

# Changes in Residential Energy Consumption: Results from the 2009 RECS

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## ABSTRACT

This paper discusses the most recent results from the 2009 Residential Energy Consumption Survey (RECS), a quadrennial sample survey of home energy characteristics, behavior, consumption, expenditures and end uses of U.S. households. The survey collected these data during a computer-assisted interview of the householder and collected the corresponding billing and consumption data from each household's energy suppliers. The 2009 version surveyed more than 12,000 households--nearly three times more than any previous survey cycle. The larger sample provided greater accuracy and data quality and permits results for 16 states (an increase from the 4 states of previous RECS). Based on the final 2009 results, this paper provides insights using new questions on televisions and peripherals, computers, and plug loads, and provides new details on appliance ages, on-site renewable generation, and household capacity to charge an electric car. The paper also includes a brief evaluation of questions added to track weatherization and other forms of energy assistance for new appliance purchases and home improvements. Because the basic survey structure is unchanged over thirty years, an impressive array of trend data is also available for analysis.

This survey is unique both for its national sample and also for the broad depth of characteristics that are asked of each housing unit. Survey data provide new information on emerging issues such as fuel switching, the growth of home electronics, the saturation of major appliances, and the age and size of housing units. The paper narrows the survey results to only discuss topics most pertinent to energy efficiency. Potential topics include the trends for heating and water heating fuels, the rise of tankless water heaters, the change in the average age of home appliances and the relation of those to changing energy standards, and the rapid growth of various home electronics and the impact of those on overall household energy consumption.

These findings are invaluable to any energy efficiency program sponsor looking to determine where the best potential savings are in their program and geographic area since the first key to understanding energy consumption and determining alternatives to reduce consumption is to understand where the consumption actually occurs. The characteristics data from this survey show a broad picture of this consumption. This paper also introduces a new audience to the survey results, updates readers who are already aware of the survey with new results and recent changes to the survey, and shows trends in household energy characteristics.

## Introduction and Background

The Residential Energy Consumption Survey (RECS) is a quadrennial survey administered by the 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. 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).

## **2009 RECS Scope**

The 2009 characteristics data collection has been completed and the first results were released in March, 2011. The supplier data are currently being collected and final consumption and expenditure data will not be available until 2012. The following sections describe major changes in the 2009 RECS and discuss some of the findings from the characteristics data.

**Questionnaire Changes.** While most RECS questions remain consistent with each survey cycle to permit longitudinal comparisons, survey questions are added or updated to accurately assess new technologies and changes in the residential sector. A major goal of the RECS is to capture characteristics of the most energy-consuming products. In order for questions about new products to be included, questions must be removed to prevent the household portion of the RECS from exceeding its current length. For example, in 2009, questions on waterbed heaters, toilets, toasters, and laser-jet printers were all removed from the questionnaire.

For the 2009 questionnaire, a greater emphasis was placed on the appliances and electronics category. This category has increased its share of total energy use over the last several survey cycles. In addition, the number and different types of appliances and electronics available to consumers have been increasing. More detailed questions were asked about televisions, including the specific screen size and type (standard tube, LCD, projection, LED, plasma) and questions were added for second and third televisions. For the three most-used televisions, questions were added for new peripherals such as Digital Video Recorders (DVRs). The categories for the hours per day that each television was used were also changed to more accurately estimate actual usage.

Along with the increase in the use of major electronic devices in recent years, households have been acquiring small personal electronics that need to be charged, such as cell phones, cameras, and portable music players. Although the energy consumed by each of these devices is low, the aggregate energy use can be significant. To better assess usage, respondents were asked the number of each device as well as its charging behavior—in other words, were the devices left plugged in all the time, or were the chargers plugged in when the devices were not being charged.

An entire set of questions was added for weatherization programs and other forms of energy assistance. With the growth of these programs there was much stakeholder interest in adding questions to capture data in this area. To decrease the burden on respondents, these questions were only asked for

newer appliances and improvements. For each appliance, respondents were asked if they had replaced the appliance in the past four years, and if the respondent had lived in the housing unit during that period, they were asked to confirm that they had replaced the appliance. If they had they were asked if they had received assistance and, if so, what type of assistance. These questions were asked for refrigerators, freezers, dishwashers, clothes washers, water heater blankets, windows, insulation, caulking and weather stripping, and compact fluorescent light bulbs. For space heating equipment and air conditioning it was asked if the respondent had received any assistance for both new equipment and for maintenance. It was also asked if the respondent had received a home energy audit and if they received assistance for the audit.

