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Residential Energy-Use and Savings Potential Study for the Governor's Energy Office

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OBJECTIVES AND INTRODUCTION

The Colorado Governor's Energy Office (GEO) engaged E Source LLC to develop a profile of the residential energy market in Colorado, along with an analysis of the saturation of energy-using equipment and appliances, the potential for energy savings, the match of existing energy-efficiency programs to that potential, and a brief road map toward achieving additional energy savings.

To characterize the housing stock and the associated energy-using equipment in the residential sector, E Source used a variety of sources, including the U.S. Census information, the Residential Energy Consumption Survey from the U.S. Energy Information Agency (EIA), utility resource plans, and E Source research. The bulk of the analysis, however, is based on primary research conducted over the past three years in a survey coordinated between E Source and The Nielsen Company, called simply "the energy survey." A highly comprehensive national survey of about 32,000 respondents, the energy survey offers an extremely rich set of data that can be used for various analyses. Over the past three years, approximately 1,400 respondents from Colorado have completed the survey, creating a strong, statistically valid sample for this project. For additional explanation of the data analysis techniques, please refer to Appendix A.

Relevant sections of the energy survey can be cut roughly into three major sections, which are outlined below, along with some of the key data elements captured in the survey.

Saturation of equipment and appliances	Participation in efficiency programs	Household characteristics
Heating and cooling	Weatherization/air sealing	Energy bill level
Refrigerators and freezers	Efficient windows	Urban/suburban vs. rural
Water heaters	Energy Star appliances	IOU vs. muni vs. co-op
Clothes washers and dryers	Programmed thermostat	Home size
Lighting	Energy audit	Home type
Programmable thermostats	Appliance rebate	Home age
Computing/phone plug loads	Appliance recycle/turn-in	Own/rent
Entertainment plug loads	Green power	Number of household members
Other equipment		Education level
		Income level
		Head of household age
		Ethnicity
		Political mind-set

In separate volumes, E Source has provided a full set of cross tabulations, analyzing the Colorado survey data, as well as national data, in the survey areas outlined in the table above.

For this report, E Source is highlighting some of the most relevant elements of Colorado energy-use patterns.

ENERGY USE IN THE RESIDENTIAL SECTOR OF COLORADO

Housing Stock Analysis

The housing stock in Colorado is quite diverse, but it is dominated by the surge in growth in the state during the past several decades. It took until the mid-1960s for Colorado to reach a population of 2 million. In the 1990s alone, Colorado grew by nearly 1 million people. Between 2000 and 2010, Colorado added another 700,000 people, about the same amount as was added in the 1970s.[1]

The age of a given dwelling is often critical when it comes to assessing how much energy-savings potential exists. Homes built before 1970 typically lacked any meaningful building-shell insulation. It wasn't until approximately 1990 that adequate insulation and windows began appearing in Colorado homes, but even these improvements varied across state jurisdictions. E Source enlisted the help of local energy experts who have experience weatherizing all types of Colorado homes to provide snapshots of typical insulation levels based on house vintage.[2] These assessments vary, of course, but they're still a helpful guideline when looking at Colorado's housing stock. The information is basically corroborated by a U.S. Department of Energy and National Renewable Energy Lab document on building simulations.[3]

- Starting in the early 2000s, homes were built with 2×6 walls with predominantly R-19 insulation; attics were built with R-38 insulation.
- In the 1990s, attics in the Denver metro area were predominantly insulated with R-30 or more, and walls were treated with between R-13 and R-19 insulation.
- In the 1980s, homes were typically insulated with R-13 walls; attics were treated with between R-19 and R-25 insulation.
- In the 1970s, walls were insulated with R-7 or R-9, and attics were insulated with R-13 or R-19 (usually fiberglass batts or blown rock wool).
- Going back to the 1960s, walls were often uninsulated, and attics were often treated with R-10 insulation.

Most homes built before 1980 (and in some cases, 1990) are therefore quite ripe for upgraded weatherization, and even newer homes can benefit from new air-sealing technology.

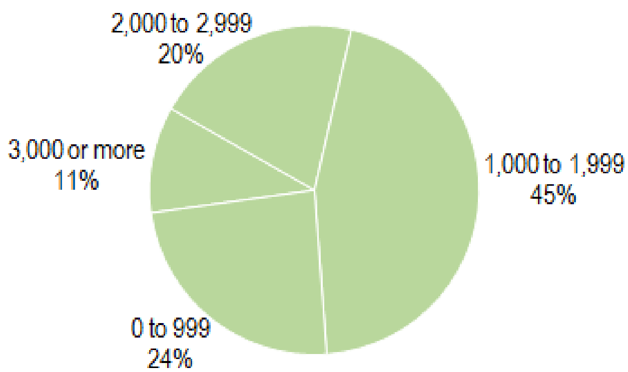
Housing Characteristics

Based upon Census data from 2010, there are 1,972,868 occupied households in Colorado. E Source estimates that 70 percent of households are single-family units, followed by 22 percent of which are three-unit or multiple-unit buildings, 5 percent are mobile homes, and 3 percent are duplexes. Of all households, 69 percent are owner-occupied, and 31 percent are rental units.

Geographies and utilities. E Source wanted to analyze whether geographic differences of rural vs. urban or suburban were significant drivers of energy use, as well as whether a household was served by an investor-owned utility (IOU), a municipal utility (muni), or a cooperative utility (co-op). To this end, E Source integrated the location (latitude and longitude) of each survey respondent with a county and a utility service territory to create an estimate of this distribution. E Source had to decide which counties are considered rural and which are considered urban or suburban. By looking at the more populated cities and towns, the following counties were included in the urban and suburban cluster: Adams, Arapahoe, Boulder, Broomfield, Denver, Douglas, El Paso, Jefferson, Larimer, Mesa, Pitkin, Pueblo, and Weld. Certainly, many of these counties have rural, urban, and suburban households, but the numbers tend be clustered in distinct areas. This resulted in 89 percent of households living in the urban or suburban cluster, and 11 percent in the rural cluster. When looking at households by utility type, about 76 percent are served by an IOU, 12 percent by a muni, and 12 percent by a co-op.

Dwelling characteristics. Home sizes were initially analyzed and grouped by square foot (ft^2). The largest homes, over 3,000 ft^2, make up just over 10 percent of all dwellings (**Figure 1**). Dwellings between 2,000 and 2,999 ft^2 make up 20 percent of Colorado housing; homes in the 1,000 to 1,999 ft^2 size make up the largest segment at 45 percent, and the smaller units, with less than 1,000 ft^2, constitute 24 percent of all dwellings.

FIGURE 1: Home square footage



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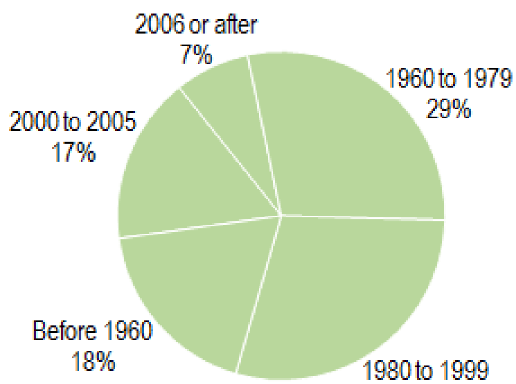
In pace with the population growth that was discussed earlier is the vintage of dwellings in Colorado. Homes built before 1960 account for 18 percent of housing units (**Figure 2**). The 1960s and 1970s accounted for 29 percent of current dwellings, with the same percentage (29 percent) built in the 1980s and 1990s. Between 2000 and 2005, another 17 percent of dwellings were constructed, and from 2006 on, only 7 percent of homes were built, reflecting a sharp downturn in the new construction market.

FIGURE 2: Year of home construction



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Energy Use per Home

By looking at total energy use per home, certain household characteristics can be discerned to find energy-savings targets. Which types of homes use the most energy? What demographics drive high or low energy use? The analysis used survey respondents' reported electricity, gas, and other fuel costs for one summer month and one winter month to create an energy bill data point for analysis.

Some of the energy bill drivers are intuitive, but it's instructional to see the level of influence on energy demand. **Figure 3** shows energy use by size of home. Homes that are more than 3,000 ft^2 use about 85 percent more energy than those that are less than 1,000 ft^2, and they use about 30 percent more than homes that are between 2,000 and 2,999 ft^2.

Household size is also a significant driver. **Figure 4** shows that households with five or more people use more than twice as much energy as those with one person, 56 percent more energy than those with two people, and 26 percent more energy than those with three or four people.

FIGURE 3: Energy spend by home square footage

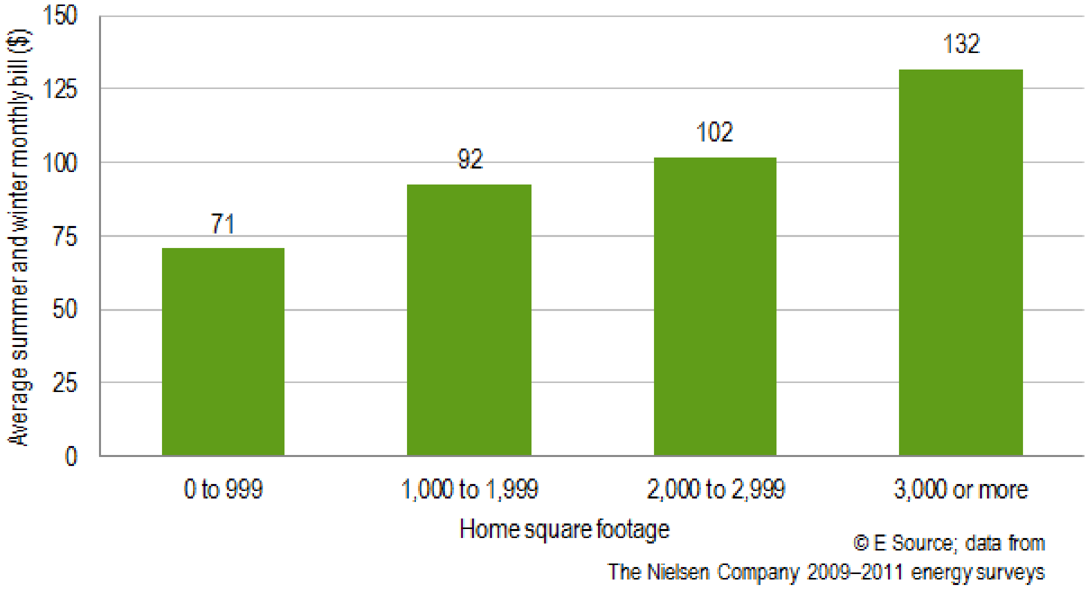
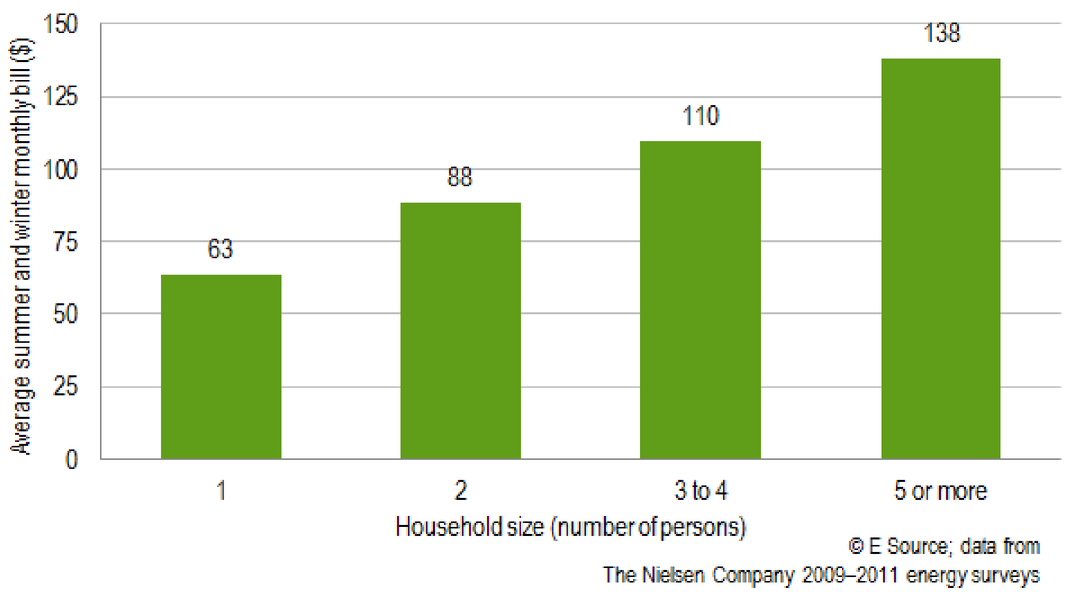
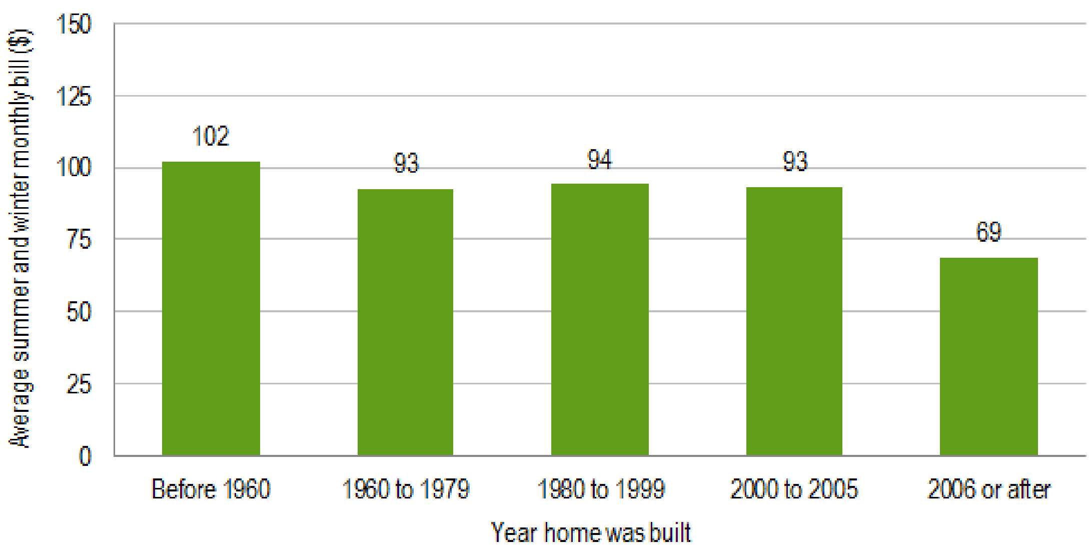


