### An Evaluation of Trends in Energy Consumption in Residential Housing

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### ABSTRACT

This paper will use recently published fuel and energy end use data from a quadrennial national study to examine key trends in household energy consumption in the United States. The first major trend is the increasing share of household energy use that is consumed by appliances and miscellaneous electric devices. As heating and cooling systems have become more efficient and more and more electric end-uses such as computers, televisions, and small electronics have been added, the share of electricity used by appliances and electronics has doubled from 17% in 1978 to 35% in 2009. This growth in appliance and electronic energy use has also occurred during a time of substantial improvements in energy standards for almost all major appliances. The paper also examines the consumption profile of new homes and how that differs from older homes in 2009. The paper will also provide a brief introduction and overview of the latest data. The 2009 survey was the largest survey to date, with a sample size three times bigger than any previous survey year, and contains characteristics, consumption, and expenditure data for 16 states and 11 groups of states so the data are useful for more regional analysis than ever before. This study serves a broad audience and should be valuable to any utility provider, efficiency program administrator, or other stakeholder interested in understanding emerging uses of energy in the home.

### **Introduction and Methodology**

The Residential Energy Consumption Survey (RECS) is a quadrennial survey of primary occupied housing units in the United States administered by the U.S. Energy Information Administration (EIA). EIA is the statistical and analytical agency within the U.S. Department of Energy and was established in 1977 as the single Federal Government authority for all energy statistics. The first residential consumption survey was conducted in 1978. The survey was conducted annually until 1984, when a triennial cycle was initiated. Since 1993 the survey has been conducted on a quadrennial cycle. RECS is the only national household energy survey conducted in the United States and it is a unique dataset that is valuable to a wide range of energy stakeholders.

RECS is a two-phase survey. Initially a sample is selected that represents all occupied housing units in the United States. For the first phase, after advance letters are sent to the selected housing unit, an interviewer visits the residence and conducts a computer-assisted interview that lasts approximately one hour. The interview collects information on the characteristics and usage of all energy end-uses in the housing unit including heating, cooling, appliances, electronics, and computers. Also collected are general characteristics of the housing

unit and demographic information on the occupants. In addition to administering the questionnaire, the interviewer measures the dimensions of the housing unit in order to estimate its square footage. Finally the interviewer collects utility billing information for all energy suppliers of the housing unit. Respondents are asked to provide copies of their utility bills, but if they cannot, the names of the suppliers are collected. If the household reports that a landlord pays any of their utility bills, a separate rental agent survey is conducted of the landlord by the same interviewer. This survey asks questions on household characteristics as well as asking for utility bills. For the second phase of the survey, the energy suppliers are contacted and billing data are collected for the survey year and four months before and after the survey year in order to cover two full winters. Suppliers for electricity, natural gas, fuel oil, propane and kerosene submit both the quantity of fuel delivered and the cost of the fuel. Once the consumption data are finalized a regression model is used to estimate the energy consumed for major end-uses (e.g., heating, cooling, and appliances).

Household interviews for the 2009 RECS were conducted between February 2010 and August 2010. This interview period was advantageous, as it allowed respondents to answer questions about all of calendar year 2009. The disadvantage was that any respondents who did not live in the sampled housing unit in 2009 were ineligible. The 2009 survey was the largest RECS ever conducted. In 2005, there were 4,382 completed interviews; in 2009, that total was nearly tripled to 12,083 completed interviews. The larger sample size allowed for the release of data for 16 individual states as opposed to just the 4 largest states released for previous RECS. The larger sample size also permitted the release of data for more specific categories and provided a much greater level of precision for all estimates.

The hot-deck method was used to impute missing data by using donor values from cases with similar characteristics. The imputed data were edited to make sure that the imputation did not create any new inconsistencies. The final data were also weighted so that the results were equivalent to the U.S. Census Bureau estimate of 113.6 million occupied housing units.

After the completion of the household interviews, the electric, natural gas, fuel oil, propane, and kerosene suppliers were contacted for each household. Nearly 18,000 supplier records were received for a response rate of 90%. The supplier data were annualized and consumption and expenditures data were released in Spring 2012.

### Household End-Use Consumption Trends – An Overview

The total amount of energy consumed in U.S. homes, known as site energy consumption, is not that much different now than it was in the early 1990s, holding steady between 10 and 11 quadrillion Btu over the last 20 years. But efficiency programs, Federal standards, population shifts, and evolving standards of living are contributing significantly to how that energy is being consumed in American homes. These factors are competing and offsetting one another, shifting consumption from those end uses most affected by weather to those with little or no relationship to the conditions outside (Figure 1).

