How Americans are Using Energy in Homes Today

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ABSTRACT

This paper will discuss the most recent results from a quadrennial study of energy characteristics, behavior, consumption, expenditures, and end uses on a national sample of U.S. homes. The 2009 study, three times larger than previous rounds, collected energy information from more than 12,000 homes and their energy suppliers. Characteristics data, released in early 2011, showed an increasing number of televisions, computers, and other electronic devices that add to household plug loads as well as the adoption of energy efficient appliances. The spring 2012 release of the consumption data provides the first standardized basis by which differences between homes can be attributed to housing structure, demographics, equipment and efficiency-related characteristics and behaviors. This paper will feature key findings, updates to the previous survey round, and discuss trends and forces driving them over the past 30 years. A closer examination at both the national and sub-national level (now 16 states and groups of remaining states) provides fresh insight on differences between states on energy consumption trends in the home. Consumption is available for all major fuels by specific end-use and the paper will focus on changes over the last two survey cycles. 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. The results identify opportunities remaining to affect efficiency goals in housing design, appliance standards and householder behavior and education.

Introduction and Background

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).

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 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.

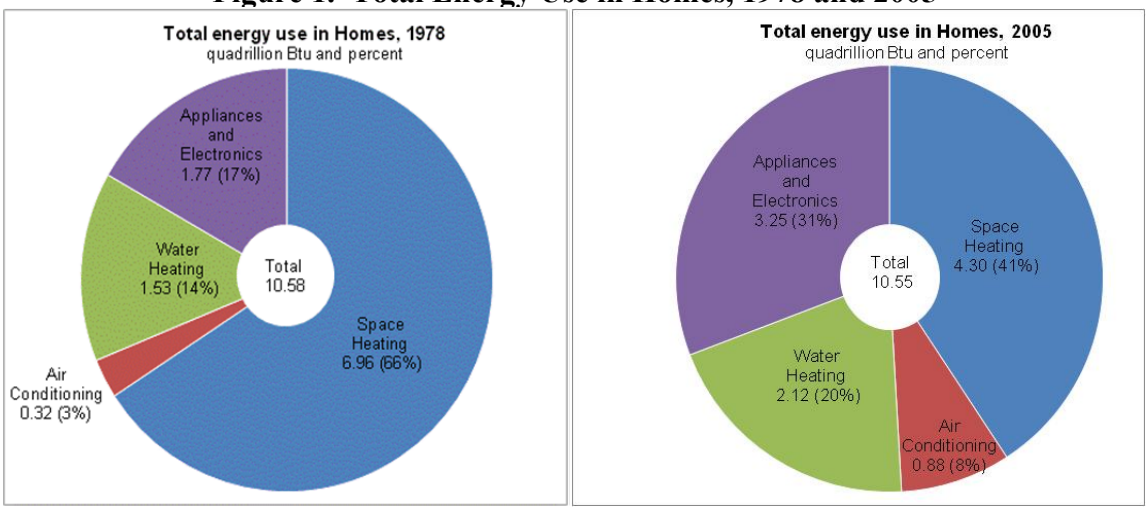
The hot-deck method was used to impute missing data by using donor values from cases with similar characteristics. The imputed data were edited to make sure that the imputation did not create any new inconsistencies. The final data was also weighted so that the results were equivalent to the U.S. Census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

Results

The results of the 2009 RECS show that the number of individual end-uses continues to increase in U.S. homes. 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



Space heating is still the largest residential energy end-use, however, federal standards, voluntary programs, and housing envelope improvements such as better insulation and improved windows, have all resulted in a marked drop in space heating end-use. In 1978, 7.0 quads of energy were used for residential space heating in the United States. By 2005, only 4.3 quads were used for residential space heating, a decrease of 39%. The magnitude of the overall decrease is even more impressive since in that time, 34.5 million additional homes were added to the stock of occupied primary housing units.

The changes are even more dramatic for specific regions. The total consumption for space heating in the Midwest region fell from 1.96 quads in 1997 to 1.45 quads in 2005 as new, efficient equipment replaced older inefficient equipment. This decrease occurred despite the addition of 1.5 million new housing units over that eight year period.

