9)	42.4(1.8)	44.6(1.5)	46.2(1.5)	47.5(1.5)

Sources: U.S. DOE, Residential Energy Consumption Surveys

* Households using natural gas as main heating fuel as of November of each year.

** More than one may be used.

*** This was a separate question from that asking about secondary heating fuel.

**** These are probably households with central gas heating who also used gas room heaters.

Values in parentheses are 1 standard error.

Table 3-3
Conservation Improvements by Gas-Heating Households
Single-Family Houses and Mobile Homes

(million households)

	Year Added:			
	1979	1980	1981	1982
Storm doors*	-	1.5	1.7	1.4
Storm windows*	-	1.2	1.9	1.0
Attic insulation	1.7	1.9	2.1	1.1
Wall insulation	0.9	1.3	0.7	0.6
Floor insulation	0.4	0.4	0.6	0.5
Duct insulation	0.3	0.8	0.4	0.5
Shutters, etc.**	1.9	2.0	3.3	2.3
Plastic sheets	-	-	2.2	1.3
Caulking	3.3	5.2	5.0	4.3
Weatherstripping	3.0	4.4	4.1	2.5
Water heater insulation	0.3	1.0	1.1	1.0
Spark ignition	0.3	-	0.4	0.2
Total households	42.4	44.6	46.2	47.5
Single-family	29.9	32.0	34.2	33.2
Owner-occupied	24.8	27.3	29.1	27.4
Heating degree-days***	5143	4992	4748	4851

Sources: U.S. DOE, RECS-1 (1979), RECS-2 (1980), RECS-3 (1981 and 1982)

* Includes multi-family housing.

** Shutters, insulating drapes, or plastic sheets

*** For single-family-detached houses and for the April-March period ending in the particular year.

B. Trends in U.S. Residential Natural Gas Consumption 1970-1984

1. State of the Data

There are three sources for national-level estimates of residential natural gas consumption: the American Gas Association (AGA), EIA's State Energy Data System (SEDS), and EIA's Residential Energy Consumption Surveys (RECS), which began with the NIECS in 1978.

The estimates in SEDS (see Table 3-4) are based on statistics that utilities are required to report. Estimates of sales exist for the years 1960-1983. The AGA estimates are also based on reports filed by utilities. The SEDS value is higher than the AGA value in some years, lower in others. Since 1979, the SEDS value has on average been 0.6% higher than the AGA value. In any given year, it is logical to conclude that the higher value is more inclusive and probably more reliable.

Neither the AGA nor the SEDS series fully capture total residential sector gas consumption. Sales to master-metered apartment buildings are often not included in the residential category by utilities. The extent to which respondents do or do not include such apartment buildings in their residential customer classification is unknown, though an estimate of the consumption missing from SEDS is possible (see below).

The estimates in RECS are based on a sample survey of some 6000 households. The consumption data come from information on sales provided by the households' fuel suppliers. RECS estimates exist for April-March 1980-81, 1981-82, and 1982-83. (Estimates also exist from RECS' precursors, the NIECS in 1978-79 and the HSS in 1979-80.) Consumption estimates for households for which no useable record was received from the supplier (or for which fuel use was included in rent)[1] were imputed by EIA with a regression model. This includes a high percentage of households in large (5 or more units) apartment buildings.

1.1. Comparing SEDS and RECS

A clear comparison between SEDS and RECS is difficult because each covers a different time period: SEDS the calendar year, RECS the April-March period (see Table 3-5). This results in differences in weather and in the number of households using gas for various purposes. The two sources also have different coverage of the residential sector. SEDS fails to capture some percentage of gas consumption in big apartment buildings. In RECS, the survey is designed to provide coverage of all residential buildings, including big apartment buildings. The consumption by many households in such buildings is imputed, but checks made by EIA suggest that the accuracy of the estimates is fairly good.

The best comparison of the two sources can be done for 1980, the year for which Robert Latta of EIA used RECS data to estimate consumption in CY 1980, taking account of weather differences and changes in household heating fuel.[2] The RECS value re-estimated for CY 1980 is

[1] 25% of gas-using households in RECS 1980-81, 28% in 1981-82, 26% in 1982-83.

[2] Energy Information Administration. *Residential Energy Consumption Survey: Consumption and Expenditures April 1980 through March 1981.* Sept. 1982, p. 244.

164 TBtu (or 3.4%) higher than the SEDS value. A rough estimate of gas consumption (mostly imputed) in apartments in buildings with 5 or more units where gas was included in the rent is 225 TBtu.[3] This suggests that around two-thirds of such gas consumption was not captured by SEDS. Given the standard error around the RECS best estimate (190 TBtu), one cannot place a great deal of confidence in this conclusion, but it does seem likely that SEDS underestimates residential gas consumption somewhat. The underestimate may have become smaller over time as more utilities made their reporting more accurate.

2. Trend of Residential Natural Gas Consumption

We see from the weather-adjusted[4] "best estimate" series (see Table 3-4) that total residential natural gas consumption declined steadily after 1975 (-1.2% per year between 1975 and 1982), fell sharply (-5.3%) in 1983, and then rebounded strongly (+6.0%) in 1984.

3. Natural Gas Consumption per Household

Statistics on average annual gas consumption per customer have been published for many years by the AGA and since 1973 by EIA (see Table 3-6). The weather-normalized AGA series shows average consumption 24% lower in 1983 than in 1973. The largest drops occurred in 1980 (-5.2%) and 1983 (-7.1%). 1984 saw an increase of 4.4%. The EIA series shows a similar picture, with some differences before 1979. The RECS show a somewhat larger decline (in the 1978-79 through 1982-83 period) than the AGA and EIA series.

Most of the decline in average gas consumption has been in space heating. Since 1978, the AGA has asked its members to estimate average gas consumption separately for space heating and baseload purposes. The weather-adjusted average consumption for space heating for all households shows a steady decline since 1978 (averaging -3.5% per year between 1978 and 1982), and a very large drop (-9.1%) from 1982 to 1983 (see Table 3-7). This parallels the drop seen in average gas consumption. Unlike the AGA series on average total gas consumption, however, the householding survey does not show any increase in 1984.

The RECS show the trend in average consumption between 1978-79 and 1982-83 for different housing types. The weather-adjusted estimate of average gas consumption in single-family detached houses shows a decline of 13% between 1978-79 and 1980-81, a small increase in 1981-82, and a drop of 9.0% in 1982-83 (see Table 3-8). Note that not all of the year-to-year differences are statistically significant (for example, the increase from 1980-81 to 1981-82).

For households in multi-family housing, higher standard errors make the trends less clearly interpretable (see Table 3-9). A decline is, however, clear for households in 2-4 unit buildings -- the average in 1982-83 was 12% lower than in 1978-79. No statistically significant trend can be

[3] Estimated by applying the fraction (gas consumption in apartments in buildings with 5 or more units where gas was included in the rent / gas consumption in all apartments in buildings with 5 or more units) for RECS 1981 to RECS 1980 gas consumption in all apartments in buildings with 5 or more units.

[4] Adjustment of annual consumption data to "normal" weather is important, but difficult to do with precision. The method of weather adjustment that we have used at LBL (described in Appendix A) involves separating the estimated space heating component of total consumption, and dividing this by the ratio of heating degree-days in year n to the long-run average degree-day total. The heating degree-day total must reflect the weather experienced by gas-heated homes, not all homes.

indentified for households in 5+ unit buildings.

Estimates of average gas consumption for space heating and water heating were made with regression analysis of RECS data for three years by Martha Johnson of EIA.[5] Adjusted for weather, the average space heating values for single-family detached homes show a decline of 21% from 1978-79 to 1980-81, and an increase of 5% from 1980-81 to 1981-82. The similar values for homes in 2-4 unit buildings show a substantial decline between 1978-79 and 1980-81. The trend for households in 5+ unit buildings is not clear.

4. Linking Changes in Consumption and the Structural Setting

The key indicator for residential natural gas consumption is average annual consumption per customer. Nearly all of the main changes in the structural setting have acted to depress average consumption (see Figure 3-1). These changes are (ranked in rough order of their importance in our judgment):

- Decline in wintertime indoor temperatures;
- Structural improvements done on gas-heated homes;
- Introduction of new homes to the stock;
- Improved energy efficiency of gas heating equipment;
- Increased use of secondary heating equipment.

Factors that have probably acted to increase average consumption are:

- Growth in use of central heating;
- Switching of formerly oil-heated homes to gas.

The effect of these has in our judgment been small.

4.1. The 1980-84 Period: A Closer Look

Average annual consumption per customer declined considerably in 1980, fell less in 1981, and was virtually unchanged in 1982 before dropping sharply in 1983. 1984 saw an increase of around 4%.

Data on indoor temperatures are unfortunately only available for 1981 and 1982. Data on conservation improvements (see Table 3-3 in Section A) show an increase in activity in 1980, but not a very large one. (It may be that a large share of the activity in 1979 was in the second half of the year.) This suggests that there was a strong behavioral action in 1980. We hypothesize that indoor temperatures remained fairly steady from 1980 to 1981, and that the continued high level of conservation improvements (and to a lesser extent, the other changes described above) acted to depress average consumption. 1982 saw virtually no decline in average consumption. This corresponds with the slight increase seen in indoor temperatures, which acted to balance the continued (though slower) penetration of conservation improvements.

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[5] Energy Information Administration. *Residential Energy Consumption and Expenditures by End Use for 1978, 1980, and 1981.* Dec. 1984.

Unfortunately, data are not yet available to shed light on the large decline in average gas consumption in 1983. Natural gas prices rose, though not more than in 1982. It may be that the continued rise in gas prices combined with the economic recession caused consumers to reduce consumption. Gas prices began to decline toward the end of 1983. This, combined with improved economic conditions, may be behind the increase in average consumption seen in 1984.

Table 3-4
U.S. Residential Natural Gas Consumption

(trillion Btu)

	AGA	EIA/SEDS	Actual	"Best" Estimate* Weather-Normalized**
1970	4924	4987	4987	4979
1971	5040	5126	5126	5201
1972	5142	5264	5264	5187
1973	4994	4977	4994	5223
1974	4865	4901	4901	5069
1975	4991	5023	5023	5155
1976	5014	5147	5147	5117
1977	4946	4913	4946	5012
1978	5107	4981	5107	4895
1979	5083	5055	5083	4964
1980	4819	4866	4866	4818
1981	4601	4665	4665	4779
1982	4770	4754	4770	4750
1983	4450	4495	4495	4497
1984	4628	4697	4697	4766

Sources: AGA; State Energy Data Report (EIA,1985) and EIA personal communication.

* The "best" estimate is taken as the higher of the two values (except for 1984, where the EIA number is provisional). The assumption behind this is that the higher value includes some small utilities that the lower value may not include.

** See Appendix A for details of weather-normalization.

Table 3-5
U.S. Residential Natural Gas Consumption
Comparing SEDS and RECS

(trillion Btu)

	1978	1979	1980	1981	1982	1983
SEDS (Jan-Dec)	4981	5055	4866	4665	4754	4516
RECS (Apr-Mar)	5575(300)	5310(230)	4940(190)	5390(210)	4770(190)	-
(Jan-Dec)			5030*			
5+ Apartments**	320(45)	380(70)	330(25)	410(30)	440(35)	
Utilities Included in Rent	-	-	-	280	-	-

Source: U.S. Dept. of Energy, State Energy Data Report (1985); NIECS, HSS, RECS-80, RECS-81, RECS-82

* Consumption in CY 1980 was estimated by EIA, taking account of weather differences and changes in household heating fuel.

** Consumption (mostly imputed) by households in buildings with 5 or more units.

Values in parentheses are 1 standard error.

Table 3-6
U.S. Residential Natural Gas Consumption per Customer

(million Btu)

	Actual			Weather Adjusted*		
	AGA	EIA	RECS**	AGA	EIA	RECS**
1970	129.2	-	-	129.0	-	-
1971	129.9	-	-	131.8	-	-
1972	130.4	-	-	128.5	-	-
1973	124.5	122.4	-	130.2	128.0	-
1974	119.6	117.8	-	123.7	121.8	-
1975	121.9	121.4	-	125.1	124.6	-
1976	121.3	124.3	-	120.6	123.6	-
1977	118.7	119.2	-	120.3	120.8	-
1978	121.0	118.9	114**	116.0	114.0	109
1979	118.6	-	107**	115.8	-	103
1980	110.9	110.6	96**	109.8	109.5	96
1981	104.4	103.4	101**	107.0	106.0	99
1982	107.1	106.5	88**	106.7	106.1	91
1983	99.1	100.0	-	99.1	100.0	-
1984	102.0	103.1	-	103.5	104.6	-

Sources: AGA, EIA, RECS
For AGA and EIA, a customer equals a meter. Average shown is annual consumption divided by the annual average number of customers as reported by utilities.