A question was added about on-site electricity generation systems such as photovoltaic (PV) systems and small wind turbines. Although the prevalence of these systems was expected to be very small, it was important to add these questions to establish a baseline for what may be a rapidly-growing technology. In addition, the presence of these systems can affect the accuracy of the end-use consumption regression model. In the past, RECS has sometimes waited until a product was well-established in the market before adding questions about it. For example, DVRs were not added until the 2009 survey and DVD players were not added until the 2001 RECS.

Residential transportation consumption information had not been collected directly by EIA since 1994 and no EIA household transportation data had been released at all since 2001. In order to provide basic residential transportation data and explore the potential to reinstitute a more complete transportation survey, a section of questions was added to the 2009 RECS to capture information on household vehicles. Respondents were asked about the number and type of vehicles owned by each household and the number of miles that each vehicle had been driven in the past year. The respondent was asked if any of the vehicles were hybrids and whether any vehicle was parked within 20 feet of an electric outlet. That last question was added to explore the potential market for plug-in hybrids or electric vehicles.

In addition to adding new question categories, several changes were made to response categories. For example, in previous versions of RECS, the age of equipment questions included the category of 10-19 years old. Since many standards and voluntary efficiency levels were enacted during that period, there is a significant difference in the energy use of a 1990 appliance as compared to a 1999 appliance. So for the 2009 RECS, that category was split into two categories, 10-14 years old and 15-19 years old, to better estimate the age distribution of the existing stock of equipment. Since the 2005 RECS refrigerators that have three or even four doors have become more common, so a response category for three or more doors was added.

## **Methodology**

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 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.

Several levels of editing were included in the data processing. The RECS questionnaire is programmed in Blaise, a software package specifically designed for computer-assisted personal interviews. The first level or Type I edits were implemented during the interview with the Blaise software with a series of checks and prompts. Some of these checks were “hard edits” where the survey

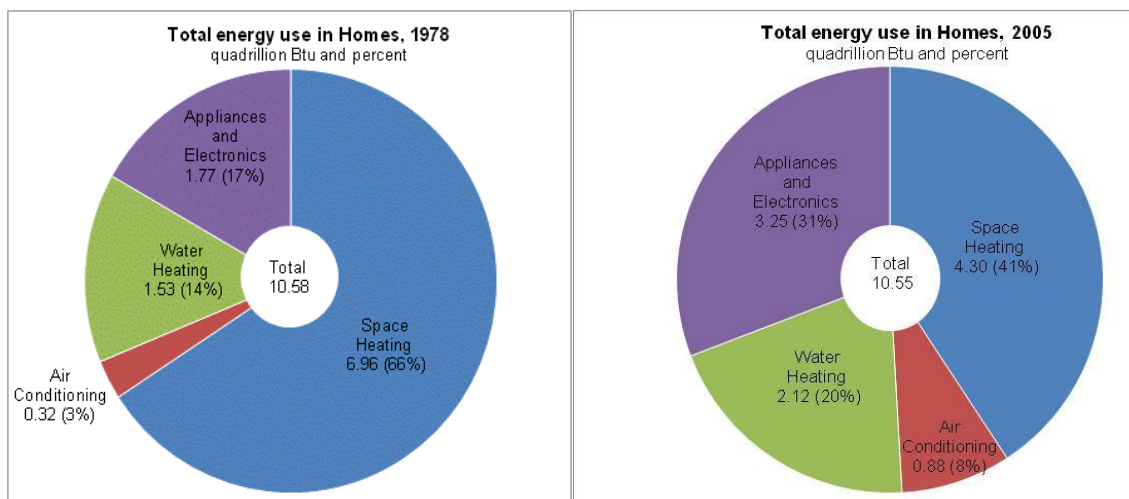
could not continue if the answer was out of an acceptable range; i.e., the respondent's answer was considered "impossible." Others checks were "soft edits" where the interviewer could suppress the prompt, accept the answer and continue with the interview. For example if a respondent said they had 15 bedrooms, Blaise would prompt them by asking if they were sure they had 15 bedrooms. That number is unlikely, but possible, so that answer could be accepted.

