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Electricity end uses, energy efficiency, and distributed energy resources baseline: *Residential Sector Chapter*

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Any remaining errors, omissions, or mischaracterizations are the responsibility of the authors.

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Scope and Organization

This report was developed by a team of analysts at Lawrence Berkeley National Laboratory, with Argonne National Laboratory contributing the transportation section, and is a DOE EPSA product and part of a series of "baseline" reports intended to inform the second installment of the Quadrennial Energy Review (QER 1.2). QER 1.2 provides a comprehensive review of the nation's electricity system and cover the current state and key trends related to the electricity system, including generation, transmission, distribution, grid operations and planning, and end use. The baseline reports provide an overview of elements of the electricity system. This report focuses on end uses, electricity consumption, electric energy efficiency, distributed energy resources (DERs) (such as demand response, distributed generation, and distributed storage), and evaluation, measurement, and verification (EM&V) methods for energy efficiency and DERs.

Chapter 1 provides context for the report and an overview of electricity consumption across all market sectors, summarizes trends for energy efficiency and DERs and their impact on electricity sales, and highlights the benefits of these resources as well as barriers to their adoption. Lastly it summarizes policies, regulations, and programs that address these barriers, highlighting crosscutting approaches, from resource standards to programs for utility customers to performance contracting.

Chapters 2 through 5 characterize end uses, electricity consumption, and energy efficiency for the residential, commercial, and industrial sectors as well as electrification of the transportation sector. Chapter 6 addresses DERs—demand response, distributed generation, and distributed storage.

Several chapters in this report include appendices with additional supporting tables, figures, and technical detail. In addition, the appendix also includes a separate section that discusses current and evolving EM&V practices for energy efficiency and DERs, approaches for conducting reliable and cost-effective evaluation, and trends likely to affect future EM&V practices.

This excerpt from the report focuses on the Residential Sector. The table of contents included here shows the detailed scope of topics in the complete report. The full report is available at https://emp.lbl.gov/publications/electricity-end-uses-energy.

Description of Energy Models[a]

Unless otherwise noted, this report provides projections between the present-day and 2040 using the "EPSA Side Case," a scenario developed using a version of the Energy Information Administration's (EIA's) National Energy Modeling System (NEMS). Since the EPSA Side Case was needed for this and other EPSA baseline reports in advance of the completion of EIA's Annual Energy Outlook (AEO) 2016, it uses data from EIA's AEO 2015 Reference Case, the most recent AEO available at the time. However, since AEO 2015 did not include some significant policy and technology developments that occurred during 2015, the EPSA Side Case was designed to reflect these changes.

The EPSA Side Case scenario was constructed using EPSA-NEMs,[b] a version of the same integrated energy system model used by EIA. The EPSA Side Case input assumptions were based mainly on the final release of the 2015 Annual Energy Outlook (AEO 2015), with a few updates that reflect current

[a] Staff from DOE's Office of Energy Policy and Systems Analysis authored this description.

[b] The version of the National Energy Modeling System (NEMS) used for the EPSA Side Case has been run by OnLocation, Inc., with input assumptions by EPSA. It uses a version of NEMS that differs from the one used by the U.S. Energy Information Administration (EIA).

technology cost and performance estimates, policies, and measures, including the Clean Power Plan and tax credits. The EPSA Side Case achieves the broad emissions reductions required by the Clean Power Plan. While states will ultimately decide how to comply with the Clean Power Plan, the Side Case assumes that states choose the mass-based state goal approach with new source complement and assumes national emission trading among the states, but does not model the Clean Energy Incentive Program because it is not yet finalized. The EPSA Side Case also includes the tax credit extensions for solar and wind passed in December 2015. In addition, cost and performance estimates for utility-scale solar and wind have been updated to reflect recent market trends and projections, and are consistent with what was ultimately used in AEO 2016. Carbon capture and storage (CCS) cost and performance estimates have also been updated to be consistent with the latest published information from the National Energy Technology Laboratory.

As with the AEO, the EPSA Side Case provides one possible scenario of energy sector demand, generation, and emissions from present day to 2040, and it does not include future policies that might be passed or unforeseen technological progress or breakthroughs. EPSA-NEMS also constructed an "EPSA Base Case" scenario, not referenced in this report, which is based primarily on the input assumptions of the AEO 2015 High Oil and Natural Gas Resource Case. Projected electricity demand values forecast by the EPSA Base Case and Side Case are very close to each other (within 3% by 2040). However, the values forecast by the EPSA Base Case are closer to those that were ultimately included in the AEO 2016 Reference Case.

EPSA Side Case data also are used when most-recent (2014) metrics are reported as a single year or are plotted with future projections. Doing so ensures consistency between current and forecasted metrics. Overlapping years between historical data and data modeled for forecasts are not necessarily equal. Historical data are revised periodically as EIA gathers better information over time, while forecasted cases, which report a few historical years, do not change once they are released to the public.

List of Acronyms and Abbreviations

Acronym / Abbreviation	Stands For
ACEEE	American Council for an Energy-Efficient Economy
AEO	Annual Energy Outlook
AMI	advanced metering infrastructure
AMO	DOE Advanced Manufacturing Office
ARRA	2009 American Recovery and Reinvestment Act
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
BEV	Battery Electric Vehicle
CAFE	Corporate Average Fuel Economy
CAISO	California ISO
CBECS	Commercial Buildings Energy Consumption Survey
CFLs	compact fluorescent lamps
CHP	Combined Heat and Power
CO^2	carbon dioxide
CPP	Clean Power Plan
CPP	Critical Peak Pricing
CPUC	California Public Utilities Commission
CSE	cost of saved energy
CUVs	crossover utility vehicles
DCLM	Direct Control Load Management
DER	Distributed Energy Resources
DOE	U.S. Department of Energy
DSM	demand side management
DSO	Distribution System Operator
EAC	DOE's Electricity Advisory Committee
EERS	energy efficiency resource standard
EIA	U.S. Energy Information Administration
EM&V	Evaluation, Measurement, and Verification
EMCS	Energy Management Control Systems
EPA	U.S. Environmental Protection Agency
EPSA	DOE Office of Energy Policy and Systems Analysis
ERCOT	Electric Reliability Council of Texas
ESCOs	energy service companies
FCTO	DOE's Fuel Cell Technology Office
FCV	Fuel Cell Vehicle
FEMP	Federal Energy Management Program
FERC	Federal Energy Regulatory Commission
FFV	Ethanol Flex-Fuel Vehicle
FITs	feed-in tariffs
FRCC	Florida Reliability Coordinating Council
GDP	gross domestic product

Acronym / Abbreviation	Stands For
GHG	greenhouse gases
GWP	global warming potential
HEVs	hybrid electric vehicles
HOV	high-occupancy vehicle
HVAC	heating, ventilation, and air-conditioning
Hz	hertz
ICEs	internal combustion engines
ICLEI	International Council for Local Environmental Initiatives
ICT	information and communication technologies
IDM	Industrial Demand Module
IECC	International Energy Conservation Code
IEMS	Industrial Energy Management Systems
IL	Interruptible Load
INL	Idaho National Laboratory
IRP	integrated resource planning
ISO	Independent System Operator
ISO-NE	ISO-New England, Inc.
ITC	investment tax credit
kWh	kilowatt-hours
LBNL	Lawrence Berkeley National Laboratory
LCOE	levelized cost of electricity
LCR	Load as a Capacity Resource
LDV	light-duty vehicle
LED	light emitting diode
LEED	Leadership in Energy and Environmental Design
Li-ion	Lithium-ion
LMP	locational marginal pricing
LR	learning rate
LSE	load serving entity
MATS	Mercury and Air Toxics Standards
MECS	Manufacturing Energy Consumption Survey
MELs	Miscellaneous Electric Loads
MISO	Midcontinent Independent System Operator
MMWh	million megawatt-hours
MRO	Midwest Reliability Organization
MRO-MAPP	Midwest Reliability Organization-Mid-Continent Area Power Pool
MUSH	municipalities, universities, schools, and hospitals
NEMS	National Energy Modeling System
NERC	North American Electricity Reliability Council
NPCC	Northeast Power Coordinating Council
NPCC-NE	NPCC-New England

Acronym / Abbreviation	Stands For
NPCC-NY	NPCC-New York
NREL	National Renewable Energy Laboratory
NYISO	New York ISO
ORNL	Oak Ridge National Laboratory
PACE	Property Assessed Clean Energy
PC	personal computer
PCTs	programmable communicating thermostats
PEV	plug-in electric vehicle
PHEV	Plug-in Hybrid Electric Vehicle
PJM	PJM Interconnection, LLC
PTC	production tax credit
PV	photovoltaic
QER	Quadrennial Energy Review
QTR	Quadrennial Technology Review
R&D	research and development
RD&D	Research, development, and deployment
RECS	Residential Energy Consumption Survey
RETI	Real estate business trust
REV	"Reforming the Energy Vision"
RFC	Reliability First Corporation
RTO	Regional Transmission Organization
RTP	real-time pricing
SDG&E	San Diego Gas and Electric
SEIA	Solar Energy Industries Association
SERC	Southeast Electric Reliability Council
SERC-E	Southeast Electric Reliability Council -East
SERC-N	Southeast Electric Reliability Council -North
SERC-SE	Southeast Electric Reliability Council -Southeast
SGIG	Smart Grid Investment Grant
SPP	Southwest Power Pool, Inc.
SSL	solid-state lighting
TBtu	trillion British thermal units
TOU	time-of-use pricing
TRE	Texas Reliability Entity
TRE-ERCOT	TRE-Electric Reliability Council of Texas
TWh	terawatt-hours
USDA	U.S. Department of Agriculture
V2B	vehicle-to-building
V2H	vehicle-to-home
VAR	volt-ampere reactive
VOS	value of shipments
VTO	DOE's Vehicle Technologies Office

Acronym / Abbreviation	Stands For
WECC	Western Electricity Coordinating Council
WECC-CA-MX	WECC-California-Mexico Power
WECC-NWPP	WECC-Northwest Power Pool
WECC-RMRG	WECC-Rocky Mountain Reserve Group
WECC-SRSG	WECC-Southwest Reserve Sharing Group
ZEV	Zero Emission Vehicle
ZNEB	Zero-Net Energy Building

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2 Residential Sector

This section discusses electricity usage and electric efficiency in the U.S. residential sector. Data on the residential sector generally comprise all "living quarters for private households,"[1] including single-family and multifamily buildings of all kinds, but excluding institutional living arrangements (which are considered part of the commercial sector). The Residential Energy Consumption Survey (RECS), a key data source for details on electricity consumption by households, classifies housing types by the number of units (see, for example, Figure 2.5). All of the data sources cited in this section of the report include housing units in large, multi-unit buildings. However, some policies and programs define the boundary between residential and commercial differently. For example, residential buildings with four or more floors must comply with commercial building energy codes, and energy efficiency program administrators generally address large residential buildings under their commercial programs if they do not have dedicated programs to address such buildings. Except where noted, "projections" in this section refer to the EPSA Side Case (see the introduction to this report for more details).

2.1 Key Findings and Insights

2.1.1 Levels and Patterns of Residential Electricity Consumption through 2040

Findings:

- Growth in national residential electricity sales has slowed significantly, but slow positive growth is projected through 2040 (Figure 2.1).
- Electricity is a large (> 40%) and growing share of national energy use in the residential sector (Figure 2.2).
- Electricity usage per capita and per square foot are declining (Figure 2.3 and Figure 2.4).

Insight: Electrical productivity is improving as measured by various metrics cited above. However, as overall load is still increasing, energy efficiency markets and policy have a key role to play in meeting energy resource and environmental goals.

Findings:

- Miscellaneous uses (largely plug loads) and air conditioning in the residential sector are growing end uses of electricity, while lighting and space heating are declining (Figure 2.7).

Insight: Residential efficiency programs and policies will need to evolve to address the drivers of future electricity consumption, which are not the same as the drivers of past consumption.

Findings:

- Low-income households spend a much greater share of their income on electricity than other households (Figure 2.11).
- The South Census Region uses more electricity per household than other regions (Section 2.2.3), and this region uses electricity for space and water heating much more than other Census regions (Figure 2.9).

Insight: Resolving the particular barriers to energy efficiency uptake in the South Census Region and among low-income households throughout the U.S. offers significant potential for achieving energy savings and improving the equity of cost burdens across consumers.

2.1.2 Status of Electric Efficiency Deployment

Findings:

- Heat pumps are a small but growing share of space-conditioning and water-heating equipment that can generate much more heat per unit of electric input than electric resistance heating. Heat pumps are most efficient in regions where winter temperatures are mild, but new technology has extended their viability into regions that reach temperatures below zero degrees Fahrenheit (Section 2.4.1).
- The South Census Region uses electricity for space and water heating much more than other regions (Figure 2.9).

Insight: Heat pumps offer a significant opportunity for electric efficiency improvement. Continued technological progress on heat pumps could facilitate even greater savings.

Findings:

- Highly advanced building envelope designs and materials exist (Figure 2.14 and Figure 2.15), but market penetration is very low. Conventional designs and materials show more incremental progress (Section 2.4.1).
- Appliance efficiency is improving, but there is still a sizeable gap between stock average efficiencies and best available technologies (Figure 2.16).
- Substantial opportunities for improving efficiency of electronics exist (Table 2.1).
- Penetration of controls and automation in the residential sector is quite low (Section 2.4.5).

Insight: Significant efficiency improvements are available through greater adoption of technologies that are available today, though cost-effectiveness of advanced technologies is often a barrier to their more widespread adoption.

Findings:

- The lighting market is transforming to much lower electricity usage due to light-emitting diodes (LEDs). A U.S. Department of Energy (DOE)-sponsored forecast projects LEDs will grow to 83% of installations and 84% of sales in 2030, saving a cumulative 25% of residential lighting electricity usage, relative to a no-LED baseline (Section 2.4.2).