* See Appendix A for details of weather-normalization.

** RECS values reflect consumption in the period beginning in April of the year in the row, and ending in March of the following year. They are therefore not directly comparable with the AGA and EIA values. The smaller size of the RECS values suggests that some of the single customers in the AGA and EIA series are some multi-unit buildings.

Table 3-7
Estimated Average Gas Consumption for Home Heating

(Million Btu)

	1978*	1979	1980	1981	1982	1983	1984
All Households							
Actual	95.3	88.9	84.6	78.5	78.5	71.1	67.8
Adjusted	90.0	85.9	83.5	81.4	78.0	71.2	69.3
Single-Family							
Actual	106.8	98.2	94.3	86.9	87.1	77.9	76.1
Multi-Family							
Actual	67.4	64.6	58.4	56.6	56.5	54.2	47.3
Heating Degree-Days**	5146	5021	4926	4688	4887	4855	4756
Index	105.9	103.4	101.4	96.5	100.6	99.9	97.9

Source: AGA Gas Househeating Survey. Values were converted from MCF using DOE conversion factors.

* 1978 values are based on a smaller sample of utilities.

** Degree-days are for all gas-heated homes.

Table 3-8
Average Natural Gas Consumption in Single-Family Detached Houses
Where Gas is Main Heating Fuel

(Million Btu)

	1978-79	1979-80	1980-81	1981-82	1982-83
			(April through March)		
Actual	144(3.6)	132(3.2)	117(1.9)	122(3.4)	106(2.4)
Weather-adjusted*	137(3.6)	129(3.2)	119(1.9)	122(3.4)	111(2.4)
Est. Consumption for Space Heating**					
Actual	114(3.8)	-	82(1.5)	88(2.0)	-
Weather-adjusted	107(3.8)	-	84(1.5)	88(2.0)	-
Est. Consumption for Water Heating**					
Actual	24.5(0.8)	-	28.5(0.5)	24.3(0.4)	-
Heating Degree-Days***	5143	4992	4748	4851	4505
Index (4848=100)	106.1	103.0	97.9	100.1	92.9
No. of Houses (mn)	26.9(1.2)	27.5(1.2)	30.1(1.3)	32.5(1.3)	30.5(1.1)

Source: U.S. DOE, Residential Energy Consumption Surveys

* The weather adjustment is on the estimated space heat share. For 1979, the 1978 share is used; for 1982, the 1981 share is used. See Appendix A for details of weather-normalization.

** From *Residential Energy Consumption and Expenditures by End Use for 1978, 1980, and 1981* (DOE, 1984).

*** Average for all single-family units.

Values in parentheses are 1 standard error.

Table 3-9
Average Natural Gas Consumption in Multi-Family Housing
Where Gas is Main Heating Fuel

(Million Btu)

	1978-79	1979-80	1980-81	1981-82	1982-83
			(April through March)		
Homes in 2-4 Unit Buildings					
Actual	115(6.0)	117(8.8)	100(2.7)	101(5.2)	84(3.5)
Weather-adjusted*	113(6.0)	113(8.8)	100(2.7)	97.5(5.2)	89.4(3.5)
Est. Consumption for Space Heating**					
Actual	90.4(8.2)	-	69.5(3.2)	79.0(4.6)	-
Weather-adjusted*	88.8(8.2)	-	69.4(3.2)	75.5(4.6)	-
Heating Degree-Days	5455	5620	5365	5611	4747
Index (5360=100)	101.8	104.9	100.1	104.7	88.6
No. of Households (mn)	6.7(1.0)	6.5(0.8)	6.6(0.5)	5.6(0.5)	7.0(0.5)
Homes in 5+ Unit Buildings					
Actual	60(4.8)	63(6.0)	64(2.5)	68(3.5)	57(2.5)
Weather-adjusted*	58(4.8)	60(6.0)	67(2.5)	67(3.5)	60(2.5)
Est. Consumption for Space Heating**					
Actual	47.6(9.3)	-	41.8(6.0)	53.3(10.3)	-
Weather-adjusted*	45.5(9.3)	-	44.6(6.0)	52.7(10.3)	-
Heating Degree-Days	5492	5586	4912	5308	4949
Index (5249=100)	104.6	106.4	93.6	101.1	94.3
No. of Households (mn)	4.4(0.6)	4.8(0.8)	4.6(0.3)	5.1(0.4)	6.2(0.5)

Source: U.S. DOE, Residential Energy Consumption Surveys

* The weather adjustment is on the estimated space heat share. For 1979, the 1978 share is used; for 1982, the 1981 share is used. See Appendix A for details of weather-normalization.

** From *Residential Energy Consumption and Expenditures by End Use for 1978, 1980, and 1981* (DOE, 1984).

Values in parentheses are 1 standard error.

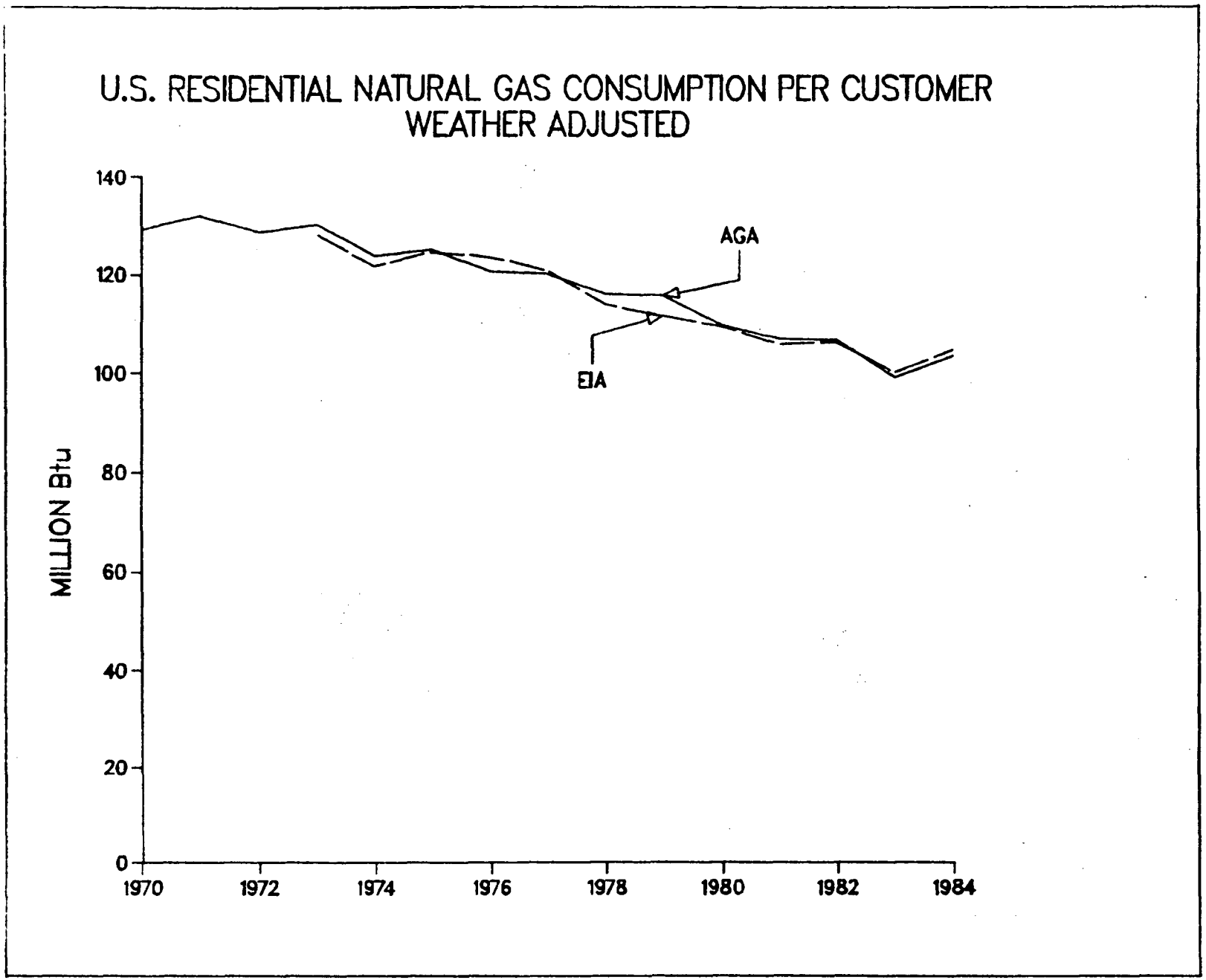
U.S. RESIDENTIAL NATURAL GAS CONSUMPTION PER CUSTOMER
WEATHER ADJUSTED
MILLION Btu
140
120
100
80
60
40
20
0
1970
1972
1974
1976
1978
1980
1982
1984
AGA
EIA

FIGURE 3-1

Chapter 4
U.S. Residential Electricity Use: 1970-84
A. The Structural Setting

1. Data Sources

The two main sources of national-level data on energy-related structural characteristics of housing are the Annual Housing Survey and the RECS. Unless specified otherwise, statistics refering to 1982 are from the RECS, while statistics refering to 1983 are from the AHS. See Chapter 2A for discussion.

2. Space Heating

The number of households using electricity as main heating fuel has increased three-fold from about 5 million in 1970 -- 8% of all homes -- to about 15.7 million in 1983 -- 18.5% of all homes. (see Table 4-1).

2.1. Switching to Electricity as Main Heating Fuel

The RECS say that there has been a modest amount of switching to electricity as a heating fuel:

1978	*1979*	*1980*	*1981*	*1982*
	(millions of homes)			
-	0.1	0.3	0.3	-

2.2. Electric Heating in New Homes

Around 65% of electric-heated homes standing in 1982 were built after 1969; around 43% were built after 1974. The number of new homes heated with electricity (not including mobile homes) has averaged 820,000 since per year 1974. The electric heat share of total completions rose during the 1970s but has stabilized at around 56% since 1978.

	1972-74	*1975-77*	*1978-80*	*1981-83*	*1984*
	(thousands of units completed)				
Single-family houses	1362	1563	1855	1170	492
Electricity share (%)	42	49	51	49	48
Multi-family units	-	723	1087	875	452
Electricity share (%)	-	61	67	68	72
Total	-	2286	2942	2045	944
Electricity share (%)	-	47	56	56	57

Source: Bureau of the Census, *Construction Reports.*
Does not include mobile homes.

2.3. Electric Heating Equipment

The shares of different types of heating equipment in electric-heated homes have changed since 1970. There is considerable disagreement between RECS and the AHS regarding the distribution of equipment types.[1] RECS shows much stronger growth between 1978 and 1982 in the share of heat pumps, but this is most likely in error. Still, the growing penetration of heat pumps in the stock means that the average electric-heated home is heated more efficiently than previously.

	1970	*1978*		*1982/83*	
	Census	*NIECS*	*AHS*	*RECS*	*AHS*
	(percent of homes)				
Warm-air furnace	27	37	-	26	-
Heat pump	-	10	9	27	14
Built-in units	66	46	-	37	-
Other	7*	7	-	9	-

* Includes heat pump.

2.4. Type and Location of Electric-Heated Homes

The shares of different house types in the electric-heated housing stock have changed somewhat since 1970:

[1] Data from the AHS on the shares of heating equipment other than heat pumps is not available from the reports. Special crosstabs from the survey tapes would be required.

	1970 Census	*1978 AHS*	*1983 AHS*
	(percent of homes)		
Single-family	61	58	56
Multi-unit building	36	36	39
2-4 unit building	-	10	11
5+ unit building	-	26	27
Mobile home	3	5	6

The geographical distribution of the electric-heated housing stock has also changed somewhat since 1970, but the net effect on the long-term average heating climate for electric heating is small.

	1970 Census	*1983 AHS*
	(percent of homes)	
Northeast	10	8.4
North Central	11	14
South	52	55
West	27	23

2.5. Use of Secondary Heating Equipment

The RECS suggest that use of secondary heating in electric-heated homes increased only modestly between 1978 and 1982. The percentage of electric-heated homes using wood as a secondary heating fuel was around 24% in 1978, around 23% in 1982. The percentage reporting use of kerosene as a secondary heating fuel rose from around 1% in 1978 to around 7% in 1982. The percentage reporting use of electricity as a secondary heating fuel was around 7% in 1978, around 5% in 1982.

3. Other Uses of Electricity

3.1. Air Conditioning

The presence of air conditioning has increased substantially since 1970.