Other edits were implemented after the initial data processing. The second level or Type II edits were a series of flags where the RECS data collection contractor would recontact respondents to resolve missing responses to key questions. Type II edits also included reviewing write-in responses and interviewer comments. The third level or Type III edits were checks for interviews with very high levels of missing data. For the 2009 survey, the survey contractor submitted a list of 110 suspect cases to EIA for further review. Ultimately, only 3 of the cases were dropped from the survey results. The final level of editing, or Type IV edits, was conducted by EIA. A SAS program was run on the survey results to check for logical inconsistencies in answers or unusual situations. A case was flagged if it failed any one of 183 edits and flagged cases were manually reviewed by EIA staff. More than 8,800 out of the 12,083 final cases or 73% were flagged for editing.

Once all the cases were edited, the hot-deck method was used to impute missing data 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 was also weighted so that the results were equivalent to the U.S. Census Bureau estimate of 113.6 million occupied housing units.

## Results

The results of the 2009 RECS show that the number of individual end-uses continues to increase in U.S. homes. Initial federal mandatory efficiency standards were enacted between 1988 and 1994 for all major appliances, but the total amount of energy consumed by household appliances and electronics nearly doubled between 1978 and 2005. Figure 1 shows the change in the share of household energy consumption from 1978 to 2005 by end-use category.



**Figure 1.** Total Energy Use in Homes, 1978 and 2005

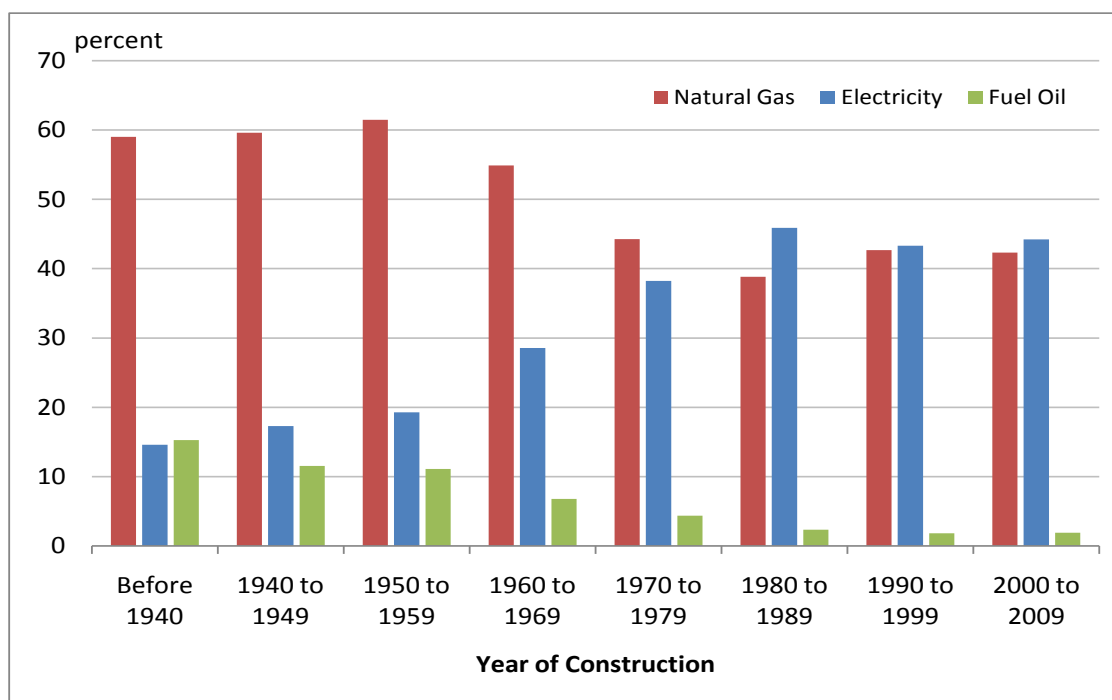
The new characteristics data show that potential gains in energy efficiency for individual types of appliances have been offset by other factors including:

- The number of U.S. households grew by 34.5 million from 1978 to 2009
- Improved living standards resulted in more households buying and using major appliances
- The share of households that use central air conditioning nearly tripled, from 23 percent in 1978 to 61% in 2009
- The saturation (percent of households with an appliance) of clothes washers increased from 74 percent to 82 percent
- The saturation of dishwashers increased from 35 percent to 59 percent

**Space Heating.** Even with dramatic improvements in efficiency, space heating is still the largest residential energy end-use. Federal standards, voluntary programs such as ENERGY STAR, and a newer housing stock, in addition to other housing envelope improvements such as better insulation and improved windows, have all resulted in a marked drop in the share of space heating end-use. In 1978, 66 percent of residential energy use was for space heating. By 2005, that percentage dropped to 41 percent.