FIGURE 4: Energy spend by number of household members



The year a home was built also is an indicator of energy use. Homes built between 1960 and 2005 use a very similar amount of energy, possibly reflecting the growth in home size over that period of time, coupled with improvements in home efficiency. The oldest homes use the most energy, but only about 8 to 10 percent more than homes built between 1960 and 2005. However, energy use in homes built in 2006 and beyond use dramatically less energy, about 26 percent less than those built between 1960 and 2005 (**Figure 5**). Also, a multifamily household uses about two-thirds the energy of a single-family home.

FIGURE 5: Energy spend by age of home



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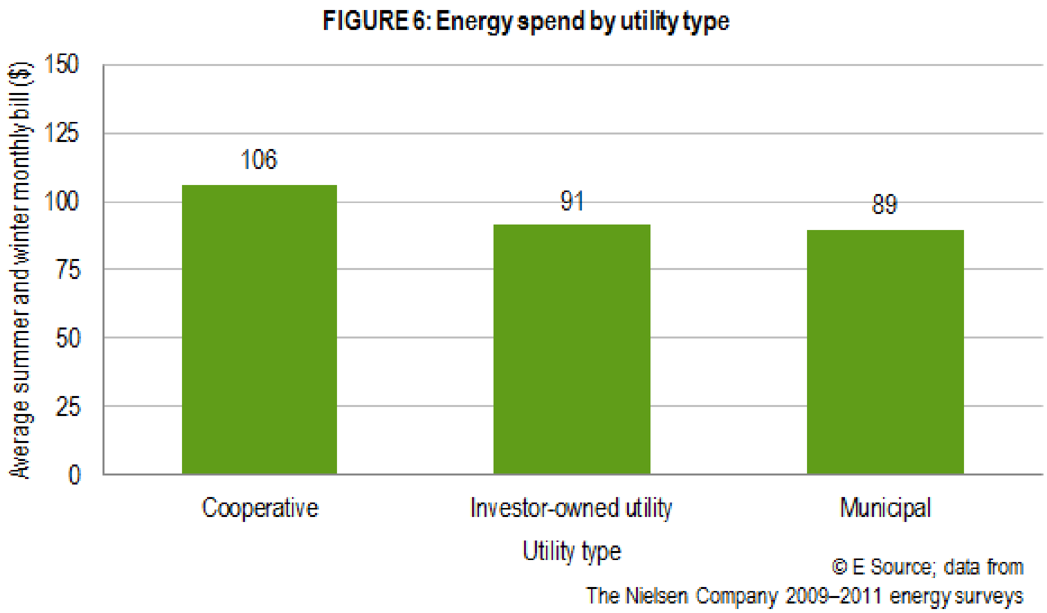
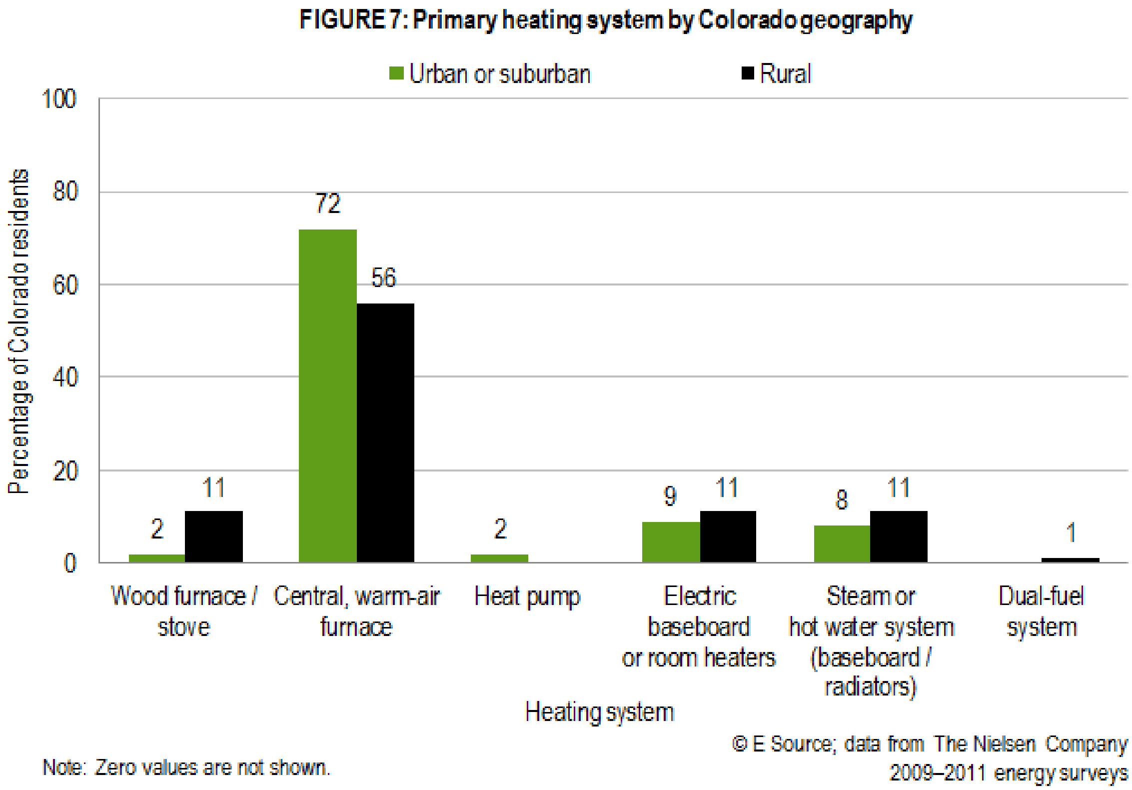
Households that are classified as rural use about 12 percent more energy on average than those that are urban or suburban. Similarly, those that are served by co-ops use about 17 percent more energy per household than those served by IOUs and munis, which use similar amounts of energy (**Figure 6**).



Heating and Cooling Systems

Heating and cooling make up the majority of energy use (combined gas and electricity) in the residential housing sector. The following analysis takes a closer look at the types of equipment that most households are using in Colorado.

Heating. Natural gas–forced air furnaces dominate household heating systems at 71 percent on average in Colorado. Another 9 percent of households use electric heating as their primary heat source, and 8 percent use hot water or steam system power by natural gas or propane. However, there are marked differences between rural heating and urban or suburban heating practices. Only 56 percent of rural households use forced-air natural gas. Wood heat is the primary source for 11 percent of rural households (vs. 2 percent for urban or suburban households). Electric heating and steam or boiler systems are also more prevalent in rural areas. A few additional items are noticeable in the data on heating systems. For homes that were built between 1960 and 1980, the prevalence of electric heating is nearly double that of other time frames, at about 13 percent. Also, hot water and steam systems were most prevalent before 1960 at 13 percent, and have been dropping in popularity over time to about 3 percent in the most recent time frame (**Figure 7**).



Cooling. The Colorado residential market has an interesting profile for cooling. Colorado's dry air and summertime cool evenings provide cooling options that aren't available to most of the country. Approximately 43 percent of Colorado homes have central air conditioning (AC). This is compared to 62 percent of homes nationally. Only 16 percent of Colorado respondents said they had no cooling system at all, however. Approximately 16 percent rely on window AC, and another 11 percent use whole-house fans, room fans, or ceiling fans. Evaporative cooling has a market share of about 4 percent. Cooling systems vary quite a lot depending on a number of factors. For example, 46 percent of dwellings in urban or suburban areas have central AC, whereas only 20 percent have central AC in rural areas (**Figure 8**). Nearly 40 percent of rural homes have no cooling system at all, whereas only 13 percent of urban or suburban homes go without cooling. The year of construction has a very significant influence on cooling system types as well. Only 22 percent of pre-1960 homes have central AC, with these older homes having the highest prevalence of evaporative cooling, fans, and window AC. It's notable that homes built after 2005 have a lower incidence of central AC (by 5 percent) compared to homes built between 2000 and 2005. The difference is reflected mostly in evaporative cooling, which saw a rise after 50 years of decline. Central AC saturation is driven to a great extent by size of home and household income, as well. Homes larger than 3,000 ft^2 have 66 percent saturation, while homes smaller than 1,000 ft^2 have a 30 percent saturation (**Figure 9**).

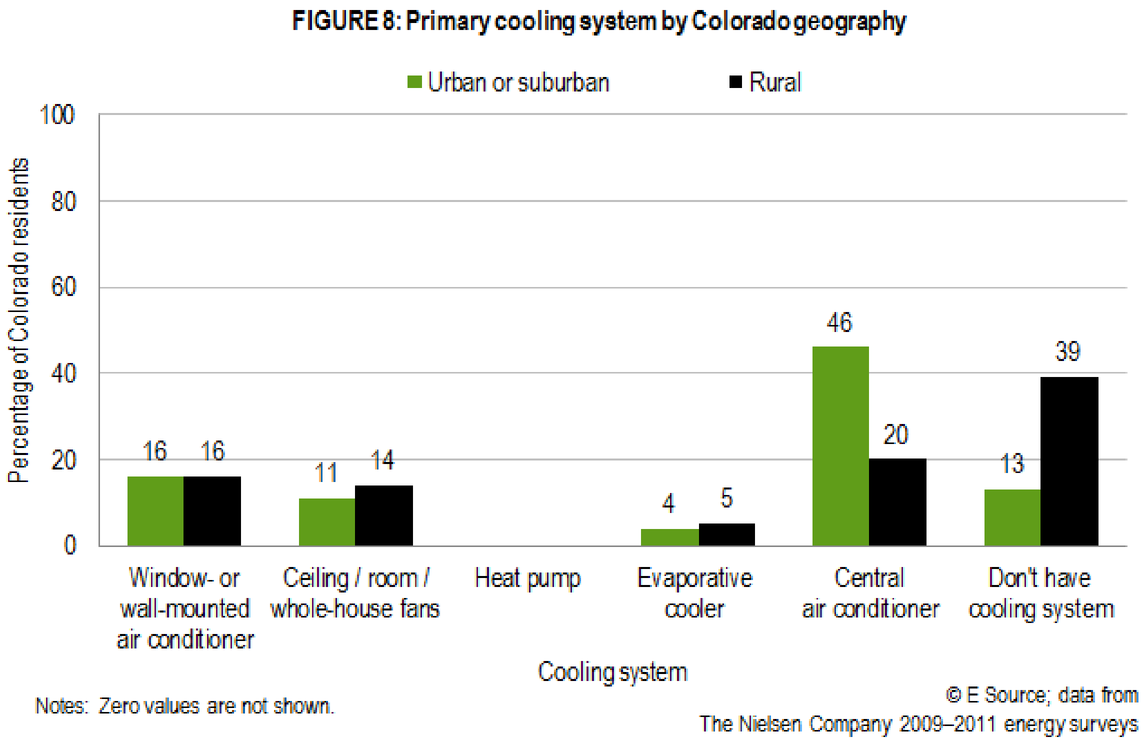


FIGURE 8: Primary cooling system by Colorado geography
Urban or suburban
Rural
Percentage of Colorado residents
100
80
60
40
20
0
16
16
11
14
4
5
46
20
13
39
Window- or wall-mounted air conditioner
Ceiling / room / whole-house fans
Heat pump
Evaporative cooler
Central air conditioner
Don't have cooling system
Cooling system
Notes: Zero values are not shown.
© E Source; data from The Nielsen Company 2009–2011 energy surveys

