Changes in the Patterns of Energy Consumption and Expenditures Over the Past Quarter Century

Michael T. Laurence, U.S. Energy Information Administration[1]

ABSTRACT

The U.S. Energy Information Administration first conducted the *Residential Energy Consumption Survey* in 1978. The RECS is a national statistical survey that measures energy consumption, expenditures, and related demographic and physical characteristics of primary U.S. housing units. The 1978 RECS survey was the first detailed statistical snapshot of the residential energy sector. In the twenty-six years since the first RECS survey it has been repeated nine times, most recently in 2001. Over the past quarter century much has changed in the residential energy sector of the U.S., changes which are documented in the RECS. This paper will examine these changes in the consumption and expenditure patterns of the past quarter century in terms of the mix of fuels used, shifts in end uses, and changes in fuel prices. The paper also discusses the sociological, demographic, and economic factors that may have contributed to these changes.

Introduction

The past quarter century have seen many sociological, demographic and economic changes that have had effects on the patterns of energy consumption in the United States. The size of the average family has decreased over time; there have been significant changes in the racial and ethnic composition of U.S. society; population densities have shifted from the northern Census regions to the South and West; median household income has increased; and energy prices have greatly exceeded the rate of inflation.

In 1978, when the U.S. Energy Information Administration conducted the first *Residential Energy Consumption Survey*, there were 216.8 million people living in 76.6 million housing units.[2] Total annual weather adjusted energy consumption was 10.02 quadrillion Btu which cost $117 billion in weather and inflation adjusted dollars. The average housing unit consumed 131 million weather adjusted Btu of energy annually and paid $1,524 in weather and inflation adjusted dollars. The average person consumed 46 million Btu of weather-adjusted energy annually, which cost $539 in weather and inflation adjusted dollars.[3]

---

[1]The opinions and conclusions expressed in this paper are solely those of the author and should not to be construed as representing the opinions or policy of the Energy Information Administration or any other agency of the United States Government.

[2]The RECS sample includes only non-institutional housing units. Housing units included in the RECS are houses, apartments, or groups of rooms occupied as separate livings quarters by a family, an individual, or group of one to nine unrelated persons. Excluded are group quarters such as military barracks, dormitories, penitentiaries, and nursing homes. Accordingly the population and housing units covered by the RECS is less that all in the U.S.

[3]All energy consumption data in this paper are presented in terms of Btu since this is the single common unit of measure that can be used for summarizing and comparing energy consumption across fuels. All the RECS consumption data presented in this paper have been normalized for variations in heating and cooling degree-days. Expenditures have been adjusted both for variations in heating and cooling degree days and inflation using U.S. Department of Commerce, Bureau of Economic Analysis implicit price deflator where 1996=100. In the interest of

Twenty-three years later, in 2001 when the most recent RECS was conducted, the RECS population increased by 26 percent to 274.2 million people and the number of housing units increased by 40 percent to 107 million. Annual total energy consumption increased by 2 percent to 10.25 quadrillion Btu. The average housing unit consumed 28 percent less energy, 96 million Btu annually, and the average person consumed 19 percent less energy, 37 million Btu. Annual expenditures for energy totaled $149 billion, an increase of 28 percent. The average housing unit spent $1,394 per year, a decrease of 9 percent, and the average person spend $544 per year, a statistically non-significant change.

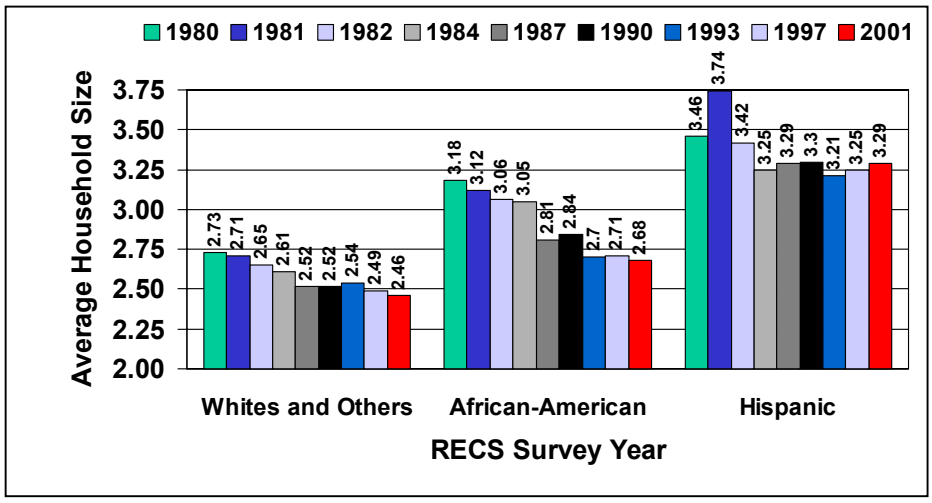
Demographic and Economic Changes

The size of the average U.S. household decreased from 2.83 persons in 1978 to 2.56 persons in 2001. The percentage of single-member households increased from 19 percent in 1978 to 26 percent in 2001, while the percentage of two and three-member households remained statistically unchanged. The percentage of households with four or more members decreased from 30 percent to 25 percent.