In 2009, nearly all homes in the U.S. had heating equipment—just 1.2 million of the 113.6 million households did not (1.1%). In addition, a small number of homes with the equipment had but did not use heating equipment (2.4 million or 2.1%). Overall, 110.1 million households (96.9%) had and used their heating equipment during 2009. Natural gas was used as the main space heating equipment in 56 million households (49%) while electricity was used as the main space heating equipment in 38 million households (34%). For comparison, in 1981, natural gas was the main heating fuel in 56% of households and electricity was the main space heating fuel in 17% of households. This increase in electric space heating is mainly due to the population shift from heating-intensive regions to warmer climates in the south and west where heating is not as important. Additionally, once secondary heating is included, a slightly larger number of households (58 million) use electricity for any space heating as opposed to natural gas (57.2 million). This is due to the use of electric space heating as a secondary heating source as a result of its flexibility and inexpensive purchase price. 85% of all households that use secondary heating use portable electric space heaters.

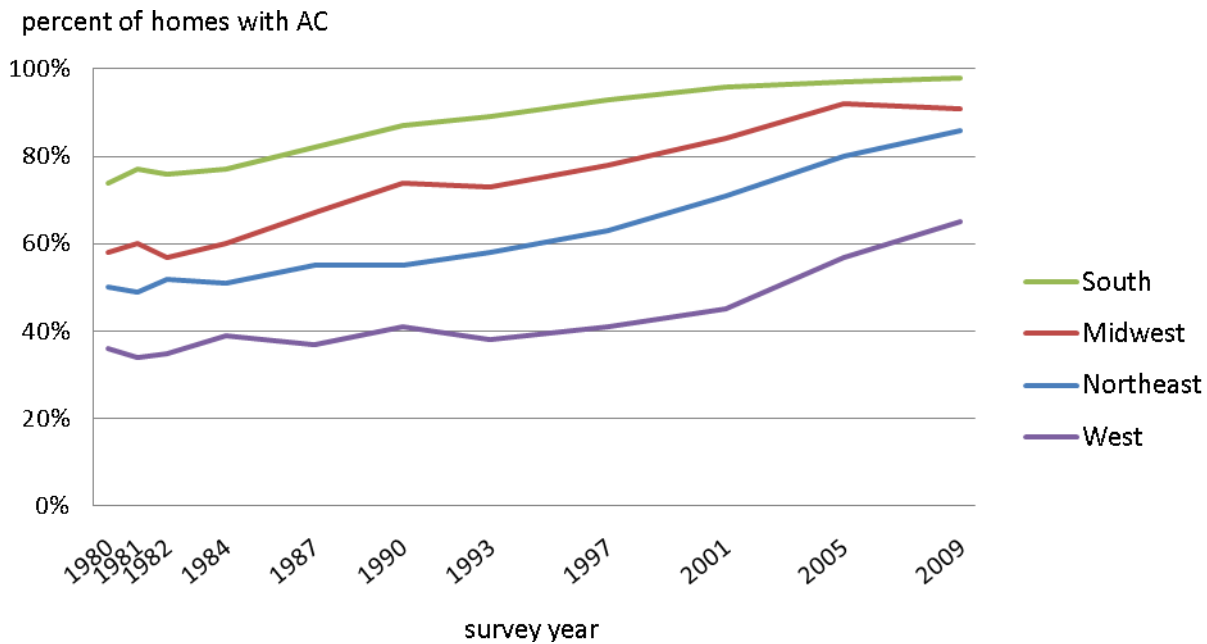
Space heating fuel also varies greatly by year of construction. For houses built before 1960, 60% use natural gas as the main space heating fuel, 17% use electricity, and 13% use fuel oil. For houses built after 1970, 43% use electricity as the main space heating fuel, 42% use natural gas, and 3% use fuel oil. This shift in main space heating fuel from natural gas to electricity is a combination of the shift in main heating equipment and the shift in new construction to warmer climates. Figure 2 shows the main space heating fuel by year of construction.