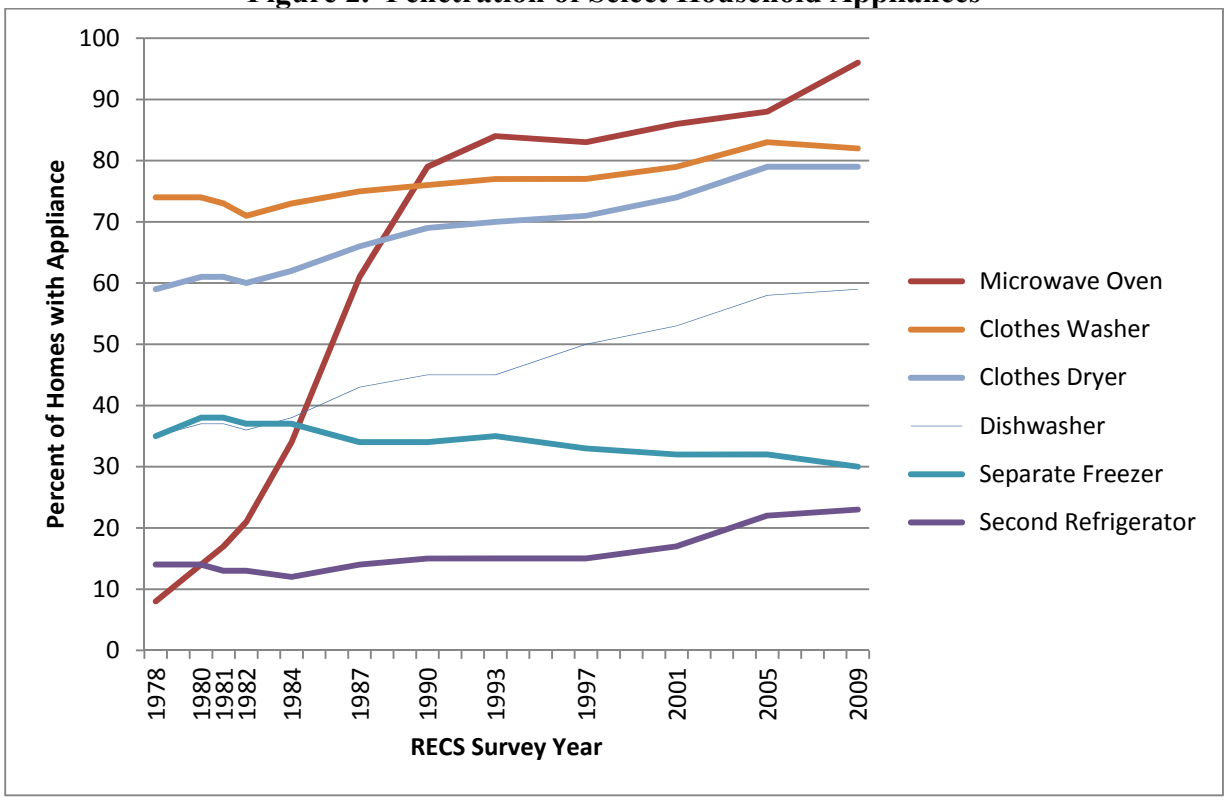
Much like space heating, improved standards and voluntary programs have resulted in significant efficiency improvements for appliances and electronics. However, improved efficiency has not led to a decrease in overall energy use. In addition to the growth in the number of homes, three competing trends demonstrate the change in home energy consumption over the past 30 years:

- Significant efficiency improvements have been made for all major appliances, but an increase in the total number of end-uses has offset the efficiency gains of the individual products.
- Air conditioning standards have increased the efficiency of individual units, but many more homes now have air conditioning and the cooled space per housing unit has also grown.
- Newer homes are built with more efficient features, but they are much larger than older homes.

Each of these factors demonstrates the challenges and barriers that efficiency programs face in trying to decrease or even maintain current energy consumption levels. The remainder of this paper will discuss these trends and show examples of each.

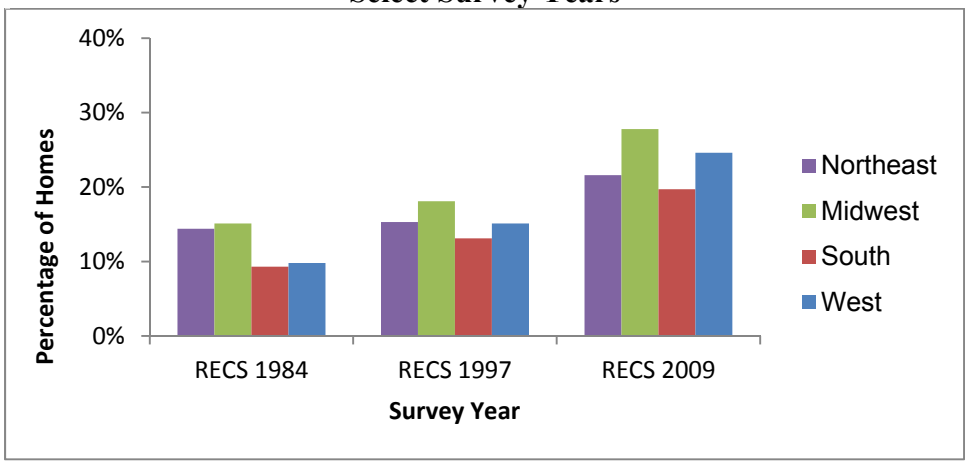
Appliances and Electronics. As noted above, the share of energy use for the appliances and electronics category nearly doubled from 17 percent in 1978 to 31 percent in 2005. That growth occurred during a time of tremendous advances in the efficiency of most major household appliances. According to the 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 homes now have clothes washers and dishwashers than did 30 years ago and the ownership rate of second refrigerators is much higher. Data from the 2005 RECS shows that refrigeration accounted for 0.51 quadrillion BTU (quads), an increase of 11% from the 0.46 quads used by refrigeration in 1993. In addition, new consumer electronics devices continue to proliferate. Data from the 2009 RECS show a continuation of these trends. Figure 2 shows the growth of select household appliances.