Insight: A combination of technology and policy efforts has achieved great success in the lighting market, which may hold lessons for other markets for products powered by electricity. Lighting has been a mainstay of programmatic efforts. With the market in transition, the best end uses for energy efficiency programs to target will be different going forward.

2.1.3 Other Trends

Findings:

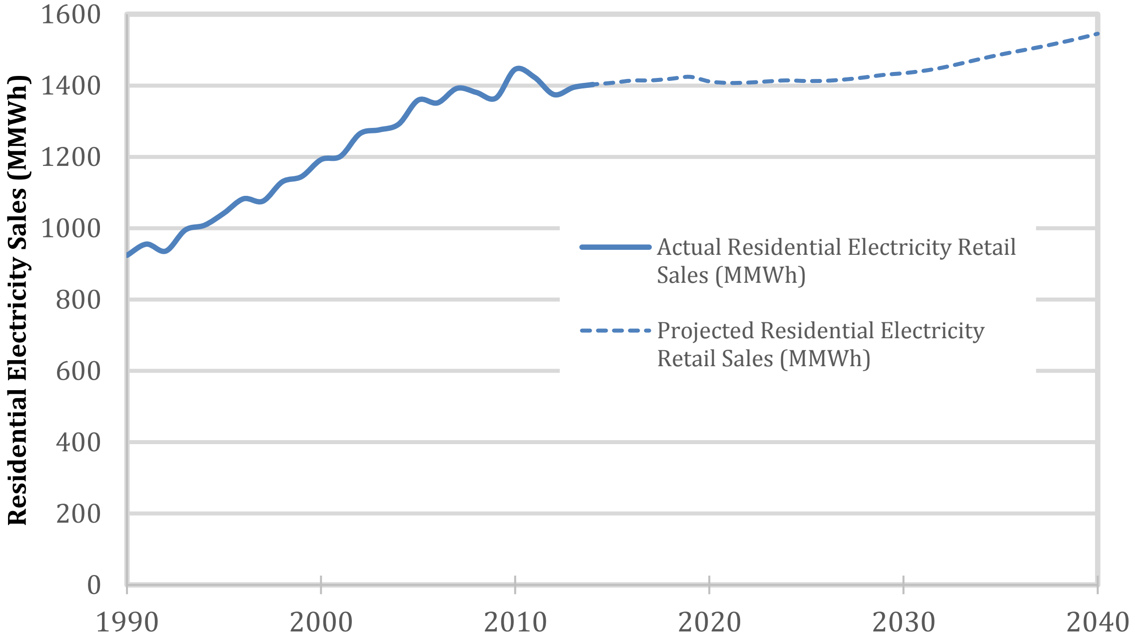
- The U.S. population is shifting to the South and West Census Regions (Section 2.2.3).
- The South Census Region, in particular, uses considerably more electricity per household than other Census regions (Figure 2.8 and 2.9).

Insight: Internal population migration is one driver of the slow but steady increase in total electricity consumption.

2.2 Characterization

Total residential electricity use generally has grown steadily since 1990 (Figure 2.1). That growth slowed in the mid-2000s,[a] [2] [3] and residential retail sales are currently lower than their peak in 2010. The *Annual Energy Outlook* (AEO) projects growth in total residential electricity sales going forward; however, the projected growth rate is lower than during the 1990s and early 2000s. The AEO projections show residential electricity sales do not reach the 2010 level again until 2032.

Figure 2.1. Residential retail electricity sales, 1990–2014 (actual) and to 2040 (projected)[4] [5]



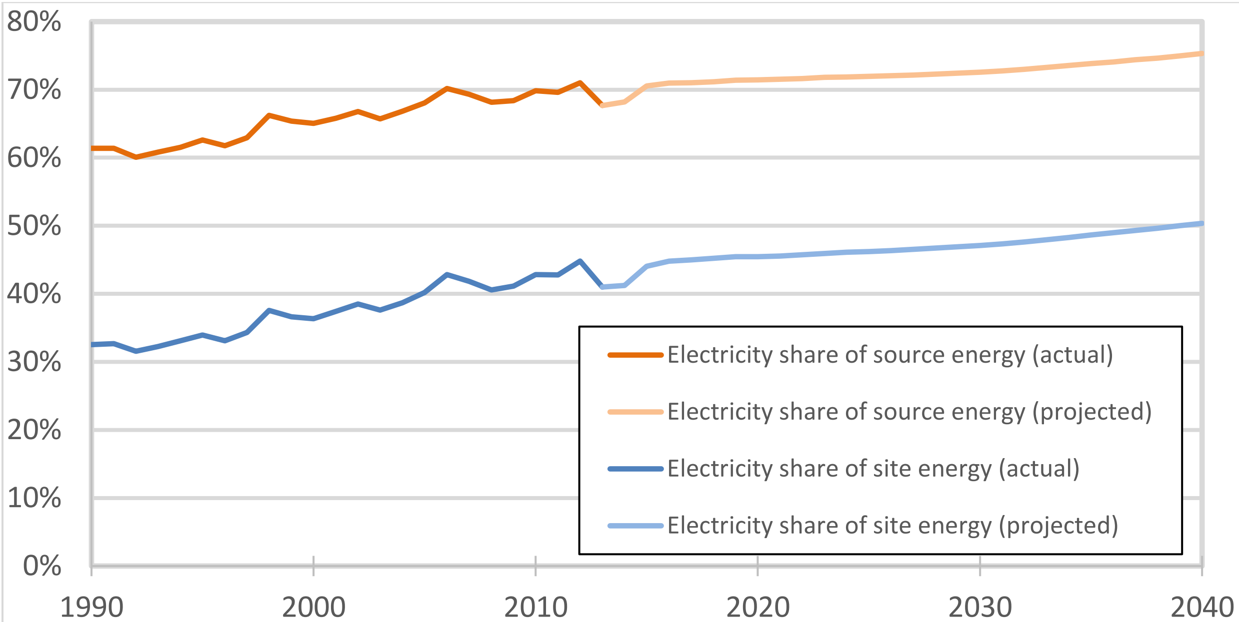
Sales grew steadily until the mid/late-2000s, when volumes rose and fell by year. Sales in the residential sector are projected to grow very slowly until the mid-2020s, then somewhat faster through 2040.

Electricity's share of total residential energy usage has also grown steadily and is projected to continue to do so (Figure 2.2). This suggests that electric end uses are growing more quickly in aggregate than end uses that are mostly powered by fuels.[b] [6] [7] [8]

[a] The economic slowdown was likely a key driver of declining consumption in 2008 and 2009. Growth had arguably begun to decrease before the slowdown, and it cannot account for falling consumption after 2010. Other potential explanations include mild weather patterns and improvements in efficiency of electric equipment and building shells

[b] Another explanation could be that space heating and water heating—the two largest end uses where electricity and other fuels are both options—are becoming increasingly dominated by electricity. However, data from the RECS do not show a clear upward trend in the fraction of space heating or water heating energy generated by electricity. The EPSA Side Case projects an increasing share of electricity for these two end uses, but the change is very modest and could explain only a small fraction of the total change in electricity share shown here.

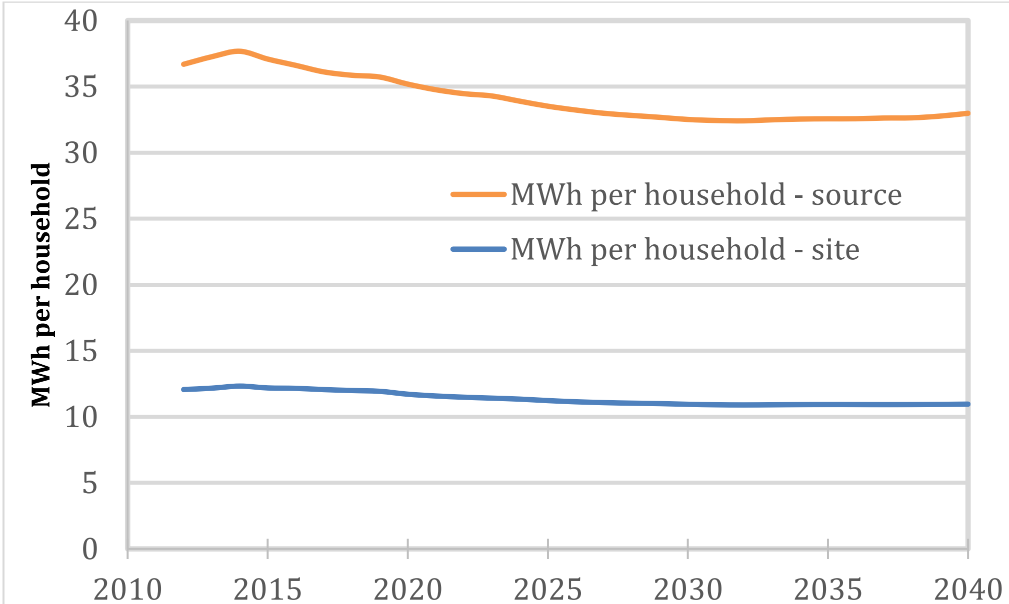
Figure 2.2. Electricity as a share of total energy use in the residential sector, 1990–2013 (actual) and to 2040 (projected)[9]



Measured as site energy (energy delivered to the building), electricity's share of energy consumption has grown over the past 25 years from about 30% to about 40% of residential energy use. Measured as source energy (including generation and line losses), the share is much higher—growing from 60% to 70% over the same time. By 2040, the electricity share of residential energy consumption is expected to exceed 50% in site terms, 75% in source terms.[10] [11]

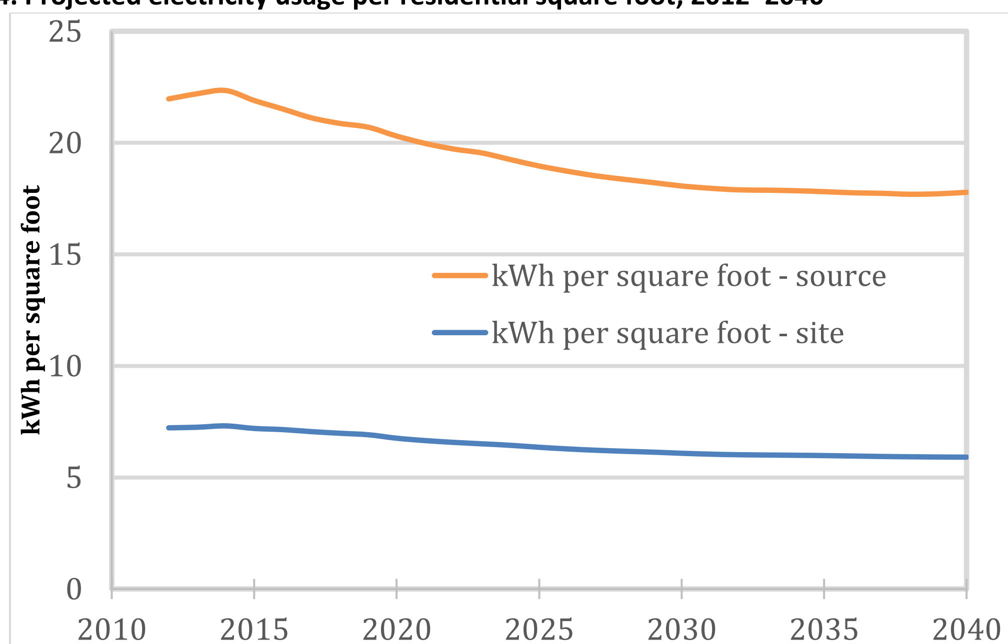
The number of U.S. households has been increasing and is projected to continue to increase. As a result, total residential electricity use is projected to rise even as electricity usage per household is projected to decline (Figure 2.3). The average size of a housing unit is also projected to increase, so electricity usage per square foot declines somewhat more rapidly (Figure 2.4). Electricity use per capita also declines, but slightly more slowly than the per-household decline, as the average household size is projected to decrease slightly. On the whole, 2040 electricity usage is projected to be 10% lower than 2013 per household, 8% lower per capita, and 18% lower per square foot.[12] By these metrics, electrical productivity in the residential sector is increasing and is projected to increase further despite growth in total electricity use.

Figure 2.3. Projected electricity usage per household, 2012–2040[13]



Electricity usage per household is projected to decline slightly in site terms, and more steeply in source terms (due to lower electricity production and line losses in the future).

Figure 2.4. Projected electricity usage per residential square foot, 2012–2040[14]



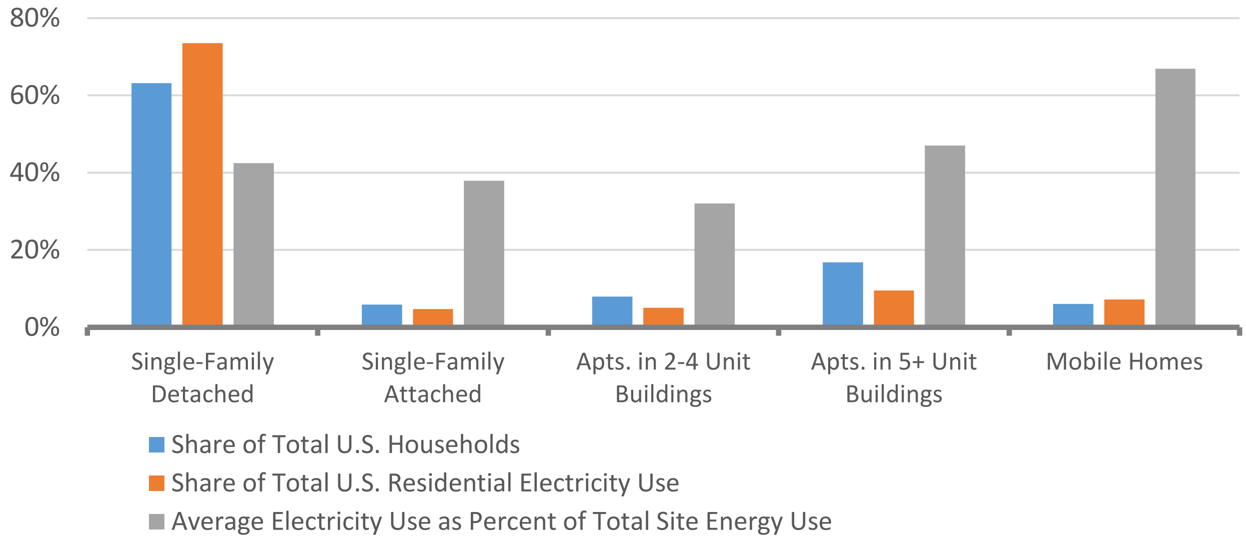
Housing units are getting larger, so, expressed per square foot, declines in electricity usage are somewhat more rapid.