**Figure 2.** Main Space Heating Fuel by Year of Home Construction.

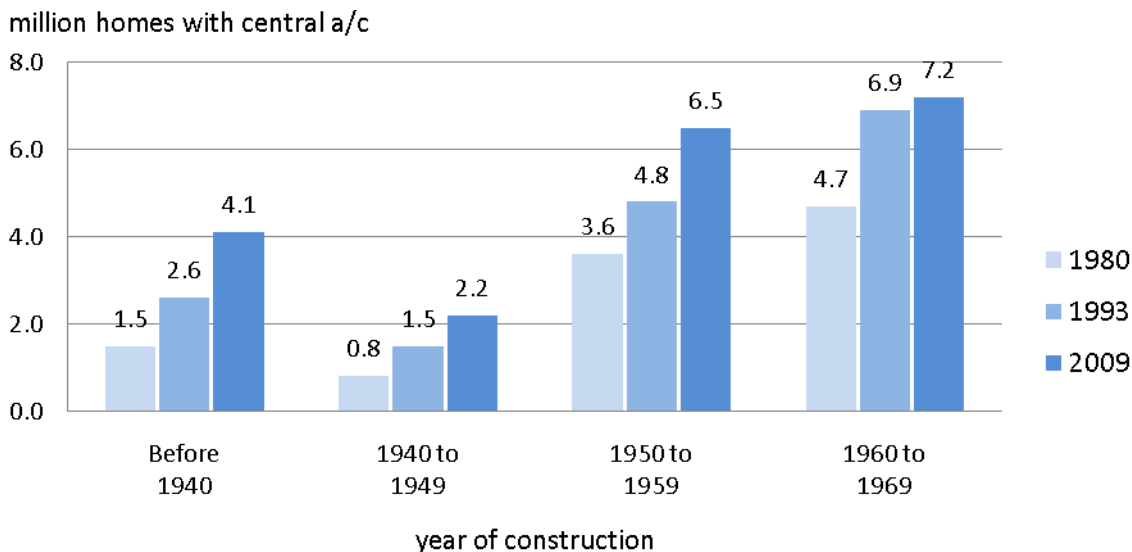
**Air Conditioning.** Air conditioning is also much more efficient than it was 30 years ago, but the share of total energy consumed for air conditioning has grown as the saturation of air conditioning equipment has increased. Central air conditioning is now included in most new houses, and a decline in price has allowed many homeowners to add central air conditioning to older housing stock. Additionally, most growth in the population and the housing stock has been in the south and west, areas where air conditioning is more widely used. The 2009 RECS shows that 87% of households now use air conditioning. Whether the per household air conditioning usage is just as high will be determined when the consumption data is available early next year. It is possible that since most households now have air conditioning, households in regions where air conditioning is not as necessary may choose to use it less frequently.

The rise in air conditioning is not just due to new home construction in the south and west. Figure 3 shows that air conditioning is increasing in all regions and the temperate Marine region along the west coast is the only densely populated area of the U.S. where the majority of homes do not have air conditioning.



**Figure 3.** Percent of Homes with Air Conditioning by Census Region.

The rise in central air conditioning is also not just due to new construction. Figure 4 shows that the oldest homes are being retrofitted with central air conditioning as the number of homes built in each decade with central air conditioning is increasing.