Figure 2. Penetration of Select Household Appliances



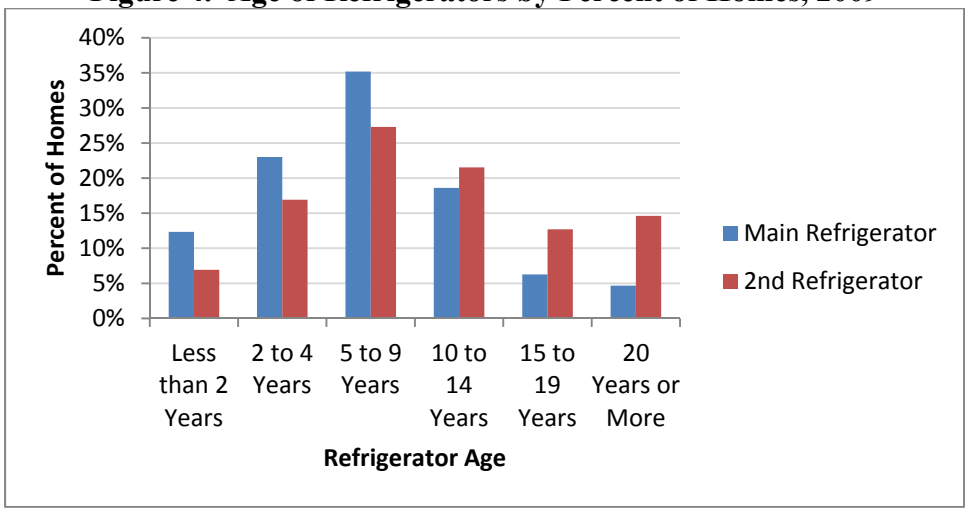
The specific example of second refrigerators shows that there has been a dramatic shift in the usage patterns of appliances. In 1978, only 14% of homes had more than one refrigerator. That number remained constant through 1997 when only 15% of homes had more than one refrigerator, but in the last twelve years, the percentage has increased rapidly and in 2009, 23% of homes had more than one refrigerator. This number also varies regionally with nearly 30% of homes in the Midwest having more than one refrigerator. Figure 3 shows the change over time by region.

Figure 3. Percentage of Homes by Region with Two or More Refrigerators, Select Survey Years



Additionally, the increase in second refrigerators has a disproportionate effect on energy consumption, since second refrigerators tend to be older and therefore less efficient than primary refrigerators. Figure 4 shows the distribution by age of both primary and secondary refrigerators.