These aggregate changes mask large differences between Whites and Others (non-African-American and non-Hispanic), the African-American, and the Hispanic sub-populations. Since 1980, the number White and Other households and African-American households increased by 22 percent and 40 percent, respectively. In contrast, the number of Hispanic households tripled, growing from 4.2 percent to 9.5 percent of all households.

As shown in Figure 1, the average size of African-American and Hispanic households are larger than the Whites and Others households. Both the White and Other and African-American households have been decreasing in average size over the past two decades. In contrast, the average size of Hispanic households, after some early fluctuations, has remained fairly constant, between 3.25 and 3.29 persons.

Figure 1. Average Household Size by Race/Ethnicity



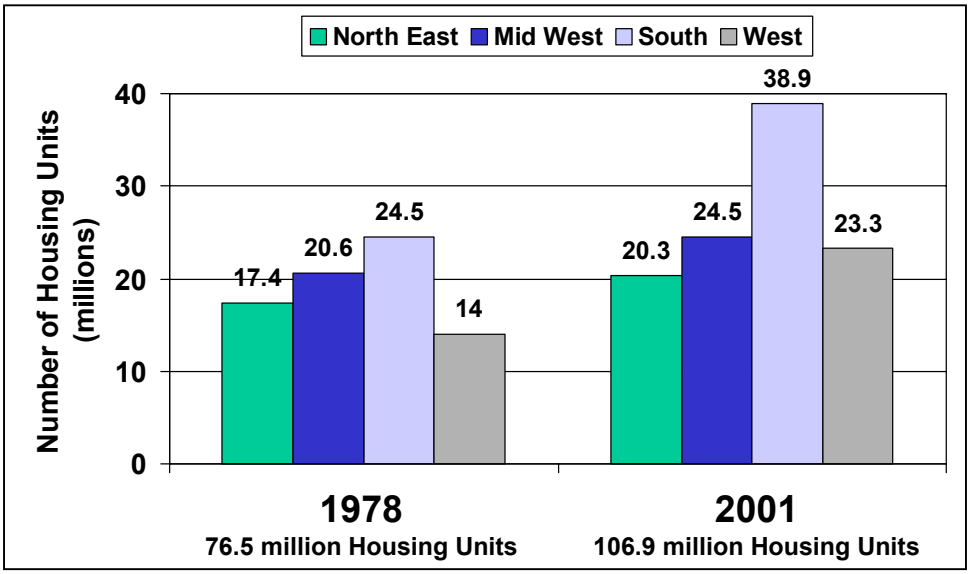
Source: Energy Information Administration, 1980—2001 Residential Energy Consumption Surveys.

brevity all the remaining consumption and expenditures data presented in this paper are adjusted data but the adjectives regarding weather variations and inflation have been omitted.

Between 1980 and 2001 there has also been a notable shift in the distribution of household size that varies by race and ethnicity. The percentage of White and Other and African-American single-member households increased from 19-20 percent in 1980 to 27 percent in 2001 while the percentage of Hispanic single-member households increased from 14 percent to 18 percent. The percentage of two and three-member households in all three race/ethnic groups are statistically unchanged. The percentage of White and Other households with four or more members decreased from 28 percent to 23 percent, while the percentage of African-American households in this category decreased from 39 percent to 28 percent. In contrast, the percentage of Hispanic households with four or more members was statistically unchanged between 1980 (44 percent) and 2001 (42 percent).

Between 1978 and 2001 the number of housing units in each of the four U.S. Census regions increased, but there was a notable shift in the distribution of housing units away from the northern states towards the southern and western areas of the U.S (see Figure 2). The South Census region, which had the most housing units in 1978, increased its 32 percent share to 36 percent in 2001 and continued to have the most housing units. The West Census region, which in 1978 had the fewest housing units, surpassed the North East Census region, which had the second fewest housing units in 1978, to become the region with the second fewest housing units in 200l. The share of housing units in the West increased from 18 percent to 22 percent. The share of housing units in the North East decreased from 23 percent to 19 percent. The Mid West Census region had the second most number of housing units in both 1978 and 2001, but the share decreased from 27 percent in 1978 to 23 percent in 2001.

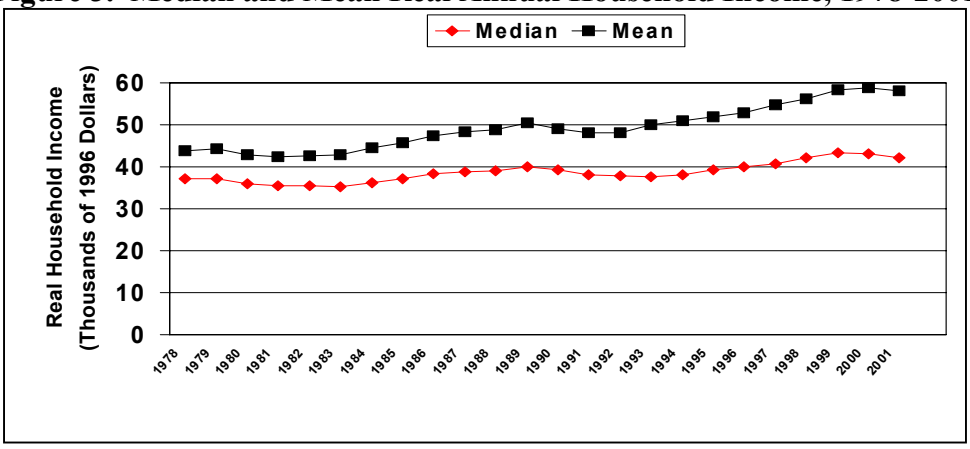
Figure 2. Number and Distribution of Housing Units, by U.S. Census Region