2.2.1 By Housing Unit Type and Year of Construction

Single-family detached homes are by far the most common housing unit in the United States, comprising 63% of households. They also use more electricity per housing unit than most other housing types (Figure 2.5). As a result, single-family detached homes use 74% of the electricity consumed in the residential sector.[15]

Collectively, apartments in buildings with five or more units consume the second-largest share of electricity. However, even though these buildings comprise 17% of housing units, they use only 9% of total electricity. Manufactured housing is the most electricity-intensive type of housing unit. Electricity represents more than two-thirds of site energy consumed in manufactured housing. However, as manufactured housing represents a small share of the housing stock, they only consume 7% of residential electricity.

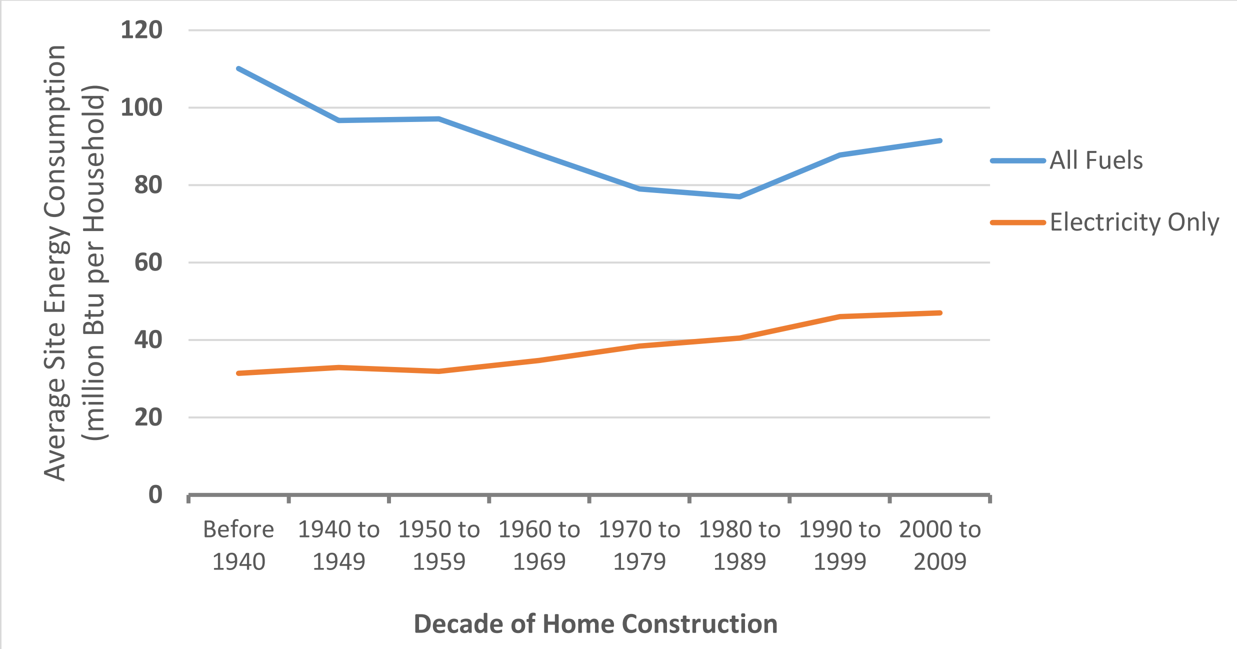
Figure 2.5. Share of Total U.S. Household and Electricity Usage, by Housing Type, 2009 [16]



Single-family detached homes use more than 70% of residential electricity. All other housing types use less electricity per household, except manufactured housing (referred to as mobile homes in the Residential Energy Consumption Survey data), for which electricity comprises a large share of total energy use. Large apartment buildings are also fairly electricity-intensive but still use much less electricity per household than single-family detached homes.

While there is no clear trend in overall *energy* usage by year of construction, newer homes clearly use more *electricity* (Figure 2.6). New homes use more energy for air conditioning, appliances, electronics, and lighting than do old homes—all categories where electricity is the dominant fuel used.[17] Conversely, new homes use less energy for space and water heating, where other fuels are common. This likely explains the trends in Figure 2.6.

Figure 2.6. Energy and electricity usage per household by year of construction[18]



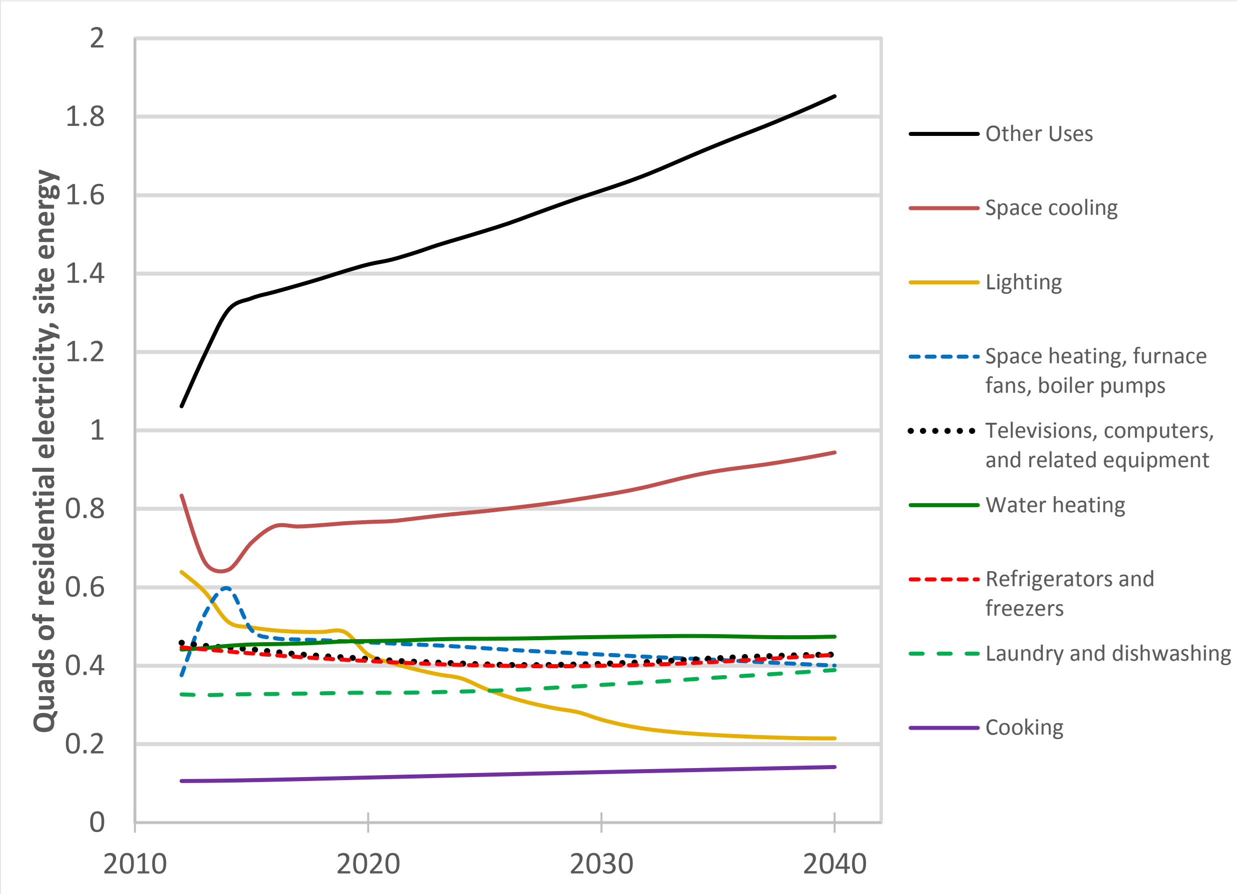
There is no clear trend in overall energy use, but electricity use is increasing with year of construction.

2.2.2 By End Use

In the U.S. Energy Information Administration's (EIA's) classification of electricity uses, "Other" uses of electricity collectively represent the largest residential electricity end use. This category is mostly miscellaneous small electronic devices, although it also includes items like fans and pool heaters (for more on Other residential end uses, see Section 2.4.4). Space cooling, space heating, and lighting are the next-largest residential end uses. Note that, for natural gas and other fuels, this distribution looks very different. These fuels are mostly used for space heating and water heating and are not commonly used for cooling, lighting, or Other uses. Also note that electricity used for home electric vehicle (EV) charging is not included in EIA's classification of residential end uses; rather, this usage is attributed to the transportation sector. For more on EV charging and residential electricity use, see Section 2.7.

Figure 2.7 shows that use of electricity for Other and space cooling is projected to grow substantially in the future. Electricity usage for space heating and lighting is projected to decline; the latter by more than half by 2040 due to increasing penetration of highly efficient lighting technologies. Expected population migration to the South and West Census Regions—regions with high cooling loads—drives much of the anticipated increase in space cooling (Section 2.3). [19] The continued profusion of miscellaneous electric loads (MELs) drives projected increases in Other uses.[20] Note that some MELs are outside the Other category in Figure 2.7. Televisions (TVs) and computers comprise their own category, and their electricity usage is projected to rise only slightly. Increased penetration of highly efficient screen technologies is reducing electricity usage from TVs and monitors, though larger screens are offsetting some of these gains in the case of TVs.[21]

Figure 2.7. Projections of residential electricity usage by end use[22]

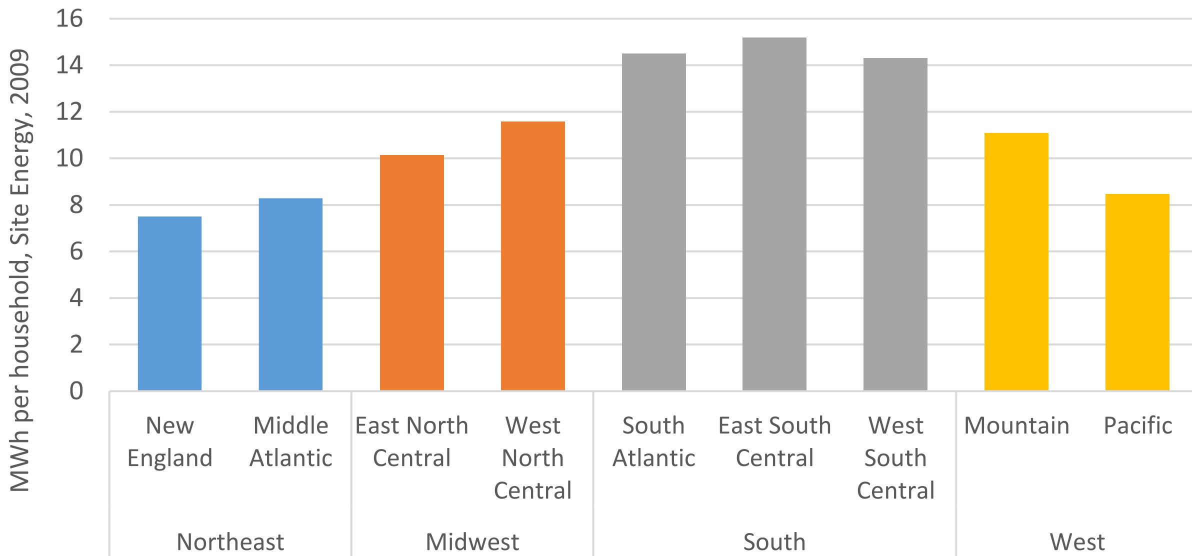


Air conditioning and Other Uses are the largest shares of electricity usage and by far the fastest growing. Lighting consumption is projected to fall by more than half. Space heating consumption is projected to decline as well.