Figure 4. Age of Refrigerators by Percent of Homes, 2009



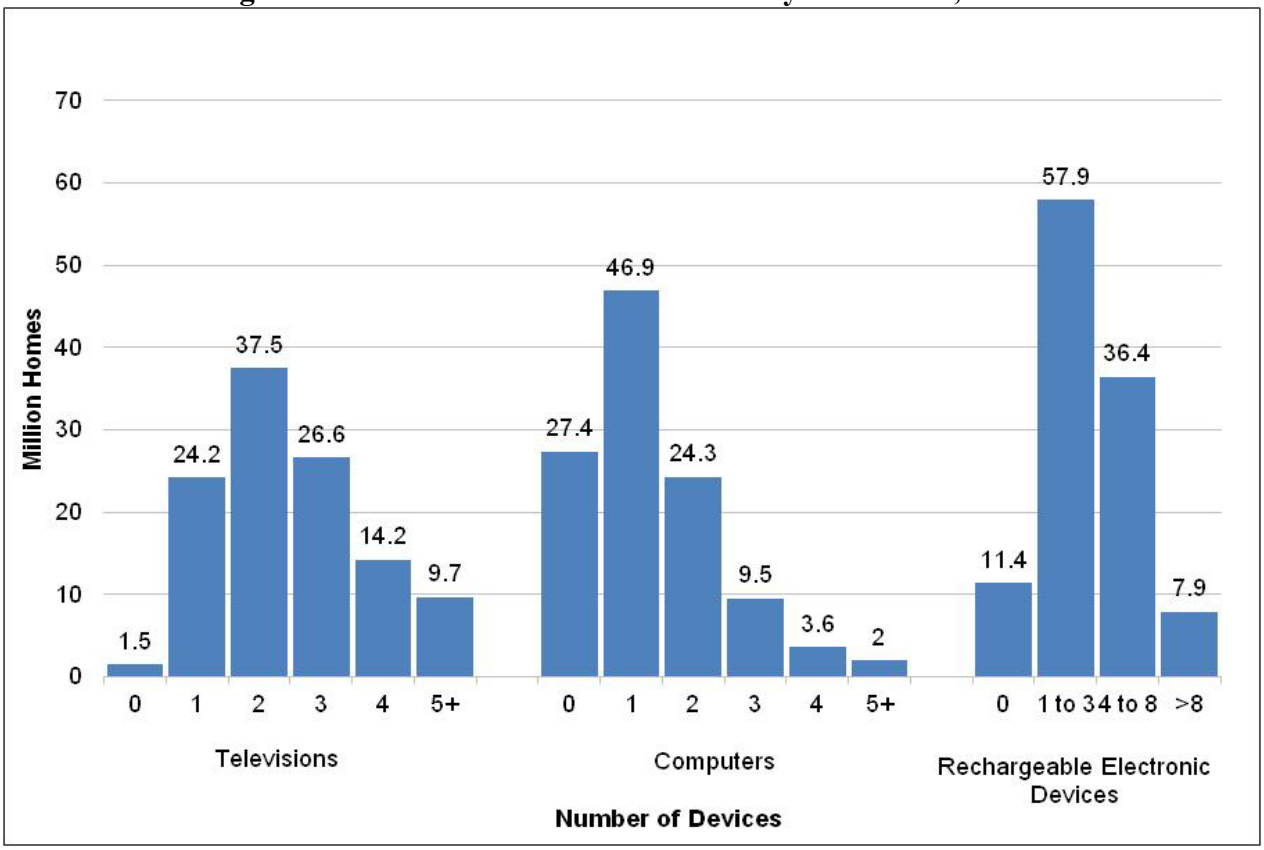
While the changes in home appliances are substantial, the changes in consumer electronics are even more dramatic. The average U.S. household uses many more consumer electronics than in previous years—in particular, personal computers, televisions and related devices. For example, in 1978, personal computers were expensive and not widely used by U.S. homes. 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 homes 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 homes also had at least four rechargeable electronic devices, such as cell phones, plugged in and charging at home. Table 1 shows the penetration of select home electronic devices and Figure 5 shows the number of homes with multiple electronic devices.