Source: Energy Information Administration, 1978 and 2001 Residential Energy Consumption Surveys

Household income has consistently out-paced the rate of inflation since 1978. The median real annual income of the U.S. household has increased by 13.4 percent from $37,200 to $42,200 (see Figure 3). Average real annual household income has increased by 32.8 percent, from $43,800 to $58,200, reflecting the larger number of households in the top income quartile compared to the bottom income quartile.

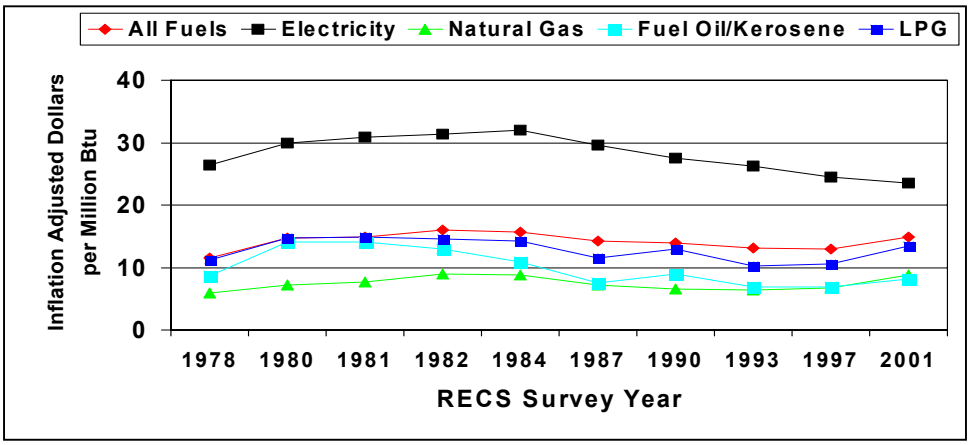
Figure 3. Median and Mean Real Annual Household Income, 1978-2001



Source: U.S. Census Bureau: Historic Income Tables, Table H-7. Divisions (All Races) by Median and Mean Income: 1976 to 2001; http://www.census.gov/hhhes/income/histicn/ho7.html

Over the past two decades the price of fuels has generally been trending downward. The increase in the aggregate price for fuels observed in the 2001 RECS was the first since the 1982 RECS. The nominal price of fuel (total annual consumption divided by total annual expenditures) used in U.S. residential housing units has, after adjustment for inflation, increased 29 percent from $11.47 per million Btu in 1978 to $14.82 per million Btu in 2001, an increase that far exceeded the rate of inflation (see Figure 4). This summary statistic masks notable differences in the price of the main fuels used in U.S. housing units.

Figure 4. Fuel Prices Observed in Successive RECS, Adjusted for Inflation



Source: Energy Information Administration, 1978—2001 Residential Energy Consumption Surveys .

The prices of electricity and fuel oil/kerosene actually fell. The real price of electricity in 1978 of $26.44 per million Btu fell 11 percent to $23.55 per million Btu in 2001. The price of fuel oil/kerosene declined 5 percent from $8.57 per million Btu to $8.18 per million Btu in 2001. The price of the other two main fuels both increased. The price of natural gas increased 48 percent, rising from $5.99 per million Btu in 1978 to $8.85 per million Btu in 2001. The price of LPG increased 20 percent, rising from $11.13 per million Btu in 1978 to $13.40 per million Btu in 2001. The aggregate Btu price of fuels observed in the 2001 RECS was 14 percent higher than that observed in 1997. Contributing to these higher fuel prices were increases of 33 percent in

the Btu price of natural gas, 19 percent for fuel oil/kerosene, and 28 percent for LPG. Offsetting these increases was a decrease in the Btu price of electricity of 4 percent.

While the recent increases in fuel prices probably had some effect on the behavior of some household members that included reducing thermostat settings, closing off rooms, using space heaters, and wearing heavier clothing in order to conserve energy and reduce expenditures, it is not likely that these higher fuel prices had much of an immediate effect on long-term energy consumption. First, most main space heating systems and central air-conditioning systems are less than 10 years old and are already energy-efficient, so replacing them in the name of efficiency is moot. Economically, the elasticity of replacement of older equipment is not particularly sensitive to fuel prices, at least in the short run. With only a quarter of water heaters and most-used refrigerators older than 10 years there is little room for major gains in efficiency and reduction in energy consumption. The dramatic improvements in energy efficiency and reductions in energy consumption that occurred in the early 1980s in reaction to very large increases in fuel prices are not likely to reoccur in the 2000s.