2.2.3 By Region

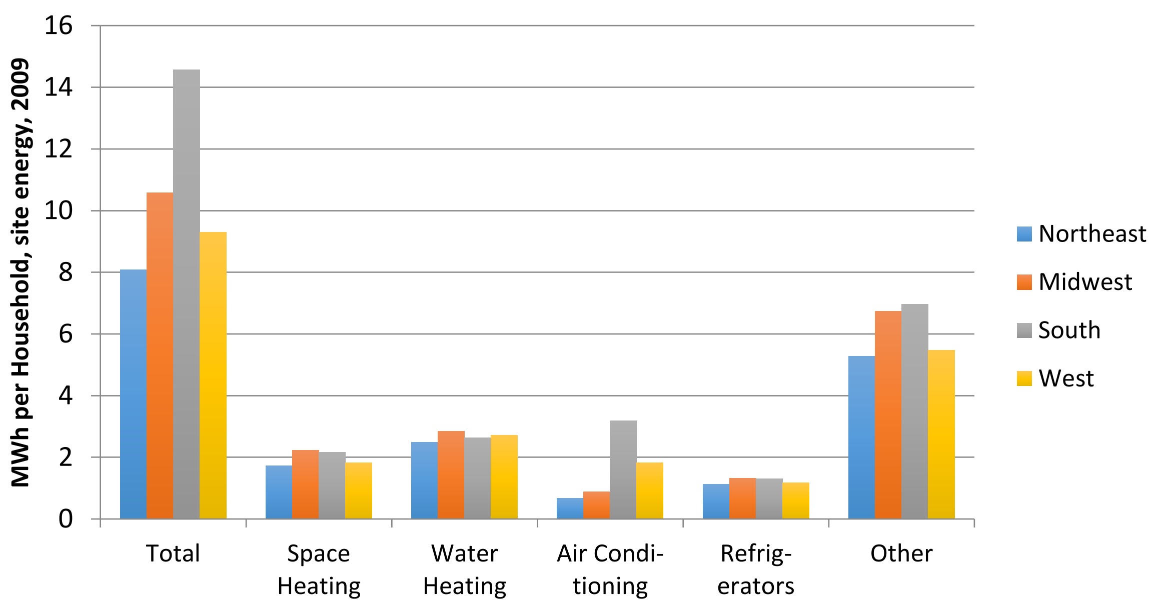
As Figure 2.8 shows, electricity usage varies substantially by region. The South Census Region uses more electricity per household than other regions, while the Northeast Census Region and the Pacific Census Division use less. Much of the variation in usage can be explained by disparities in specific end uses across Census regions (Figure 2.9). The South, and to a lesser extent the West, Census Regions have high cooling loads. Moreover, the South Census Region uses electricity for space heating much more than other regions do. Differences in housing type may also help explain these discrepancies (see Figure 2.5). The Northeast Census Region, which has low electricity consumption per household, has relatively more single-family attached homes and apartment units and fewer single-family detached homes and manufactured homes than other Regions. The Midwest Census Region, with moderate electricity consumption, is dominated by single-family homes and has few large apartment buildings. The South Census Region, with high consumption, has many manufactured homes and fewer single-family detached and small apartment buildings than other Regions. And the West Census Region, with moderate to low consumption, has a housing distribution broadly comparable to the nation as a whole.[23]

Figure 2.8. Electricity usage per household, by Census Divisions, 2009 [24]



Usage varies significantly. An average household in the East South Central Division using more than twice as much electricity as the average New England household, driven by weather and by the share of household energy use that comes from electricity.

Figure 2.9. Residential electricity usage (MWh per household) by Census Region and end use, 2009[25]

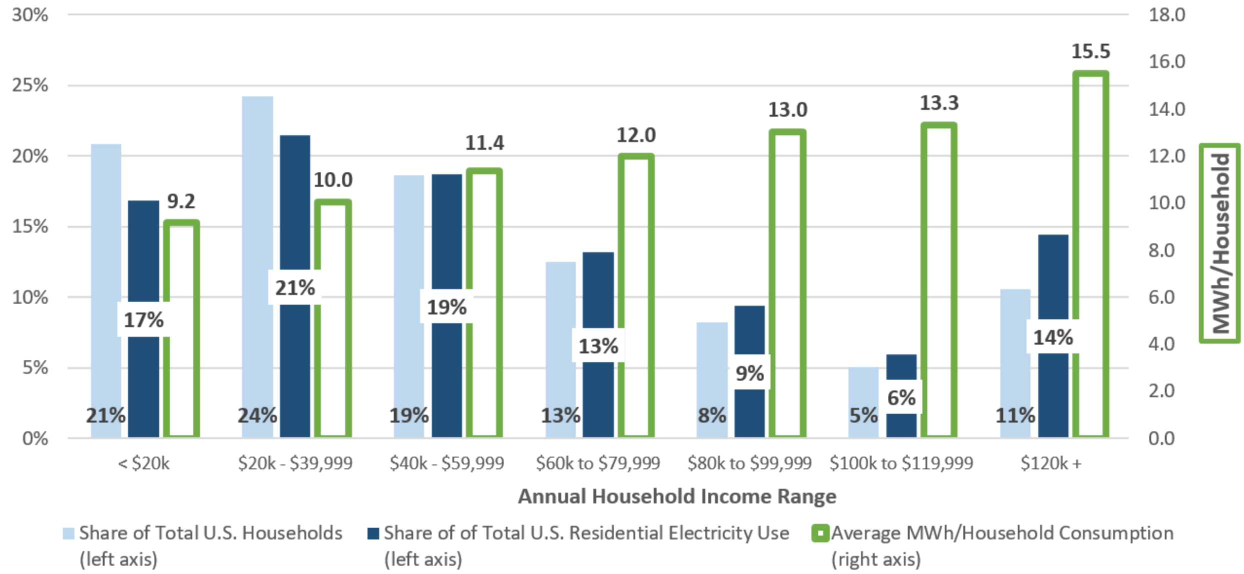


Variation in air conditioning and Other usage is significant between regions. However, the South Census Region uses a similar amount of electricity per household for space and water heating as other regions despite milder winter temperatures. Note that averages for end uses are based on the households that use electricity for that end use. For example, households that use natural gas for space or water heating are not included in the averages for those end uses.

2.2.4 By Occupant Demographics

Electricity usage increases steadily with household income (Figure 2.10 and Figure 2.11). Households with incomes above $120,000 use about 70% more electricity per household than households with incomes less than $20,000. However, low- and moderate-income households are much more numerous and collectively account for a large share of residential electricity use. Households with incomes below $60,000 collectively consume more than 60% of residential electricity.

Figure 2.10. Electricity consumption and share of U.S. households by income, 2009[26]

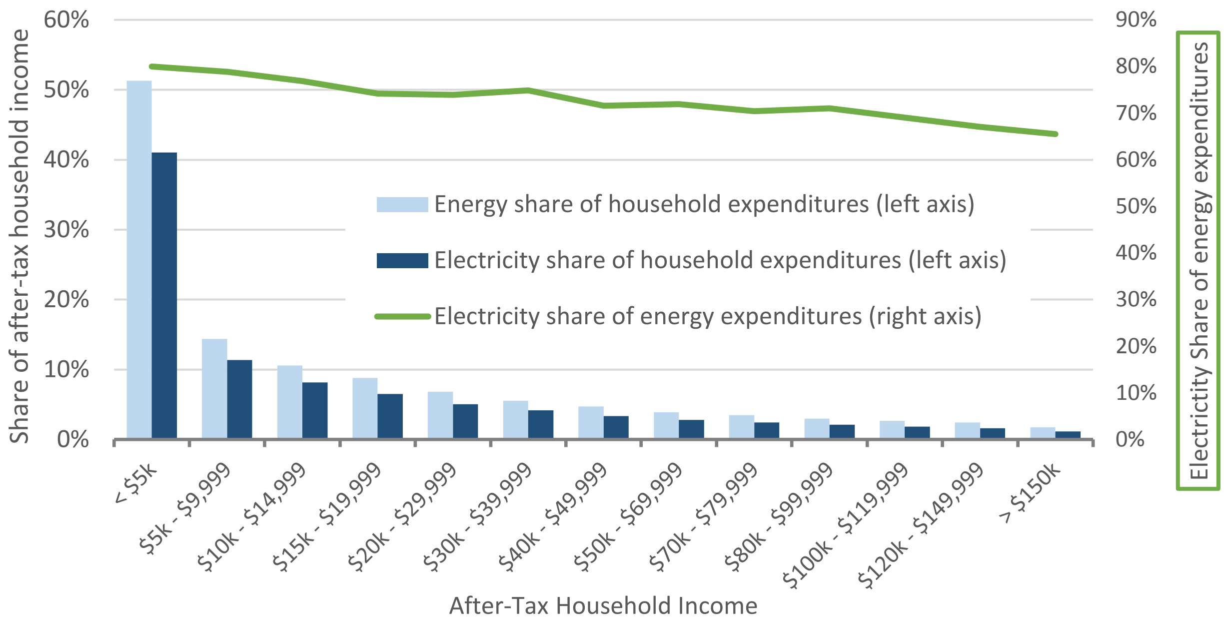


Site electricity use per household rises steadily as income increases. Households at the highest income level account for a significant share of total electricity use in the United States. Due to the large number of low- and middle-income households, households with less than $60,000 in income use more than 60% of U.S. residential electricity. Note that these data are not normalized by square footage of households in each income category.

Households with more members use more electricity than do smaller ones. However, electricity consumption per person declines with household size. This reflects the fact that additional housing unit occupants have relatively little impact on many electricity end uses, such as space conditioning and some appliances.

On average, 3.6% of annual U.S. household income after taxes ($2,075 per household) goes toward energy and 2.5% ($1,484 per household) toward electricity specifically. Households with incomes below $20,000 pay a higher share of after-tax income for energy (9.0%, $1,571 per household) and electricity (6.2%, $1,082 per household) (Figure 2.11). Moreover, electricity's share of household energy costs is highest for low-income households and declines steadily as income increases. It is also important to note that, per household, renters pay 26.7% more on energy expenditures per sq. foot compared to homeowners.[27]

Figure 2.11. Energy and electricity expenditures as a fraction of after-tax income, by household income level[28]



Lower-income households spend a greater share of their income on energy and a greater share of their energy expenditures on electricity. Income includes public assistance such as social security income, food stamps, and unemployment and veterans' benefits.

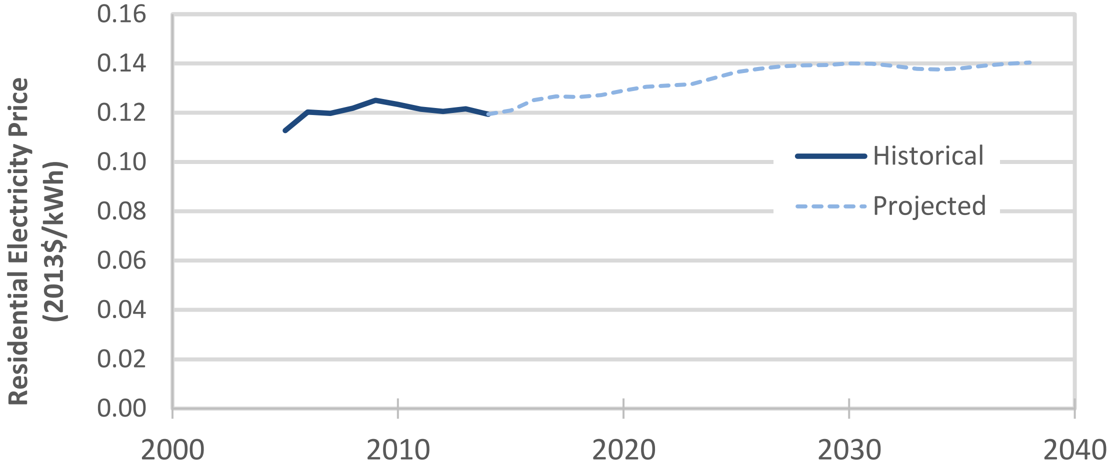
Regional differences in electricity's share of household expenditures also exist, especially with regard to the South Census Region. Electricity expenditures are on average 2.0% of household after-tax incomes in the West, 2.2% in the Northeast, 2.3% in the Midwest, and 3.3% in the South Census Regions. Drivers of this difference are discussed above.

2.3 Metrics and Trends

Section 2.2 covered trends in residential electricity use overall (Figure 2.1), as a share of total energy use (Figure 2.2), per household (Figure 2.3) and per square foot (Figure 2.4), by household vintage (Figure 2.6), and by end use (Figure 2.7).

Electricity prices are an important driver of electricity usage and of the economic attractiveness of efficiency measures. Figure 2.12 shows the trend in average electricity prices, which have been mostly flat over the last 10 years but are expected to rise slowly but steadily to 2040. The "average price" shown is total utility revenues divided by total electricity sales, but the actual prices utility customers pay vary due to many factors. Prices are different in different parts of the country. The average price per kilowatt-hour is different for different customers of a given utility based on their electricity usage and income level. In addition, in a small but growing number of cases, residential electricity prices also vary by the time of usage. See Section 2.6.5 for more on residential electricity rate design. The Residential Appendix includes historical prices for the residential sector since 1990 (See Figure 7.16).

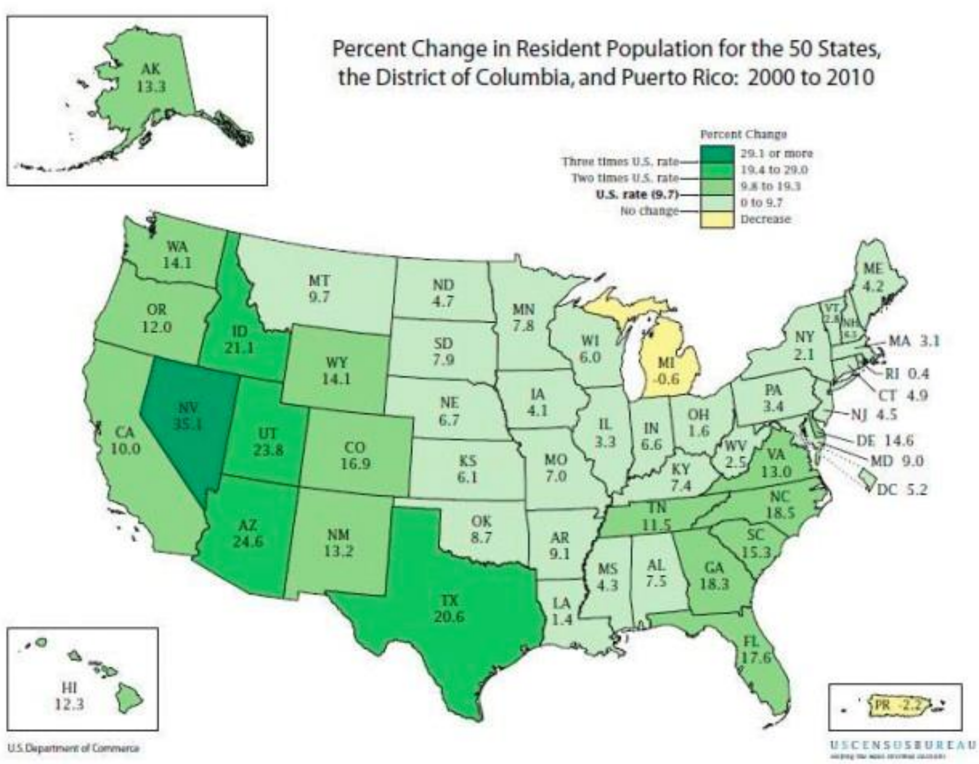
Figure 2.12. Trends in average residential electricity price (revenue from residential customers divided by utility sales from residential customers), 2005–2013 (measured) and to 2040 (projected)[29 30]



While prices have been mostly flat over the past 10 years, they are projected to increase steadily to 2040.