**Figure 4.** Rise of Central Air Conditioning by Year of Home Construction.

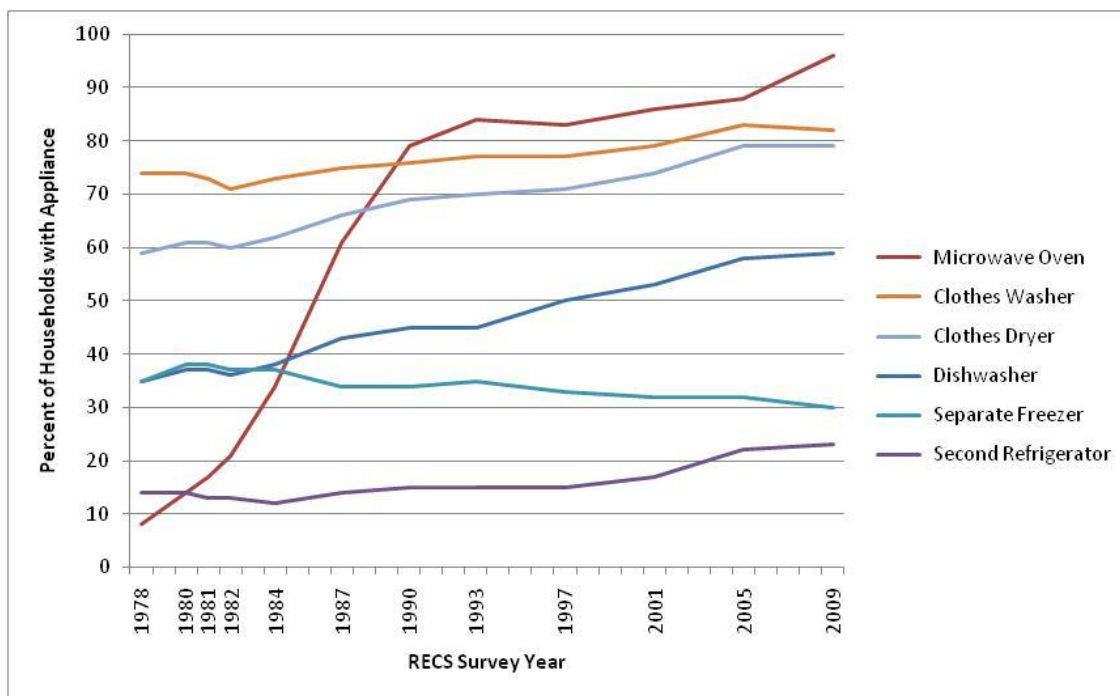
These older homes also have some of the most efficient systems. Standards enacted since the early 1990s mean that newer equipment cools the same amount of space and uses less energy than models that are over 20 years old. Homes built in the 1970's and 1980's, in fact, have the highest percentage of AC equipment that is 20 or more years old, which are the least efficient systems. Many of

these homes are likely being cooled with the original system installed when the homes were constructed.

**Water Heating.** Federal standards and efficiency programs have been less aggressive for water heaters than for other products. The technology of water heaters is mature and until the introduction of tankless and heat pump water heaters, it was very difficult to significantly improve efficiency levels. As a result, the total energy consumed by water heaters has grown with the increase in households.

Questions were added in 2009 for the first time about tankless or instantaneous water heaters. The current market share of tankless water heaters is very low, less than 3%, but it is expected that these products may increase so this provides a baseline for future comparison. The share of natural gas water heaters continued to decrease, dropping from 53% in 2005 to 51% in 2009. Electric water heaters replaced gas water heaters as the share of electric water heaters increased from 39% in 2005 to 41% in 2009.

**Appliances and Electronics.** As noted above, the share of energy use for the appliances and electronics category more than doubled from 17 percent in 1978 to 41 percent in 2005. That growth occurred during a time of tremendous advances in the efficiency of most major household appliances. According to the Association of Home Appliance Manufacturers, the average refrigerator sold in 1980 used 1278 kWh/year, but by 2007 the average was down to 498 kWh/year. That efficiency gain occurred while the average size of a refrigerator increased from 19.6 cubic feet to 21.9 cubic feet. The average clothes washer used 2.59 kWh/cycle in 1981 but by 2008, the average washer used 0.82 kWh/cycle. However, these efficiency gains have been offset by the increasing number of appliances and electronics in use in the average home. More households now have clothes washers and dishwashers than did 30 years ago and the ownership rate of second refrigerators is much higher. In addition, new consumer electronics devices continue to proliferate. Data from the 2009 RECS show continuation of these trends. Figure 5 shows the growth of select household appliances.



**Figure 5.** Saturation of Select Household Appliances



The increase in appliance usage is not uniform across housing type or ownership status. Households in single-family detached housing units are much more likely to have appliances. Owner-occupied households are also more likely to have clothes washers, dishwashers, and second refrigerators as are households with a higher annual income. Newer homes also have more clothes washers, dishwashers, and second refrigerators. This difference is the greatest for dishwashers where 85% of homes built in the 2000s have a dishwasher whereas only 40% of homes built before 1940 use a dishwasher. Table 1 shows the differences in appliance ownership between renters and owners, single-family detached houses, housing age, and household income.