The facts that the increase in total energy consumption between 1978 and 2001 was not a statistically significant change despite the large increases in population and the number of housing units, and that the average household and per person consumption declined so substantially, is testimony to the dramatic improvements in energy efficiency over this 23-year period. But these summary statistics mask the true magnitude of improvements in energy efficiency. In addition to the obvious energy inefficiency of the smaller size of households, other changes in behavior and expectations have resulted in increases in energy consumption that offset decreases resulting from more energy efficient home construction and energy consuming equipment.

Housing Unit Characteristics

Their has been a notable shift from relatively smaller apartments to larger single-family attached housing units among one and two-member households. The percentage of these smaller households living in single-family detached homes was statistically unchanged. In 1978, 46 percent of single-member households and 28 percent of two-member households lived in apartments. In 2001, 40 percent of single-member households and 23 percent of two-member households lived in apartments. The percentage of single-member and two-member households living in single-family attached housing units increased from 3.4 percent and 3.9 percent, respectively, in 1978 to 9.5 percent and 10.0 percent, respectively, in 2001.

More newer, "energy-efficient" homes existed in 2001 than in 1978. In 2001, 51.0 percent of the housing units were reported as built before 1969--before the oil shocks of the 70s and before the notion of energy-efficiency had any real meaning. Of the 77 million housing units reported as existing in 1978, 4 percent no longer exist, leaving 73 million still in the housing stock in 2001. Of the housing stock in 1978, 25 percent of those built before 1940 are no longer in existence in 2001. Finally, 31 percent of the 2001 housing stock was built after 1979—after the second oil shock of the 70s and after the notion of energy-efficiency attained real meaning.

Offsetting the gain in energy savings resulting from the larger number of newer, energy-efficient homes in the stock and decreases in energy consumption per housing unit, is the increase in the size of U.S. housing units. The average square footage of all housing units in 1981 (the first year reliable and accurate measurements were obtained) was 1,734 square feet. In

2001 the average housing unit measured 2,066 square feet, an increase of 19 percent. Single family homes, including detached, attached, and mobile homes, increased in size in the 21-22 percent range, while apartments in 2-4 unit buildings decreased in size by 7 percent and apartments in 5 or more unit buildings was unchanged.

It can be asserted that all of the space heating and central air-conditioning systems, water heaters, and most-used refrigerators that existed in 1978 were all less energy efficient than those placed in service thereafter, since they were manufactured before the imposition of energy-efficiency standards in the 1980s and the 1990s. The 2001 RECS respondents reported that 41 percent of their main space heating equipment, 55 percent of their central air-conditioning equipment, 56 percent of their water heating equipment, and 62 percent of the most-used refrigerators were all less than ten years old, and thus were manufactured after 1991 and after the imposition of energy efficiency standards.

When segmented by the age of the housing unit, the percentage of housing units with equipment less than ten years old is even more pronounced. Among housing units built after 1979, 54 percent have main space heating equipment that is less than ten years old, compared to 35 percent of the housing units built before 1980. This latter statistic represents older units that have been retrofitted with newer, more efficient heating equipment. Noteworthy among the housing units built before 1980 is the finding that 35 percent have main space heating equipment that is more than 19 years old, suggesting that in large part, they are still using their original equipment or energy inefficient equipment that replaced their original equipment in the oldest housing units.

Among housing units built after 1979, 59 percent have central air-conditioning equipment that is less than ten years old compared to 51 percent of the housing units built before 1980. Among the housing units built before 1980 only 17 percent have central air-conditioning equipment that is more than 19 years old. In 1978 relatively few housing units, 23 percent, had central air-conditioning systems, so the proportion still using their original equipment, or energy inefficient equipment that replaced their original equipment, in the oldest of housing units, which were few to begin with, is small.

Among housing units built after 1979, 64 percent have water heaters that are less than ten years old, compared to 52 percent of the housing units built before 1980. Among the major system appliances water heaters tend to have the shortest useful life. This may account for the relatively low percentage of housing units with water heating equipment more than 19 years old, 11 percent, in housing units built before 1980.

Among housing units built after 1979, 68 percent have most-used refrigerators that are less than ten years old compared to 59 percent of the housing units built before 1980. Unlike the major system appliances in a housing unit, refrigerators are more noticed by the residents of the home, who for reasons other than the equipment simply wearing out, may replace it. This may help account for the relatively small difference between newer and older housing units. Only 9 percent of housing units built before 1980 had a most-used refrigerator that was more than 19 years old.

Energy Consumption and Expenditures

Table 1 presents the annual total, per housing, and per person energy consumption and expenditures data from the 1978 and 2001 RECS. These data are the source for the discussion of changes in consumption and expenditures that follows.

With the exception of the absence of statistically significant changes in the total Btu consumed and total expenditures per person, there are notable changes in the per household and per person totals, and end-use totals as well as significant changes in the distributions of consumption and expenditures by end-use.