Table 1. Penetration of Select Home Electronic Devices

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

Figure 5. Number of Electronic Devices by Household, 2009

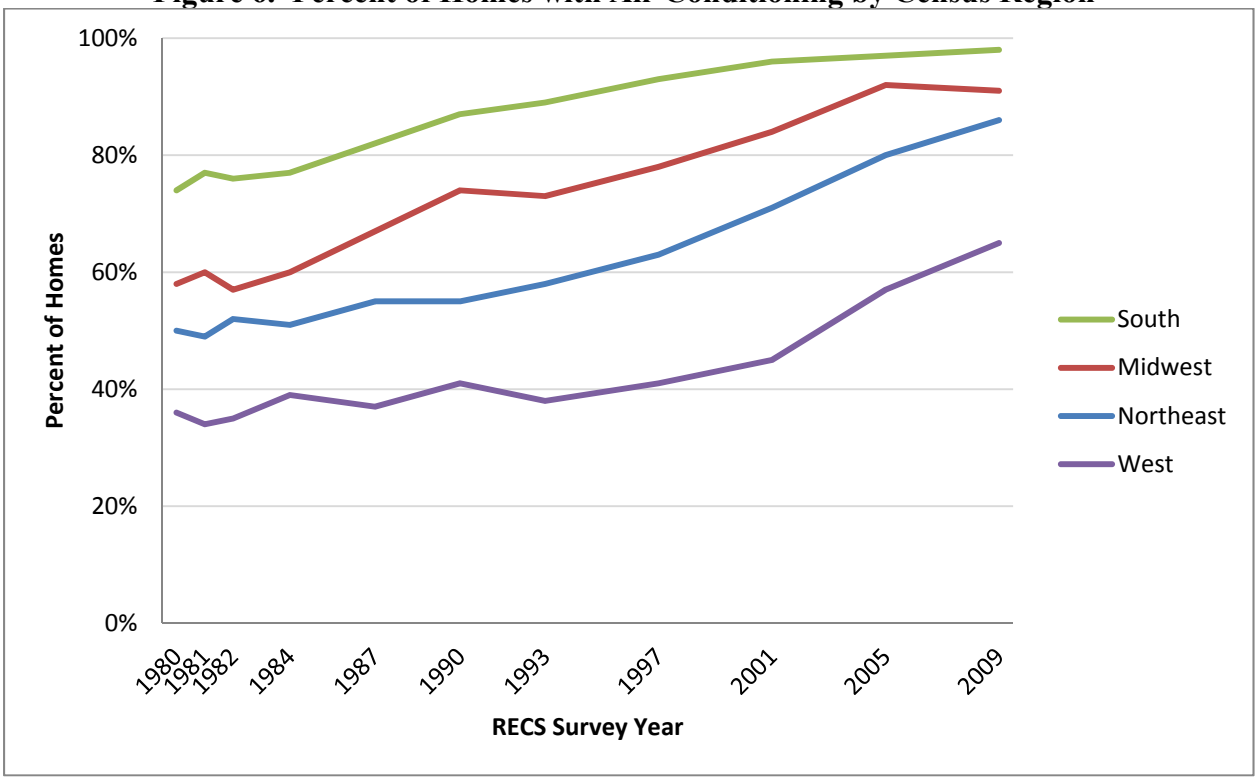


The cumulative effect on household energy consumption of more and varied consumer electronics has offset the energy efficiency gains in traditional, large appliances and heating and cooling systems.

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 penetration of air conditioning equipment has increased. Central air conditioning is now included in most new homes, 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 warmer climates of the south and west, areas where air conditioning is more widely used. The 2009 RECS shows that 87% of homes now use air conditioning.

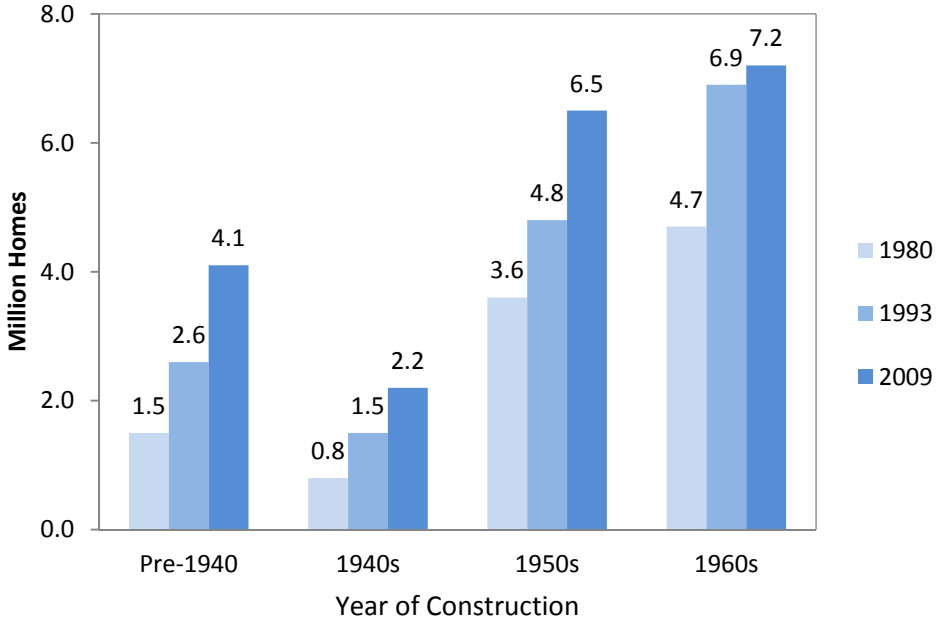
The rise in air conditioning is not just due to new home construction in the south and west. Figure 6 shows that air conditioning is increasing in all regions and the temperate Marine region along the west coast is the only densely populated area of the U.S. where the majority of homes do not have air conditioning.

Figure 6. Percent of Homes with Air Conditioning by Census Region



The rise in central air conditioning is also not just due to new construction. Figure 7 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.