	1970 Census	*1978 AHS*	*1983 AHS*
	(percent of all homes)		
Have AC	37	54	59
Central system	11	24	29

3.2. Water Heating

The percentage of U.S. homes with electric water heating has risen since 1970:

1970 Census	*1978 AHS*	*1982 RECS*
(percent of all homes)		
25	31	32

The RECS say that the percentage of electric-heated homes where electricity was also used for water heating remained the same between 1978 and 1982 at around 89%.

3.3. Cooking

The percentage of U.S. homes where electricity was the most used cooking fuel rose from 41% in 1970 to around 54% in 1982:

1970 Census	*1978 AHS*	*1982 RECS*
(percent of all homes)		
41	50	54

3.4. Other Electric Appliances

The saturation of most major electric home appliances has increased since 1970.

	1973	*1981/82*
	(percent of all homes with)	
Refrigerator	99	100*
Frost-free	51	60/63
Freezer	34	41/37
Elec Range	46	54/53
Auto clotheswasher	70	70/69
Clothes dryer	38	45/45
Dishwasher	25	37/36
Color television	53	82/85
Microwave oven	3	17/21

Sources: Washington Center for Metropolitan Studies, Lifestyles and Energy Survey (for 1973); RECS (1981/82)

* 14% of households had 2 or more refrigerators (1982).

4. Structural Improvements on Electric-Heated Residences

The RECS provide a picture of structural improvements undertaken on electric-heated homes in the 1979-82 period (see Table 4-2).[2] (Improved thermal integrity of homes without electric heat but with air conditioning also contributed to lower electricity consumption.) The major improvements apply mainly to single-family housing. Addition of attic insulation was the most popular major improvement. The data do not show any one year with considerably more activity than the others, though activity seems to have declined slightly in 1982.

The addition of conservation improvements has been less for electric-heated homes than for gas- and oil-heated ones. This reflects their location in warmer climates, their relative newness, and the slower increase in electricity prices.

5. Improved Efficiency of New Electric Appliances[3]

The operating efficiency of new electric appliances has improved considerably since the early 1970s (Table 4-3). The percentage improvement in shipment-weighted energy factors for several major appliances is as follows:

	1972-80	*1972-84*
Refrigerators	46%	71%
Freezers	49%	59%
Room Air Conditioners	17%	25%
Central Air Conditioners	13%	30%

New electric appliances have entered the stock in new homes and as replacements or additions in other homes. The effect of the new appliances on the average efficiency of all electric appliances is estimated by the LBL Residential Energy Model. The change in average equipment primary energy consumption (independent of changes in consumer usage patterns) between 1977 and 1984 is estimated as follows:[4]

Refrigerators	-10%
Freezers	-10%
Room Air Conditioners	-5%
Central Air Conditioners	-5%
Heat Pump (Heating)	-3%
Heat Pump (Cooling)	-7%
Water Heaters	-1%

[2] Data for 1978 are available for major measures from the NIECS. Data for the May 1973-May 1975 period are available for major measures from the 1975 WCMS survey.

[3] Source: Levine, *et al.*, Economics of Efficiency Improvements in Residential Appliances and Space Conditioning Equipment, Lawrence Berkeley Laboratory, 1985.

[4] See Chapter 2A, Table 2-6 for the estimated values.

Stove/Ovens	-8%
Dryers	-3%

6. Energy-Conserving Behavior

The data to compare indoor temperatures for electric heating and air conditioning in the mid-1970s and the early 1980s are not readily available.[5] From the data for all households, however, we can infer that they fell considerably (see Chapter 2A, Table 2-7).

RECS provides data on wintertime indoor temperatures for 1981 and 1982. They suggest little change in daytime temperatures and a slight decrease in nighttime temperatures from 1981 to 1982 (see Appendix B).

RECS also provides data on use of air conditioning equipment for 1981 and 1982. (1981 was about 5% warmer than 1982.) The data show little change on practices at the national level.[6]

[5] The 1973 and 1975 WCMS national household surveys collected data on indoor temperatures, but these were not published by heating fuel. The data could be retrieved from the survey tape.

[6] In both years, 21% of homes with air conditioning had it turned on all summer, 16-18% "quite a bit," about 50% had it on "a few times," and 6-8% did not use it.

Table 4-1
Electricity-Heated* Homes in the U.S.

(millions)

	Census (April)	AHS (October)	RECS (November)
1970	4.9 5.0**	-	-
1971	-	-	-
1972	-	-	-
1973	-	7.2	-
1974	-	8.4	-
1975	-	9.2	-
1976	-	10.2	-
1977	-	11.1	-
1978	-	12.3	12.1(1.2)
1979	-	13.2	12.8(1.2)
1980	14.8	14.2	14.3(1.0)
1981	-	15.5	14.2(1.1)
1982	-	***	13.4(0.8)
1983	-	15.7	***

* Used electricity as main heating fuel.

** Includes estimate of units missed by census (details available)

*** Survey not conducted.

Note: The Annual Housing Survey and RECS are done by interview, while the Census is self-enumeration. The AHS asks "How is this house (apt.) heated?" RECS asks "What is the main fuel used for heating this house (apt.)? In the case of RECS, telephone interviews to check information on heating fuels were conducted with rental agents and landlords of households living in multi-unit buildings.

Values in parentheses are 1 standard error.

Table 4-2
Conservation Improvements by Electricity-Heating Households
Single-Family Houses and Mobile Homes

(million households)

	Year Added:			
	1979	1980	1981	1982
Storm doors*	x	0.2	0.5	0.3
Storm windows*	-	0.4	0.3	0.2
Attic insulation	0.5	0.3	0.4	0.2
Wall insulation	0.3	0.1	0.1	0.2
Floor insulation	0.2	0.2	0.3	..
Duct insulation	0.2	0.1	0.1	..
Shutters, etc.**	0.7	0.4	1.0	0.7
Plastic sheets	-	-	0.6	0.4
Caulking	0.8	0.7	1.1	1.0
Weatherstripping	0.7	0.5	0.8	0.4
HW heater insulation	0.3	0.4	0.5	0.4
Total households	12.8	14.3	14.2	13.4
Single-family	7.4	8.2	7.2	7.5
Owner-occupied	6.5	7.1	6.0	6.3

Source: RECS-1 (1979), RECS-2 (1980), RECS-3 (1981 and 1982)

* Includes multi-family housing.

** Shutters, insulating drapes, or plastic sheets

Table 4-3
Energy Efficiency of Electric Appliances

(Shipment weighted energy factors)

	1972	1978	1980	1982	1984
Refrigerator*	3.84	4.96	5.59	6.12	6.57
Freezer*	7.29	9.92	10.85	11.28	11.60
Room AC**	5.98	6.72	7.02	7.14	7.48
Central AC***	6.66	7.34	7.55	7.78	8.66

Source: Association of Home Appliance Manufacturers, Air-Conditioning and Refrigeration Institute (central AC)

* Unit: corrected volume (cu. ft)/daily energy consumption (kWh)

** Energy Efficiency Ratio (EER): useful space cooling (Btu's per hour)/ electrical power input (W)

*** Seasonal Energy Efficiency Ratio

B. Trends in U.S. Residential Electricity Consumption 1970-1984

1. State of the Data

There are three sources for national-level estimates of residential electricity consumption: the Edison Electric Institute (EEI); EIA's State Energy Data System (SEDS), and EIA's Residential Energy Consumption Surveys (RECS), which began with the NIECS in 1978.

The estimates in SEDS (see Table 4-4) are based on statistics that utilities are required to report to DOE. Estimates of sales exist for the years 1960-1983. The EEI estimates are also based on reports filed by utilities. The SEDS value is higher than the EEI value in some years, lower in others. Disagreemeent was particularly large before 1975. Since 1979, the SEDS value has on average been 0.9% lower than the EEI value. In any given year, it is logical to conclude that the higher value is more inclusive and probably more reliable.

Neither the EEI nor the SEDS series fully capture total residential sector electricity consumption, as sales to master-metered apartment buildings are often not included in the residential category by utilities. The extent to which respondents do or do not include such apartment buildings in their residential customer classification is unknown, though it appears that utilities have mostly moved such buildings into the residential classification for reporting purposes.

The estimates in RECS are based on a sample survey of some 6000 households. The consumption data come from information on sales provided by the households' fuel suppliers. RECS estimates exist for April-March 1980-81, 1981-82, and 1982-83. (Estimates also exist from RECS' precursors, the NIECS in 1978-79 and the HSS in 1979-80.) Consumption estimates for households for which no useable record was received from the supplier (or for which fuel use was included in rent)* were imputed with a regression model. This is less of a problem for electricity than with other fuels, but still includes a high percentage (around 45%) of households in large (5 or more units) apartment buildings.[1]

1.1. Comparing SEDS and RECS

A clear comparison between SEDS and RECS is difficult because each covers a different time period: SEDS the calendar year, RECS the April-March period (see Table 4-5). This results in differences in weather and in the number of households using electricity for various purposes. The two sources also have slightly different coverage of the residential sector, as SEDS fails to capture some percentage of electricity consumption in master-metered apartment buildings. In RECS, the consumption by many households in such buildings is imputed. Analysis by EIA suggests that the accuracy of the imputed values is fairly good for households without electric air conditioning, but not so good for those with air conditioning. (Beginning in 1981, a corrective multiplier was applied to the imputed vales.)

The best comparison of the two sources can be done for 1980, the year for which Robert Latta of EIA used RECS data to estimate consumption in CY 1980, taking account of weather

[1] 17% of electricity-using households in RECS 1980-81, 19% in 1981-82, 17% in 1982-83.

differences and changes in household heating fuel.[2] The RECS value re-estimated for CY 1980 is only 22 TBtu (or 0.9%) higher than the SEDS value (see Table 4-5). (The SEDS value is well within one standard error of the RECS estimate.) This suggests that SEDS captures most of the consumption in master-metered apartment buildings. (Consumption in units where electricity was included in the rent was 70 TBtu in 1981.)

2. Trend in Residential Electricity Consumption

We see from the weather-adjusted[3] "best estimate" series (Table 4-4) that total residential electricity consumption has increased at a slower rate after 1979 (2.2% per year between 1979 and 1984) than before (3.0% per year between 1973 and 1979). There was little growth at all in the 1981-83 period, but there was a strong rebound (+4.6%) in 1984. Some of this rebound was due to growth in customers (the post-recession resurgence of new housing).

3. Electricity Consumption per Household

Statistics on average annual electricity consumption per customer have been published by the EEI since 1970 and before (Table 4-6). The weather-normalized series[4] shows growth averaging 1.5% per year between 1973 and 1979 and 0.3% per year between 1979 and 1984. Average consumption actually declined in 1982 and 1983, but rebounded strongly (+2.8%) in 1984. The RECS estimates of average electricity consumption show more decline in the 1978-79 through 1982-83 period than the EEI series. Since it appears that the 1978-79 NIECS overstates total electricity consumption (see Table 4-5), however, this may not be an accurate portrayal of the true trend.

The RECS give estimates of average annual electricity consumption in different housing types. The apparent overstatement of electricity consumption in the 1978-79 NIECS means that the averages for that year may be overstated. This would explain in part why the RECS series show more decline in consumption than seems plausible. For single-family detached houses (see Table 4-7), we see a considerable decline of around 20% between 1978-79 and 1982-83. For households in 2-4 unit buildings (see Table 4-8), high standard errors do not permit identification of a trend. For households in 5+ unit buildings,[5] average electricity consumption shows an unusual down and up path.

Estimates of average electricity consumption for several end-use categories in electric-heated homes were made with regression techniques for three years by Martha Johnson of EIA. Estimates for different housing types are shown in Tables 4-7 and 4-8. For single-family detached

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[2] See *Consumption and Expenditures April 1980 through March 1981* (Sept. 1982), p. 244.

[3] Adjustment of annual consumption data to "normal" weather is important, but difficult to do with precision. The method of weather adjustment that we have used at LBL (described in Appendix A) involves separating the estimated space heating component of total consumption, and dividing this by the ratio of heating degree-days in year n to the long-run average degree-day total. The heating degree-day total must reflect the weather experienced by electricity-heated homes, not all homes. A similar method using cooling degree-days is used for normalizing the estimated air conditioning component of electricity consumption.

[4] Weather-normalization of these values is done with both the space heating and air conditioning components of consumption.

[5] Consumption values for 40-50% households are imputed.

houses, the weather-adjusted values for space heating show a large decline (-39%) between 1978-79 and 1980-81, and a slight increase (not statistically significant) in 1981-82. The values for cooling suggest some increase in average consumption. The values for water heating show no significant change, while those for miscellaneous uses show some decline. For multi-family housing, high standard errors make interpretation difficult. (For households in large apartment buildings, the analysis has produced questionable results).

Averages over all electric-heated homes are shown in Table 4-9. By far the largest decline was in average consumption for space heating, which declined 33% between 1978-79 and 1981-82.