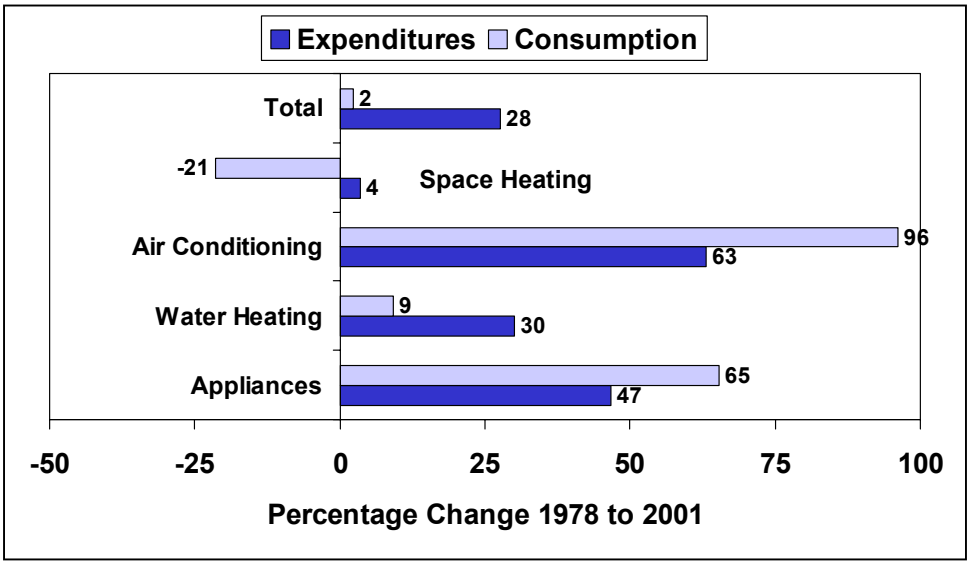
Total Btu consumption per year increased from 10.02 quad-rillion Btu in 1978 to 10.25 quadrillion Btu in 2001, a non-statistically significant in-crease of 2 percent, while annual expenditures increased from $117 billion to 149 billion, an increase of 28 percent (see Figure 5).

Table 1. Total, Per Housing Unit, and Per Person Consumption and Expenditures

Consumption						
	Total (Quadrillion Btu)		Per Housing Unit (Million Btu)		Per Person (Million Btu)	
End-Use	1978	2001	1978	2001	1978	2001
Space Heating	6.42	5.04	86	48	30	19
Air-Conditioning	0.30	0.59	7	7	3	3
Water Heating	1.52	1.68	20	16	7	6
Appliances	1.77	2.94	23	28	8	18
Total	10.02	10.25	131	96	46	37
Expenditures						
	Total (Billion US Dollars)		Per Housing Unit (U.S. Dollars)		Per Person (U.S. Dollars)	
End-Use	1978	2001	1978	2001	1978	2001
Space Heating	49	50	648	478	230	187
Air-Conditioning	8	14	203	170	71	67
Water Heating	15	20	201	185	71	72
Appliances	45	65	582	611	203	239
Total	117	149	1,524	1,394	539	544

Source: Energy Information Administration, 1978 and 2001 Residential Energy Consumption Surveys.

Figure 5. Percentage Changes in U.S. Energy Consumption and Expenditures, Adjusted for Inflation and Weather Variations



Source: Energy Information Administration, 1978 and 2001 Residential Energy Consumption Surveys.

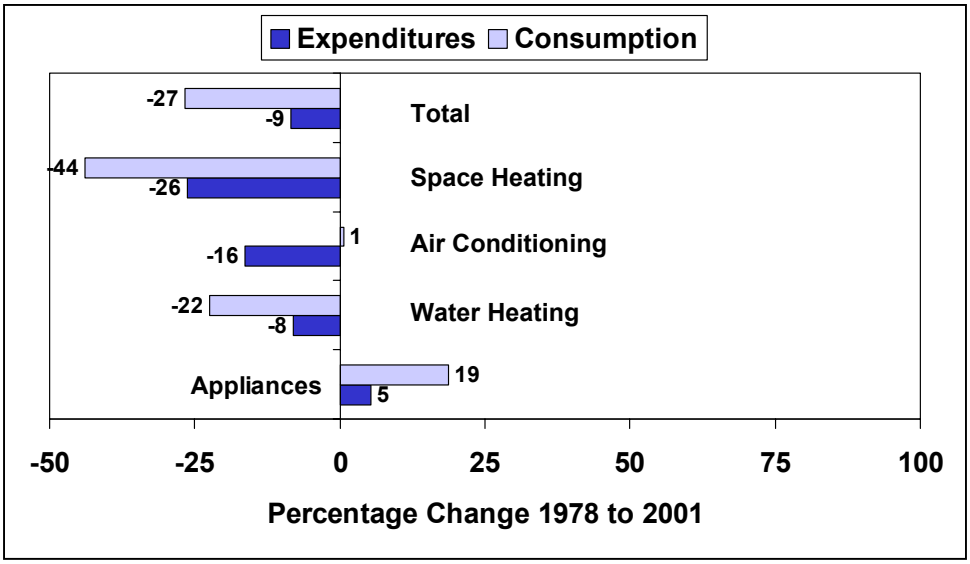
In contrast to the 63 percent increase in total annual expenditures for air-conditioning, 30 percent increase for water heating, and 65 percent for appliances, space heating increased only 4 percent. As shown in Figure 5, the only end-use in which total consumption decreased was in space heating, despite the fact that there are 30 million more housing units in 2001 than in

1978. Compared to the 6.42 quadrillion Btu consumed in 1978, only 5.04 quadrillion Btu were consumed in 2001, a decrease of 21 percent. This certainly is a positive commentary on the success of more energy-efficient heating equipment and housing units.