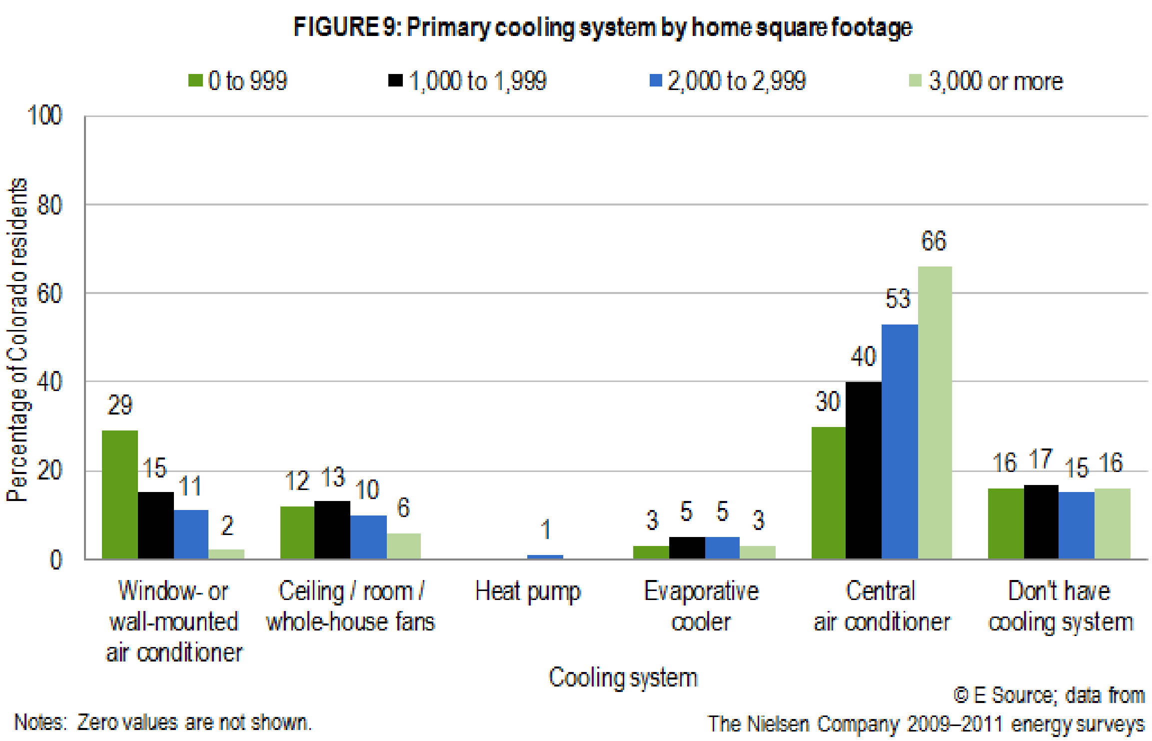


FIGURE 9: Primary cooling system by home square footage
0 to 999
1,000 to 1,999
2,000 to 2,999
3,000 or more
Percentage of Colorado residents
100
80
60
40
20
0
29
15
11
2
12
13
10
6
1
3
5
5
3
30
40
53
66
16
17
15
16
Window- or wall-mounted air conditioner
Ceiling / room / whole-house fans
Heat pump
Evaporative cooler
Central air conditioner
Don't have cooling system
Cooling system
Notes: Zero values are not shown.
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Colorado Potential for Building-Shell Improvements

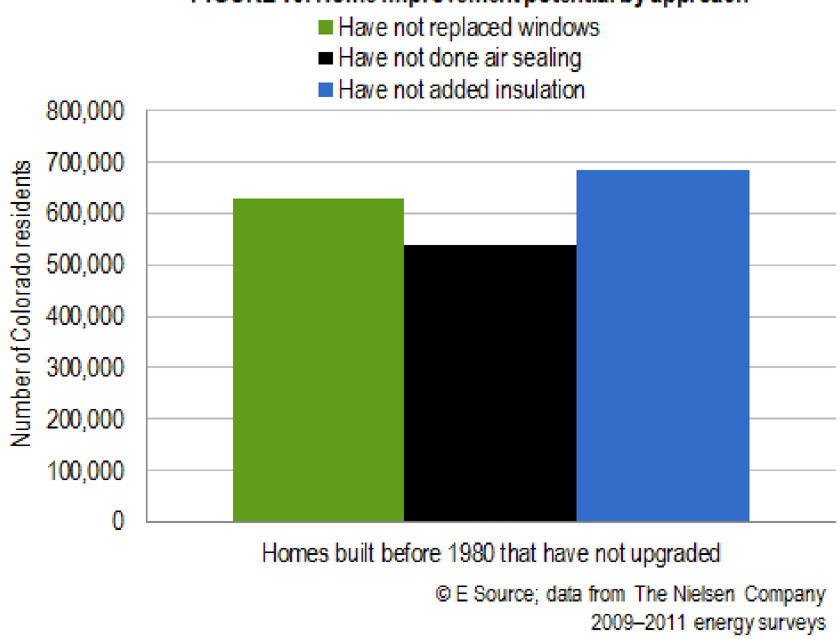
Some of the most effective methods for permanently improving the energy efficiency of a home are to upgrade the building-shell insulation, seal air leaks, and improve the efficiency of the windows. These upgrades help save energy in both heating and cooling seasons. Insulation and air sealing can be quite cost-effective. And though windows can be expensive, they continue to be a favorite upgrade for homeowners. To determine how many homes in Colorado are still good candidates for these types of improvements, the analysis looked at homes built before 1980 (those that are likely to have inadequate insulation, infiltration, and windows) where those options have not yet been made (**Figure 10**).

Insulation. Approximately 930,000 homes in Colorado were built before 1980. Based on the survey data, just over 240,000 of those homes are estimated to have added insulation to the dwelling. That leaves nearly 690,000 homes that would be strong candidates for insulation upgrades.

Air sealing. Even simple measures such as caulking and weatherstripping have not been completed in a high percentage of older homes. Approximately 540,000 pre-1980 Colorado homes could benefit from these activities and upgrades.

Window upgrades. Homes built before 1980 are likely to have poorly insulated windows, with the additional problems of cracked window sealing and inadequate filtration. It is estimated that approximately 630,000 homes would benefit from more up-to-date windows.

FIGURE 10: Home improvement potential by approach



Note that advanced air-sealing approaches have been refined over the past decade or so, and almost every dwelling in Colorado, besides those that have been built to high green standards, could benefit from air-sealing improvements.

Savings Potential from Insulation and Air Sealing

Energy Star modeled energy savings in a typical home built between 1975 and 1985 to determine the extent to which energy use could be reduced from the addition of insulation and air sealing.[4] To measure how various heating and cooling loads affect savings, Energy Star researchers modeled homes in both the northern and southern regions, using insulation upgrades ranging from R-14 (average) to R-38 in the attic, R-0 to R-11 in the basement rim joists, and R-0 to R-11 in the floors over crawl spaces. In addition, the homes were air sealed to improve the natural air changes per hour from 0.925 (average northern and southern home) to 0.50. The results showed that heating and cooling energy needs on a Btu basis were reduced 20 percent in the northern home model and 23 percent in the southern home model. Energy Star says these models aren't just theoretical; they've been corroborated by extensive field experience.

Calculating how much energy air sealing alone can save is very site specific, and there are limited public data available on the measure. The Iowa Energy Center cites a potential savings of 10 percent from air sealing, based upon a Department of Energy study.[5] New Jersey's Clean Energy Program uses a deemed home heating and cooling energy savings number of 5 percent for air-sealing work completed through its low-income program.[6] In general, the savings from sealing home air infiltration can be substantial for many homes and is a highly recommended practice by energy and utility organizations.

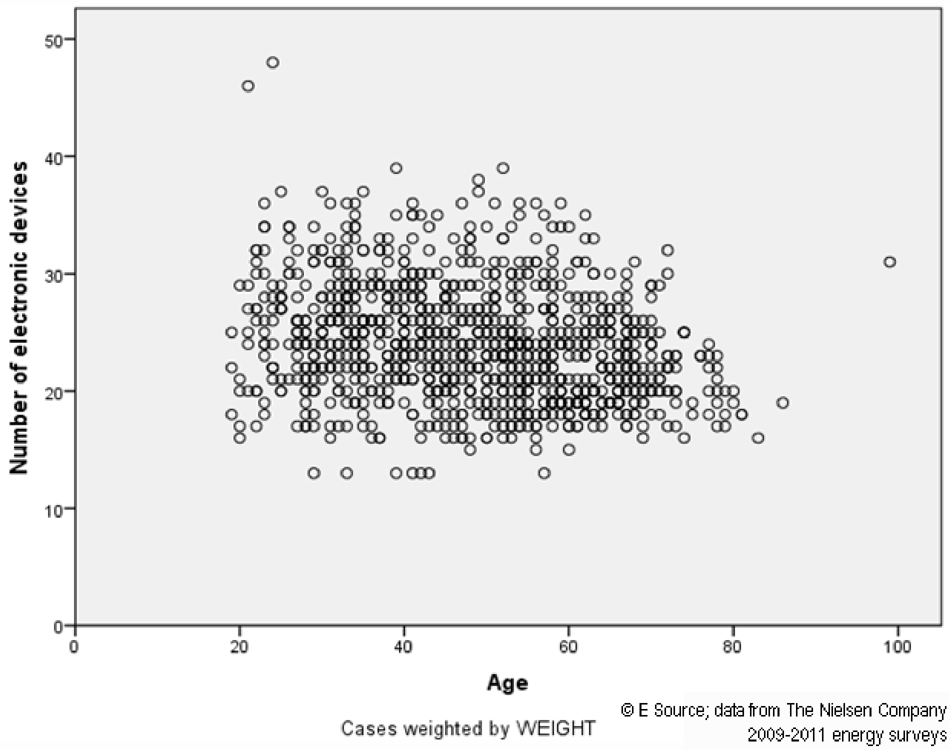
Saturation of Electronics, Computers, and Entertainment Technology

The explosion of technology has had a profound effect on the electricity-use patterns of households over many decades. The proliferation of computers, TVs, cell phones and smartphones, gaming systems, entertainment systems, and numerous other gadgets adds to the plug loads that already exist for appliances. According to the EIA, appliances and electronics accounted for 17 percent of household energy use on average vs. 31 percent in 2005.

To analyze how various household attributes drive demand for electronics, E Source considered the Colorado data across many different dimensions. This was done by creating a number called "gadgets per home," which consists of TVs, cable boxes, digital recording devices (DVRs), DVD players, video game consoles, computers, tablet PCs, printers, modems, home theater systems, and cell phones and smartphones.

The results show that against virtually every household and demographic cross tabulation, the number of gadgets per home is remarkably constant at around 24 per household (**Figure 11**). For example, the newest homes have only two more gadgets than the oldest homes, and homes over 3,000 ft^2 have only four more gadgets than homes under 1,000 ft^2. The group with the highest income only has four more gadgets than the households with the lowest income. And despite the notion that older people are not tech savvy, those over 65 have about 22 gadgets, and those under 35 have about 26 gadgets.

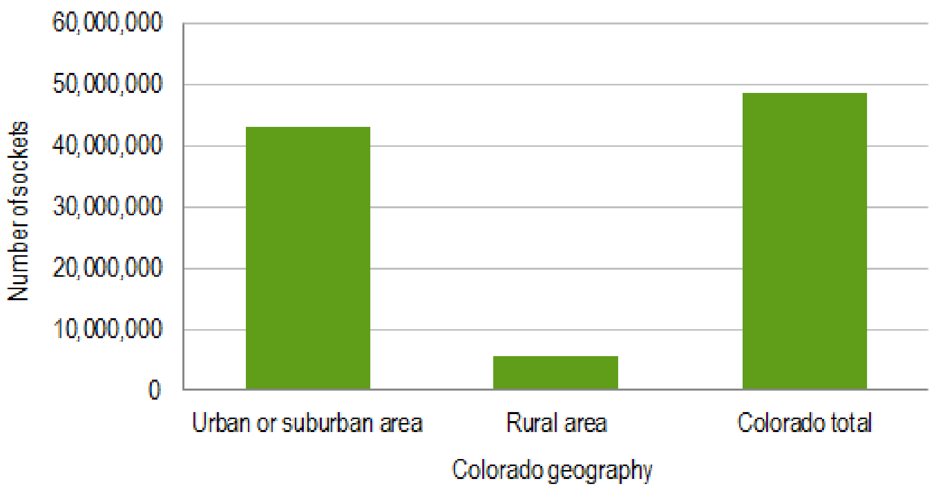
FIGURE 11



Lighting Market Penetration

While compact fluorescent lamps (CFLs) have been around for many years, they're still lacking in adoption, especially in some market sectors. According to the Energy Star CFL Market Profile 2010,[7] even though the average number of household light sockets is around 40, a reasonable technical maximum for CFLs is about 32 per household. The report references Colorado specifically, saying that about 23 percent of household sockets have CFLs. Using those figures, the market potential in Colorado for energy-efficient lighting is still very large. **Figure 12** shows that almost 50 million light sockets in Colorado have the potential to be upgraded to a higher-efficiency lamp.