4. Linking Changes in Consumption and the Structural Setting

The key indicator for residential electricity consumption is average annual consumption per customer (see Figure 4-1). Linking changes in consumption with changes in the structural setting is more complicated for electricity than is the case for oil and gas. This is because there are many uses of electricity, and space heating does not dominate electricity use in the way it does use of oil and gas.

Those changes in the structural setting that have acted to **depress** average consumption are (ranked in rough order of their importance in our judgment):

- Introduction of new homes to the stock;
- Decline in winter and increase in summer indoor temperatures;
- Improved energy efficiency of non-heating equipment;
- Improved energy efficiency of electric heating equipment (including heat pumps);
- Structural improvements done on electric-heated homes;
- Increased use of secondary heating equipment.

Factors that have probably acted to **increase** average consumption are:

- Growth in saturation of electric heating;
- Growth in saturation of air conditioning;
- Growth in saturation of electric water heating, cooking, and other appliances.

4.1. The 1980-84 Period: A Closer Look

Average annual electricity consumption per customer (weather-normalized) was fairly steady between 1980 and 1983 and then rose in 1984. With so little change and so many factors at work, it is risky to try to explain too much. Space heating and cooling do not constitute a majority of average electricity consumption.[6] Thus, most of average electricity consumption is relatively insensitive to behavioral changes and structural improvements. Effects of other changes in the structural setting manifest themselves gradually over time. And with electricity, there are more factors working to increase consumption than is the case for oil and gas. It does seem likely, however, that the increase in consumption seen in 1984 is the result of changes in thermostat settings

[6] R. Latta of EIA used regression techniques with 1980 RECS data to estimate the space heating share of electricity consumption at 11% and the air conditioning share at 13%. The RECS 1980 period had average heating weather but a much warmer than normal summer.

for electric heating and cooling systems.

Data on indoor temperatures are unfortunately only available for 1981 and 1982. Data on conservation improvements (see Table 4-3 in Section A) show an increase in activity in 1980, but not a very large one. (It may be that a large share of the activity in 1979 was in the second half of the year.) This suggests that there was a strong behavioral action in 1980. We hypothesize that indoor temperatures remained fairly steady from 1980 to 1981, and that the continued high level of conservation improvements (and to a lesser extent, the other changes described above) acted to depress average consumption. 1982 saw virtually no decline in average consumption. This corresponds with the slight increase seen in indoor temperatures, which acted to balance the continued (though slower) penetration of conservation improvements.

Unfortunately, data are not yet available to shed light on the large decline in average electric consumption in 1983. Natural electric prices rose, though not more than in 1982. It may be that the continued rise in electric prices combined with the economic recession caused consumers to reduce consumption. Gas prices began to decline toward the end of 1983. This, combined with improved economic conditions, may be behind the increase in average consumption seen in 1984.

Table 4-4
U.S. Residential Electricity Consumption

(Trillion Btu)

	EEI	EIA/SEDS	"Best" Estimate*	
			Actual	Weather -Normalized**
1970	1528	1591	1591	1588
1971	1635	1704	1704	1710
1972	1745	1838	1838	1855
1973	1891	1976	1976	1986
1974	1894	1973	1973	2015
1975	2001	2007	2007	2024
1976	2092	2069	2092	2120
1977	2226	2202	2226	2206
1978	2318	2301	2318	2284
1979	2370	2330	2370	2379
1980	2460	2448	2460	2427
1981	2511	2465	2511	2514
1982	2498	2489	2498	2520
1983	2564	2562	2564	2542
1984	2653	2653	2653	2660

Source: Edison Electric Institute; State Energy Data Report (EIA,1985)

* The "best" estimate is taken as the higher of the two values. The assumption behind this is that the higher value includes some small utilities that the lower value may not include.

** Heating and cooling component of consumption are weather-normalized. See Appendix A for details of weather-normalization.

Table 4-5
U.S. Residential Electricity Consumption
Comparing SEDS and RECS

(trillion Btu)

	1978	1979	1980	1981	1982	1983
SEDS (Jan-Dec)	2301	2330	2448	2465	2489	2562
RECS (Apr-Mar)	2470(105)	2420(120)	2460(45)	2480(60)	2420(70)	-
(Jan-Dec)			2470*			
5+ Apartments**	175(25)	210(45)	200(20)	270(15)	260(20)	-
Utilities Included in Rent	-	-	-	70	-	-

Source: U.S. Dept. of Energy, State Energy Data Report, May 1985; NIECS, HSS, RECS-80, RECS-81, RECS-82

* Consumption in CY 1980 was estimated by EIA, taking account of weather differences and changes in household heating fuel.

** Consumption (partially imputed) by households in buildings with 5 or more units.

Values in parentheses are 1 standard error.

Table 4-6
U.S. Residential Electricity Consumption per Customer

(million Btu)

	Actual		Weather-Normalized*	
	EEI	RECS**	EEI	RECS**
1970	24.1	-	24.1	-
1971	25.2	-	25.3	-
1972	26.2	-	26.5	-
1973	27.6	-	27.7	-
1974	27.0	-	27.6	-
1975	27.9	-	28.1	-
1976	28.5	-	28.9	-
1977	29.7	-	29.4	-
1978	30.2	32.3**	29.8	32.8
1979	30.1	31.2**	30.3	31.1
1980	30.6	30.2**	30.2	30.6
1981	30.2	29.8**	30.3	29.8
1982	29.8	28.9**	30.1	28.7
1983	30.1	-	29.9	-
1984	30.6	-	30.7	-

Source: Edison Electric Institute, RECS

* Heating and cooling component of average consumption are weather-normalized. See Appendix A for details.

** RECS values reflect consumption in the period beginning in April of the year in the row, and ending in March of the following year. They are therefore not directly comparable with the EEI values.

Table 4-7
Average Electricity Consumption in Single-Family Detached Houses
Where Electricity is Main Heating Fuel

(Million Btu)

	1978-79	1979-80	1980-81	1981-82	1982-83
			(April through March)		
Actual	84.5(5.7)	74.6(5.5)	71.3(3.4)	66(3.4)	64(3.3)
Weather-adjusted*	81.9	73.6	71.0	67.6	65.4
Est. Consumption for Space Heating**					
Actual	38.4(2.6)	-	23.5(1.5)	22.1(1.1)	-
Weather-adjusted	35.8(2.6)	-	23.2(1.5)	23.7(1.1)	-
Est. Consumption for Water Heating**					
Actual	12.9(0.5)	-	13.5(0.4)	12.7(0.5)	-
Est. Consumption for Cooling**					
Actual	8.2(1.3)	-	9.7(0.6)	8.9(0.6)	-
Weather-adjusted	-	-	9.3(0.6)	8.9(0.6)	-
Est. Consumption for Miscellaneous Use**					
Actual	25.0(3.4)	-	24.6(0.7)	22.2(0.7)	-
Heating degree-days*	4312	4054	3984	3638	3689
Index (3935=100)	109.6	103.0	101.2	92.4	93.7
Cooling degree-days	-	-	1615	1553	1487
Index (1552=100)	-	-	104.1	100.1	95.8
No. of houses (mn)	6.4(0.9)	7.1(0.9)	7.7(0.6)	6.6(0.5)	6.9(0.5)
Avg. Heated Area*** (ft^2)	-	-	1751	-	1609

Source: U.S. DOE, Residential Energy Consumption Surveys

* The weather adjustment is on the estimated space heat share. For 1979, the 1978 share is used; for 1982, the 1981 share is used. See Appendix A for details of weather-normalization.

** From *Residential Energy Consumption and Expenditures by End Use for 1978, 1980, and 1981* (DOE, 1984).

*** Average for all single-family units.

Values in parentheses are 1 standard error.

Table 4-8
Average Electricity Consumption in Multi-Family Housing
Where Electricity is Main Heating Fuel

(Million Btu)

	1978-79	1979-80	1980-81	1981-82	1982-83
			(April through March)		
Homes in 2-4 Unit Buildings					
Actual	47(5.2)	40(6.8)	38(4.0)	42(3.7)	48(4.6)
Weather-adjusted*	-	-	-	-	-
Est. Consumption for Space Heating**					
Actual	18.5(3.5)	-	13.5(4.4)	15.8(1.8)	
Weather-adjusted*	-	-	-	-	-
Est. Consumption for Water Heating**					
Actual	7.6(0.9)	-	7.2(0.7)	8.0(1.1)	-
Est. Consumption for Cooling**					
Actual	6.8(3.6)	-	5.3(2.0)	5.0(4.6)	-
Est. Consumption for Miscellaneous Use**					
Actual	14.5(4.7)	-	12.3(1.0)	13.5(1.0)	-
Heating degree-days	xx	-	2569	3733	4783
Cooling degree-days	xx	-	1808	1392	1855
No. of homes (mn)	1.6(0.5)	1.1(0.4)	1.3(0.4)	1.8(0.3)	1.1(0.2)

Continued...

	1978-79	1979-80	1980-81	1981-82	1982-83
			(April through March)		
Homes in 5+ Unit Buildings					
Actual	45(2.9)	37(3.7)	31(1.1)	40(2.3)	40(2.4)
Weather-adjusted*	-	-	-	-	-
Est. Consumption for Space Heating**					
Actual	19.2(3.1)	-	8.5(1.1)	16.8(2.6)	-
Weather-adjusted*	-	-	-	-	-
Est. Consumption for Water Heating**					
Actual	5.6(0.8)	-	6.7(0.6)	8.0(0.6)	-
Est. Consumption for Cooling**					
Actual	7.6(1.9)	-	3.9(0.5)	3.9(1.0)	-
Est. Consumption for Miscellaneous Use**					
Actual	21.1(9.3)	-	12.2(0.6)	11.3(0.6)	-
Heating degree-days	-	-	3225	4062	-
Cooling degree-days	-	-	1415	1416	1218
No. of homes (mn)	2.5(0.6)	3.4(0.6)	3.7(0.5)	4.3(0.6)	3.9(0.4)

Source: U.S. DOE, Residential Energy Consumption Surveys

* The weather adjustment was not done due to either insufficient degree-day data or excessive variation among years.

** From *Residential Energy Consumption and Expenditures by End Use for 1978, 1980, and 1981* (DOE, 1984).

Values in parentheses are 1 standard error.

Table 4-9
Estimates of Average Electricity Consumption by End Use
in Homes Where Electricity is Main Heating Fuel

(Million Btu)

	1978-79	1979-80	1980-81	1981-82	1982-83
			(April through March)		
Space Heating					
Actual	31.6(2.2)	-	18.2(1.6)	19.2(1.3)	-
Weather-adjusted*	29.7(2.2)	-	18.2(1.6)	19.9(1.3)	-
Cooling					
Actual	7.4(1.0)	-	7.3(0.5)	6.6(0.6)	-
Weather-adjusted*	-	-	6.9(0.5)	6.6(0.6)	-
Water Heating	10.2(0.5)	-	10.4(0.4)	10.4(0.4)	-
Miscellaneous Use	20.2(0.9)	-	19.6(0.6)	17.2(0.6)	-
Heating degree-days	4230	4068	3956	3812	3686
Index (3950=100)	107.1	103.0	100.1	96.5	93.3
Cooling degree-days	-	-	1585	1506	1403
Index (1498=100)					
No. of homes (mn)	12.1(1.2)	-	14.3(1.0)	14.2(1.1)	-

Source: U.S. DOE, Residential Energy Consumption Surveys; *Residential Energy Consumption and Expenditures by End Use for 1978, 1980, and 1981* (Dec. 1984).

* See Appendix A for details.

Values in parentheses are 1 standard error.