Finally, population movement is a driver of several of the trends affecting residential electricity use. As Figure 2.13 shows, population growth (including immigration and internal migration) has been highest in the South and West Census Regions and lowest in the Northeast and Midwest Census Regions. As discussed in Section 2.2.3, the West and South Census Regions use more electricity than other regions, due to high cooling loads and in the South to greater use of electricity as a home heating fuel.

Figure 2.13. Population growth by state, 2000–2010[31]



Growth has been high in the South and West relative to the Northeast and Midwest Census Regions.

2.4 Residential Energy Efficiency Technologies and Strategies

This section provides an overview of the current and projected state of play for energy efficiency technologies in residential buildings, with a focus on those technologies that are currently deployed. Chapter 5 of the *Quadrennial Technology Review* (QTR) provides much more detail on energy technologies in buildings.

2.4.1 Space Conditioning

Overall, space conditioning represents a declining share of electricity consumption. However, as noted in Section 2.2.2, the trends diverge for heating and cooling; electricity use is projected to fall for heating but rise for cooling.

Two major factors influence electricity demand for space conditioning: the building envelope (including doors, windows, insulation, and air-flow control) and the efficiency of heating and cooling units (furnaces, boilers, room and central air conditioning units, heat pumps, and the distribution system for the conditioned air). Generally, separate units provide heating and cooling, although these units often share duct systems. Heat pumps can provide both heating and cooling services with a single unit.

In the case of heating, most households can access other fuels—primarily natural gas and, less often, fuel oil, propane, or wood. Electricity usage for heating and water heating is substantially driven by the relative economics of the available options, although the high fixed costs of switching between fuels mean that long-run shifts in those relative economics are more important than short-term changes.[a] Because of issues such as fuel-switching and migration to regions with different fuel mixes, changes in national electricity usage for heating do not necessarily reflect changes in the efficiency or usage of devices or efficiency of building envelopes. As of 2009, 33.5% of U.S. housing units used electricity as the primary heating source. About half of these households (16.8% of all households) used central warm-air furnaces, 26% (8.6% of all households) used heat pumps, and the remainder (8.2% of all households) used other electric heating technologies, mostly built-in or portable electric units.[32] Some 24% of all households use secondary electric heaters.

Conversely, electricity powers essentially all space-cooling technologies, so space-cooling electricity usage is directly determined by usage and device efficiency. As of 2009, 87% of U.S. households had air conditioning equipment. Nearly three-quarters (73%) of those households (61% of all households) had central air conditioning; 19% of central air conditioning units were heat pumps. Nearly a third (29%) of households with air conditioning had one or more window or wall units.[33]

Little technological improvement is possible in electric resistance heating, which is 98% to 99% efficient in converting site electricity to heat. Heat pumps, however, can generate two to four times as much heat per unit of electric input as electric resistance heating.[b] As temperatures drop, the performance advantage of air source heat pumps over electric resistance heating decreases. Ground-source heat

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[a] Policy also may play a role. For example, California's Title 24 building standards no longer allow electric-resistance heat as a primary heating source except in certain, unusual circumstances.

[b] Electric resistance heat uses electricity to *generate* heat. A heat pump, however, uses electricity to power a mechanical compressor and refrigerant system that *moves* heat from where it is needed to where it is not. Heat pumps extract heat from outdoor air to warm a home (or extract heat from indoor air to cool a home). At most temperatures, this process yields substantially more heat energy than the electric energy used to power the system.

pump efficiency is less affected by ambient temperatures. Until recently, air source heat pumps were only considered appropriate technology in regions where temperatures rarely drop well below freezing, most notably the South. Newer heat pump technologies are improving performance at lower temperatures and may facilitate the penetration of air source heat pumps in other parts of the country. Air source heat pumps are projected to comprise 13.3% of main space heaters by 2040, up from 8.6% in 2012, while electric resistance heaters decline from 26.1% to 23.4% of main heating units. Ground-source heat pumps comprise 0.8% of space heating units in 2012 and are projected to increase to 1.3% in 2040.[34] Uptake of ground-source heat pump is limited by high installed cost at present. They also require a suitable underground location for burial. Space may not be available for some housing units. The Residential Appendix provides details on expected improvements in performance of space conditioning equipment between now and 2040 (Table 7.3).

Heat pump technology is also available in water heaters and offers similar performance advantages over electric resistance water heaters. New standards for electric water heater efficiency adopted in 2015 (Section 2.6.1) will effectively require heat pumps for electric water heaters with storage capacity between 55 and 120 gallons[a] that are not grid-enabled.[b] DOE has identified continued research on heat pump technologies as a major priority for energy efficiency in buildings.[35]

The building envelope affects cooling as well as heating efficiency in electrically heated buildings. Housing units that comply with current building energy codes regulate heat gains and losses much better than older homes, many of which are not well sealed, not insulated, and have single-pane windows. Modern building envelopes allow for significant downsizing of heating and air conditioning units. Beyond heat gains and losses, the building envelope also influences the amount of solar heat gained by the home, especially through windows and roofs.

As Figure 2.14 and Figure 2.15 show, advanced envelope technologies available today can dramatically reduce or entirely eliminate the need for space conditioning in many climates.[c] The challenge is to make these technologies cost-competitive with conventional alternatives, to manage potential moisture accumulation brought on by tight building envelopes,[d] [36] and to provide equivalent or superior amenities.[e] [37] As noted in Section 2.5, research on retrofit-friendly technologies that can easily be deployed in existing buildings is another research priority for DOE.[38]

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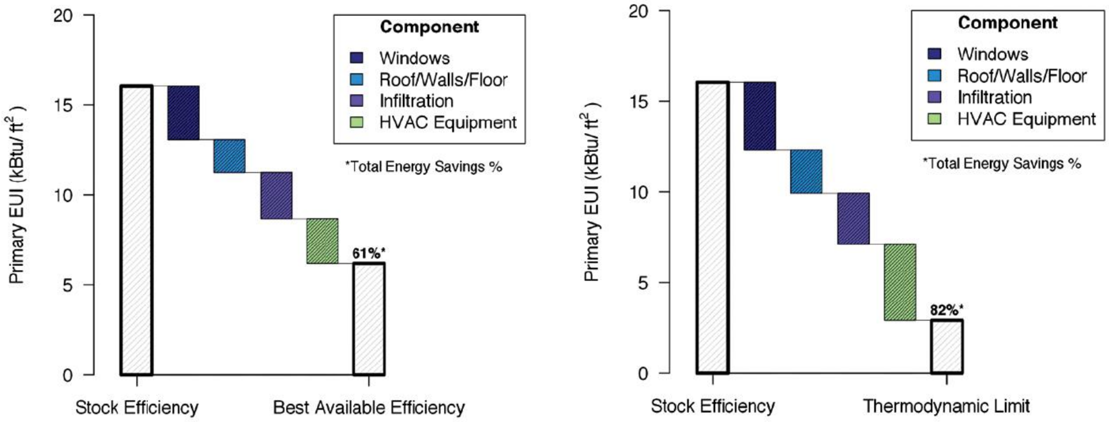
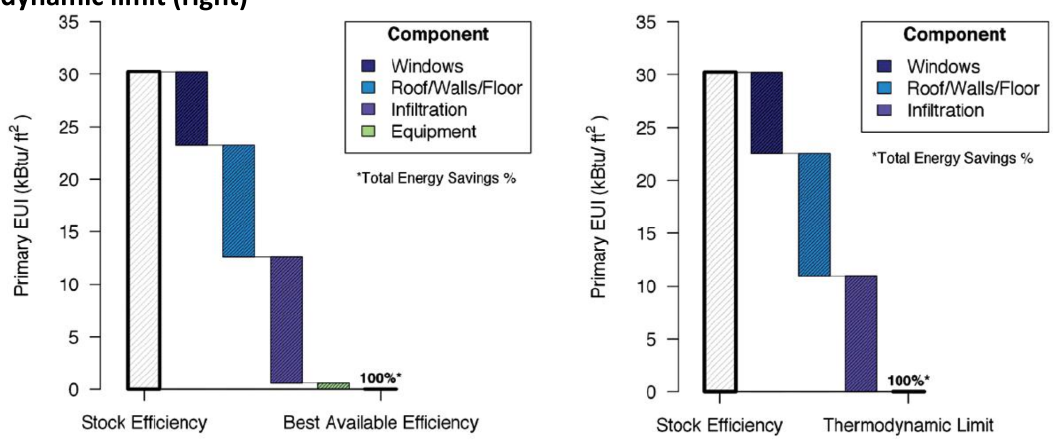
[a] This standard will cover water heaters with tanks that serve some single housing units. However, small housing units may have tank sizes smaller than this, while water heaters that serve multiple units may be larger than this.
[b] Some electric utilities are deploying grid-integrated water heaters for demand response, as they offer storage by heating water during off-peak hours. Efficiency standards for grid-enabled water heaters are lower to enable greater demand response.
[c] In the case of space heating, these efficient envelope technologies would reduce demand for natural gas and other home-heating fuels, not just for electricity.
[d] "[A]advanced envelope systems are rarely selected by building designers. Current solutions are expensive and/or unfamiliar to many designers, builders, contractors, and code officials and therefore perceived as risky. Furthermore, the dominant perceived risk is durability specifically related to condensation and moisture accumulation in building assemblies."
[e] For example, very tightly constructed houses with low air-exchange rates can feel stale and create indoor air-quality issues; mechanical ventilation can ameliorate these problems.

Figure 2.14. Potential for reductions in residential cooling, using best available technology (left) and thermodynamic limit (right) [39]



Use of the most efficient wall, window, and HVAC equipment now available could reduce residential cooling 61% (left). The theoretical limit is an 82% reduction (right).

Figure 2.15. Potential for reductions in residential heating, using best available technology (left) and thermodynamic limit (right) [40]



Use of the most efficient wall, window and HVAC equipment now available could eliminate the need for residential heating. Note that much of space heating energy consumption in the U.S. is not electrically powered, so the potential reductions shown here pertain only partly to electricity.

2.4.2 Lighting

As Figure 2.7 earlier in this chapter suggests, the residential lighting market is in the midst of a significant transition to more efficient technologies that are projected to dramatically reduce lighting's share of residential electricity use. A DOE-sponsored forecast[41] projects that LED lighting will grow from < 1% of installations and 3% of sales in 2013 to 83% of installations and 84% of sales in 2030, saving a cumulative 25% of residential lighting electricity usage, relative to a no-LED baseline. This projection assumes continued price and performance improvements in LED lighting technology. LEDs have been rapidly increasing in efficiency of light production per electricity input and decreasing in price.[42]

2.4.3 Appliances

Most major home appliances (refrigerators, freezers, clothes washers, and dishwashers) are powered by electricity. Clothes dryers, stoves, and ovens can be gas or electric, but electric units represent the significant majority (81% for clothes dryers; 61% for cooking equipment) in each case.[43] As with space heating, future electricity consumption depends on fuel choice, as well as equipment efficiency and both adoption and usage rates.