Total annual energy consumption for air conditioning nearly doubled from 0.30 quadrillion Btu in 1978 to 0.59 quadrillion in 2001, reflecting the 95 percent increase in the number of housing units that have central air-conditioning equipment. The increase in total water heating Btu consumption from 1.52 quadrillion Btu in 1978 to 1.68 quadrillion in 2001, an increase of 9 percent, is a reflection of the increase in the number of housing units that is in part attenuated by the use of more energy-efficient equipment. Finally, the 65 percent increase in total appliances Btu consumption, from 1.77 quadrillion Btu in 1978 to 2.94 quadrillion in 2001, reflects both the increase in the number of housing units and the increase in the number and variety of appliances used in those units.

Figure 6 presents the percentage change in consumption and expenditures between 1978 and 2001 on a per housing unit basis. Remarkably, with the exception of appliances, consumption and expenditures have both declined in total and by end-use over this 23-year period. (The 1 percent in expenditures for air-conditioning is not a statistically significant increase.) Overall, with the exception of appliances, the decreases in consumption were larger than the decreases in expenditures, reflecting the 29 percent increase in cost of energy over this 23-year period. For appliances the percentage increase in expenditures was smaller than the increase in consumption, reflecting the facts that the 86 percent of the Btu consumed by appliances are from electricity, the Btu price of which has declined by 11 percent since 1978.

Figure 6. Percentage Changes in Energy Consumption and Expenditures per U.S. Housing Unit, Adjusted for Inflation and Weather Variations



Source: Energy Information Administration, 1978 and 2001 Residential Energy Consumption Surveys.

Total annual Btu consumption per housing unit declined by 27 percent from 131 billion Btu in 1978 to 96 billion Btu in 2001, while expenditures declined by 9 percent from $1,524 in 1978 to $1,394 in 2001. Despite increases in the size of housing units, Btu consumption for space heating declined by 44 percent from 86 billion Btu in 1978 to 48 billion Btu in 2001. Expenditures for space heating declined by 26 percent from $648 in 1978 to $478 in 2001.

Expenditures for air-conditioning declined by 16 percent from $203 in 1978 to $170 in 2001 while the Btu consumed by each housing unit to operate them was unchanged.

The lower Btu price of electricity in 2001 compared to 1978 accounts for this result since all the air-conditioners included here use only electricity, which declined in price. Finally, consumption per housing unit of Btu for appliances has increased by 19 percent from 23 billion Btu in 1978 to 28 billion Btu in 2001. Per housing unit expenditures increased by 5 percent from $582 in 1978 to $611 in 2001, which once again reflects the decrease in the price of electricity.

The increases in energy consumption and expenditures to operate appliances reflect the large increase in the types and number of appliances in American households. In 1978, numerous appliances that are a normal part of contemporary American life simply did not exist or were rarely used. Among these appliances were cordless telephones, large-screen televisions, microwave ovens, personal computers, telephone answering machines, and VCRs and DVD players. In 2001 the percentage of housing units using these appliances was not insubstantial. It should also be noted that many of these newer appliances use DC adapters and "instant-on" technology that use electricity even though it appears that the appliance is "off". Thus, though these appliances may employ energy-efficient technology in their actual operation, there is a substantial total amount of "stand-by" energy being used.

There have also been large increases in the number of housing units using major appliances that were once only the province of the more affluent. The percentage of housing units using clothes dryers increased from 59 percent in 1978 to 74 percent in 2001. Housing units using dishwashers increased from 35 percent in 1978 to 53 percent in 2001. While nearly all housing units used a refrigerator in both 1978 and 2001, the most-used ones in 2001, while more energy-efficient, were larger, nearly all of which were frost-free, and frequently (21 percent) included a through-the-door water and ice feature. Thus the improved efficiency is offset by the addition of these features. Televisions in 2001 were virtually all solid-state electronic devices, in contrast to the vacuum-tube technology sets, many of which were still in use in 1978. Thus, while televisions are more energy-efficient, nearly three-quarters of housing units used two or more in 2001, which typically included an "instant-on" feature that is constantly using electricity, compared to about half in 1978, when few used "instant-on" technology.