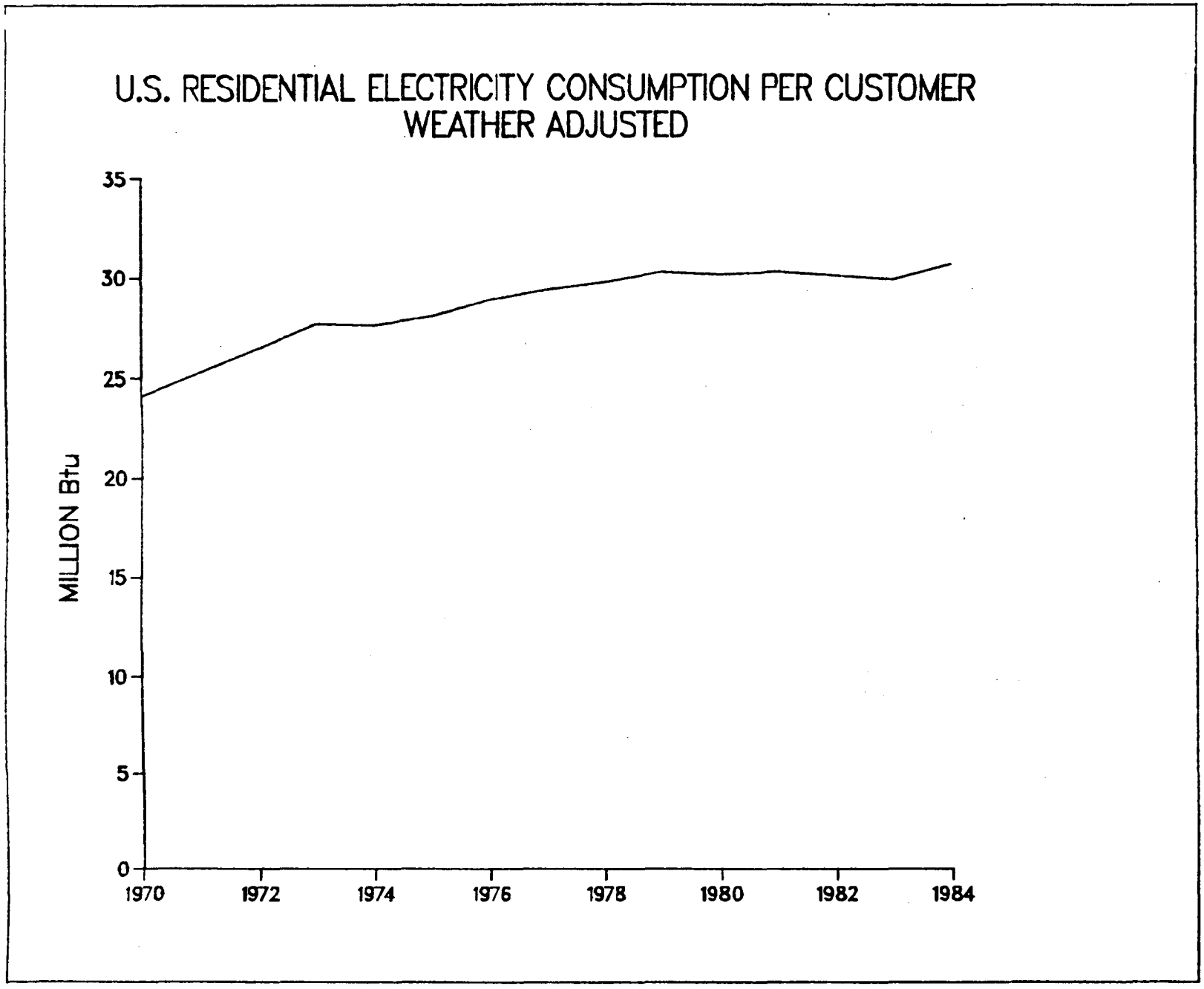
U.S. RESIDENTIAL ELECTRICITY CONSUMPTION PER CUSTOMER
WEATHER ADJUSTED
MILLION Btu
35
30
25
20
15
10
5
0
1970
1972
1974
1976
1978
1980
1982
1984

FIGURE 4-1

Chapter 5
U.S. Residential Oil Use: 1970-84
A. The Structural Setting

1. Data Sources

The two sources of national-level data on energy-related structural characteristics of housing are the Annual Housing Survey and the RECS. Unless specified otherwise, statistics refering to 1982 are from the RECS, while statistics refering to 1983 are from the AHS. See Chapter 2A for discussion.

2. Space Heating

The total number of oil-heated[1] homes has fallen substantially from about 16.8 million in 1970 -- 26% of all homes -- to around 13 million in 1983 -- 15% of all homes (see Table 5-1). The decline began in 1974, and accelerated during and after the 1979-80 upturn in oil prices. Because of the heavy use of wood stoves in homes with oil furnaces, it is difficult to say precisely how many households used oil as main heating fuel in recent years. The 1981 AHS estimated the number of homes using fuel oil or kerosene as main heating fuel at 14.5 million, while the 1981 RECS gave 12.2(±0.6) million. The 1983 AHS gave 13.0 million, while in the 1982 RECS, the similar number was 12.0(±0.6) million. Part of this difference could be an upturn in oil heating in 1983 (i.e.-- households going from wood back to oil as main heating fuel). An important difference is that the 1982 RECS gives 5.6(±0.5) million households using wood as main heating fuel, while the 1983 AHS gives 4.1 million. Clearly, there are many households using both oil and wood, and there is ambiguity regarding which is the **main** heating fuel.

2.1. Switching Away from Oil as Main Heating Fuel

Switching away from oil has been the main reason for the decline in oil heating (the other being demolition). Conversions to gas peaked in 1980 and 1981.

	1978	*1979*	*1980*	*1981*	*1982*	*1983*
	(millions of homes)					
RECS	-	0.5	0.7	0.8	-	-
AGA	0.1*	0.3*	0.5	0.4	-	0.1

* Estimated from total conversions to gas.

[1] The term "oil-heated" refers to the use of fuel oil or kerosene as *main* heating fuel. The 1983 AHS says that 3.4% of oil-heated homes used kerosene as main heating fuel.

Switching from oil to wood has also been important:

	1978	*1979*	*1980*	*1981*	*1982*
			(millions of homes)		
RECS	-	0.7	0.3	0.1	-

In contrast to switching to gas, in this case the household may continue to partially use the oil furnace. This is indicated by data from RECS 1981 where around 0.9 million households reporting using wood as main heating fuel also also used a fuel oil central heating system for secondary heating. These households have great ease of returning to use of fuel oil as main heating fuel.

2.2. Oil Heating in New Homes

Only around 13% of oil-heated homes standing in 1982 were built after 1969; around 8% were built after 1974. The annual number of new homes heated with oil (not including mobile homes) has fallen substantially since 1974. The oil heat share of total completions fell sharply in 1980 to around 2% and has not recovered since.

	1972-74	*1975-77*	*1978-80*	*1981-83*	*1984*
			(thousands of units completed)		
Single-family houses	301	312	224	55	24
Oil share (%)	9	10	6	2	2
Multi-family units	-	72	63	19	5
Oil share (%)	-	3	4	1	..
Total	-	384	287	74	29
Oil share (%)	-	8	5	2	2

Source: Bureau of the Census, *Construction Reports.*
Does not include mobile homes.

2.3. Oil Heating Equipment

The share of central heating equipment in oil-heated homes has increased since 1970. The increase in the share of steam and hot water systems reflects the decline in the number of oil-heated single-family houses seen in the RECS.

	1970 Census	*1978 NIECS*	*1982 RECS*
		(percent of homes)	
Warm-air furnace	37	45	38
Steam or hot water	43	43	52
Floor, wall, or pipeless furnace	3	3	2
Other	17	9	8

2.4. Type and Location of Oil-Heated Homes

The share of single-family houses in the oil-heated stock fell slightly during the 1970s and has remained about the same since 1978, according to the AHS. The share of homes in small multi-unit buildings fell between 1978 and 1983, while that of homes in large apartment buildings rose.

	Census 1970	*AHS 1978*	*AHS 1983*
		(percent)	
Single-family	65	63	63
Multi-unit building	30	33	33
2-4 unit building	-	14	12
5+ unit building	-	18	21
Mobile home	5	4	4

RECS data show a much larger decline than the AHS in the number of oil-heated single-family houses:

	1978	*1979*	*1980*	*1981*	*1982*	*1983*
			(millions)			
RECS	11.1(±1.1)	9.9(±1.0)	7.9(±0.5)	7.0(±0.5)	7.2(±0.5)	-
AHS	10.2	10.0	9.5	9.2	-	8.2

As mentioned above, many of these single-family homes retained their oil furnace but did not use it as main heating source. It may be that 1983 and 1984 will see an upturn in the number of oil-heated single-family homes as some homes return to their oil system for primary heating.

The changes in oil heating have affected the geographical distribution of the oil-heated housing stock. The net effect is that the long-term climate for oil heating is 1-2% colder today than in 1970.

	1970 Census	*1983 AHS*
	(percent of homes)	
Northeast	51	63
North Central	21	14
South	22	20
West	6	4

2.5. Use of Secondary Heating Equipment

The use of secondary heating equipment increased between 1978 and 1982. The RECS suggest that the percentage of oil-heated homes using a secondary heating fuel rose from around 30% in 1978 to around 40% in 1982. The most common secondary heating fuel was wood, followed by electricity and kerosene. The data on secondary heating understate the use of wood stoves, since many previously oil-heated homes used a wood stove as main heating fuel. Of the households reporting burning wood for secondary heating, the percentage burning one-third cord or more was around 70% in 1981 and in 1982.

The number of households not using oil for main heating fuel but using it for secondary heating has increased. The total number of households using fuel oil[2] for secondary heating rose from around 0.4 million in 1978 to around 3.9 million in 1982. The number using kerosene for secondary heating increased from around 1.1 million in 1981 to around 2.7 million in 1982.

3. Water Heating With Oil

The number of homes with oil water heating has declined since 1978:

1970 Census	*1978 AHS*	*1982 RECS*
	(millions of homes)	
6.3	7.0	5.7

The AHS and the RECS show a somewhat different picture with respect to oil water heating:

	1978	*1979*	*1980*	*1981*	*1982*	*1983*
	(millions of homes)					
AHS	7.0	6.9	6.4	*	-	*
RECS**	5.8	5.6	7.1	6.1	5.7	-

* Question not asked. ** Standard errors are 0.4-0.5.

The RECS suggest that the percentage of oil-heated homes where oil was also used for water heating increased from around 34% in 1978 to around 43% in 1982. This is due to the increase in the share of multi-family housing, which tends to use oil for room and water heating.

4. Structural Improvements on Oil-Heated Residences

Improvements to the thermal integrity of residences and to furnaces affected many oil-heated homes in the 1979-82 period (see Table 5-2).[3] The major improvements apply mainly to single-family housing.[4] Attic insulation and storm windows have been most popular. The RECS data suggest that activity peaked in 1980. 1982 saw a decline for some measures.

5. Improved Efficiency of Space Heating Equipment[5]

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[2] Households with a central oil system who used wood as main heating fuel.

[3] Data for 1978 are available for major measures from the NIECS. Data for the May 1973-May 1975 period are available for major measures from the 1975 WCMS survey.

[4] Improvements to heating equipment in apartment buildings are not captured by the RECS.

[5] Source: Levine, *et al.*, Economics of Efficiency Improvements in Residential Appliances and Space Conditioning Equipment, Lawrence Berkeley Laboratory, 1985.

The average (shipment-weighted) annual fuel utilization efficiency of new oil central space heaters has improved since 1972:

Source	*1975*	*1978*	*1984*
		(AFUE%)	
DOE survey	73.6	75.0	-
GAMA	-	-	78.6

Since the uptake of new oil central space heaters has been low, the effect on the stock of this improvement is minimal.

6. Energy-Conserving Behavior

We do not have data to compare winter indoor temperatures for oil-heated homes in the mid-1970s and the early 1980s.[6] From the data for all households, however, we can infer that they fell considerably (see Chapter 2A, Table 2-7).

The RECS provide data on wintertime indoor temperatures for 1981 and 1982. They suggest a major increase in both daytime and nighttime temperatures in 1982 (see Appendix B).

[6] Data on indoor temperatures are available from the data tapes from the 1973 and 1975 WCMS national household surveys.

Table 5-1
Oil-Heated Homes in the U.S.*

(Millions)

	Fuel Oil		Kerosene		Total		
	AHS	RECS	AHS	RECS	AHS	RECS	Census
1970	-	-	-	-	-	-	16.5 16.8**
1971	-	-	-	-	-	-	-
1972	-	-	-	-	-	-	-
1973	-	-	-	-	17.2	-	-
1974	-	-	-	-	16.8	-	-
1975	-	-	-	-	16.3	-	-
1976	-	-	-	-	16.5	-	-
1977	15.6	-	0.4	-	16.1	-	-
1978	15.6	-	0.4	-	16.1	16.9(1.3)	-
1979	15.3	-	0.4	-	15.7	14.6(1.3)	-
1980	14.5	12.6(0.6)	0.4	0.8(0.1)	14.9	13.4(0.7)	14.7
1981	14.1	11.3(0.6)	0.4	0.8(0.1)	14.5	12.2(0.6)	-
1982	***	11.3(0.6)	***	0.7(0.1)	***	12.0(0.6)	-
1983	12.6	***	0.4	***	13.0	***	-

Sources: Annual Housing Surveys; Residential Energy Consumption Surveys; 1970 and 1980 Census

* The AHS and RECS are done by interview, the Census by self-enumeration. The AHS asks "How is this house (apt.) heated?" RECS asks "What is the main fuel used for heating this house (apt.)? In the case of RECS, telephone interviews to check information on heating fuels were conducted with rental agents and landlords of households living in multi-unit buildings. The AHS began in 1973, the RECS in 1978. The split between fuel oil and kerosene was not published for some years. Census values are as of April, AHS as of October, RECS as of November.