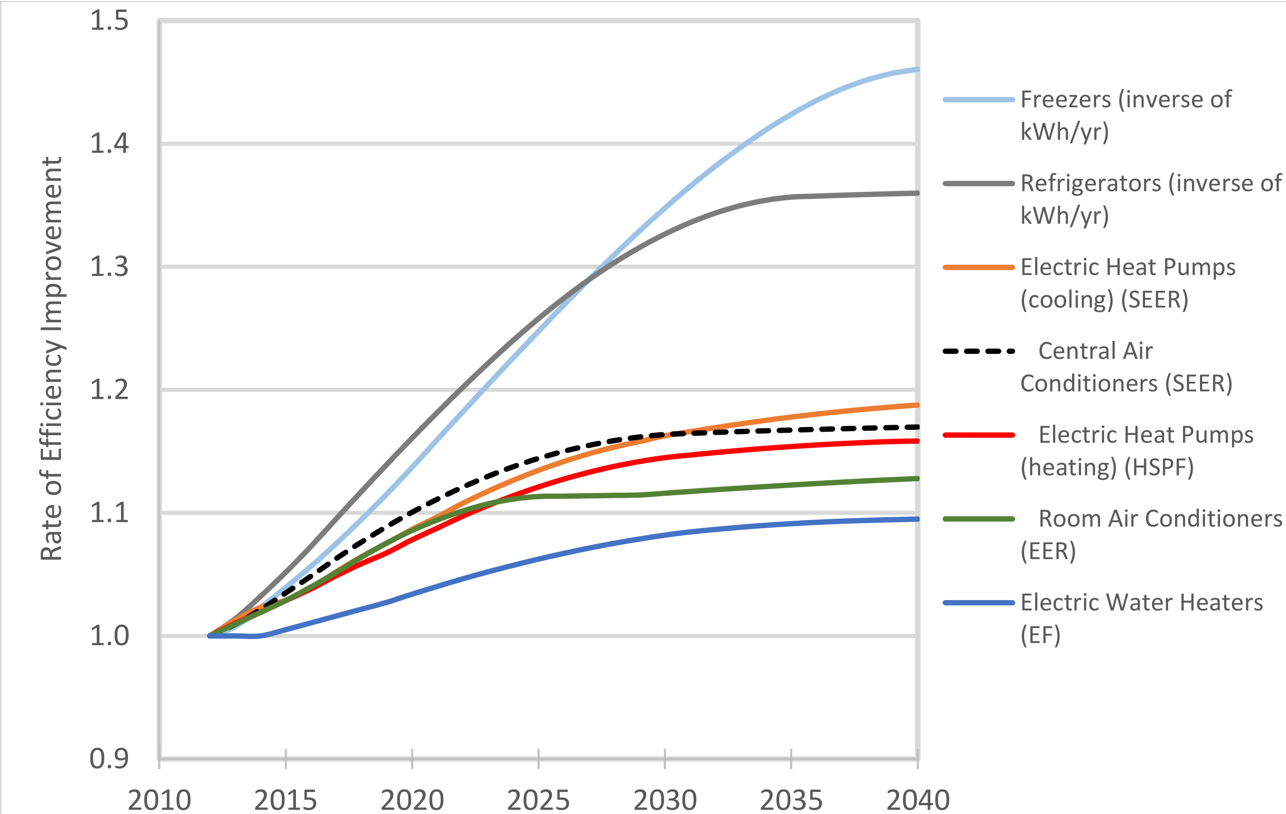
Electricity usage of refrigerators, freezers, and clothes washers depends significantly on the design of the unit. For example, refrigerators with top-mounted freezers (average consumption 407 kilowatt-hour (kWh)/year for a typical 2013 model) are considerably more efficient than those with bottom-mounted freezers (540 kWh/year) or side-mounted freezers (596 kWh/year);[a] [44] all three have significant market share.[b] [45] Front-loading clothes washers are considerably more efficient than top-loading models, both of which also have significant market share.[c] [46]

In terms of usage, stoves and refrigerators are near ubiquitous, and some homes have second refrigerators and freezers. Some 59% of households have dishwashers, 82% have clothes washers, and 79% have clothes dryers.[47] Increasing household adoption of these units—in addition to second refrigerators—will increase residential electricity use even as improved unit efficiency decreases it.

Refrigerators, freezers, and clothes washers are expected to see moderate improvements in efficiency through 2040. Efficiency of dryers is not expected to improve much; while heat-pump clothes dryers that are about 50% more efficient than electric resistance dryers are available in the U.S. market, the projected "typical" unit remains an electric resistance dryer through 2040.[48] Figure 2.16 shows projected improvements in the stock average efficiency for several major electric space-conditioning devices and appliances, with 2012 stock efficiency normalized to 1. Note that different metrics apply to different pieces of equipment, so these trajectories are not directly comparable to one another.

[a] Different standards apply to each of these product designs, reflecting the fact that the inherent efficiency of each design is different. Standards also vary based on whether an icemaker is present and whether defrost is automatic, as well as with the volume of the unit.
[b] Each of the three technologies accounted for at least 20% of shipments in 2012.
[c] Each technology comprised almost exactly half of electric clothes-washer shipments in 2012.

Figure 2.16. Projected improvements in stock efficiency of selected electric equipment and appliances[49]



All equipment is projected to improve in efficiency. Note that different efficiency metrics apply to different pieces of equipment, and rates of improvement are not directly comparable across metrics.

2.4.4 Electronics and "Other" loads

This section discusses computers, televisions, and related equipment, as well as a wide variety of uses that fall into the Other category in EIA data: audiovisual equipment, telephones, small appliances (e.g., dehumidifiers), fans, pool and spa heating, and pumps.

The electric loads in this section are generally referred to as MELs. (The term *plug load* is also used, though this term is more ambiguous since some appliances are also plugged in.) The term MELs is generally understood to include TVs, computers, and related equipment, as well as the Other uses mentioned above.[a]

Table 2.1 shows that the best available, current technology uses only a fraction of the electricity of the average television and computing unit, suggesting that improved efficiency can offset greater penetration of these technologies. Indeed, as Figure 2.7 shows, computer and TV electricity usage is projected to increase only slightly by 2040. Set-top boxes[b] account for about 28% of TV- and computer-related electricity use,[50] more than all computer-related equipment combined. Currently available technology provides less opportunity to reduce consumption in this category through stock turnover

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[a] See Appendix Table 7.5 for list of example MELs.

[b] Set-top boxes are devices that convert an external signal into one that can be displayed on a television set. Common examples are cable TV converter boxes, satellite TV converter boxes, Ethernet devices, and video game consoles.

than in computers and TVs, suggesting a potential target for research and development. A DOE rulemaking to establish standards for set-top boxes was recently withdrawn after manufacturers reached a voluntary agreement. The agreement requires that by 2014, 90% of new set-top boxes meet ENERGY STAR standards, [51] representing an efficiency improvement of 10 to 45 percent, depending on box type, by 2017.[52]

Table 2.1. Efficiencies of Selected Electronic Devices[53]

Devices	Current stock (kWh/yr)	Best available (kWh/yr)	Max tech (kWh/yr)
TVs	213	63	24
Residential computers	158	34	N/A
Commercial computers	336	34	N/A
Set-top boxes	142	86	65

There is tremendous potential to increase efficiency of these devices through stock turnover and further innovation, although less so in the case of set-top boxes.

“Other” uses are considerably harder to address. Given that this group of uses is so varied, it is difficult to find crosscutting technological solutions. However, advances in power management and efficient electrical circuitry may decrease electricity consumption of MELs across the board.[54] Understanding these uses and making them more efficient are major research priorities given their rapidly growing importance.

2.4.5 Controls, Automation, and “Smart” Homes

Home controls and automation have significant potential to improve residential electric efficiency. Per the 2015 QTR, building control systems can potentially:

- “Control room temperatures, humidity, ventilation rates, tunable windows, variable louvers, and dimmable lights
- Control major appliances—most devices are controlled by turning them off or on, but the new generation of appliances allows more sophisticated adjustment of operation
- Use weather forecasts to develop optimum strategies for preheating or cooling the structure
- Detect and identify component failures and look for signs that equipment is about to fail
- Adapt performance in response to communications from utilities using new rate structures to minimize overall system costs
- Learn and anticipate user behaviors including adjusting for holidays and integrate user preferences dynamically”[55]

Currently, most residential buildings are equipped to automate only a small fraction of these tasks. Programmable thermostats are widely available and are present in 37% of housing units, though only 53% of households with these thermostats use them to lower temperatures during the day, and only 61% use them to lower temperatures overnight.[56] “Smart” thermostats learn from occupant behavior and adjust schedules to minimize energy use. These devices can also enable automated demand response, adjusting thermostats during peak load events to shave usage.[57] However, they are not yet widespread. “Smart” power strips can control “phantom” loads,[a] [58]drawn by plugged-in electric devices even when they are powered off, but these are not widely used. Lighting controls are becoming common in commercial buildings, but they are much less widespread in residential buildings.

Smart meters, which measure electricity demand at 15-minute intervals or less, now represent about half of U.S. meters.[59] These meters are key enablers of demand response (discussed in Chapter 6) and may enable a wide variety of consumer engagement strategies, including the potential for more economical and less intrusive “remote auditing” technologies to identify energy efficiency improvements revealed by consumer load profiles. They have also raised privacy concerns.[60] Data gathered by these meters could reveal details on activities inside the home that are reflected in the temporal profile of their electricity usage. If inadequately protected, smart meters could also create cybersecurity vulnerabilities and create the potential for data theft.

Expanding use of these systems presents a significant savings opportunity. While residential estimates are not available, an estimate for commercial buildings suggests these systems can increase building efficiency by up to 30% without any other equipment replacement.[61]

2.4.6 Zero-Energy Homes

In concept, zero net energy homes (and zero net energy buildings in general) either (1) consume no grid electricity, or (2) offset the entirety of their grid electricity consumption over some time period (e.g., a year) though surplus on-site electricity generation that flows back to the grid. Policy that encourages zero-energy homes increases demand for not only energy efficiency but also distributed energy resources (DERs) such as distributed generation and battery storage (discussed in Chapter 6). High levels of market penetration could have significant impacts on the grid, reducing overall grid electricity consumption. More distributed generation driven by zero-energy targets can potentially lead to higher levels of demand response.

California has announced a target of making all new residential buildings zero net energy by 2020.[62] It is likely that a significant fraction of existing residential buildings would struggle to attain zero energy on-site due to roof angles, poor insolation[b], insufficient roof area (particularly in the case of high-rise buildings), and other factors. This may place a premium on finding a way to procure off-site sources to offset whatever amount of site energy remains.[63]

2.5 Markets and Market Actors

This report identifies four markets related to residential electric efficiency: new build, equipment replacement, renovation/retrofit, and housing unit sale/rental.

New build includes the commissioning and construction of new housing units. This is a critical market for electric efficiency, especially for electrically heated buildings and buildings in areas with high cooling loads. It is generally far less expensive to build a new, efficient building than to upgrade an existing one to an equivalent efficiency level. However, diffusion of best practices in the new housing market can be slow; the National Association of Home Builders Research Center has noted that it can take from 10 to 25 years for new technology to achieve full market penetration.[64]

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[a] “Phantom” loads may account for nearly 10% of residential electricity use.

[b] Insolation is the measure of incoming solar radiation on an object or surface.

Building energy codes (Section 2.6.1), ENERGY STAR and other home-certification labels (Section 2.6.2), and financial incentives for efficient construction (Section 2.6.3) all aim to improve the efficiency of new residential buildings. Important actors in new build markets include homebuilders (particularly those that develop many housing units at once in new communities), materials manufacturers, architects, contractors, investors in home development, and building inspectors. New build markets vary in activity by region, with higher rates of new housing units in the South and West than in other parts of the country (see Sections 2.2.3 and 2.3).

Renovation/retrofit involves significant upgrades to existing buildings, whether motivated by electric efficiency concerns or not. These projects represent the other opportunity to improve building shells and, potentially, appliances and lighting, depending on the nature of the project.

Table 2.2 shows typical payback periods for common retrofitting activity. As the table makes clear, building shell retrofits are generally carried out on older buildings that were constructed before building energy codes and may have little or no insulation, single-paned windows, and poor air and duct sealing. On the other hand, lighting and appliances are regularly replaced in all types of buildings; these activities are discussed in the equipment replacement section below.

Table 2.2. Typical Payback Periods for Residential Retrofitting Measures [65]

Measure	Payback Period, Old Homes	Payback Period, New Homes	Discussion
Lighting	1–2 years	1–2 years	Almost always cost-effective
Air sealing and duct sealing/insulation	0–8 years	Generally N/A	Cost-effective in most old homes; paybacks are climate-dependent
Insulation (walls, attic, floors)	1–18 years	Generally N/A	Most cost-effective in cold and hot climates; depends on climate and date of construction
Windows	8–20+ years	20+ years	Most cost-effective in cold or hot climates; long paybacks in more temperate zones
ENERGY STAR appliances and equipment	5–20+ years	5–20+ years	Generally cost-effective when replacing broken or obsolete equipment; generally not cost-effective when the existing equipment is still functional

Considerable policy and programmatic efforts are directed at encouraging efficiency retrofits and increasing the savings each retrofit delivers. These include programs that encourage energy audits to identify interventions (Section 2.6.2), programs that compare a building's usage to other similar buildings to motivate energy-use reduction (Section 2.6.2), grants and rebates for whole-building retrofits (Section 2.6.3), and financing to spread out the up-front cost of these projects (Section 2.6.4). Often, programs wrap all these interventions together. Despite this effort, it has proven challenging to motivate retrofits, specifically in pursuit of improved efficiency. While good data on efficiency retrofits are not available, most experts believe that considerably less than 1% of U.S. residential units receive an efficiency retrofit each year.[66] Raising this rate is a central concern of efficiency policy.[67] Injecting efficiency considerations into renovations that are not efficiency retrofits *per se* but still afford substantial opportunities for savings is perhaps just as important an objective.

The most important actors in the renovation/retrofit market are housing-unit owners and contractors (both dedicated efficiency retrofit providers and general contractors). Renters are important actors as well especially since renovation of rental units can be disruptive to tenants. Additionally, if the tenants pay the electric bills, owners will be less likely to make efficiency improvements since it is the tenant who would see the benefit. Energy efficiency retrofit programs that have achieved significant market share typically develop strong partnerships with contractors and craft programs and financial products that make contractors motivated to sell projects.[68] There is also an active market in developing financial solutions that can improve on thin project margins, and substantial private capital is beginning to engage,[69] though it is not clear that any dominant solution has yet emerged. Finally, retrofit-friendly materials and techniques could lower costs.

Equipment replacement is distinct from the previous category in that it generally involves changing out equipment. Equipment replacement projects often occur when equipment fails. While each project is smaller than a renovation/retrofit, the number of transactions in this market far exceeds those in the renovation/retrofit market. One important aspect of equipment replacement is proper equipment installation. Poor installation can reduce the efficiency of installed equipment.

Key policies affecting the equipment replacement market include equipment labels (Section 2.6.2) and rebates (Section 2.6.3). Many of these products are financed through vendors and contractors. Efficiency financing programs (Section 2.6.4) for equipment replacements need to be designed without long underwriting processes since many decisions are made quickly in the face of equipment failure.[70]

Important actors for the equipment replacement market are housing unit owners, contractors and vendors, equipment repair companies (these professionals are often the point of engagement for equipment failures), and equipment manufacturers. Housing-unit occupants who are not owners also make some consequential decisions on equipment, notably on lighting and electronics, which are important drivers of residential electricity use (see Section 2.2.2).