FIGURE 12: Potential sockets for CFL or LED adoption



Notes: CFL = compact fluorescent lamp; LED = light-emitting diode.

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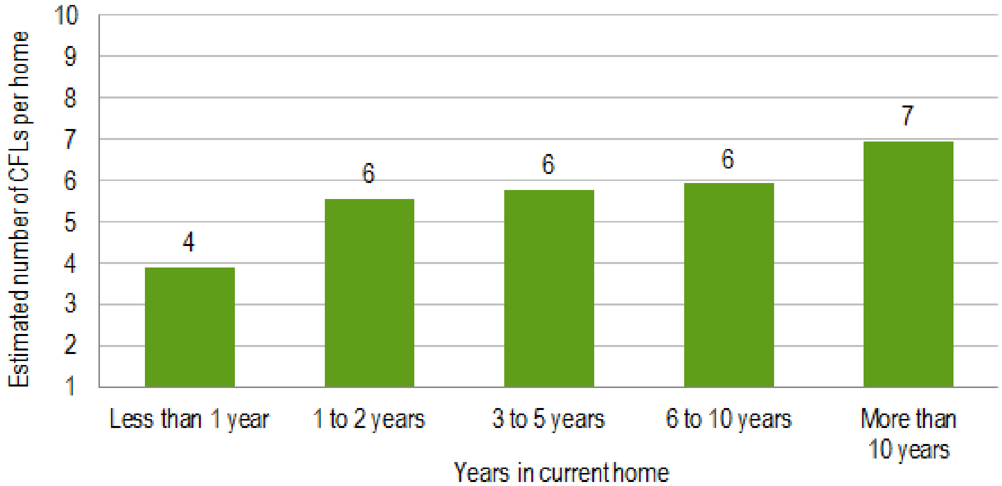
How do different households adopt CFLs? The data show that the vintage of a dwelling only has a mild effect on CFL adoption, with homes built before 1960 having only slightly fewer sockets than more-recent homes. Though homes with fewer than 1,000 ft^2 have fewer CFLs, homes with more than 1,000 ft^2 only show a modest increase in their number of CFLs, even as home size increases above 3,000 ft^2. Household size also has only a moderate effect on CFL adoption, with two-person households reporting the highest level of adoption. Additionally, owners report having approximately 50 percent more CFLs than renters. CFL adoption increases slightly with older respondents, but only the youngest group—ages 18 to 24—shows much lower numbers (**Figure 13**). When we look at CFLs by type of utility, the co-ops come out on top, illuminating about 25 percent more CFLs than IOUs. Munis rate slightly higher than IOUs (**Figure 14**).

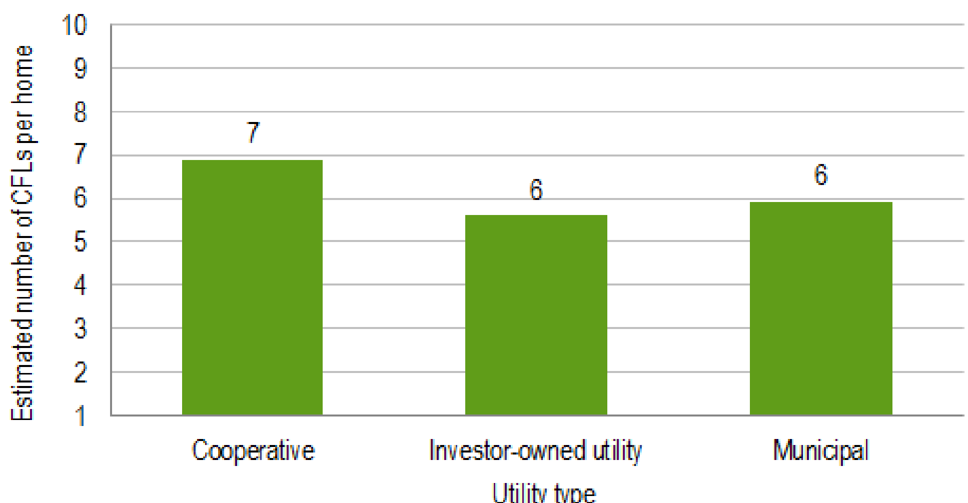
FIGURE 13: Number of CFLs by time in residence



Note: CFL = compact fluorescent lamp.

© E Source; data from The Nielsen Company 2009–2011 energy surveys

FIGURE 14: Number of CFLs by utility type



Note: CFL = compact fluorescent lamp.

© E Source; data from The Nielsen Company 2009–2011 energy surveys

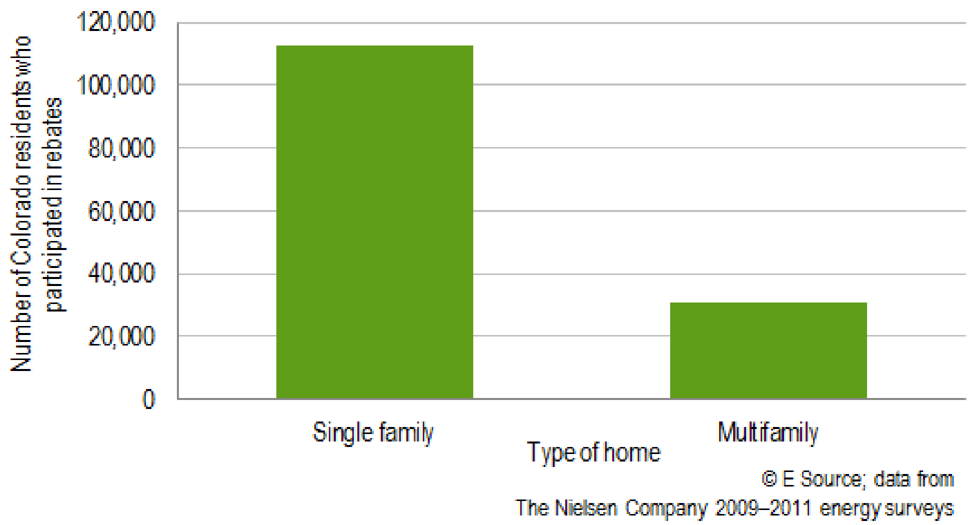
E Source ran a regression analysis on the Nielsen data to determine which attributes were the largest drivers for high CFL adoption. The top three drivers were (1) older age, (2) home ownership, and (3) higher income. For example, for every 10 years' increase in age, a respondent is likely to use 2 more CFLs in their home, when controlling for all other variables.[8] As mentioned, those who own their homes are more likely to use more CFLs than renters are; the analysis shows similar results for single-family homes vs. multifamily homes. As annual household income increases, so does the likelihood of using CFLs in the home.

Active Participants in Energy-Efficiency Programs

Many Colorado households have the opportunity to take advantage of a wide variety of energy-efficiency programs through their utility or through the state of Colorado.

About 113,000 single-family Colorado homes applied for or received an appliance or energy equipment rebate from their state or local government in the past year, compared with about 31,000 multifamily homes (**Figure 15**).

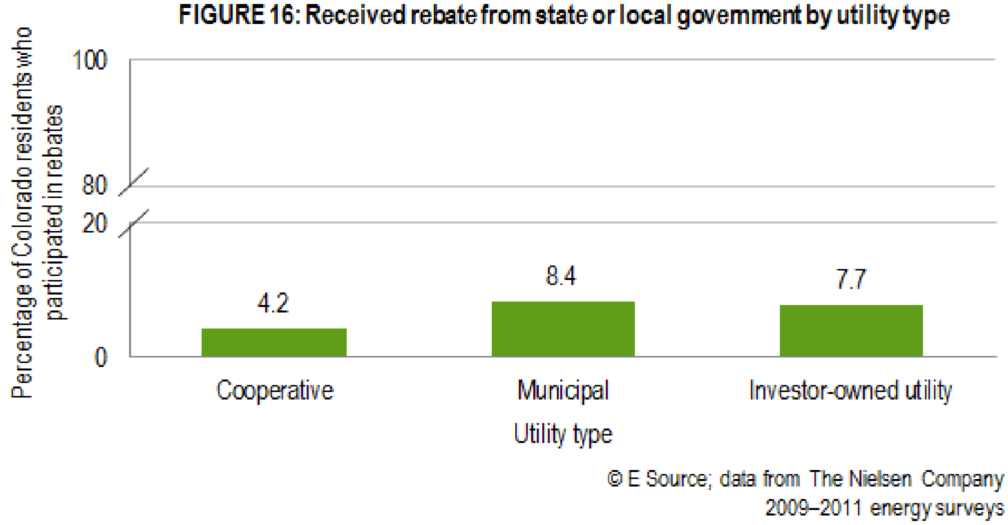
FIGURE 15: Received rebate from state or local government by type of home



About 8 percent of those who are served by a muni or IOU reported applying for or receiving a rebate from state or local government for an appliance or energy equipment upgrade, compared with about 4 percent of those served by a co-op (**Figure 16**).

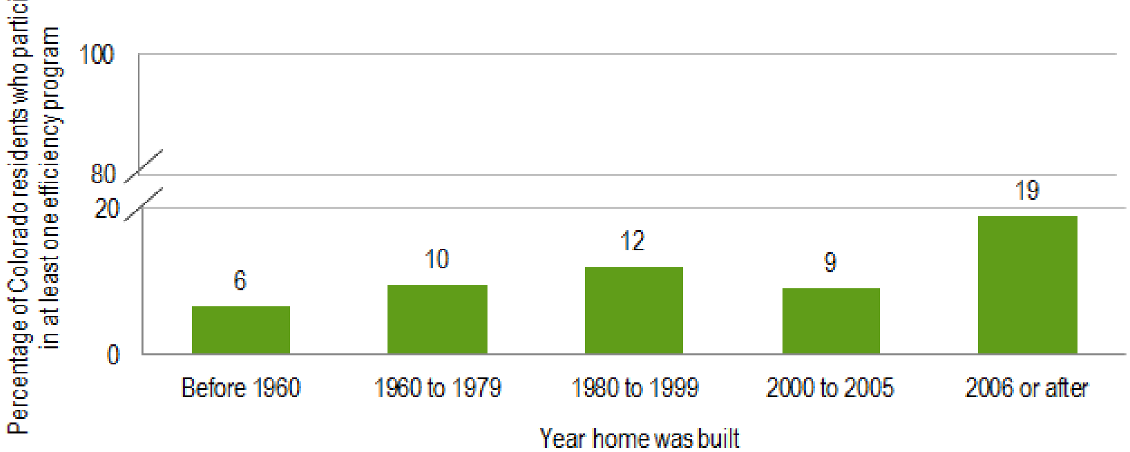
The households that participated in a weatherization service, equipment rebate, appliance rebate, or appliance-recycling program with their *utility* in the past year were analyzed to see what market characteristics they possess.

FIGURE 16: Received rebate from state or local government by utility type



When it comes to the age of the home, the most active segment consists of the newest homes built since 2006 (**Figure 17**). About 14.0 percent of that cluster participated in one program, with another 5.0 percent participating in more than one program. Thus, even in newer homes, there is a high need and demand for energy-efficiency investments. The second highest target cluster are homes that were built from 1980 to 2000, where about 12.0 percent of households participated in one or more programs. The lowest numbers were seen in the oldest homes, with about 6.5 percent of customers participating.

FIGURE 17: Participation in at least one utility energy-efficiency program by year home was built



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Based on the size of a home by square footage, there was very little difference among household participation for homes larger than 1,000 ft^2. Respondents who live in homes smaller than 1,000 ft^2 participated at about half the rate of respondents who live in larger homes. Household size as measured by the number of people living in the home showed quite a high variation in energy-efficiency participation. Households with three or four members participated at the highest rate, with almost 14 percent involved in at least one program. Two-member households were next on the list, at about 11 percent. Surprisingly, the largest households (five or more members) had the lowest participation, at about 6 percent, similar to one-member households.