** Includes estimate of units missed by census (details available)

*** Survey not conducted.

Values in parentheses are 1 standard error.

Table 5-2
Conservation Improvements by Oil-Heating Households
Single-Family Houses and Mobile Homes

(million households)

	Year Added:			
	1979	1980	1981	1982
Storm doors*	x	0.4	0.3	0.2
Storm windows*	-	0.5	0.5	0.7
Attic insulation	0.5	0.7	0.5	0.3
Wall insulation	0.3	0.3	0.1	0.2
Floor insulation	0.1	0.2	0.1	0.1
Duct insulation	0.1	0.1	0.1	0.1
Shutters, etc.**	0.8	0.7	1.3	0.5
Plastic sheets	-	-	1.0	0.3
Caulking	0.9	1.4	1.1	0.9
Weatherstripping	1.0	1.3	1.1	0.6
Head burner	0.1	x	0.2	0.1
Spark ignition	0.1	x	0.2	0.1
Water heater insulation	0.2	0.3	0.3	0.1
Total households	14.6	13.4	12.2	12.0
Single-family	10.4	8.6	7.5	7.7
Owner-occupied	9.0	7.5	6.7	6.8

Source: RECS-1 (1979), RECS-2 (1980), RECS-3 (1981 and 1982)

* Includes multi-family housing.

** Shutters, insulating drapes, or plastic sheets

B. Trends in U.S. Residential Oil Consumption 1970-1984[1]

1. State of the Data

There are two sources for national-level estimates of residential oil consumption: EIA's State Energy Data System (SEDS), and EIA's Residential Energy Consumption Survey (RECS), which began with the NIECS in 1978. There is no oil industry tabulation of oil consumption by sector similar to those compiled for gas and electricity by industry associations.

The estimates in SEDS (see Table 5-3) are based on a sample survey of some 7000 companies selling fuel oil and kerosene. Estimates of sales exist for the years 1960-1983. Prior to 1979, the estimates are made by applying the 1979 sectoral distribution (among residential, commercial, etc.) to total distillate or kerosene supplied in each year. This is because the primary data on oil deliveries in this period reflected a classification system that did not distinguish between residential, commercial, and industrial uses. The result of this is that there are no data of high reliability on residential oil consumption prior to 1979. This is not to say that the pre-1979 numbers in SEDS are completely inaccurate, but that the nature of their construction argues against major efforts to "improve" the numbers through various modifications.

Even with the improved data collection begun in 1979, SEDS still does not capture total residential sector oil consumption. Sales to large apartment buildings are not generally included in the residential category. This is a consequence of the manner in which fuel suppliers keep their accounts. The extent to which survey respondents do or do not include medium-size apartment buildings in their residential customer classification in unknown, though an estimate of the consumption missing from SEDS is possible (see below). Farm houses are also excluded from the SEDS residential classification, but the effect of this is small.

The estimates in the RECS are based on a national survey that interviews some 5000-6000 households. The consumption data come from information on deliveries provided by the households' fuel suppliers. RECS estimates exist from April-March 1980-81, 1981-82, and 1982-83. (Estimates also exist from RECS' precursors, the NIECS in 1978-79 and the HSS in 1979-80). Consumption estimates for households for which no usable record was received from the supplier (or for which fuel use was included in rent[2] were imputed by EIA with regression model. This includes nearly all households in large (5 or more units) apartment buildings.

In the case of both sources, the estimates reflect sales or deliveries in the period in question, not consumption. Consumption could be more or less, depending on the size of the stocks stored at buildings. Since each RECS covers a complete heating season, there is likely to be better correspondence between deliveries and consumption that is the case for SEDS.

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[1] By "oil" we refer to distillate fuel oil and kerosene. LPG is covered in Chapter 6.

[2] 45% of oil-using households in RECS 1980-81, 53% in 1981-82, 44% in 1982-83.

1.1. Comparing SEDS and RECS

A clear comparison between SEDS and the RECS is difficult because each covers a different time period: SEDS the calendar year, RECS the April-March period (see Table 5-4). This results in differences in weather and in the number of households using oil.

The two sources also have different coverage of the residential sector. SEDS fails to capture a large percentage of oil consumption in big apartment buildings. In the RECS, the survey is designed to provide coverage of all residential buildings, including big apartment buildings. Since all of the consumption by households in such buildings is imputed, however, the accuracy of the estimates is open to question.

The best comparison of the two sources can be done for 1980, the year in which Robert Latta of EIA used RECS data to estimate consumption in CY 1980, taking account of weather differences and changes in household heating fuel.[3] The RECS value re-estimated for CY 1980 is 200 TBtu (or 14%) higher than the SEDS value (see Table 5-4). Imputed oil consumption in apartments in buildings with 5 or more units in RECS 1980 was 300 (±35) TBtu. If we assume that SEDS is missing 200 TBtu, and that most of this is large apartment buildings, this suggests that around two-thirds of the oil consumption in such buildings was excluded from SEDS.

The 1980 comparison suggests that a better estimate of residential fuel oil and kerosene consumption is: the SEDS value + 200 TBtu. This value is fairly robust for the post-1980 period, as the number of apartments in buildings with 5 or more units using fuel oil or kerosene for heating declined only slightly (from 2.4 million in 1980 to 2.1 million in 1982).

2. Trend of Residential Oil Consumption

The weather-normalized values in Table 5-3 show a decline in total oil consumption after 1973, some increase in 1976-77, and a drop in 1978 and 1979.[4] The biggest drop occurred in 1980 (-21%). This was followed by declines of 11% in 1981, 6% in 1982, and 11% in 1983. 1984 saw a slight increase.

3. Oil Consumption per Household

Statistics on average oil consumption over all oil-using households are not reliable due to the uncertainty about and the lack of good correspondence between sectoral consumption data and data on households.

The RECS show a **decline in average oil consumption in single-family detached houses of around 24% between 1978-79 and 1981-82** (see Table 5-5).[5] **The decline slowed in 1982-83.** The series shows a total decline in average consumption between 1978-79 and 1982-83 of 27%. **The largest single drop occurred from 1979-80 to 1980-81: 10%.**

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[3] See *Consumption and Expenditures April 1980 through March 1981* (Sept. 1982), p. 244.

[4] Because of the questionable accuracy of the pre-1979 data, the year-to-year fluctuations and the transition between 1978 and 1979 should not be interpreted too exactly.

[5] Note that failure to adjust the data would lead to serious misinterpretation of the trend, especially in 1982-83.

Estimates of average oil consumption for space heating were made with regression techniques for three years by Martha Johnson of EIA. Once adjusted for weather, the values for single-family detached houses show a decline of 24% from 1978-79 to 1980-81, and a decline of 7% from 1980-81 to 1981-82.

Because the RECS consumption estimates for homes in multi-unit buildings are imputed, use of such data to form indicators is of questionable value.

An independent estimate of average oil consumption per customer comes from an annual survey conducted since 1970 by an industry publication, *Fuel Oil and Oil Heat.* A valuable aspect of this survey is its longevity. Another good feature is that data are available much more quickly than is the case for the RECS. A less desirable feature is the fact that this is not a random survey: the values given are a simple average of the respondents. Another problem is that the customer types are not completely clear. The "residential" classification probably includes mostly single-family homes, but may also include some multi-unit buildings that are not classified as "commercial apartment."

The weather-adjusted series for average deliveries to "residential customers" shows a strong decline in 1973/74[6] followed by gradual decline throughout the 1970s (see Table 5-6). We see a huge drop in 1980/81, a smaller one in 1981/82, and an increase in 1982/83. (The RECS series shows a less sharp drop between 1979/80 and 1980/81.)

The series for average deliveries to "commercial apartments" exhibits such a high degree of fluctuation from year to year that its accuracy as an indicator is suspect.

The values for residential customers from the *Fuel Oil and Oil Heat* survey are consistently higher than those from the RECS:

	1978-79	*1979-80*	*1980-81*	*1981-82*
FO & OH	161	152	129	123
RECS	131	118	106	99

This suggests that the former may include some small apartment buildings in the consumption averages. The two sources show somewhat different trends, but both show a decline of about 25%.

[6] Consumption data refer to deliveries for the heating season.

4. Linking Changes in Consumption and the Structural Setting

The key indicator for residential oil consumption is average annual consumption per customer (see Figure 5-1).[7] **Nearly all of the main changes in the structural setting have acted to depress average consumption.** These changes are (ranked in rough order of their importance in our judgment):

- Decline in wintertime indoor temperatures;
- Improvements done on oil-heated homes and heating equipment;
- Increased use of secondary heating equipment, especially wood stoves.

We hypothesize that the reduction in indoor temperatures mainly took place in two stages: once in 1974, and then again (further down) in 1980. **The gradual decline in average consumption after 1975/76 suggests the effect of structural improvements on homes.**

Introduction of new homes to the stock and improved energy efficiency of new oil heating equipment have not been very important factors. The apparent increase in the share of apartments in the oil-heated stock has probably had a depressing effect on average oil consumption of all oil-heated homes, though this is not reflected in the indicator shown (since it does not include large apartment buildings).

A factor that probably acted to slightly increase average consumption is:

- Growth in use of central heating (between 1970 and 1978);

4.1. The 1980-84 Period: A Closer Look

Average annual oil consumption (weather-adjusted) per customer (excluding apartments) declined considerably in 1980/81, fell much less in 1981/82, and has risen somewhat since.

Data on indoor temperatures are unfortunately only available for 1981 and 1982. Data on conservation improvements (see Table 5-2 in Section A) show an increase in activity in 1980, but not a very large one. **It is obvious from the large decline in average consumption in 1980/81 that indoor temperatures must have declined sharply. Growth in wood consumption also played a role.**

The data from the RECS show a **major increase in indoor temperatures between 1981 and 1982.** (This reflects the decline in oil prices.) This **would explain the increase seen in average oil consumption in 1982/83.** The increase in temperatures was obviously large enough to counteract the effect of continued (though slower) structural improvement in 1982. It is interesting that the use of plastic sheets (as window insulation) fell sharply from 1981 to 1982, as (to a lesser extent) did caulking and weatherstripping.

Given the continued decline in oil prices, it is noteworthy that average consumption did not increase further in 1983/84.

---

[7] We refer to the *Fuel Oil and Oil Heat* time-series because it goes back to 1970.

Table 5-3
U.S. Residential Oil Consumption
(Sales/Deliveries)

(Trillion Btu)

	Actual			Weather-Normalized*	
	Distillate Fuel	Kerosene	Total	Total	Revised Total**
1970	1878	298	2176	2150	2350
1971	1897	295	2192	2223	2423
1972	1996	271	2267	2209	2409
1973	2003	227	2230	2362	2562
1974	1844	184	2028	2103	2303
1975	1807	161	1968	2057	2257
1976	1987	185	2172	2103	2303
1977	1994	167	2161	2148	2348
1978	1951	153	2104	1981	2181
1979***	1626	133	1759	1750	1950
1980	1316	107	1423	1383	1583
1981	1147	85	1232	1232	1432
1982	1050	95	1145	1153	1353
1983****	929e	85e	1014	1029	1229
1984	958	70	1028	1047	1247

Source: U.S. Dept. of Energy, *State Energy Data Report*, May 1985, and personal communication (for 1984). Values are based on annual surveys of oil retailers/resellers. Most large apartment buildings are not included in the DOE data, although the extent of this is uncertain. Farm houses are excluded.

* See Appendix A for details of weather-normalization.

** The revised total includes estimated consumption in large apartment buildings. The estimate is based on comparison of SEDS and RECS data for 1980 (see text).

*** A new survey of oil retailers/resellers was implemented by EIA in 1979. Values for 1970-78 were estimated by applying the 1979 residential share of residential/commercial/industrial/farm distillate and kerosene deliveries to the sum of "heating" and "industrial" deliveries in each pre-1979 year (see Source, pp. 541, 549). As the residential share changed from year to year due to weather and other factors, the values resulting from this method are not very robust.

**** The 1983 value was estimated by EIA based on 1982 and 1984 data, as the survey was not conducted in 1983 due to probems with the sample of respondents.

Table 5-4
U.S. Residential Fuel Oil and Kerosene Consumption
Comparing SEDS and RECS*

(Trillion Btu)

	1978	1979	1980	1981	1982	1983
SEDS (Jan-Dec)*	2104	1759	1423	1232	1145	1082e
RECS (Apr-Mar)	2190(165)	1710(160)	1550(85)	1330(75)	1140(65)	-
(Jan-Dec)			1620**			
5+ Apartments***	250(70)	220(50)	300(35)	250(30)	190(25)	-

Source: U.S. Dept. of Energy, State Energy Data Report, May 1985; Residential Energy Consumption Surveys

* SEDS: Most apartment buildings are included in commercial use, although the extent to which apartment buildings are excluded from the above data is uncertain. Farm houses are excluded. RECS: The survey is designed to provide coverage of all residential buildings, including big apartment buildings.