Housing unit sale/rental often motivates renovation or equipment replacement. Independent of the primary motivation for this action, this market is important because these transactions potentially capitalize energy efficiency into sale prices. Evidence suggests this capitalization varies by market, but that it often does occur in significant magnitudes for homes that meet various "green home" certifications.[71]

Little existing policy addresses this issue. Energy efficient mortgages allow homebuyers to finance larger amounts for properties that meet certain efficiency standards, but their take-up has been very low. Building rating and labeling schemes (see Section 2.6.2) seek to standardize the definition of a "green home" or an energy efficient home to reduce confusion in the real estate market, though their usage is not yet routine. Some jurisdictions require disclosure of energy information at point of sale, or require specific energy upgrades at time of sale. These requirements also are not yet widespread.

Important market actors are homebuyers and sellers; renters and landlords; mortgage lenders, appraisers, and real estate agents; and home energy raters.

Finally, while less of a market in a traditional sense, housing unit operations is another area of growing activity. Operations involve a myriad of choices about how and how often to use electrical devices and features in homes. Key actors are housing-unit occupants (who often face principal-agent issues[a] in

[a] As noted in the renovation/retrofit section above, tenants generally do not make choices about appliances, space conditioning, and water heating in their housing units and may not be able to lower their electricity usage as much as they might wish to.

attempting to control electricity usage [see Section 2.6]), as well as regulators who set retail electricity prices.

2.6 Barriers and Policies, Regulations, and Programs That Address Them

Energy efficiency policies, regulations, and programs in the residential sector attempt to address well-known barriers, including the following:

- Information and awareness – Homeowners, renters, and homebuyers have imperfect information about the energy performance of housing units and about the costs and benefits of high efficiency appliances, equipment, and building shells, as well as potential efficiency improvements.
- First costs – More efficient homes[a] and equipment cost more initially but provide savings over time. Individual decision makers generally dislike having to pay up front for future benefits.
- This is particularly burdensome for low-income households who have less disposable income, despite the large share of their budget that is required to pay energy bills (Figure 2.11).
- Materiality – Energy costs are a small share of household expenses for most households (though not all; see Figure 2.11), so it is hard to get most homeowners and tenants to pay attention to energy efficiency.
- Limited access to capital – Many consumers are cash- and credit-constrained and may not be able to take on debt to finance efficiency upgrades.
- Transaction costs – Energy efficiency improvements, especially home retrofits, are time-consuming to understand, arrange, and execute.
- Split incentives – Building owners may not have an incentive to invest in energy efficient equipment if they do not pay utility bills, and tenants will not want to buy energy efficient equipment if they are planning to move out soon.
- Price signals – Electricity prices are set to recover utility and electricity service-supplier costs, not to reflect the true social cost of electricity consumption. In addition, tariff structures may discourage customer investments in energy efficiency.
- Insufficient research and development (R&D) – To the extent that efficient technologies do not realize demand from transparent, robust markets, companies will underinvest.[72] The housing sector significantly underinvests in technical innovation and R&D for energy efficiency—less than 0.4% compared to the industry average of 3%.[73]

Table 2.3 summarizes the major policies, regulations, and programs enacted to encourage efficiency in residential buildings, in addition to efficiency policies across all sectors such as an energy efficiency resource standard (see 7.2.1).

[a] Most new homes are mortgaged, potentially reducing the first-cost barrier. However, efficient homes are more expensive to build, increasing the amount that must be mortgaged if their lower operating costs are not taken into account in mortgage underwriting—which they often are not. This may lead prospective homeowners who don't want to or cannot take on larger mortgages to refrain from investing in efficiency.

Table 2.3. Major Policies, Regulations, and Programs to Address Barriers to Energy Efficiency in the Residential Sector

Policy, Regulation, or Program	Description and Implemented Examples	*Principal Barriers Addressed*
Codes and standards	• Mandatory prescriptive or performance energy codes that regulate building envelopes • Minimum performance standards for appliances and equipment • Voluntary "green" or "reach" codes	*Information/awareness, materiality, split incentives* • Standards set a minimum level of performance, guarding against uninformed or inattentive purchase of inefficient devices and limiting the impact of split incentives.
Clean energy mandates and target-setting	• Energy efficiency resource standards that mandate levels of savings across a sizable jurisdiction (e.g., across the entire state or all regulated utilities in a state) • Other mandates (e.g., a mandate by a state public utility commission to achieve all cost-effective energy efficiency)	*Price signals, lack of private incentive for R&D, various others* • These policies are generally enacted for clean energy policy reasons, meaning they are primarily intended to serve as a proxy for social costs of carbon emissions and other non-energy benefits.
Grants and rebates	• Payments to consumers that reduce or offset the incremental cost of efficient technologies, such as those offered by utility customer-funded programs • Most are technology-specific; some are offered based on whole-building energy savings achieved	*First costs, price signals, materiality, information/awareness* • Rebates lower the incremental up-front cost of efficient technologies, serving as a proxy for non-priced social benefits of energy efficiency adoption.
Resource planning	• Utility integrated resource planning (IRP) to ensure system reliability that appropriately factors in energy efficiency	*Price signals* • IRPs can ensure efficiency is valued appropriately in utility planning for energy and capacity.
Informational interventions	• Programs that encourage or subsidize home energy audits • Information and awareness campaigns run by utilities and other program administrators or government agencies • Product energy labels (e.g., ENERGY STAR, Energy Guide • Building energy labels and ratings (e.g., ENERGY STAR, Home Energy Rating System) • Demand side management (DSM) programs that leverage consumer behavior to save energy	*Information/awareness, materiality* • Consumers may lack capacity to identify opportunities for energy-saving improvements. • Data on energy usage may not be transparent. • Efficiency may not be adequately salient to consumers due to lack of information or the lack of focus on energy.
Rate design	• Tiered (inclining block) rates	*Price signals* • Tariff structures may discourage customer investments in energy efficiency.

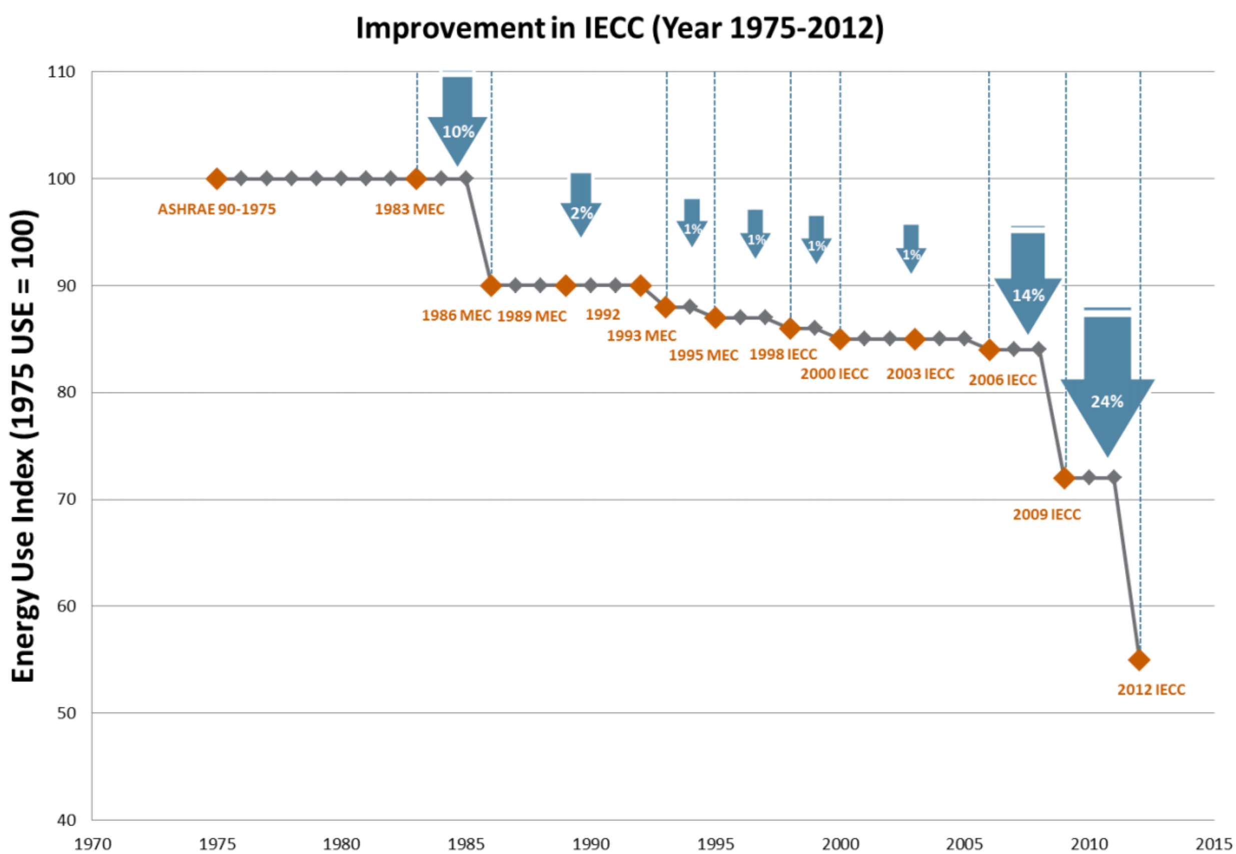
RD&D for end-use technologies	• Direct support for RD&D • Prizes, contests, and other manufacturer incentives	*Lack of private incentive for R&D* • In general, and particularly in the energy industry, RD&D is undersupplied absent policy intervention.
Financing	• Utility DSM financing programs • Financing offered by state energy offices, green banks, or by programs that are largely private (e.g., property assessed clean energy [PACE] programs)	*Lack of capital, first costs, transaction costs* • Financing programs extend capital and often eliminate entirely up-front cost to consumers. • Financing is often packaged with other programmatic offerings and potentially removes the need to seek out a source of capital, which can otherwise be a barrier to program participation.
Tax incentives	• Personal income tax credits (federal/state) • Sales tax incentives (state) • Property tax incentives (state or local)	*Price signals* • Like rebates, tax incentives can be a proxy for non-priced social benefits.

2.6.1 Building Energy Codes and Appliance and Equipment Standards

State building energy codes reduce energy use in new homes and major renovations by establishing minimum energy efficiency standards for building design, construction, and remodeling. These codes address wall, ceiling, and duct insulation; window and door specifications; heating, ventilating, and air-conditioning equipment; and lighting fixtures. States are generally responsible for adopting residential building energy codes,[a] while local governments are generally responsible for enforcing the codes.

Most state codes are based on the national model code, the *International Energy Conservation Code®* (IECC), often with state-specific revisions. The IECC is updated every 3 years to keep current with new technology and market norms. In recent years, the codes have become significantly more efficient. Homes built per the 2009 IECC, for example, are 14% more efficient compared to the 2006 IECC, and homes built per the 2012 IECC are 24% more efficient compared to the 2009 IECC (Figure 2.17). In May 2015, DOE estimated that homes built per the 2015 IECC will be 0.98% more efficient compared to houses built to the 2012 IECC.[74]

Figure 2.17. Code-on-code savings estimates for International Energy Conservation Code model codes[75]

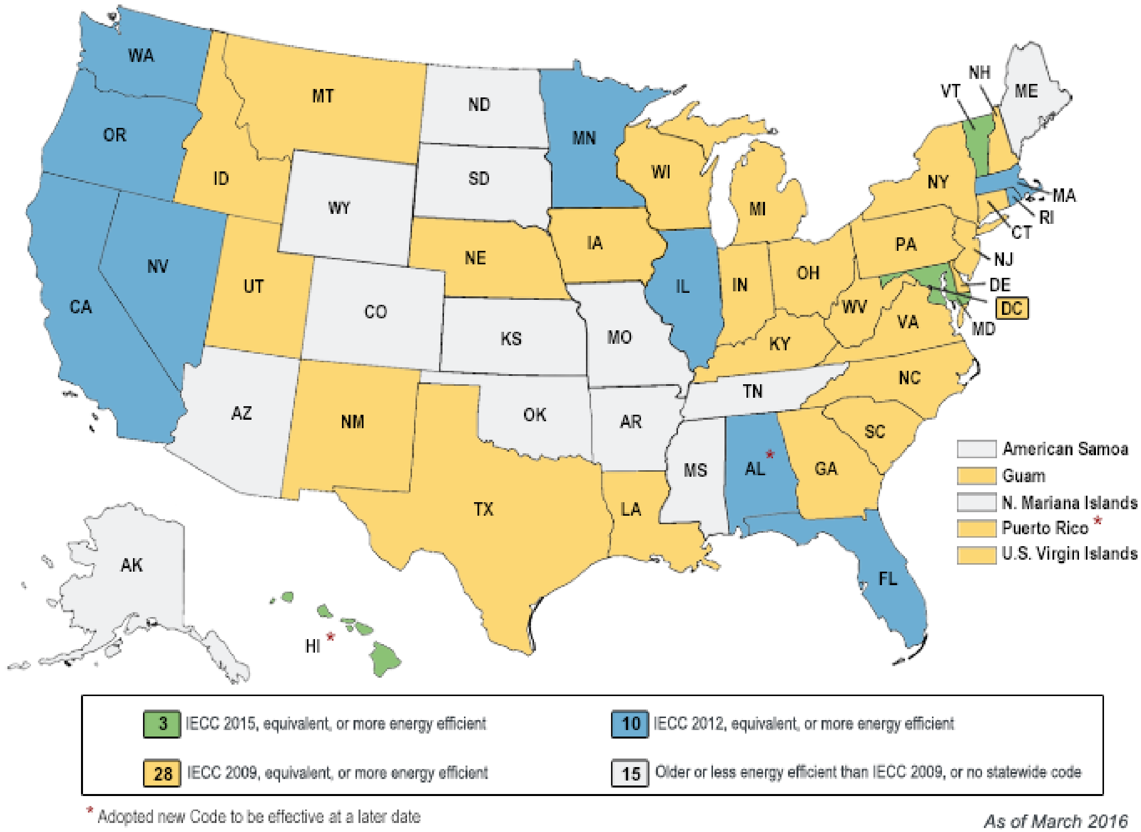


Advances in the stringency of the model code have been irregular. The 1986, 2006, and 2009 codes tightened significantly.