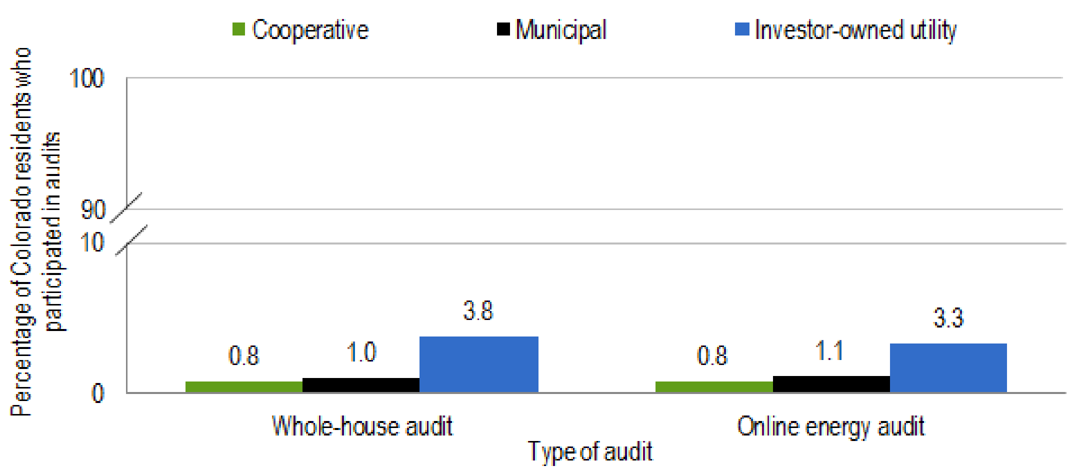
Online and In-Home Energy Audits

Survey respondents were asked whether they had either performed an online audit or had an in-home audit conducted in the past 12 months. Each year, approximately 7 percent of the Colorado population says they have had an audit. If this trend continues over a decade, approximately two-thirds of homes will have had an audit completed. Looking more deeply into the types of households that have completed audits is educational.

Surprisingly, respondents in homes built before 1980 are the least likely to have had audits performed (6 percent). The most likely respondents are those in homes built in 2006 or later, at about 10 percent. While larger homes (by ft^2) have audits at a higher rate than smaller homes, the number of people in the household also drives participation, but in a different pattern. Households with only one person have audits at a 3 percent rate, but that rises to 8 percent for two people, 9 percent for three or four people, and 7 percent for more than five people.

Though owner-occupied and rental properties conduct audits at about the same overall rate, owners use in-home audits at twice the rate as online audits, and renters conduct online audits at four times the rate as in-home audits. Audits are conducted by single- and multifamily households at a very similar rate. Probably the most telling difference is when audits are compared by utility service territory (**Figure 18**). Those who are served by IOUs conduct audits at about an 8 percent rate per year, while municipal and cooperative utilities have audits at about a 3 percent rate per year. This marked difference is likely to be an outcome of a more concerted effort on the part of IOUs to market in-home and online audits.

FIGURE 18: Participation in audits by utility type



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THE MODEL FOR ECONOMIC POTENTIAL FOR ENERGY SAVINGS IN COLORADO

There are many ways to look at potential energy savings in the residential sector, but a fairly standard approach has been developed over several decades in the utility demand-side management (DSM) industry. The process typically takes the following steps:

1. Determine the housing stock in the region of interest.
2. Divide the housing stock into smaller segments to better address the energy-usage patterns of various groups, such as different building types, building sizes, building vintages, and income levels.
3. Determine the saturation of energy-using equipment in each segment.
4. Calculate the average energy use for each equipment category (or end use) for each segment.
5. Calculate baseline energy usage for each end use within each segment as the product of housing stock, equipment saturation, and average energy use; then sum the usage across end uses and segments to calculate total energy use.
6. Compare baseline energy use to a scenario where all equipment is replaced or modified with technologies of the highest available efficiency, or “energy-efficiency measures”. The difference between the two values is considered the technical potential.
7. Assess the cost-effectiveness of each measure and then compare baseline energy usage to a scenario where all equipment is replaced or modified by measures of the highest cost-effective efficiency. This is called the economic potential.
8. Many studies also include an additional assessment of how likely the changes called for in the economic potential are to happen in the real marketplace. This is typically called the achievable or market potential.

Doing a full demand-side potential assessment is an intensive job, where researchers must assess hundreds of technologies, run a wide variety of economic tests, collect market research on appliance saturation and building conditions, forecast future demand, and evaluate the avoided cost of future energy supply. Because this type of analysis is beyond the scope of this project, E Source is instead adjusting results of Colorado potential studies that have recently been completed to estimate statewide totals. For several reasons, we rely heavily on the Xcel Energy DSM plan:

- Servicing the most households of any single utility in the state, Xcel Energy is responsible for over 50 percent of residential electric sales and over 70 percent of natural gas sales in Colorado. Because no other single utility has a 10 percent market share, Xcel’s specific analysis is germane to more households than other utilities’ studies.

- Among the local utilities, Xcel has completed the most rigorous market potential assessment, and its analysis has made public most of the detailed assumptions driving the results.
- The utility's analysis simultaneously addresses both electricity and natural gas potential.

In general, the approach we used to extrapolate Xcel's results to the entire state of Colorado began with Xcel's economic potential results by market segment and measure. These results were then adjusted for two factors: the difference in household counts between Xcel and the entire state, and the difference in end-use saturations between Xcel and the entire state.

More specifically, we used the following steps to adjust Xcel's analysis to estimate savings potentials for Colorado:

1. We applied Xcel's market segmentation approach, which addresses the range of building types, sizes, vintages, and income levels (**Table 1**). By selectively defining certain segments, Xcel was able to collapse the segmentation scheme into the 10 segments shown in **Table 2**.

   Using square footage as the defining characteristic, we segmented single-family households into three building sizes: Twenty percent of the homes were defined as large; 60 percent were defined as medium, and another 20 percent were defined as small. We defined low-income customers to be generally consistent with those customers eligible for the GEO's low-income weatherization assistance program. Low-income customers were categorized as a uniform segment and were not distinguished by other building type and size characteristics.

2. We relied on Xcel's list of end uses, which, as shown in **Table 3**, was quite comprehensive. While Xcel only addressed gas customers with natural gas end uses, we extended these to also cover homes in the state relying on propane.
3. We estimated Colorado household counts for each market segment using 2010 Census data.
4. We relied on the E Source and Nielsen data for appliance and equipment saturations because the information applies more broadly to the entire state. However, in a few cases, we relied on the Xcel data when we felt they were more representative of statewide conditions.
5. We relied on Xcel's estimates of average energy use for each end use to calculate baseline energy usage.
6. We relied on Xcel's analysis of costs, savings, and cost-effectiveness for energy-efficiency measures. The measures included in Xcel's analysis were rather comprehensive, covering 125 measures in existing houses, showing separate costs, savings, and cost-effectiveness for each of the five building types (large single family, medium single family, small single family, multifamily, and low income). For

new construction, Xcel evaluated two comprehensive measure bundles for each of the five building types.

7. Using the statewide household and saturation data, as well as the Xcel measure savings data, we then calculated statewide economic potential.

TABLE 1

Building type	Building size	Building vintage	Income
Single family	Large	Existing	Low income
Multifamily	Medium	New construction	Not low income
Low income	Small		

© E Source; data from Xcel Energy

TABLE 2

	Building vintage	
Building type	Existing	New construction
Large single family	✓	✓
Medium single family	✓	✓
Small single family	✓	✓
Multifamily	✓	✓
Low income	✓	✓

© E Source; data from Xcel Energy

TABLE 3

Electricity end uses
Split-system air conditioner
Room air conditioner
Evaporative cooler
Dehumidifier
Furnace fan, furnace, and air conditioner
Resistance space heating (primary)
Incandescent lighting
Fluorescent lighting
Refrigerator
Freezer
Water heater
Clothes washer
Clothes dryer
Dishwasher
Pool pump
TV
Big-screen TV

Electricity end uses (cont.)
Set-top box
DVD player
Desktop PC
Laptop PC
Natural gas / propane end uses
Furnace
Boiler
Room heat
Water heating
Clothes drying
Cooking
Miscellaneous

© E Source; data from Xcel Energy

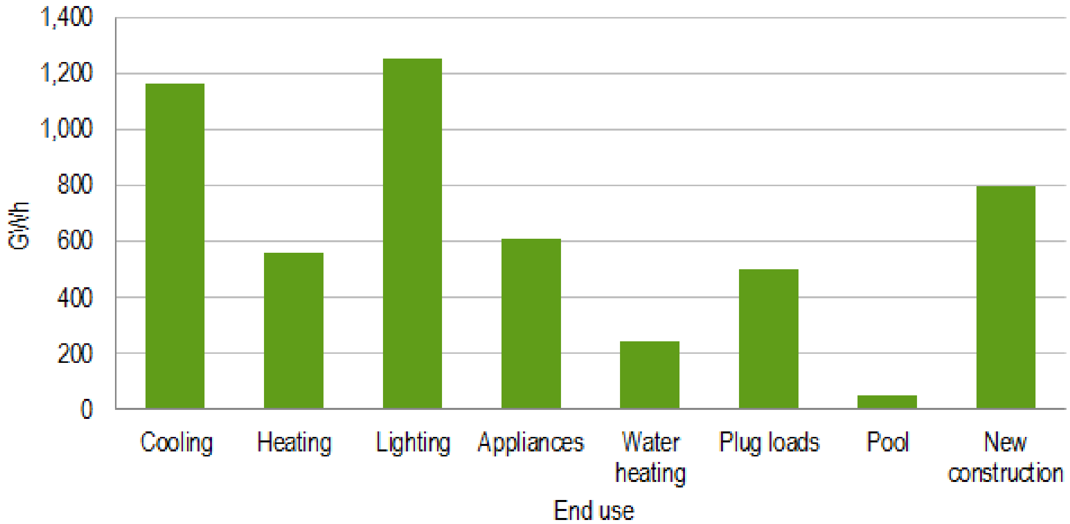
Overall, this approach allowed us to calculate statewide savings potential and break down savings for a number of dimensions, including:

- Fuel (electricity, natural gas, and propane)
- Building type and size (single family and multifamily, with single-family further broken down into three size categories)
- Income group (low income and other households)
- Building vintage (existing buildings and new construction)
- End use (for example, heating and cooling)
- Measure
- Measure group (for example, efficient equipment and building-shell improvements)

Economic Potential for Electricity Savings in Colorado

On the electricity side of energy use, according to the EIA data,[9] Colorado households used 18,102 GWh in 2010. That was up from just over 14,000 GWh in 2000, and just under 10,000 GWh in 1990. The economic potential for electricity savings is estimated by E Source to be 5176 GWh; that is, if every house was upgraded to include economic measures improving the efficiency of equipment, appliances and building shell. This is almost 29 percent of current electricity use. **Figure 19** shows how this savings potential breaks down by end-use area.

FIGURE 19: Electricity economical potential by end use



Note: GWh = gigawatt-hour.

© E Source; data from The Nielsen Company 2009–2011 energy surveys

Electric Heating and Cooling

With an electricity savings potential of 1,722 GWh, home heating and cooling offers the highest savings potential most room for improvement. Cooling improvements are derived from various upgrades, including better weatherization, higher-efficiency air-conditioning units, and the use of evaporative cooling and whole-house fans. Electric heating improvements mostly occur through building weatherization improvements.

Targets for heating and cooling improvements: Single-family, owner-occupied homes that are larger than 1,000 ft^2 are the best targets for heating and cooling improvements. The age of a home is not a significant driver for a homeowner's participation in utility equipment rebate programs according to The Nielsen Company survey results, but larger homes have higher impact potential if they are treated. It is critical to work with contractors and vendors during the purchase process to ensure that central air-conditioning units and other equipment are the highest efficiency possible.

Lighting

Efficient lighting provides the second largest potential for savings at 1,251 GWh. This is primarily accomplished by replacing incandescent lamps with CFLs, with additional potential likely to come as light-emitting diode (LED) lamps become viable in the market in future years.

Targets for lighting improvements: Based on market analysis conducted by E Source, the best candidates for lighting upgrades are households that are headed by older, higher-income owners.

Appliances

The next largest electricity savings area is appliances, such as refrigerators, clothes washers, clothes dryers, and freezers. Savings potential is estimated at about 612 GWh. These improvements are mostly derived when consumers replace inefficient models with newer Energy Star models, and Energy Star refrigerators hold much of this potential.

Targets for appliance improvements: The targets for appliance rebates are somewhat different than those for appliance-recycling programs. Because newer homeowners are purchasing new appliances at a high rate, these consumers should be targeted first. In addition, homes built between 1980 and 1999 show higher rebate potential as their first wave of appliances start to fail. Single-family homes, especially in the 1,000 to 3,000 ft^2 range, show higher appliance rebate potential as well. For appliance recycling, the 1980 to 2000 vintage homes were the highest. In addition, younger households took greater advantage of recycling programs, as did those households earning a lower income.