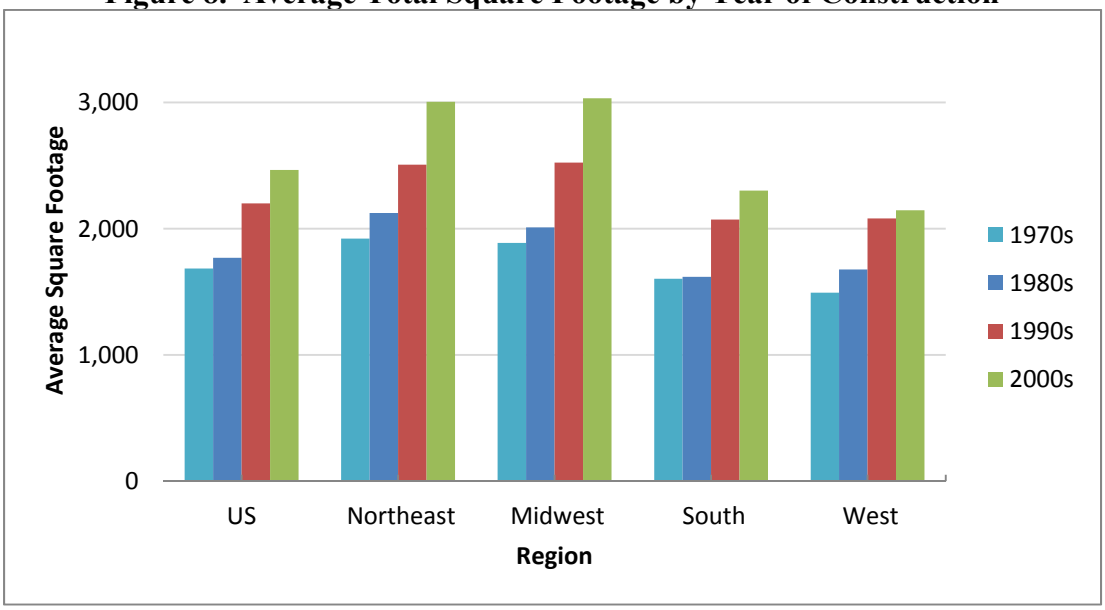
Figure 7. Rise of Central Air Conditioning by Year of Home Construction and RECS Survey Year



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.

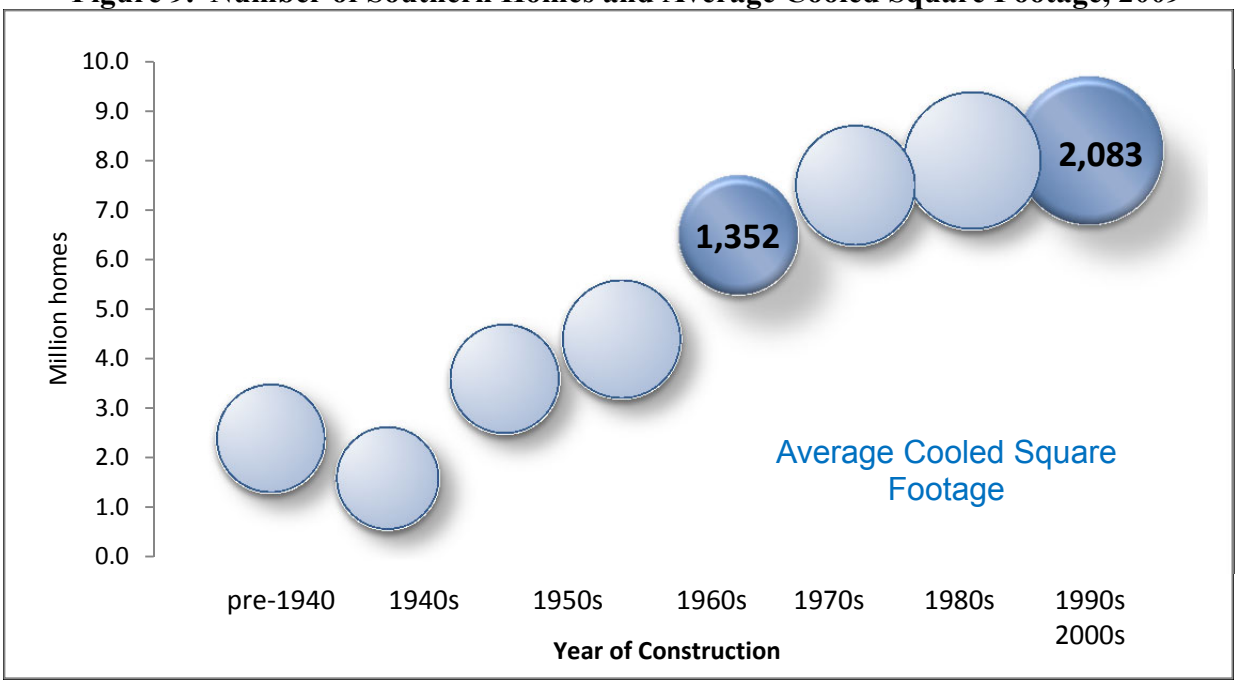
Another trend in home construction that counters the increased efficiency of air conditioning equipment is the increase in home size. As Figure 8 shows, homes built in the last two decades are much larger than homes built in the previous decades. With an increase in home size comes an accompanying increase in the area that needs to be cooled. As opposed to room air conditioning where it is common to just cool one or two rooms, with central air conditioning the entire unit is usually either on or off, and so the entire home is cooled.