RECS estimates of end-use consumption in 1993 reflect a time before many energy efficiency standards and programs were implemented, and a period with less energy consuming devices. In 1993, space heating accounted for 53% of consumption in U.S. homes. Air conditioning, which was present in about 66% of homes, was 5% of consumption. The remaining

end uses, loosely called "non-weather-related end uses," comprised 42%. These non-weatherrelated end uses included items present in nearly every home now and then, such as water heaters and refrigerators, as well as devices that were less ubiquitous, like computers. When taken together, all household end uses totaled nearly 103.6 million Btu of site energy consumption per home in 1993.



By 2009, total consumption in homes was virtually unchanged (10.01 quads versus 10.18 quads), but the shares of major end uses and average consumption were noticeably different. Space heating fell from 53% of consumption to 41%, and non-weather-related end uses climbed from 42% to 53%. The average consumption per home declined to less than 90 million Btu, a 17% decrease. Although these changes can be partly explained by a population shift to areas of the country where heating is less intense, device efficiencies and building standards are primary drivers. In all areas of the country, we now require less energy per square foot to heat a home, need fewer kilowatt-hours to keep food cold, and spend less money to wash a load of laundry. But homes are not the same as they were in 1993, and households have different expectations about communication, comfort, and convenience today. This paper will explore these changing characteristics and their impact on the energy profile of U.S. homes.

Total space heating consumption in U.S. homes has declined 21% from 1993, even as nearly 17 million occupied homes have been added to the stock of the country's housing units. As Figure 2 shows, this has led to a decrease in average space heating consumption in every region, with those in the coldest areas of the country benefiting the most. In total, space heating, which used to dominate consumption, now accounts for little more than 40% of energy used in homes.

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million Btu per household using the end use



As with heating equipment, similar efficiency gains have been associated with air conditioning. A new central air conditioning unit purchased today is at least 30% more efficient than when Federal standards began to take effect in the early 1990s. But unlike space heating, where per household usage has fallen dramatically over the past few decades, the RECS data do not indicate a downward trend in average air conditioning usage. In the South region, average air conditioning consumption was nearly identical in 1993 and 2009, two years with similar summer weather. Several factors could explain this trend; a higher percentage of homes with a central air conditioning system (which correlate with higher consumption than homes with window/wall units), an increase in home size, or household behavior influenced by changes in acceptable levels of comfort.



Figure 3. Per household AC consumption holds steady in the South as total AC

# Changing features of home life are driving increase in non-weather-related end uses

As weather-related end uses have become a smaller share of residential consumption, non-weather related end uses have increased in their variety and share. In 1993, households averaged 24.8 million Btu for appliances, electronics, and lighting, which amounted to just 24% of consumption. Now, homes consume more than 31 million Btu or 35% of their total home consumption for appliances, electronics, and lighting.





Many of the devices within this major category of end uses are subject to Federal efficiency standards or voluntary programs like Energy Star, but the number of homes now with these devices, and the accumulation of multiple devices per home has offset the gains realized from the programs. For example, a new refrigerator today will consume about 50% less energy than a new model in 1993. But average refrigeration consumption per household has been slow to decrease, as many more homes now have two or more refrigerators (see Figure 4). Other devices, such as computers, that were just starting to enter homes are now commonplace as shown in Figure 5. And devices such as digital video recorders (DVRs) that are now quite common were not in existence 20 years ago. RECS 2005 did not even include a question about DVR use, but by 2009, 43% of all homes had at least one DVR. Finally the proliferation of handheld devices such as cell phones has led to a dramatic increase in the number of end uses that require charging.



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# Figure 5. Number of electronic devices by household million households

Unlike heating and cooling, there is very little regional variation across the country. There are only minor differences in per household consumption for non-weather-related end uses across states. However, as shown in Figure 6, the percentage consumed for non-weather-related end uses is higher in the South and West due to lower space heating consumption.



# Americans living in newer homes consume more energy

Household expectations about communication, entertainment, and convenience are not the only aspects of American life having profound impacts on energy consumption in homes. As the number of TVs and appliances has risen over the past 20 years, so too has the average home size. U.S. homes built between 2000 and 2009 are on average about 30% larger than homes built prior to 2000. New homes are larger than older ones across all regions and housing unit types.

Despite more energy-efficient features, Americans living in newer homes consume about 2% more energy on average than those in older ones.