Plug Loads

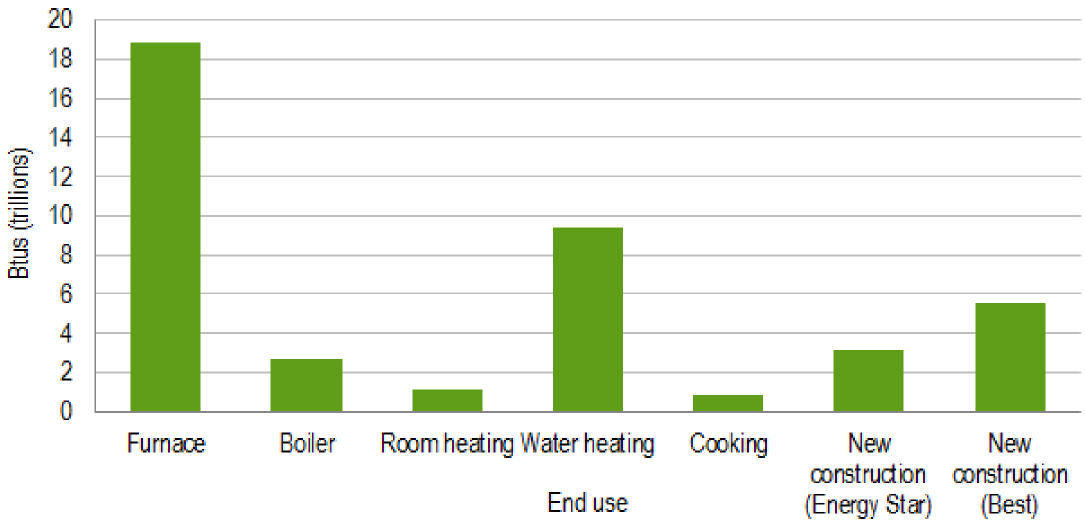
Plug loads also have very high potential for electricity savings at 502 GWh. These savings come primarily from moving to Energy Star versions of a variety of electronic equipment such as TVs, gaming systems, set-top boxes, computers, and DVD players.

Targets for plug-load improvements: In E Source's experience, energy efficiency for electronic equipment is derived primarily from programs that influence the supply chain as opposed to targeting end users. By influencing what manufacturers create and what retailers carry, significant improvement in efficiency can be created. The GEO can play a role in influencing both national and regional demand for improved efficiency in electronics.

Economic Potential for Gas Savings in Colorado

On the gas side of energy use, according to EIA data,[10] Colorado households used approximately 131 million cubic feet (ft^3) of natural gas, which roughly translates to 133 trillion Btus. The economic potential for gas savings is calculated by E Source to be 41.6 trillion Btus, which is almost 31 percent of all current natural gas use for households in Colorado (total gas figure excludes propane). **Figure 20** shows how this savings potential breaks down by end-use area.

FIGURE 20: Gas economical potential by end use



© E Source; data from The Nielsen Company 2009–2011 energy surveys

Gas Heating

With 22.7 trillion Btu gas savings potential, home heating offers the area of largest energy reduction. Heating improvements are primarily derived from increasing the efficiency of gas furnaces and boilers, and through better weatherization.

Targets for heating improvements: Single-family, owner-occupied homes that are larger than 1,000 ft^2 are the best targets for heating improvements. The age of a home is not a significant driver for a homeowner's participation in utility equipment rebate programs according to The Nielsen Company survey results, although the potential for savings is higher as homes get larger. It is critical to work with contractors and vendors during the purchase process to ensure that central heating units are the highest efficiency possible.

Gas Water Heating

Water heating also offers substantial savings opportunities for improvement at 9.4 trillion Btu. This is primarily accomplished through installing high-efficiency water heaters or tankless water heaters, supplemented by smaller savings for retrofitting showerheads and faucets with low-flow fixtures.

Targets for water heating improvements are essentially the same as for gas heating.

Low-Income and Multifamily Market Sector Potential

Because they lack the ability to invest in most energy-efficiency measures, low-income customers have special needs when it comes to energy-efficiency improvements. E Source's data show that activity in the past few years with the low-income sector has been quite high for weatherization, for example. The GEO has attractive programs for weatherization, and the potential for savings is high. Overall, the economic potential for the low-income sector represents about 16 percent savings on the gas side, and 16 percent savings on the electricity side.

In addition, much of the low-income potential lies in target markets outside of the weatherization retrofits that have historically made up the core of U.S. federal and state low-income programs. Savings in low-income new construction comprise 16 percent of electricity and 22 percent of natural gas and propane potential. And savings in replacement HVAC and appliance purchases constitute 33 percent of electricity and 39 percent of natural gas and propane potential.

Accounting for more rentals, multifamily households are also a special sector. These homes require landlord involvement for building upgrades, and the building shell matters less than the plug loads for overall energy use. Multifamily households take less advantage of appliance and equipment rebate programs than single-family households. However, interest in efficiency is high, as highlighted by these households' high use of both online and in home energy audits. Overall, the economic potential for multifamily households is about 16 percent on both the gas and electricity sides.

Opportunities for Emerging Technologies

The economic potential numbers outlined above exclude efficiency measures that are not cost-effective to pursue, although not all efficiency improvements are made solely on the basis of economics. For example, window replacements are a favorite upgrade for homeowners, yet they rarely pay back the cost purely on energy savings. Other efficiency decisions could be made based on improved comfort, home value, or environmental stewardship.

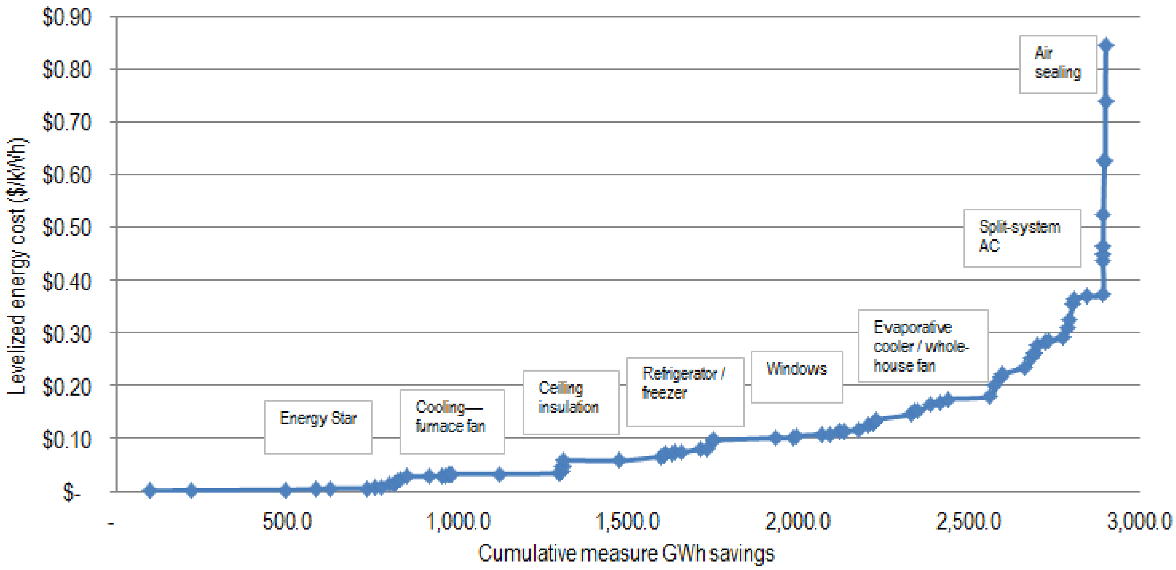
Some of the efficiency measures that could provide substantial savings but are too expensive today include gas-condensing water heaters, tankless water heaters, certain window upgrades, weatherization for houses that have some existing insulation (but are not meeting current building codes), very efficient air conditioners, ground-source heat pumps, indirect evaporative coolers, and LED lighting.

In addition, a range of measures included in the economic potential are not yet making substantial inroads with residential purchase decisions or in utility energy-efficiency programs. Examples include heat pump water heaters, evaporative cooling systems, convection ovens, whole-house fans, solar screens, and improved installation and maintenance for HVAC equipment.

Sample Energy-Efficiency Supply Curves

Figure 21 provides a supply curve for electricity energy-efficiency improvements in the Xcel service area. This graphic shows the total technical potential against the cost of implementing those measures. The measures on the left side of the curve are highly cost-effective, but as the savings measures move to the right, they get more expensive. The total savings potential is graphed along the x-axis. **Figure 22** shows a similar supply curve for gas-efficiency improvements. By drawing a horizontal line at the price of the avoided cost of supply, one can make an estimate of those measures that are cost-effective under local conditions.

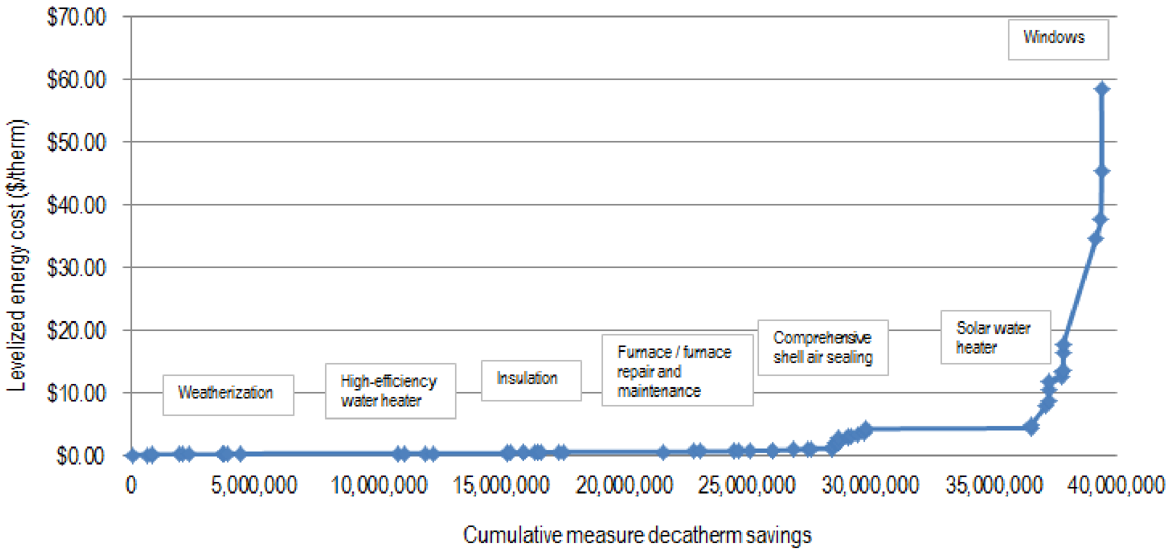
FIGURE 21: Supply curve (electric)



Note: GWh = gigawatt-hour; kWh = kilowatt-hour.
For Xcel territory only.

© E Source; data from Xcel Energy

FIGURE 22: Supply curve (natural gas)



Note: For Xcel territory only.

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BEHAVIOR-CHANGE PROGRAMS FOR ENERGY SAVINGS

Historically, energy-efficiency programs have been highly dependent upon equipment change-outs, such as lighting and HVAC retrofits. For utilities, this approach allowed system planners to feel secure in the amount of savings the programs would receive so that planning on the supply side could be altered. However, there is substantial evidence that savings from areas such as building tune-ups, improved controls, and behavior change of occupants can also have substantial effects on energy use. In this section, a brief overview of behavior-change programs is presented. These programs were virtually nonexistent four years ago in the energy world, but are now an area of great interest. One catalyst for behavior-change programs is the availability of additional consumption information through smart meters, as well as more-advanced billing and demographic data analysis, and easier presentation of information through the web.

Mixing and matching techniques, energy companies are testing and implementing several types of behavior-change programs, none of which fit neatly into categories. General areas are described below, along with estimates of energy savings seen to date. Virtually all of these programs are residential focused.

Web-based portals. Several companies have created web portals that provide a wide variety of information and engagement. These portals may offer energy-use feedback, provide comparisons of energy use with neighbors, present customized tips for energy savings, enable visitors to sign up for energy teams, or even offer games, contests, and prizes. One portal from Grounded Power (now part of Tendril) was evaluated after the Cape Light Compact feedback pilot project. This 2009 to 2010 pilot relied on advanced metering infrastructure (AMI) feedback on energy use that customers accessed through a web portal. Results indicate significant energy savings of 9.3 percent compared to both control groups;[11] these savings are higher than normally expected, but not unreasonable given a highly motivated group of participants as well as sound program design. Another portal, Efficiency 2.0, claims that engagement on its website drives energy savings of about 6 percent on average.[12] The state of Utah also has a concise table of different portal and energy report vendors.