Figure 8. Average Total Square Footage by Year of Construction



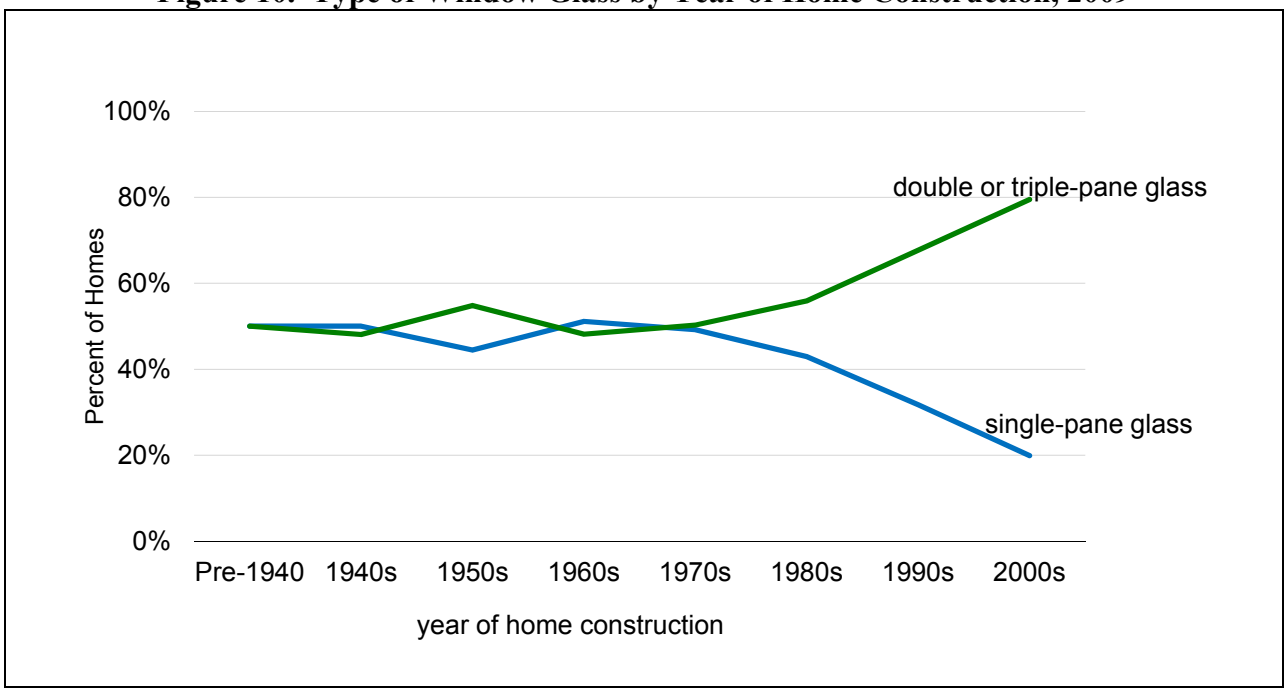
The combined factors of a large increase in the number of homes, the higher percentage of homes with central air conditioning, and the larger size of new homes have resulted in a much larger cooling load for all regions. This difference is most pronounced in the South where home construction has increased at a faster rate than in any other region and where nearly all new homes have central air conditioning. Figure 9 shows the number of homes and the average cooled square footage by year of construction.

Figure 9. Number of Southern Homes and Average Cooled Square Footage, 2009



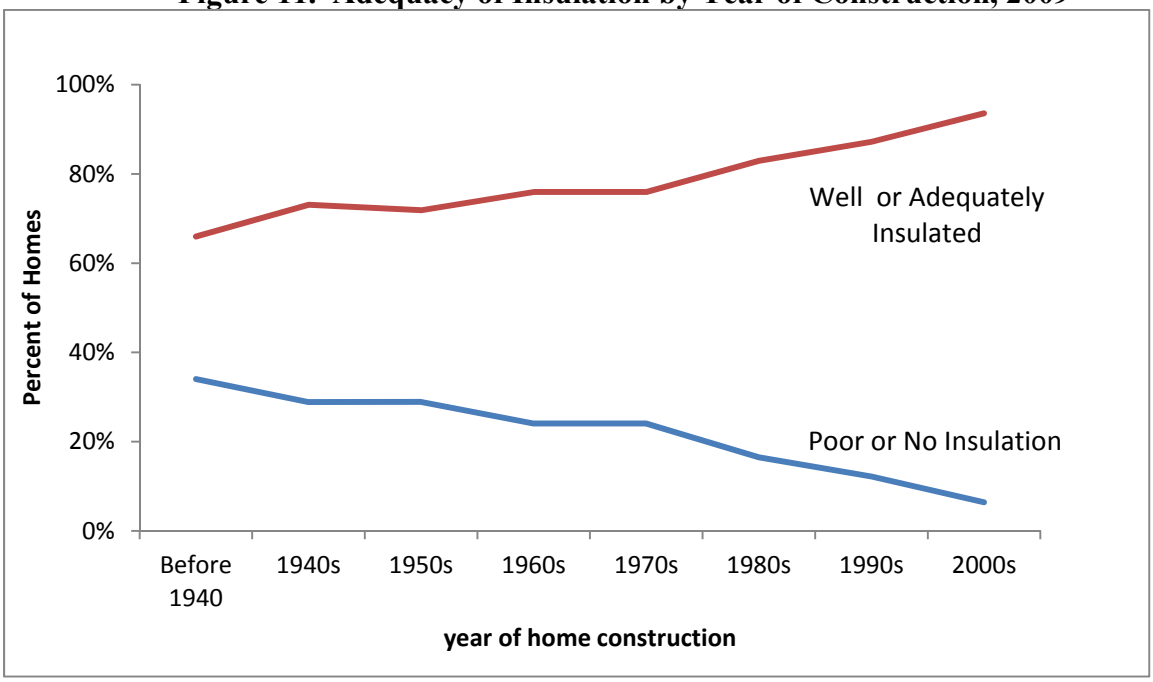
Although new homes are larger than older homes, they do tend to be more efficient. A new home will have newer heating and cooling equipment as well as newer major appliances such as refrigerators and clothes washers. With the increasing efficiency standards on these products, newer products will almost always be more efficient than older products. Additionally, other products that affect the home envelope such as windows are more efficient. Figure 10 shows the increase in double or triple-pane glass in newer homes.