**Table 1.** Saturation Differences of Household Appliances by Select Characteristics

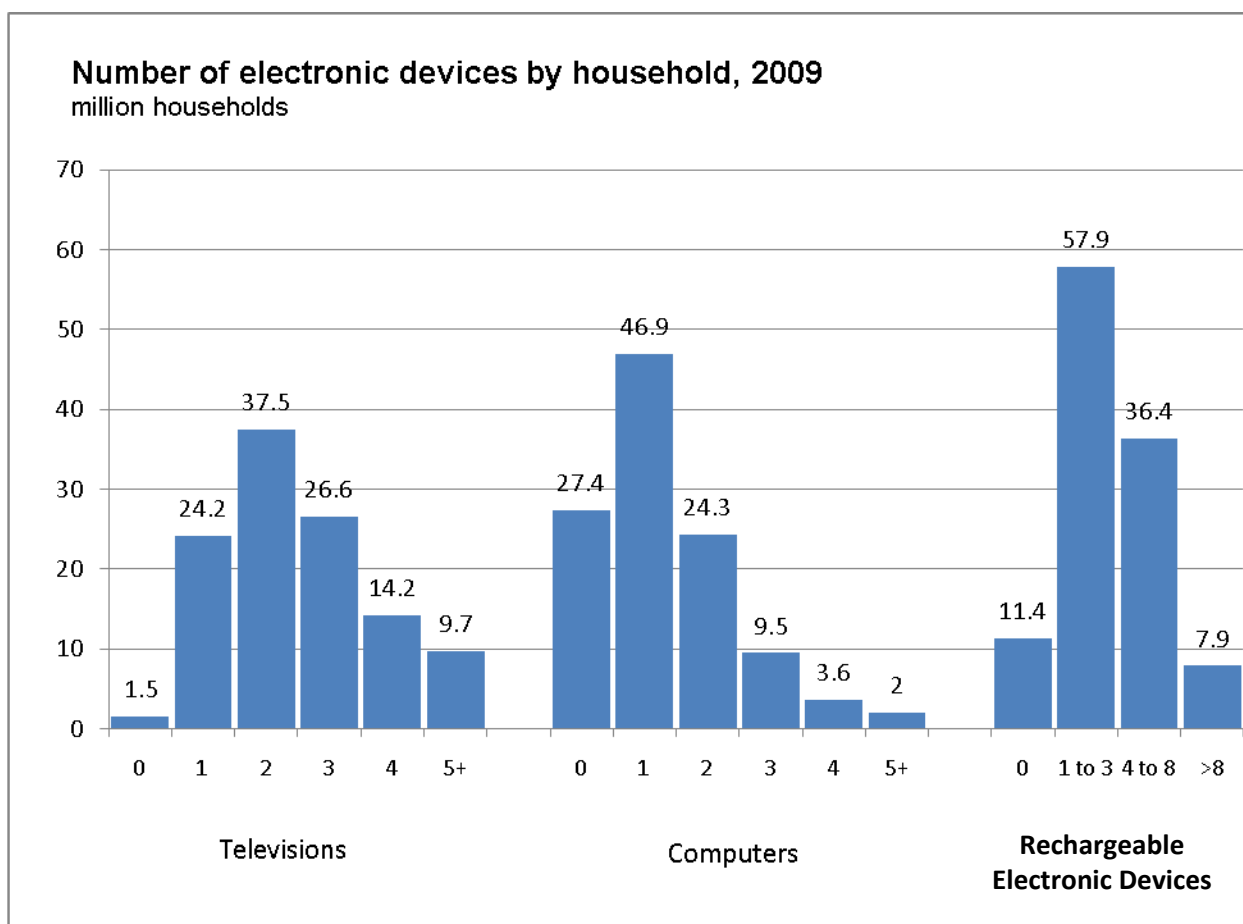
Appliance Type	2009 Saturation (percentage of households with the specific appliance)							
	Ownership		Housing Type		Age of Home		Household Income	
	Owner	Renter	Single Family	Apart-ments	Before 1940	2000s	Less \$20K	More than \$120K
Clothes Washers	98%	69%	98%	58%	87%	97%	77%	98%
Dishwashers	69%	39%	67%	44%	40%	85%	31%	90%
Second Refrigerators	31%	7%	31%	4%	18%	28%	9%	48%

Some other interesting statistics are available for appliances. In 2005, 17.1 percent of refrigerators were less than two years old. In 2009, that number fell to 12.3 percent. This aligns with industry data showing that refrigerator shipments dropped substantially in 2008 due to the drop-off in new home construction and the decrease in remodeling projects.