** Consumption in CY 1980 was estimated by EIA, taking account of weather differences and changes in household heating fuel.

*** Imputed consumption by households in buildings with 5 or more units. Many of such buildings are not included in the SEDS residential classification.

Values in parentheses are 1 standard error.

Table 5-5
Average Oil Consumption in Single-Family Detached Houses
Where Fuel Oil or Kerosene is Main Heating Fuel

(Million Btu)

	NIECS 1978-79	HSS 1979-80	RECS-1 1980-81	RECS-2 1981-82	RECS-3 1982-83
			(April through March)		
Actual	130(3.8)	112(3.7)	110(2.6)	105(3.8)	92(3.2)
Weather-adjusted*	131(3.8)	118(3.7)	106(2.6)	99(3.8)	96(3.2)
Est. Consumption for Space Heating**					
Actual	123(5.0)	-	98.0(2.5)	93.1(3.1)	-
Weather-adjusted*	124(5.0)	-	94.5(2.5)	87.5(3.1)	-
Est. Consumption for Water Heating**					
Actual***	23.3	-	33.0	32.0	-
Heating Degree-Days****	5560	5282	5809	5996	5328
Index	99.4	94.4	103.8	107.2	95.2
No. of Houses (mn)	11.1(1.1)	9.9(1.0)	7.9(0.5)	7.0(0.5)	7.3(0.5)

Source: U.S. DOE, Residential Energy Consumption Surveys

* For 1979, the estimated space heat share for 1978 is used; for 1982, the 1981 share is used. See Appendix A for details of weather-normalization.

** From *Residential Energy Consumption and Expenditures by End Use for 1978, 1980, and 1981* (DOE, 1984).

*** Refers to households that used oil for water heating.

**** Average for all single-family units.

Values in parentheses are 1 standard error.

Table 5-6
Average Fuel Oil Deliveries per Residential Customer*
U.S. Average

Heating Season	Actual (gallons)	Weather-Adjusted** (gallons)	(million Btu)
1970/71	1410	1398	194
1971/72	1339	1396	194
1972/73	1463	1512	210
1973/74	1294	1372	190
1974/75	1305	1336	185
1975/76	1249	1326	184
1976/77	1371	1288	179
1977/78	1297	1219	169
1978/79	1198	1161	161
1979/80	1081	1099	152
1980/81	941	928	129
1981/82	942	890	123
1982/83	911	963	134
1983/84	960	947	131

Source: Annual survey of dealers conducted by *Fuel Oil and Oil Heat* magazine.

* The category "No. 2 Residential" probably includes mostly single-family residences, as there is a separate category for "No. 2 Commercial Apartment." Most of the consumption is for space heating; the water heating share has probably changed over time. (About 1/3 of single-family-detached households who used oil for space heating in 1980 also used oil for water heating.)

** See Appendix A for method of weather-adjustment. The heating degree-day numbers used here reflect the July-June period and are thus different from those shown in Appendix A. The heating degree-day numbers used here reflect the geographic distribution of all oil-heating households, not just single-family. This is a source of some inaccuracy in the above weather-adjustment.

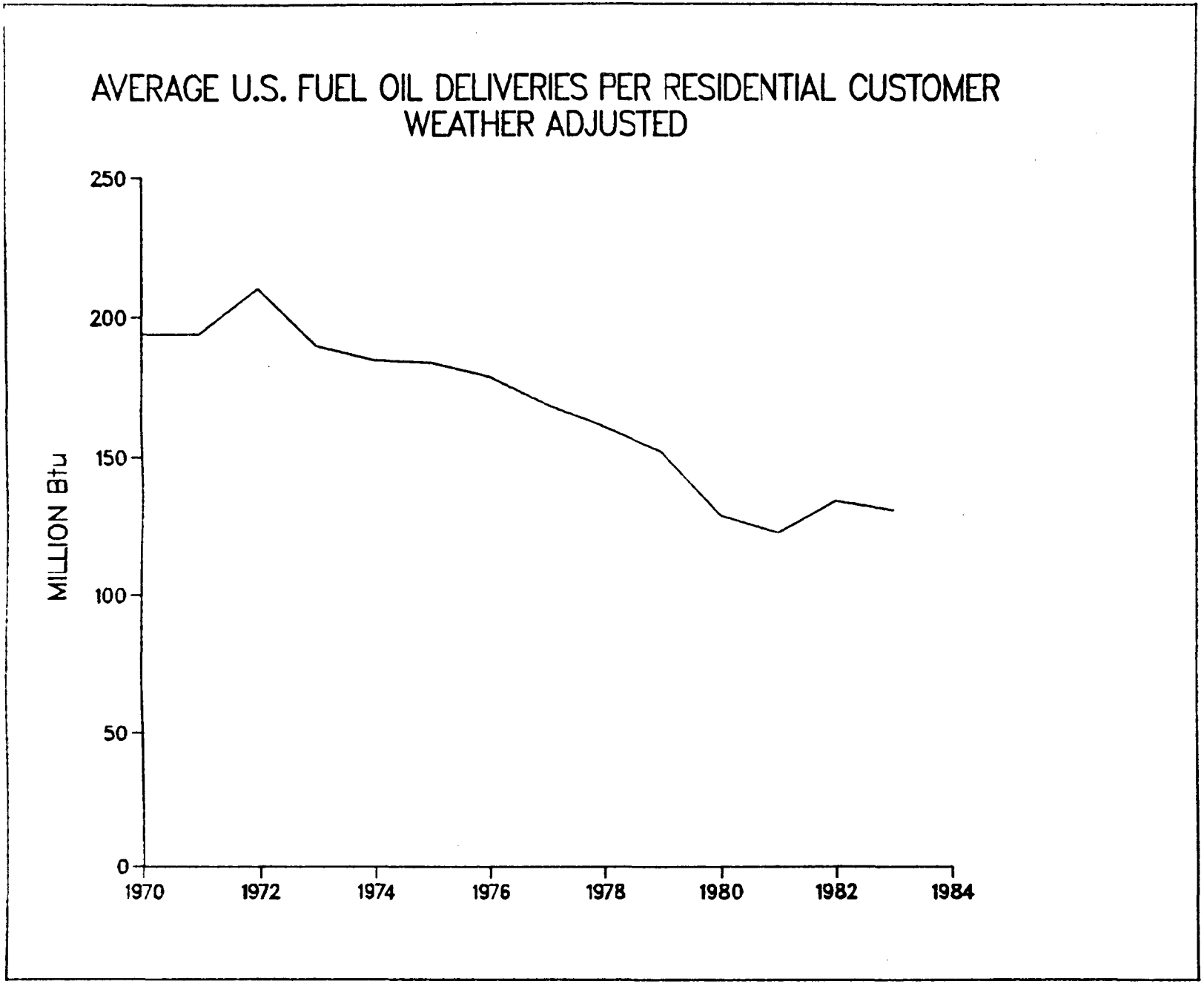
AVERAGE U.S. FUEL OIL DELIVERIES PER RESIDENTIAL CUSTOMER
WEATHER ADJUSTED
MILLION Btu
250
200
150
100
50
0
1970
1972
1974
1976
1978
1980
1982
1984

FIGURE 5-1

Chapter 6
U.S. Residential Use of LPG, Wood, and Coal: 1970-84
A. The Structural Setting

1. LPG

The number of households using LPG as main heating fuel has remained fairly stable since 1970 at around 4 million, though the percentage of homes with LPG heating has fallen from 6% in 1970 to 4-5% in 1983 (see Table 6-1).

LPG is used for water heating by around 3.5 million households and for cooking by around 5 million households.

1.1. Type and Location of LPG-Heated Homes

The share of mobile homes in the LPG-heated housing stock has increased since 1970, but single-family homes are still predominant:

	1970 Census	*1978 AHS*	*1983 AHS*
	(percent)		
Single-family	80	75	73
Multi-unit building	8	3	3
Mobile home	12	22	24

The geographical distribution of the LPG-heated housing stock is basically unchanged since 1970:

	1970 Census	*1983 AHS*
	(percent of homes)	
Northeast	4	4
North Central	29	30
South	55	56
West	11	10

2. Wood

The number of households using wood as main heating fuel has increased substantially from below 1 million in the early 1970s to 4-5 million in 1983 (see Table 6-2). Most of these households (85% in 1982 according to the RECS) use a wood stove.

The numbers given by the sources differ considerably. For 1980, the range is from 1.4 million households (the AHS) to 4.7($\pm$0.6) million (RECS), with the 1980 Census intermediate at 2.6

million.[1] Part of the reason for this large range is that many households use wood in combination with some other fuel, and responses may differ as to which is the *main* heating fuel. The RECS estimated that in 1982 around 1 million households who used wood as main heating fuel used fuel oil as a secondary heating fuel. That is, their furnace had become their secondary heat source. But the mix between wood and oil can change with time.

The number of households using wood for secondary heating increased substantially from around 10 million in 1979 to around 13.5 million in 1980 and increased again in 1981 to around 15.5 million (see Table 6-3). Around one-fourth of these households make use of a wood stove. Many of the households using wood for secondary heating in fireplaces actually receive little net heating benefit.

2.1. Type and Location of Wood-Heated Homes

Over 90% of households using wood as main heating fuel are in single-family houses.

The geographical distribution of the wood-heated housing stock has changed somewhat since 1970:

	1970 Census	*1983 AHS*
	(percent of homes)	
Northeast	3	13
North Central	10	18
South	69	46
West	18	22

According to the 1983 AHS, three-fourths of wood-heated homes are located outside SMSAs.

3. Coal

Coal was used by some 1.8 million households (2.9% of all households) as main heating fuel in 1970, but by 1980 it was used by only 0.3-0.5 million households (0.4-0.6%). Its use had already fallen substantially before the 1973-74 oil shock.

[1] The 1983 AHS gives a number (4.1 million) that is closer to the RECS.

Table 6-1
LPG-Heated* Homes in the U.S.

(Millions)

	Census (April)	AHS (October)	RECS (November)
1970	3.8 3.9**	-	-
1971	-	-	-
1972	-	-	-
1973	-	4.4	-
1974	-	4.1	
1975	-	4.1	
1976	-	4.2	
1977	-	4.2	
1978	-	4.1	3.1(±0.5)
1979	-	4.1	3.7(±0.7)
1980	4.5	4.2	3.7(±0.4)
1981	-	4.2	3.7(±0.4)
1982	-	***	3.8(±0.4)
1983	-	3.9	***

* Used LPG as *main* heating fuel.

** Includes estimate of units missed by Census (details available)

*** Survey not conducted.

Note: The Annual Housing Survey and RECS are done by interview, while the Census is by self-enumeration. The AHS asks "How is this house (apt.) heated?" RECS asks "What is the main fuel used for heating this house (apt.)? In the case of RECS, telephone interviews to check information on heating fuels were conducted with rental agents and landlords of households living in multi-unit buildings.

Table 6-2
Wood-Heated* Homes in the U.S.

(Millions)

	Census (April)	AHS (October)	RECS (November)
1970	0.8	-	-
	0.8**		
1971	-	-	-
1972	-	-	-
1973	-	0.6	-
1974	-	0.7	
1975	-	0.9	
1976	-	0.9	
1977	-	1.2	
1978	-	1.1	1.9(±0.3)
1979	-	1.1	3.4(±0.7)
1980	2.6	1.4	4.7(±0.6)
1981	-	1.9	5.4(±0.4)
1982	-	***	5.6(±0.4)
1983	-	4.1	***

* Used wood as *main* heating fuel.

** Includes estimate of units missed by Census (details available)

*** Survey not conducted.

Note: The Annual Housing Survey and RECS are done by interview, while the Census is by self-enumeration. The AHS asks "How is this house (apt.) heated?" RECS asks "What is the main fuel used for heating this house (apt.)? In the case of RECS, telephone interviews to check information on heating fuels were conducted with rental agents and landlords of households living in multi-unit buildings.

Table 6-3
Secondary Heating With Wood

(Millions of Homes)

	NIECS 1978	HSS 1979	RECS-1 1980	RECS-2 1981	RECS-3 1982
Total	10.8(0.6)	9.9(0.9)	13.4(0.6)	15.7(0.7)	16.5(0.8)
Fireplace	-	-	-	12.2(0.6)	13.2(0.7)
Heating stove	-	-	-	3.4(0.3)	3.3(0.3)
Amount Wood Burned*					
More than 1/3 Cord	-	-	9.5(0.5)	10.2(0.6)	9.6(0.6)
Less than 1/3 Cord	-	-	4-5(est)	7.2(0.5)	6.3(0.5)

Sources: NIECS, RECS-80, RECS-81, RECS-82

* This was a separate question from that asking about main and secondary heating fuel. Apparently, some households that burned wood did not claim it as a secondary heating fuel. The number of households who burned more than 1/3 cord for secondary heating was determined by subtracting the number of households who used wood as main heating fuel from the total number of households who burned more than 1/3 cord.