Homes built in the 2000s accounted for about 14% of all occupied housing units in 2009 and 14% of the energy consumed. These new homes consumed 21% less energy for space heating than older homes, which is mainly because of increased efficiency in the form of heating equipment and better building shells built to more demanding energy codes. Additionally, new homes were more likely to include energy-efficient features such as double- or triple-pane glass windows, which were found in 80% of new homes, but only 55% of older homes. Geography is also a factor in the lower space heating demand of new homes and thus the impact on total per household consumption. About 53% of newer homes are in the more temperate South, compared with only 35% of older homes.

The increase in energy used for air conditioning reflects this population migration, in addition to higher saturation of central air conditioning and increased square footage in all regions. New homes have about 50% more cooled square footage on average than older homes. Similar to space heating, increased energy use for air conditioning was likely moderated by increases in the efficiency of cooling equipment and improved building shells.

The share of energy consumed for non-weather related end uses is higher in homes built in the 2000s, which include more appliances and electronics than older homes. RECS data show that newer homes were more likely than older homes to have dishwashers, clothes washers, clothes dryers, and two or more refrigerators. Newer homes, with their larger square footage, have more computers, TVs, and TV peripherals such as digital video recorders (DVRs) and video game systems. In total, newer homes consumed about 18% more energy on average in 2009 for appliance, electronics, and lighting than older homes.

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Figure 9. Households with selected appliances and electronics, 2009 percent of households

The use of electricity in the residential sector has been growing for many decades, while consumption of natural gas has stayed flat and consumption of other fuels has declined. This trend is reflected in newer homes, which are more reliant on electricity to meet their home energy needs than older homes. In homes built in the 2000s, half of all energy is consumed by appliances, electronics, lighting, and air conditioning, end uses principally powered by electricity. However, characteristics of the new and old housing stock help explain these differences in fuel usage. Compared to older homes, new homes are more likely to be single-family dwellings, located in the South, and found in rural areas; all of these characteristics are associated with increased reliance on electricity for home energy use.

#### **2009 RECS data allows detailed comparisons between states**

The larger sample size for the 2009 RECS allowed for the release of data and comparisons to be made for 16 individual states. For example, the average energy consumption for an Illinois household was 129 million Btu, more than twice as much as the 62 million Btu for the average

California household. This difference in consumption is mainly due to the higher demand for space heating in Illinois. Additionally, the 2009 RECS allows for comparisons of household characteristics that may be useful to program evaluators. For example:

- Almost half (48 percent) of households in Wisconsin use separate freezers, but only 14 • percent of households in Massachusetts do the same.
- Twelve percent of households in Tennessee use front-loading clothes washers in their • home, half as many households as in neighboring Virginia (24 percent).



Figure 10. Average home energy consumption for selected states, 2009 million Btu per housing unit

# **Conclusion and Recommendations**

Although the total amount of energy consumed in U.S. homes has not changed much in the past three decades, where and how the energy is consumed has changed remarkably. In the 1980s, the majority of energy consumption was for space heating. In all regions (even the warmer South and West), more energy was consumed for the weather-related end uses of space heating and air conditioning than for all other end uses combined. Since then, dramatic changes in technology and standards have led to reductions in the amount of energy used for space heating. Similar improvements in efficiency for air conditioning have led to only slight increases in the amount of energy consumed for air conditioning even with a large increase in the number of homes in warmer climates as well as an increase in the number of both new and existing homes with central air conditioning equipment. Despite improvements in equipment efficiency, total consumption has not declined.

Total household energy consumption has remained constant due to widespread adoption of numerous energy-consuming devices, which has occurred in three main ways. First, homes now have more devices, and in the case of refrigerators, an increasing share have multiple

devices. Second, devices that were only entering the market 30 years ago, like computers, are now in most homes. Finally, a variety of products that did not even exist are now widespread, including Digital Video Recorders, cell phone and other portable device chargers, and laptops and tablets.

In order to create an effective energy efficiency program, it is no longer possible to target just one or two large end uses and expect significant savings. Those efficiency gains have already been realized. An effective program now needs to either target a wide range of products, or else seek savings in another way, such as through behavior change. The ongoing shift in home energy consumption makes designing a program to realize significant energy savings much more challenging. The RECS data also show that there are substantial regional differences in how energy is used in the household. Program designers and implementers can use the latest RECS data to benchmark the residential energy consumption of their state against other states in order to create a more specific program. This should be easier with the expanded state data available in the 2009 RECS.

## References

U.S. Energy Information Administration, Residential Energy Consumption Survey, <u>http://www.eia.gov/consumption/residential/</u>.