While the changes in home appliances are substantial, the changes in consumer electronics are even more dramatic. The average U.S. household uses many more consumer electronics than in previous years—in particular, personal computers, televisions and related devices. For example, in 1978, personal computers were expensive and not widely used by U.S. households. In 2009, 76 percent of U.S. homes had at least one computer, eight percentage points more than just four years prior, and 35 percent had multiple computers. In 1978, most households had only one television. In 2009, the average household had 2.5 televisions and over 45 percent of homes had at least one television with a screen size of 37 inches or larger. Screen size and average energy consumption per television have continued to increase over time. DVD players and Digital Video Recorders (DVRs), which were not available 15 years ago, are now widespread. As of 2009, 79 percent of homes had a DVD player, and 43 percent had a DVR. Nearly 40 percent of all households also had at least four rechargeable electronic devices, such as cell phones, plugged in and charging at home. Table 2 shows the saturation of select home electronic devices and Figure 6 shows the number of households with multiple electronic devices.

**Table 2.** Saturation of Select Home Electronic Devices

Electronic Device	Saturation (percentage of households with the specific device)	
	2005	2009
Personal Computer (includes laptops)	68%	76%
Laptop	25%	46%
VCR	81%	51%
DVD Player	80%	79%
DVR	N/A	43%
Video Game System	31%	36%



**Figure 6.** Number of Electronic Devices by Household, 2009

The cumulative effect on household energy consumption of more and varied consumer electronics has offset the energy efficiency gains in traditional, large appliances and heating and cooling systems.

**Miscellaneous Characteristics.** Due to the increasing emphasis on efficiency programs, several questions were added to the 2009 RECS to both measure the diffusion of energy efficiency programs

and also create a baseline for future studies. The main set of efficiency questions asked the respondent if they had performed an energy efficient measure and if so, if they had received any assistance for this measure. For example, if a respondent stated that they had an ENERGY STAR qualified refrigerator and the refrigerator was replaced by the current respondent, it was asked if they received a manufacturer or retailer rebate, a utility or energy supplier rebate, a tax credit, a subsidized loan, weatherization assistance, or no assistance.

As expected, none of these actions was widespread. 13.5% of households did receive assistance for at least one energy efficiency measure. The most common action where the respondent received assistance was heating equipment replacement or maintenance (3.2%) followed by CFLs (3.2%), windows (3.0%), clothes washers (2.5%), and refrigerators (2.4%). The largest single form of assistance was tax credits for windows at 2.1%. This is due to the large federal tax credits that were available for windows in every year since 2006 except for 2008.

Four percent of households stated that they received an energy audit on their home. However, only 0.8% received any assistance for this energy audit. The prevalence of onsite generation is very small with only 0.5% of households having any type of onsite generation. Three-quarters of the existing onsite generation is solar.

Less than 2% of all households have at least one hybrid vehicle. However, 44% of households currently park a car within 20 feet of an electrical outlet and nearly 60% of single-family households with cars park a car within 20 feet of an electrical outlet. This provides the size of the potential market for plug-in hybrids.

## **Conclusion**

The housing characteristics data from the 2009 RECS show several trends in home energy use. As major equipment such as heating, air conditioning, and major appliances have become more efficient, the share of home energy used by these products has decreased substantially. Unfortunately, the energy savings have been offset by additional products that are continuing to be added to homes. The saturation of major appliances such as clothes washers, dishwashers, and central air conditioning has increased over the past 30 years and new products such as computers and home electronics have been introduced. The number of televisions has increased dramatically and products that didn't even exist a few years ago such as DVRs and DVD players are now widespread. Additionally, more and more portable electronics such as music players and cell phones are now owned and charged in the average home. All of these factors combine to make any attempt to decrease or even maintain household energy consumption very challenging.

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