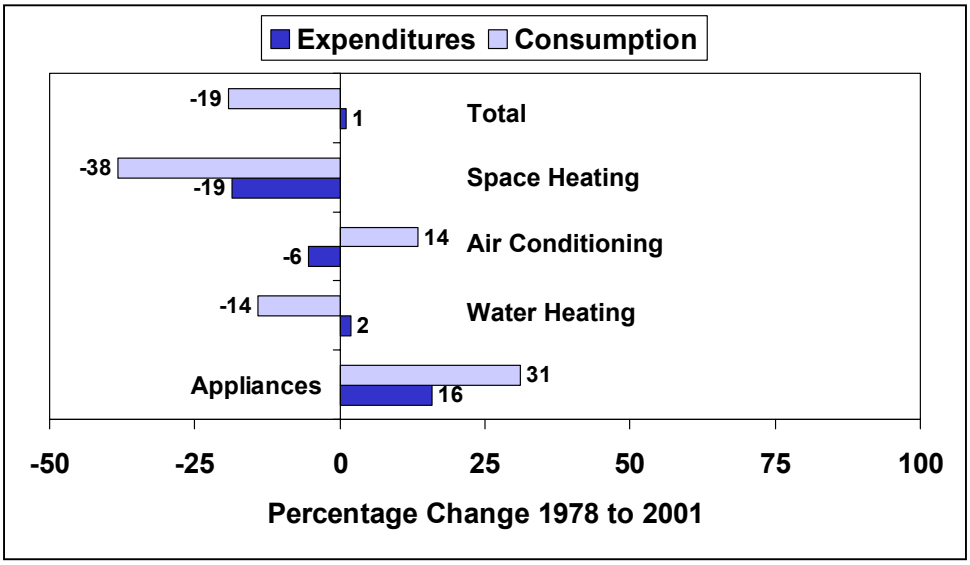
Consumption and Expenditures per Person

Figure 7 presents the percentage changes in consumption and expenditures between 1978 and 2001 on a per person basis. This figure reflects the effects on energy consumption and expenditures resulting from the decrease in average household size from 2.83 persons in 1978 to 2.56 persons in 2001. Compared to Figure 6 it is clear that all the percentages have shifted to the right. That is, the decreases in consumption and expenditures are smaller and the increases larger.

As noted earlier, the decrease in average household size is energy-inefficient. To assess how inefficient, the 1978 distribution of housing units by household size was applied to the 2001 population and average per housing unit energy consumption and expenditures. If the distribution of housing units by household size in 2001 been the same as in 1978 there would have been 10 million fewer housing units, 97 million instead of the actual 107 million. The average annual total Btu consumption per household would have increased by 4 percent, 99 billion Btu instead of the actual 96 million Btu. However, total Btu consumption would have

decreased by 6 percent, 9.63 quadrillion Btu instead of the actual 10.25 quadrillion Btu. Instead of a non- significant 2 percent increase in total Btu consumption from 1978 to 2001, there would have been a statistically significant decrease of 4 percent. While expenditures would have increased by 4 percent per household, $1,446 instead of the actual $1,524, and they would have decreased by 6 percent per person $511 instead of the actual $544, and resulted in a total annual savings of $9 billion.

Figure 7. Percentage Changes in Energy Consumption and Expenditures per Person, Adjusted for Inflation and Weather Variations



Source: Energy Information Administration, 1978 and 2001 Residential Energy Consumption Surveys.

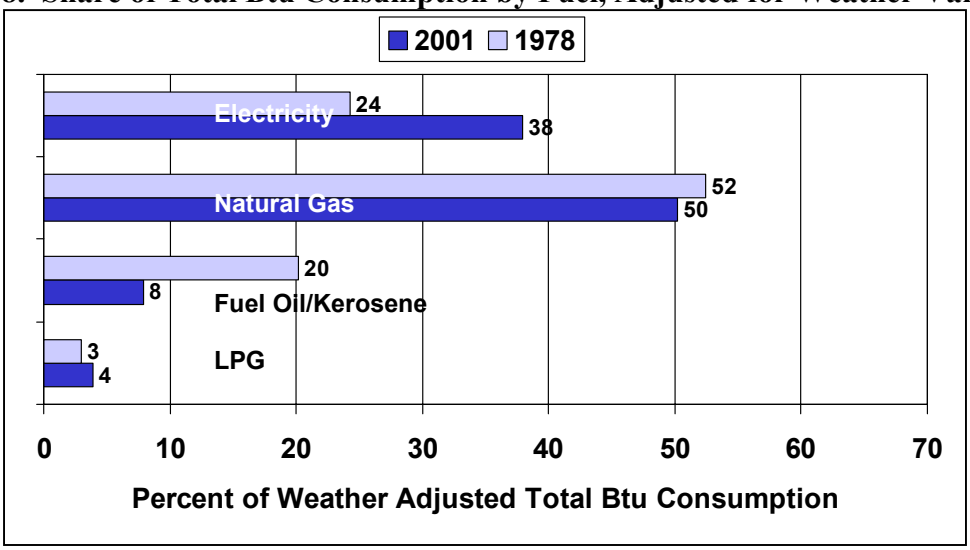
Distribution of Btu and Fuel Consumption and Expenditures

As shown in Figure 8, the distribution of sources of energy used in housing units has changed over the past 23 years. Energy in the form of electricity accounted for 38 percent of the total Btu consumed in 2001, compared to 24 percent in 1978. The increased used of electricity for space heating, the increase in the use central air conditioning equipment, and the increase in the type and number of appliances account for this large shift. The increases in consumption of electricity for air conditioning and the operation of appliances have been discussed earlier in this paper. Since 1978 the number of housing units using electricity as their main space heating fuel has more than doubled. In 2001, 31 million housing units, 29 percent of all units, used electricity as their main space heating fuel, compared to 12 million housing units, 16 percent of all housing units, in 1978.