Values in parentheses are 1 standard error.

B. Trends in U.S. Residential Consumption of LPG, Wood, and Coal: 1970-84

1. State of the Data

1.1. LPG

There is no reliable time-series of residential LPG consumption prior to 1979. The pre-1979 values in EIA's State Energy Data System (SEDS) are rough estimates of the residential/commercial split. They are much higher than both the 1979-82 values in SEDS (which are based on an updated sampling frame) and the estimates of LPG consumption from EIA's Residential Energy Consumption Surveys (RECS), which began with the NIECS in 1978. We have roughly estimated a new series for the 1970-79 period using the values from RECS and data on numbers of households using LPG (see Table 6-4).

A comparison of SEDS and RECS values suggests that the SEDS values for 1979 and after are reasonably accurate (see Table 6-5).

1.2. Wood

There are two sources for estimates of residential wood consumption: a study done for EIA by Applied Management Sciences,[1] which developed an historical time-series, and the RECS surveys, which present estimates of wood consumption beginning with 1980. A comparison of these two sources shows good agreement (see Table 6-5).

1.3. Coal

The values in SEDS (see Table 6-4) are rough estimates of the residential/commercial split. The quantities involved are relatively inconsequential.

2. Trend of Total Consumption (see Table 6-4)

2.1. LPG

Because of the work involved and the rather imprecise nature of the time-series on LPG consumption, we have not adjusted annual consumption data to "normal" weather. (It is also the case that a smaller share of LPG is used for space heating than is the case for oil and gas.) The SEDS data suggest some decline in total consumption between 1979 and 1982.

2.2. Wood

Because of the rather imprecise nature of the data on wood consumption and household numbers and location, we have not adjusted the series on wood consumption to "normal" weather. Such adjustment would not affect the general trend seen. The AMS study shows wood

[1] *Estimates of U.S. Wood Energy Consumption from 1949 to 1981* and *Estimates of U.S. Wood Energy Consumption 1980 to 1983*

consumption increasing gradually after 1973, with larger increases in the 1978-80 period. We have made an approximate weather adjustment for the 1978-83 period:

	1978	*1979*	*1980*	*1981*	*1982*	*1983*
			(trillion Btu)			
"Actual"	622	728	859	869	937	925
Weather-adjusted*	590	716	859	903	962	933

* Based on the regional distribution of households using wood as main heating fuel as given by the 1980 Census.

We see considerable increase in 1979 and 1980, modest increase in 1982 and 1982, and a slight decline in 1983. A more precise weather adjustment would probably not change this trend very much.

2.3. Coal

SEDS data show a 50% decline in coal consumption since 1970.

3. Consumption per Household

The RECS show trends in average consumption between 1978-79 and 1982-83 for LPG and between 1981 and 1983 for wood. For homes using LPG as main heating fuel, we see that average consumption (weather-adjusted) declined around 25% between 1978-79 and 1982-83 (see Table 6-6). Average LPG consumption in homes not using LPG for heating was stable during the period.

Data on average wood consumption are only available for 2-1/2 years. For households using wood as main heating fuel, average consumption was fairly steady between 1981 and the 1982-83 heating season (see Table 6-7). The same holds true for households using wood as a secondary heating fuel.

Table 6-4
U.S. Residential Energy Consumption:
LPG, Wood, and Coal

(Trillion Btu)

	LPG	Wood	Coal
1970	340*	400	152
1971	350*	382	144
1972	360*	380	110
1973	370*	354	108
1974	375*	371	106
1975	375*	425	87
1976	380*	482	84
1977	380*	542	85
1978	375*	622	85
1979	355	728	74
1980	325	859	61
1981	311	869	73
1982	296	937	78
1983	352e	925	78
1984**	350	900	75

Sources: U.S. Dept. of Energy, *State Energy Data Report,* May 1985 (for LPG and coal); *Estimates of U.S. Wood Energy Consumption: 1949 to 1981; 1980-1983.*

* The pre-1979 values in SEDS are much higher than the later SEDS values, which are based on a new survey frame, and estimates from RECS. (The published SEDS values range from a high of 628 TBtu in 1972 to a low of 516 TBtu in 1978.) We have estimated values that seem more appropriate based on RECS consumption estimates and data on the number of households using LPG. The 1983 value was estimated by EIA, as their survey was discontinued.

** Our provisional estimates.

Table 6-5
U.S. Residential LPG Consumption
Comparing SEDS and RECS

(Trillion Btu)

	1979	1980	1981	1982	1983
SEDS (Jan-Dec)	355	325	311	296	352e
RECS (Apr-Mar)	310(55)	360(32)	310(35)	290(39)	-
(Jan-Dec)		377*			

Source: U.S. Dept. of Energy, *State Energy Data Report* (May 1985); HSS, RECS-1, RECS-2, RECS-3

* Consumption in CY 1980 was estimated by EIA, taking account of weather differences and changes in household heating fuel.

Values in parentheses are 1 standard error.

U.S. Residential Wood Consumption
Comparing RECS and AMS Estimates

(trillion Btu)*

	1980	1981	1982	1983
RECS	760(130)	886(90)	972(112)	
AMS	859	869	937	925

Source: U.S. Dept. of Energy, RECS-1, RECS-2, RECS-3; *Estimates of U.S. Wood Energy Consumption: 1980-1983.*

* Conversion factors used were 20 million Btu per cord for RECS and 17.2 million Btu per oven-dry ton for AMS.

Values in parentheses are 1 standard error.

Table 6-6
Average LPG Consumption per Household Using LPG

(Million Btu)

	1978-79	1979-80	1980-81	1981-82	1982-83
			(April through March)		
LPG Used As Main Heating Fuel					
Actual	80(9.4)	67(6.7)	77(2.8)	67(6.0)	59(3.6)
Weather-adjusted*	80(9.4)	71(6.7)	73(2.8)	67(6.0)	60(3.6)
Est. Consumption for Space Heating**					
Actual	67.3(8.6)	-	60.7(3.4)	55.2(4.5)	-
Weather-adjusted*	67.6(8.6)	-	56.7(3.4)	55.1(4.5)	
Heating Degree-Days	3998	3760	4386	4024	3928
Index (4019=100)	99.5	93.6	109.1	100.1	97.7
No. of Households (mn)	3.1	3.7	3.7	3.7	3.8
% Mobile Homes***	30	27	32	30	24
LPG Not Used As Main Heating Fuel					
Actual	20	18	20	18	19
No. of Households (mn)	3.8	3.3	3.8	3.5	3.4

Source: U.S. DOE, Residential Energy Consumption Surveys

* The weather adjustment is on the estimated space heat share. For 1979, the weather-adjusted 1978 share is used; for 1982, the 1981 share is used. See Appendix A for details of weather-normalization.

** From *Residential Energy Consumption and Expenditures by End Use for 1978, 1980, and 1981* (DOE, 1984).

*** Most of the other homes are single-family detached structures.

Values in parentheses are 1 standard error.

Table 6-7
Average Wood Consumption per Household

(Million Btu)*

	1981	1982	1982-83**
Main Heating Fuel			
Wood			
Actual	96(8)	102(9)	92(10)
Weather-adjusted***	99(8)	103(9)	97(10)
Fireplace	62	64	60
Airtight Stove	90	100	90
Non-airtight Stove	102	108	94
Natural Gas	-	20	20
Oil	-	32	30
Electricity	-	24	24
Heating Degree-Days****	4653	4756	4546

Source: U.S. DOE, Residential Energy Consumption Surveys

* Converted from cords at 20 million Btu per cord.

** April through March

*** Done on 100% of wood consumption.

**** Average for all U.S. households.

Values in parentheses are 1 standard error.

Appendix A
Method of Weather Normalizing Energy Consumption Data

The first step of the weather-normalization process is calculation of a degree-day average for the particular houses in question -- e.g., all oil-heated houses. Except where degree-day averages are available from a survey (as is the case with RECS), this requires an estimation of the regional distribution of the houses for each year. We use data for the nine census divisions. With this estimate, data from the National Climatic Center giving population-weighted[1] monthly degree-day totals (base 65F) by the nine census divisions can be used to calculate an appropriate degree-day total for the homes in question. The heating degree-day values we have used are shown in Table A. These are less than perfect, since we did not have available the nine-division distribution for all years, but they are close to what the "right" values would be.

The second step is normalization of the consumption figure. This requires estimation of the space heating (or cooling) component of consumption. The "base" space heat share is estimated as 70% for natural gas, 85% for oil, and from 10% (in 1970) to 19% (in 1984) for electricity.[2] We assume that the space heat share is greater in cold years and less in warm years. We thus adjust the "base" space heating share by multiplying by the modified climate index.[3]

The space heating component is then divided by the modified degree-day index for the period in question. Dividing actual consumption by the simple index (the ratio of degree-days in the year to the normal) may tend to overcompensate in very cold or very warm years, since consumption in all likelihood does not continue to scale linearly with degree-days past a certain point. To account for this, we take the square root of the deviation from normal past 5% (that is, if the index for the year is 107, we take the square root of 107-105 and add that to 105 rather than simply using 107).

For the cooling component of electricity consumption, the same method is used. In this case, the national population-weighted number of cooling degree-days (base 65F) was used, since we did not have the values that would reflect the divisional distribution of only air-conditioned homes. The effect of this is small.

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[1] According to the population distribution as given by the 1980 (or in some cases, 1970) census.

[2] These values are based on previous work. Details available from the author.

[3] This was not done in the case of electricity, since the space heat and cooling shares are relatively small.

Table A
Degree-Day Averages for U.S. Homes
Calendar Year Totals

(Base 65F)

	HEATING				COOLING
	Homes Heated With:				
	Gas	Oil	Electricity	All Homes	All Homes
1970	4869	5487	4010	4940	1155
1971	4757	5322	3929	4789	1119
1972	4958	5575	3970	4975	1057
1973	4494	4931	3716	4504	1174
1974	4619	5177	3690	4622	1040
1975	4675	5122	3837	4653	1110
1976	4899	5612	4052	4930	976
1977	4765	5449	3970	4782	1231
1978	5146	5873	4243	5142	1172
1979	5021	5491	4131	4943	1068
1980	4926	5637	4045	4857	1281
1981	4688	5463	3909	4653	1168
1982	4887	5412	3931	4756	1097
1983	4855	5319	4030	4754	1233
1984	4756	5294	3861	4643	1174
Average	4858	5411	4044	4796	1137

Heating Degree-Days: Values are weighted by the distribution of homes in the nine census divisions. This distribution comes from the 1970 census for years 1970-74, from the 1977 AHS for years 1975-77, from the 1978 AHS, the 1979 AHS, and from the 1980 Census for years 1980-84. Heating degree-day totals are from the National Climatic Center and are based on the 1980 Census population in each division. Values for all homes reflect interpolation of the national totals based on 1970 Census and 1980 Census population-weighting.

Cooling Degree-Days: Values reflect interpolation of the national totals based on 1970 Census and 1980 Census population-weighting.

Appendix B

Reported Winter Indoor Temperatures in U.S. Homes by Main Heating Fuel*

(% of households with heating controls)**

	Gas		Electricity		Fuel Oil	
	1981	1982	1981	1982	1981	1982
Daytime temperature when someone is at home						
70 or above	47	50	52	53	32	41
73 or above	11	14	17	16	3	10
Under 70	49	41	40	40	66	53
65 or less	17	16	17	15	25	21
Heat off	2	3	2	3	..	..
Daytime temperature when no one is at home						
70 or above	18	20	19	22	11	22
73 or above	4	5	5	7	2	6
Under 70	63	55	48	46	81	67
65 or less	43	38	33	31	59	44
Heat off	17	20	29	29	7	4
Nightime (sleeping hours) temperature						
70 or above	22	22	30	25	10	19
73 or above	5	5	9	7	2	5
Under 70	66	59	52	52	86	72
65 or less	25	38	35	33	55	49
Heat off	10	14	13	19	3	3

Source: EIA, Residential Energy Consumption Surveys

* The surveys were largely completed in the fall of each year. The question was "At what temperature do you usually keep your house (apt.) in the wintertime?"

** 81% of households had heating controls in 1981, 80% in 1982. Controls refer to thermostat or other type of control.

Totals do not sum to 100% because some households did not know the temperature or did not respond.

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