Home energy reports. Data show that sending a periodic letter to a household that compares its energy use to a selected peer group of neighbors can drive energy savings. Though some utilities are designing their own home energy reports, OPOWER (formerly Positive Energy) is a notable private-sector presence that has popularized a proprietary behavioral tool. However, there is an optional web portal in the latest version of OPOWER's programs, so again, hybrid approaches are common with behavioral programs.

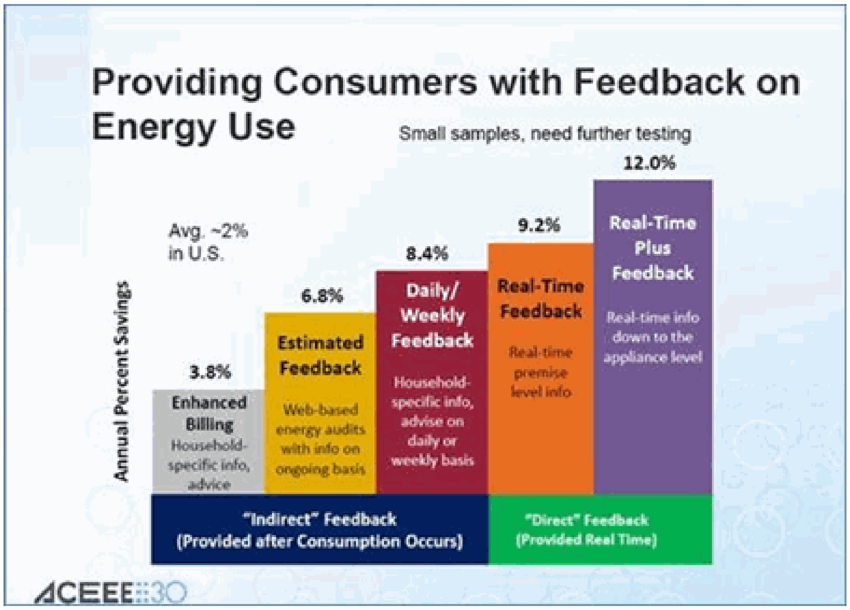
There are many evaluations available on the OPOWER website, but typical savings from home energy reports tend to be in the 1.8 to 2.0 percent area.[13, 14]

AMI feedback through IHDs. Many feedback programs using in-home displays (IHDs) are designed to reduce peak demand as well as save energy overall. Most of the IHD research and evaluation has been done on the Blue Line PowerCost Monitor. In one Massachusetts pilot, participants' bills were analyzed before and after their use of an IHD. Results showed savings, on average, of nearly 3 percent.[15]

Gaming and feedback. To collect energy-use information from its customers, San Diego Gas & Electric (SDG&E) integrated social gaming with its feedback program in a three-month pilot contest called the Biggest Energy Saver. The social gaming interface was created by Simple Energy, and the energy feedback interface was designed by Tendril. SDG&E reported that San Diego participants who used the social gaming application integrated with the automated control device saved, on average, 20 percent, whereas those who used the feedback devices alone only saved 9 percent.[16]

Summary of savings from feedback. The American Council for an Energy-Efficient Economy conducted a meta-analysis of a wide variety of behavior-change and feedback program evaluations.[17] **Figure 23** provides a shorthand visual summary of expected savings ranges from different types of feedback programs.

FIGURE 23



Courtesy: ACEEE

This large research review included pilots from around the world, therefore, some of the data requires caveats. For example, enhanced billing (a form of indirect feedback) generates around 2 percent savings in U.S.-based studies. Other feedback that is estimated or provided more frequently (for example, daily or weekly) generates more savings—between 6 and 9 percent. Real-time feedback tends to get the highest savings, but these pilots are less numerous and therefore the savings range is less reliable. However, the general principle illustrated here is that providing feedback closer in time to when customers actually use energy is more likely to create savings behaviors.

EXEMPLARY ENERGY-EFFICIENCY PROGRAMS

There are several exemplary case studies in the marketplace today that highlight best practices in energy-efficiency program design and implementation. For example, in the area of weatherization, Xcel Energy's Energy Star–qualified homes program achieved a 40 percent market penetration in Colorado, earning Xcel the prestigious Energy Star Partner of the Year award. In the area of plug load and consumer electronic programs, California's IOUs partner with many more retailers than the utilities highlighted below, and earn much higher energy and demand savings. However, the case studies selected below are utilities that E Source believes demonstrate excellence in their energy-efficiency program methodology and, in some cases, are similar in size and structure to the Colorado marketplace. One case study was selected for each major energy-efficiency area for the residential sector.

Weatherization and HPwES

New Jersey's Clean Energy Program: HPwES

Developed by the New Jersey Board of Public Utilities, New Jersey's Clean Energy Program (NJCEP) launched a Home Performance with Energy Star (HPwES) program to its 7,111,130 customers who achieved exemplary market traction.[18] In 2009, the organization's budget was $25.8 million to roll out an impressive program that required a short ramp-up time complemented by attractive incentives. This program resulted in energy savings of up to 25 percent in homes that conducted the highest amount of retrofit work. NJCEP's methodology changed over the course of its rollout and has now landed on a methodology that delivers results:

- NJCEP learned that reporting requirements were a burden for contractors. The organization began offering $175 cash incentives for each set of audit paperwork that motivated the contractors.
- NJCEP expedited incentive processing and stays close to contractors by conducting two conference calls per month to conduct updates and review quality assurance issues.
- Contractor incentives include $175 for every audit reported, 50 percent subsidy to help certified contractors purchase equipment, 75 percent reimbursement of Building Performance Institute fees and training registration fees, and rebate of 10 percent of total work scope up to $1,400.
- Homeowner incentives include an audit discount of $125 ($300 value); a rebate if there are over $2,000 of improvements; and a tiered rebate system where Tier 1 includes $1,000 worth of free air sealing, Tier 2 includes 10.0 percent cash rebate up to $2,000 or 5.0 percent interest loan if estimated heating savings are between 5.0 and 25.0 percent, and Tier 3 includes a 50 percent cash rebate up to $10,000 or 0.0 percent interest loan if estimated heating savings are greater than 25.0 percent.

NJCEP continues to provide great incentives to both contractors and homeowners. All subsidies, rebates, and reimbursements are driving factors for contractor recruitment and participation in the program. These incentives have become so important, in fact, that in 2008, the program only saw 163 completions, but in 2009, completed retrofits reached 1,138. In addition, between those two years, there was significant uptick in participation in the top-level rebate: Over 90 percent of completed jobs have included the subsidized air-sealing incentive.

HVAC

Arizona Public Service

Best practices surrounding HVAC programs involve offering quality installation (QI) measures, providing incentives, and training contractors to ensure equipment right-sizing, proper installation, and duct testing and sealing. According to E Source research, Arizona Public Service (APS) has done a notable job with its HVAC programs.[19]

APS Residential Existing Homes Heating, Ventilation, and Air Conditioning ("Residential HVAC") program is divided between HVAC measures and HPwES. Focusing primarily on the HVAC side of the program, APS provides financial incentives, customer education, and contractor training to ensure proper HVAC installation. Some of the highlights of the program's methodology include:

- A QI measure increases standards on air-conditioning sizing, airflow, and refrigerant charge to ensure high levels of efficiency during operation.
- Duct test and repair measures offer financial incentives to customers who have their equipment tested for leakage and then repaired as necessary.
- A total of 7,142 rebates were paid through the HVAC portion of the program, including a $50 incentive to the contractor.
- 610 contractors participated in APS-sponsored training courses in order to meet APS Qualified Contractor program training requirements.
- From July through December 2010, 50,789 unique user visits were reported to the APS Energy Survey home energy audit at aps.com.

The qualities of the program listed above had a significant impact on participation and savings opportunities. APS's 2010 energy-efficiency implementation plan anticipated that the HVAC portion of the program could reduce peak demand by approximately 6.7 megawatts. The utility also predicted that consumption could be reduced by 7,700 megawatt-hours (MWh) annually and 105,300 MWh over the life of the measures expected to be installed in 2010 (**Table 4**).

TABLE 4

Incentive type	Number of units	Annual kWh savings per unit	Total annual MWh savings	Estimated measure life	Total lifetime MWh	Coin. kW demand savings per unit	Total MW savings
Duct test and repair	9 07	1,042	9 45	10	9,451	1.294	1 .2
13 SEER / 10.8 EER with QI, $175	8 07	510	412	15	6174	.436	0.4
14 to 16 SEER / 10.8 EER with QI, $425	4,771	791	3,774	15	56,608	.616	2.9
17or more SEER / 10.8 EER with QI, $425	657	1,260	828	15	12,417	.997	0.7

Notes: EER = energy-efficiency ratio; kWh = kilowatt-hour; MW = megawatt; MWh = megawatt-hour; QI = quality installation; SEER = seasonal energy-efficiency ratio.

© E Source; data from APS

Plug Loads and Consumer Electronics

NV Energy

E Source has found that best practices around plug-load programs typically target the retailers, distributors, and manufacturers. E Source chose NV Energy's program as an example to highlight because its service territory is similar to many utilities within Colorado in terms of demographics and size.[20]

Point-of-sale incentives and point-of-sale marketing materials appear to have the greatest effects on consumer awareness and program sign-ups. The Consumer Electronics and Plug Loads program from NV Energy is a midstream and upstream incentive program that tries to move the entire market toward more-efficient options. NV Energy leverages relationships with retailers and equipment manufacturers to influence supply-chain vendors and manufacturers by encouraging retailers purchase a large percentage of high-efficiency appliances and equipment. Because they change rapidly, and slow movement can result in lost efficiency opportunities, it's critical to stay one step ahead of the electronics and plug-load markets. Managing several hundred thousand transactions each year, NV Energy's online incentive processing system integrates with the retailer and manufacturers' data systems to ensure ease of use and consistent reliability.

Launched in September 2010, the program has seen participation from the following retailers:

- Best Buy
- Wal-Mart

- Costco
- Sam's Club
- Sears
- Target

Additionally, the following products qualified for the program in 2010:

- Televisions that exceed Energy Star 4.1 requirements
- Televisions that exceed Energy Star 5.1 requirements
- Energy Star 5.0 computers
- Computer monitors that exceed Energy Star 5.0 requirements by at least 10 percent

Table 5 provides the verified quantities of units for which NV Energy provided incentives through the Consumer Electronics and Plug Loads program during the 2010 program year. The program achieved annual energy savings of 6,128,187 kWh and peak demand reduction of 922 kW.

TABLE 5

	Target	Actual	Percentage of target
Budget	$742,000	$541,041	73
Demand savings (kW)	698	922	132
Energy savings (kWh)	2,514,945	6,128,187	244
Total resource cost-effectiveness	2.43	3.99	164

Notes: kW = kilowatt; kWh = kilowatt-hour. © E Source; data from NV Energy

Energy savings per measure are summarized in the energy impact summary table (**Table 6**).

TABLE 6

Unit type	Energy savings realized in 2010 (kWh)	Annual energy savings (kWh)		Effective useful life (years)	Lifetime energy savings (kWh)	
	Verified	Ex ante	Verified		Ex ante	Verified
Energy Star 4.1 TVs	391,391	3,932,015	4,052,955	10	39,320,150	40,529,550
Energy Star 5.1 TVs	192,707	1,807,026	1,995,532	10	18,070,260	19,955,320
Desktop computers	3,460	43,992	35,833	5	219,960	179,165
Monitors	4,236	43,867	43,867	5	219,335	219,335
Total	591,794	5,826,900	6,128,187		57,829,705	60,883,370

Note: kWh = kilowatt-hour. © E Source; data from NV Energy

Lighting

Puget Sound Energy

There are still tremendous opportunities for energy savings in residential lighting. Effective marketing seems to push certain utilities to the top when it comes to distribution and impacts around CFLs. One great example is Puget Sound Energy (PSE).[21]

In addition to web promotions, bill inserts, and e-mail marketing, PSE advertised its Rock the Bulb campaign through retail stores and door-to-door canvassing via Project Porchlight. E Source believes Rock the Bulb was a success because the utility used behavioral tactics as well as creative strategies to raise customer awareness. This approach helped strengthen PSE's brand and became an important tool that the utility could use in designing rebate- , incentive- , and behavioral programs. The results indicate that the approach was indeed successful:

- Large participation in contests and events
- 275,000 CFLs distributed door to door and through community events
- Increase in sales of Energy Star–qualified products at sponsoring retailers' locations
- Required trade-in of an incandescent bulb to help ensure energy savings
- 16 two-day retail events (Lowe's and Ace Hardware)
- "Be an Energy Rock Star" contest which, earned points for:
    - Exchanging bulbs
    - Visiting event stations
    - Taking the Energy Star pledge
    - Recruiting friends and family
    - Reducing energy use
    - Volunteering for Project Porchlight
- Prizes for the contest:
    - Grand prize: $7,500 hardware store gift card, plus home energy audit
    - Two second-place prizes: $2,500 hardware store gift card, plus home energy audit
    - 65 third-place prizes: $500 hardware store gift card
- Golden Bulb promotion
    - 20 bulbs hidden with "bulb keepers"
    - Clues sent via social media
    - Award: $250 hardware store gift card

With its diverse and innovative marketing methods, PSE's Rock the Bulb program has received high praise for successfully interesting customers in CFLs. In only a few months in 2009, Rock the Bulb distributed nearly 500,000 CFLs but only claimed savings (7,422,426 kWh) for the 224,922 directly installed CFLs. This campaign also proved cost-effective with a total resource cost of 2.27 as compared to 3.00 for the utility's regular CFL rebate program. PSE distributed nearly half a million bulbs in a very short time frame, and this campaign-based model can be scaled to different utility sizes.