Figure 10. Type of Window Glass by Year of Home Construction, 2009



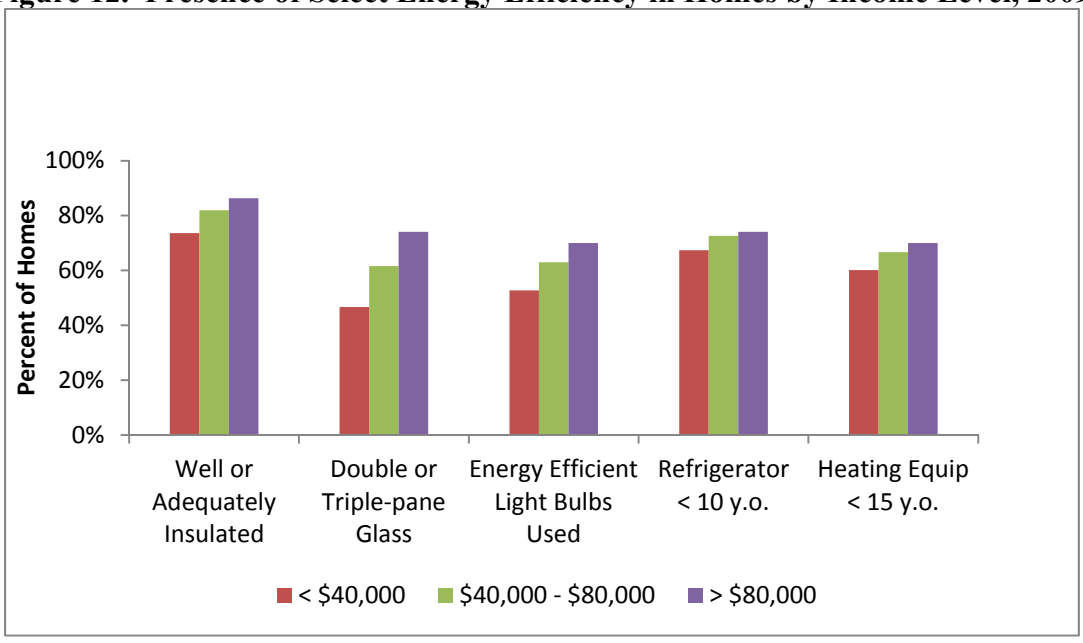
Included in the RECS is a question asking respondents how well insulated their home is. This question serves to collect a generalization of the effectiveness of the building envelope. Figure 11 shows the relationship between the perception of insulation and the age of the home. The newer the home, the better the perception of the building envelope.

Figure 11. Adequacy of Insulation by Year of Construction, 2009



The factors that determine whether a home is efficient vary by income. Higher income households are much more likely to include a wide range of energy efficient measures from very capital- intensive measure such as adequate insulation, double-pane glass, and newer HVAC equipment and major appliances to comparably low-cost energy efficiency measure such as the use of energy efficient light bulbs. Households that can least afford additional costs are therefore more likely to have higher energy bills. Figure 12 shows the percentage of homes with select efficiency features by income.

Figure 12. Presence of Select Energy Efficiency in Homes by Income Level, 2009



Conclusion

The data from the 2009 RECS show several trends in home energy use. As major equipment used for heating, cooling, and refrigeration have become more efficient, the unit consumption of these products has decreased substantially. However, the energy savings have been offset by additional products that are continuing to be added to homes. The penetration 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 energy-intensive 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. Efficiency programs must decrease energy use not just from current products but from an ever increasing number of end-uses.