The dramatic increase in the electricity share inevitably lead to decreases in the share of the three other major fuels. The smaller share of Btu consumed in the form of natural gas is a reflection of the decrease in total Btu used for space heating. The share of Btu consumed in the form of fuel oil has decreased from 20 percent to 8 percent. This decrease can be accounted for by the overall decrease in the number of housing units using fuel oil as their main space heating fuel. In 1978, 20 percent of housing units used fuel oil as their main space heating fuel. By 2001 this percentage decreased to 8 percent. Also contributing to the decrease in fuel oil share is the decrease in the number of older housing units using steam/hot water systems fueled by fuel

oil. In 1978, 6.7 million housing units using steam/hot water heating equipment used fuel oil to operate them. By 2001 this number dropped by 34 percent to 4.4 million. The change in the share of LPG between 1978 and 2001 is not a statistically significant one.

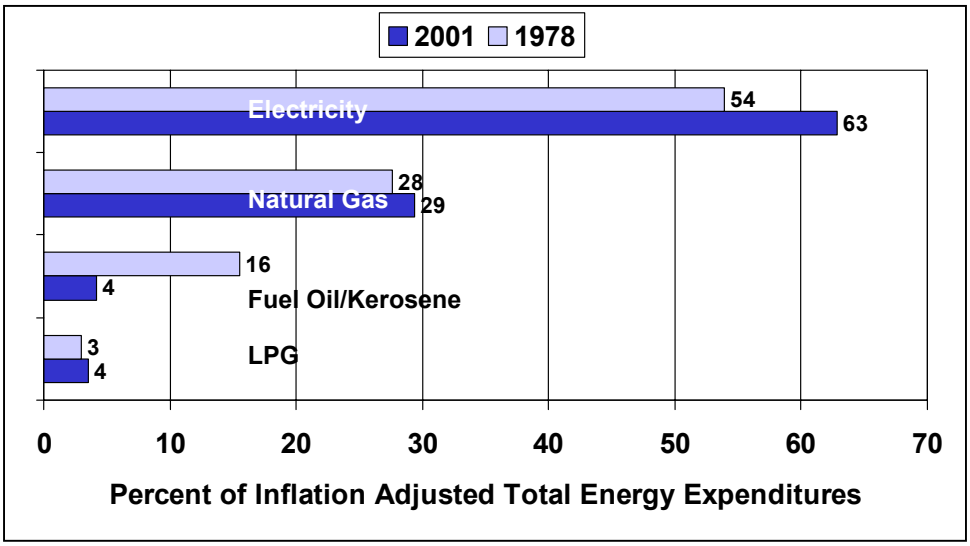
Figure 8. Share of Total Btu Consumption by Fuel, Adjusted for Weather Variations



Source: Energy Information Administration, 1978 and 2001 Residential Energy Consumption Surveys.

As shown in Figure 9, electricity, which accounted for majority of dollars expended for energy in 1978, 54 percent, continued to claim the largest share of total expenditures in 2001, 63 percent. The share of expenditures for natural gas increased by 1 percentage point, which is a not a statistically significant change. The share of expenditures for fuel oil/kerosene dropped from 16 percent in 1978 to 4 percent in 2001. This decrease reflects not only the increase in the shares of electricity and natural gas but also the decrease in the use of these fuels for space heating.

Figure 9. Share of Total Energy Expenditures by Fuel, Adjusted for Inflation



Source: Energy Information Administration, 1978 and 2001 Residential Energy Consumption Surveys.

Summary

Energy consumption and expenditures over the past 23 years, as recorded by the RECS, have undergone dramatic changes. A number of sociological, demographic and economic changes have had effects on the patterns of energy consumption in the United States. The size of the average family has decreased over time; there have been significant changes in the racial and ethnic composition of U.S. society; population densities have shifted from the northern Census regions to the South and West; median household income has increased; and energy prices have greatly exceeded the rate of inflation.

Other factors have resulted in the mitigation of the growth of total energy consumption and decreases in per-household and per-person consumption. The principal factor is that older, energy-inefficient housing units have left the stock and been replaced with newer, energy efficient housing units containing newer and more energy efficient equipment. On the other hand, there are many offsetting factors whose effects are to increase energy consumption. Household size has decreased, resulting in more housing units being constructed. The size of housing units, measured by square footage and number of rooms, has increased. These newer homes, as well as older ones, contain many more appliances that, while generally built to be energy-efficient, often include conveniences such as "instant-on" features that consume energy even when they are ostensibly "off".

Reference

Energy Information Administration. *1978, 1980, 1981, 1982, 1984, 1987, 1990, 1993, 1997, and 2001 Residential Energy Consumption Surveys*. Washington, D.C.: Energy Information Administration, Office of Energy Markets and End Use. http://www.eia.doe.gov/emeu/recs/contents.html.