EMERGING TECHNOLOGY

The assessments provided in the technical and economic potential sections of this report assume a moderate advancement of energy-efficiency improvement in technology over time. However, some emerging technologies could potentially provide more-substantial leaps in efficiency, but they are not yet market ready. These technologies should be watched carefully, as sometimes influences through the government or utilities can have a profound effect on the success of new products.

Residential Cooling: Ductless Mini-Split Air-Conditioning Systems

While traditional air-conditioning has seen steady efficiency improvements over time, new approaches may be able to further enhance savings. Although ductless split systems can save energy and demand through several mechanisms, the large variability inherent in these savings mechanisms and a lack of field studies to quantify savings make it difficult to project what potential these units offer. Unlike unitary air conditioners, which distribute cooled air through ductwork, ductless split systems have no ductwork and distribute cooled refrigerant from the outdoor condenser coil to at least one combined indoor evaporator and fan assembly. Systems with only one indoor assembly are often called mini-splits, while systems with multiple indoor assemblies are called multi-splits.[22]

The split configuration saves energy in several ways.

Eliminating duct losses. Ducts allow energy loss through air leakage at duct joints as well as through conduction, convection, and radiation through the duct material. These losses become particularly important where ducts are run through unconditioned spaces.

- *Enabling zone control.* It's much easier to turn off cooling for unused spaces with ductless split systems than with unitary equipment.
- *Eliminating SEER degradation due to duct static pressure.* Both unitary systems and ductless split systems include fan energy use in their seasonal energy-efficiency ratio (SEER) ratings, so theoretically, identical SEER ratings would mean identical energy use. But in practice, ducts often have a higher static pressure than the SEER rating assumes, therefore, a ducted system's efficiency in the field is typically lower than rated. Ductless systems don't have this problem. Also, because many factors

affect the peak draw of unitary equipment, it's still unclear whether choosing a ductless split system over a unitary system with the same SEER would reduce demand.

Heat Pump Water Heaters

Heat pump water heaters are more viable in warmer climates unlike Colorado, but they are an interesting technology to watch.[23] Residential heat pump water heaters (HPWHs) are in the midst of a significant resurgence and have the potential to save consumers substantial amounts of energy—if they are installed and used correctly. HPWHs are more complex than traditional water heaters, have a cooling effect on the surrounding environment, and offer savings that can vary based on a number of factors. For these reasons, the increasing presence of these units in the marketplace will have many ramifications for utilities that are interested in creating programs around water heating efficiency, demand response, or load shifting.

In essence, HPWHs work by pulling heat out of the surrounding air using a reverse-refrigeration cycle. By using the heat pump whenever possible, along with a backup electric heating element to meet peak demands, HPWHs can yield dramatic savings relative to a standard electric or gas tank water heater—in many cases, cutting water heater energy consumption by more than half. However, because HPWHs interact with the environment around them, the control system must determine when to run the heat pump and when to use the electric heating element instead. Operationally, HPWHs tend to be much more complex than a typical water heating unit—they have sophisticated onboard controls and require the proper configuration of a number of different settings to achieve expected savings levels.

Although the underlying technology has been around for decades, HPWHs have historically been plagued by a variety of problems. Often, HPWHs were set up and installed incorrectly simply due to negligence or ignorance on the part of the installer; the high up-front costs limited the number of installed units and reduced the opportunity for technicians to become practiced with the technology. Even when the units were installed correctly, the systems' complexity meant that malfunctions were relatively common and few people knew how to properly service them. With low sales numbers (largely as a result of these types of problems), manufacturers did relatively little to promote better trade-ally education or to develop more-robust technology, and HPWH adoption rapidly declined.

Fortunately, the development of Energy Star certification criteria, increasing U.S. federal efficiency standards, and a widespread desire for improved efficiency on the part of utilities and end users alike has led to a reinvigorated production effort by manufacturers, and many of these lingering problems are finally being addressed. Though there were no integrated residential HPWHs on the market as recently as 2007, 34 models from 18 different manufacturers have achieved Energy Star qualification at the time of this writing, and manufacturers are working to develop even more.

In addition, the federal standards will help to ensure that HPWHs don't fade away as they have in the past. As of April 16, 2015, all residential electric water heaters with a capacity greater than 55 gallons will be required to have an energy factor of 1.96 or higher (the specified energy factor varies based on tank volume), which effectively mandates the use of HPWHs because traditional water heaters can only achieve energy factors of less than 1.0. Although the number of installations affected by this legislation will be relatively small, it appears that this is a first step toward the development of more-comprehensive federal standards with a much larger impact. In any case, this legislation should serve as an indicator to utilities that HPWHs—at least those in larger sizes—are here to stay. Some issues with HPWHs to keep in mind include:

- *Effect on heating and cooling loads.* Because HPWHs draw energy out of the surrounding air, they have a net cooling effect wherever they are installed. This means that although HPWHs can provide a significant extra benefit for customers in hot climates, in cold climates, customers' space-heating systems may have to work even harder to maintain comfortable conditions if the unit is installed in conditioned space, thereby eliminating any net energy savings. For this reason, the northern climate HPWH specifications recently released by the Northwest Energy Efficiency Alliance mandate that all qualifying HPWH models provide configuration options for semi-conditioned spaces such as unheated basements and unconditioned spaces such as garages or crawl spaces.
- *Cost.* HPWHs currently cost two or three times as much as standard tank water heaters, so if customers decide (or are forced due to federal standards) to purchase a new HPWH, they may have to incur significant costs to do so. Utilities can help customers overcome the cost barrier by offering incentives.
- *Space requirements.* Not only do HPWHs tend to be slightly bigger than comparable tank water heaters, they also need enough air circulation to perform as designed. Depending on the application, in a retrofit scenario, these units may be able to fit into the footprint of an existing tank water heater, but they may need to be installed in a new location.

Despite all of these complicating factors, it's important to remember that HPWHs can nonetheless yield tremendous savings and may be good candidates for utility incentive programs.

LEDs for Residential Applications

LEDs are becoming cost-effective in a growing number of residential applications.[24] For example, LEDs are gaining ground in kitchen under-cabinet lighting, shelf-mounted under-cabinet lighting, portable desk or task lamps, outdoor wall-mounted porch lights, outdoor step illumination, and outdoor pathway lighting. These applications are all covered by Energy Star ratings—indicating that Energy Star program managers believe that they are ready, or nearly so, for the market. Several promising near-term applications are on the horizon for the residential sector.

Recessed downlighting. Because LEDs offer longer lifetimes, they're a welcome solution for homeowners who need to access recessed cans that are located in areas where changing bulbs can be cumbersome. In addition, LEDs are more efficient and offer better dimming capabilities than CFLs.

A-lamps. LEDs that provide light equal to that of a 60-watt (W) incandescent are readily available; a few 75-W products are now on the shelves, and 100-W equivalents may make it to market within a year. These lamps are pricey but can pay for themselves in energy savings and reduced replacements costs over their useful life. Products vary widely in color quality, dimming capabilities, and light distribution.

Outdoor lighting. Porch lamps, landscape lights, and architectural lighting can be illuminated for many hours, so these are great applications for LEDS, and their payback times may be accelerated.

Task lighting. LEDs deliver higher efficiencies than incandescent bulbs, can more effectively direct the light to where it's needed, and have much longer lifetimes. For applications like desk lighting and under-cabinet lighting, LEDs are a better solution than traditional incandescent lights and CFLs.

LED lamps are changing rapidly, so it's important to keep abreast of the evolution in efficiency and efficacy of these lamps, as well as the economics.

CONCLUSION

Colorado's residential sector holds great potential for increased energy efficiency. Analysis on the electricity side shows a cost-effective savings potential of almost 29 percent of current usage, assuming a 10-year planning horizon. Analysis on the gas side predicts economic savings of around 31 percent of current usage. In E Source's review of DSM plans and accomplishments across the U.S., the most aggressive states are trying to achieve just above 2 percent savings per year through utility programs. Other states in the middle tier, which includes Colorado, have utilities that are aiming to achieve closer to 1 percent savings per year. Clearly, there is a large gap in planned savings versus potential savings. In addition, many utilities in Colorado aren't offering aggressive DSM programs at all, leaving a larger gap.

This study concludes that no single element provides a silver bullet for residential energy savings. To realize its savings potential, Colorado must go after many areas of energy efficiency, including:

- *Efficient lighting.* Almost 50 million Colorado light sockets are available for improvements from incandescent lamps to CFLs or LEDs.
- *Building-shell improvements.* Nearly 700,000 homes need upgrades of insulation levels, air sealing, and more-efficient windows.
- *Plug-load efficiency and management improvements*. Appliances and other electronics account for nearly 25 percent of electricity use. High savings potential can be achieved by encouraging residents to retire old and second refrigerators and

freezers, promoting Energy Star models, and helping households manage their electronics energy use through behavioral and automated methods.

- *Heating and cooling equipment improvements.* Higher-efficiency air conditioning will rise to SEER 17 and beyond in upcoming years, and gas furnaces with efficiencies above 90 percent are readily available.

Targeting the best households for savings is also important. Our analysis shows that owner-occupied, single-family homes are the best initial targets for efficiency programs, but all types of households hold potential for efficiency improvements. With proper targeting and messaging, most Colorado residents can find opportunities for energy and dollar savings.

APPENDIX A

Although the E Source and Nielsen data provided a statistically valid sample for Colorado, we wanted to ensure that all segments of the population were appropriately represented. To that end, E Source made the following adjustments and allowances for the study.

Weighting the Data

Taken from the larger Nielsen energy survey sample, the Colorado sample offered demographic characteristics that we compared to those from the 2010 U.S. Census estimates for adults living in Colorado. We weighted the Colorado sample results using the 2010 Census population norms to reflect the appropriate percentage of the state's adult residents. Other discrepancies between the whole population and the sample were weighted according to the intercorrelation of many socioeconomic characteristics.

The variables used for weighting were respondent age, ethnicity, and housing ownership (rent versus own). This decision was based on:

- The disparity between the survey respondent characteristics and the population norms for these variables.
- The saliency of these variables in differences of opinion among subgroups.

The primary objective of weighting survey data is to make the survey sample reflective of the larger population of the community. This is accomplished by (1) reviewing the sample demographics and comparing them to the population norms from the most recent Census, and (2) comparing the responses to different questions for demographic subgroups. The demographic characteristics that are least similar to the Census and yield the most conflicting results are the best candidates for data weighting.

Comparing to RECS

After the Colorado survey sample data was weighted, E Source compared survey results to the U.S. Energy Information Administration's Residential Energy Consumption Survey (RECS) results where questions were the same. For example, we looked at the proportion of single-family and multifamily homes, the use of programmable thermostats, and electronics saturation data. The comparisons were made to data from the preliminary 2009 RECS Public Use Microdata File for the State of Colorado, which was weighted to match the most current American Community Survey (ACS) Census data available.

Estimating Savings Potential

Following Xcel Energy's market segmentation approach and using square-footage data for the Colorado survey sample from the larger Nielsen energy audit, we segmented the data into five groups: single-family large, single-family medium, single-family small, multifamily, and low income. The proportions for each segment very closely matched Xcel's segment proportions. In addition, we compared household characteristics between urban and suburban dwellings and rural dwellings to see whether there were significant differences within a housing category. Because we discovered no large differences, the same per-household data were used statewide in the five groups. Leveraging Xcel's list of end uses, we applied the equipment and appliance saturation data from the Colorado sample of the Nielsen energy audit to the total number of occupied housing units reported by the 2010 Census for the state. In a few cases, we relied on the Xcel data when we felt they were more representative of statewide conditions.

APPENDIX B

The attached Excel file contains a list of active residential rebate programs in Colorado.

NOTES

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