[a] Local governments occasionally adopt codes, particularly when their states do not.

Three states have codes in place that are equivalent to, or are more efficient than, the 2015 model code; 13 states have adopted residential building energy codes at least as stringent as the 2012 model code; and 41 states have codes as strong as the 2009 model code (Figure 2.18).

Figure 2.18. State-by-state adoption of residential building energy codes[76]



Some 41 states or territories have adopted a code at least as stringent as the 2009 national model code—International Energy Conservation Code.

Local building inspectors enforce codes by checking construction sites and reviewing building plans. *Code compliance* refers to meeting the requirements specified by the code and demonstrating that the requirements have been met. It is through code compliance that actual energy savings are enforced.

In 2012, the United States saved an estimated 11 billion kWh of residential site electricity through building energy codes (compared to baseline 1992 codes).[77] Between 2013 and 2040, if current trends in adoption and compliance continue, the cumulative electricity savings from residential codes in post-2012 new construction are estimated at 2,100 billion kWh.[78] A 2014 Pacific Northwest National Laboratory study estimates that, in 2030, code development, adoption, and compliance efforts could reduce residential electricity consumption in the United States by more than 4% compared to 2012.[79]

DOE issues standards for consumer products and lighting products. It is required to review each standard at least once every 6 years and to set standards at levels that achieve the maximum improvement in energy efficiency that is technically feasible and economically justified. Once an appliance or piece of equipment is covered by a standard, manufacturers must test, rate, and certify all such products they produce for compliance with the standard per mandated testing procedures, and they cannot distribute any product that is not in compliance with the standard.[80] Federal end-use standards reduced U.S. energy consumption (all fuels) by an estimated 4% in 2014, compared to usage absent the standards.[81] In some cases (see Residential Appendix, Table 7.4. Status of Consumer Product and Lighting Standards that Impact Residential Electricity Use, states have adopted residential standards in advance of the federal standards. Many of the products now covered by national standards were first addressed by state standards. Once a federal standard exists, it preempts state standards.[a]

As Residential Appendix Table 7.4. shows, DOE recently updated standards for many consumer products, including air conditioners, heat pumps, clothes washers, clothes dryers, refrigerators, and freezers, as well as lighting. Additional products that consume significant amounts of energy, including computers, are not yet covered by a federal standard. (DOE is currently working on standards for a number of products.)

A study by the Appliance Standards Assistance Project and the American Council for an Energy-Efficient Economy (ACEEE) found that average savings from new standards are more than four times greater than average incremental costs to the consumer. They found the average payback for increased efficiency was 3.3 years.[82] For example, the California Energy Commission estimates that state and federal equipment efficiency standards saved California 2.4 million megawatt-hours (MWh) in 2013.[83]

2.6.2 Labeling and Other Informational Interventions

Labeling provides energy-related information to consumers on homes and equipment that would otherwise be difficult and time-consuming to obtain. Two national labeling schemes, EnergyGuide and ENERGY STAR, provide point-of-sale information about energy use for consumer products.

EnergyGuide labels are required on most major appliances. The labels provide information on energy usage and approximate annual cost of using the product. The Federal Trade Commission administers EnergyGuide.

ENERGY STAR labels cover a broad range of consumer products, including electronics, computers and related equipment, windows and doors, heating and cooling devices, water heating, and lighting. ENERGY STAR and ENERGY STAR Most Efficient are certification labels, denoting products that meet or exceed a specific level of performance. ENERGY STAR updates these performance levels periodically as product efficiencies improve.[b] The U.S. Environmental Protection Agency administers ENERGY STAR.

Information barriers extend beyond product choice. It is difficult to identify potential interventions and the energy and cost savings they might yield absent professional assistance. As a result, many programs offered by utilities and other program administrators offer subsidized or free energy audits. Approved private contractors generally conduct these audits and perform the follow-on work. The Home Performance with ENERGY STAR program takes a whole-home approach to retrofitting.

Building energy labels and ratings are another potential informational tool to encourage capitalization of energy performance and are under development in several states and cities[84] as well as at the federal level. The ENERGY STAR Homes label certifies new homes that use 15% to 30% less energy than typical new homes.[85] DOE's Zero Energy Ready Home program promotes and labels homes that use 40% to 50%

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[a] States can only set standards for appliances that are not currently covered by a federal standard unless they obtain a waiver to do so.

[b] These updates are not directly tied to changes in the appliance and equipment standards discussed in the previous subsection.

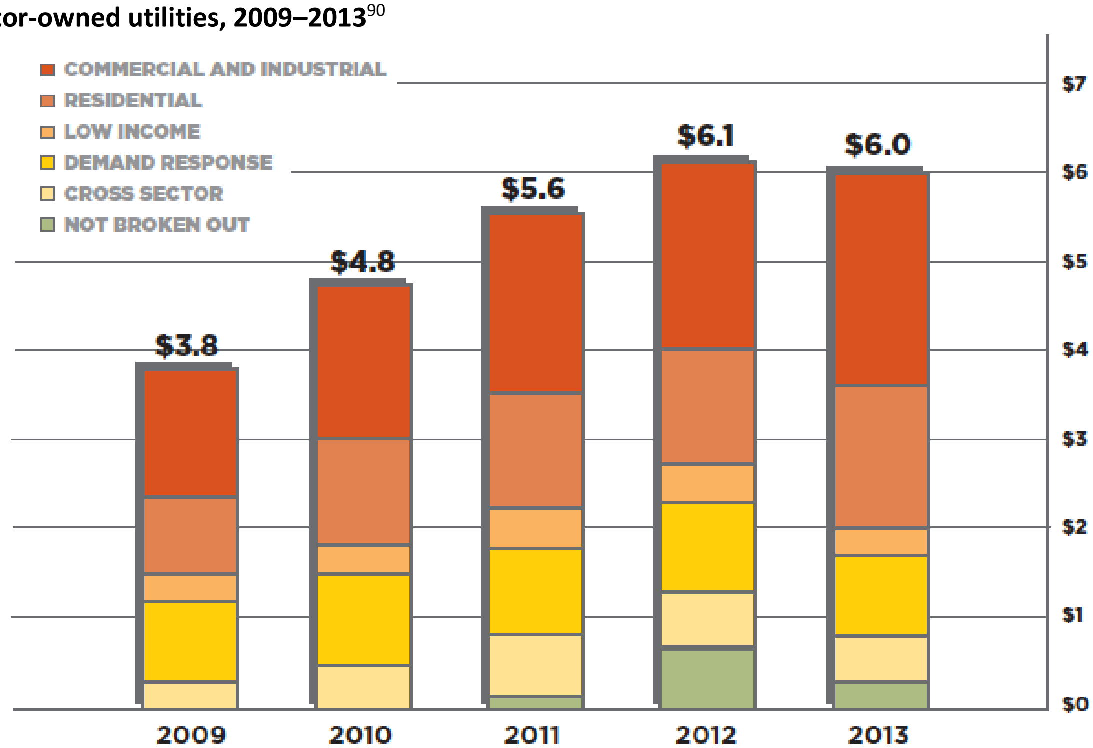
less energy than typical new homes and can be readily retrofitted with solar energy panels.[86] The Home Energy Rating System scores a home's energy performance and has been adopted by some whole-home programs (such as Energy Upgrade California, offered by California's investor-owned utilities) as a method for qualifying for performance-based savings.

Recently, utilities and other program administrators have begun to offer informational programs that leverage consumer behavior to reduce energy use. Home energy reports, which compare a customer's utility bills to those of similar customers, are growing in popularity. These reports are now sent to about 15 million utility customers' homes[87] and are generating energy savings[88] at a relatively low cost.[89] Behavioral approaches are expanding to include demand response programs that seek to reduce electricity usage at peak times. While home energy reports generally serve single-family residences, a growing number of jurisdictions are employing benchmarking practices for multifamily buildings, which also compare these buildings against their peers to identify and motivate savings opportunities. See Section **Error! Reference source not found.** for more on benchmarking.

2.6.3 Grants and Rebates

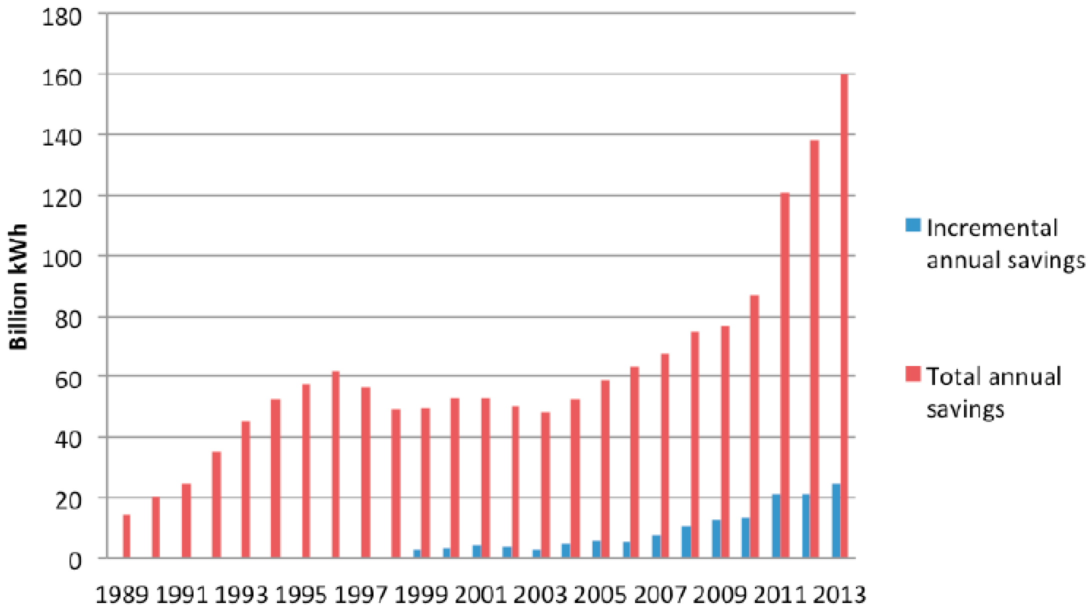
Programs funded by utility customers and run by utilities and other program administrators offer many rebates for the purchase of energy-efficient products. Programs funded by utility customers have grown substantially in recent years, both in terms of dollars spent (Figure 2.19) and energy savings achieved (Figure 2.20). Note that these programs comprise many activities other than rebates, although rebates account for more than half the spending (Figure 2.21).

Figure 2.19. Growth in spending ($ billion) on energy efficiency programs funded by customers of investor-owned utilities, 2009–2013[90]



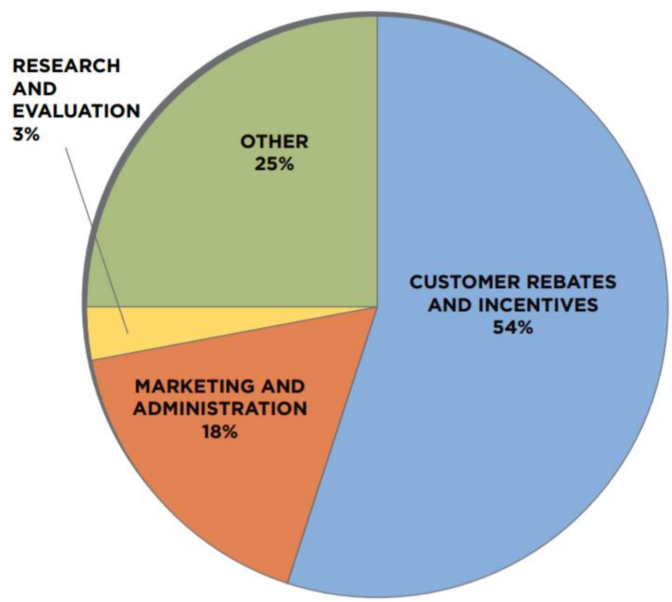
Like other energy efficiency programs, residential programs have expanded substantially. Municipal and rural cooperative utilities also fund energy efficiency programs.

Figure 2.20. Electricity savings from energy efficiency programs funded by utility customers, 1989–2013[91]



Savings have grown from the mid-2000s, especially in the past several years. Incremental annual savings are savings from measures installed that year. Total annual savings are those achieved in a year from measures installed that year and in prior years (for those measures still providing savings based on estimated measure life).

Figure 2.21. Utility customer-funded energy efficiency program spending, 2013[92]



More than half of spending goes toward rebates and other incentives.

Rebates are provided for equipment that meets efficiency levels specified by the program. Many rebates are provided to utility customers, either at point of sale or by submitting documentation to the program administrator after purchase. Other rebates are offered to manufacturers or retailers for producing or stocking efficient equipment. Some programs are developing performance-based rebates, which depend on the actual energy savings achieved, as an alternative approach to rebates for predicted energy savings for whole-home retrofitting programs.

Federal grant programs are largely targeted at low-income consumers, for whom energy costs are a large share of expenditures (See Figures 2.10 and 2.11). DOE's Weatherization Assistance Program [93] offers grants covering the full cost of efficiency upgrades to income-qualified households, up to a defined spending limit. Beyond air sealing, the Weatherization Assistance Program also can pay for insulation, heating and cooling systems, and appliance replacement. The U.S. Department of Health and Human Services' Low-Income Home Energy Assistance Program pays a portion of a qualifying household's energy bills and can also provide partial funding for weatherization.

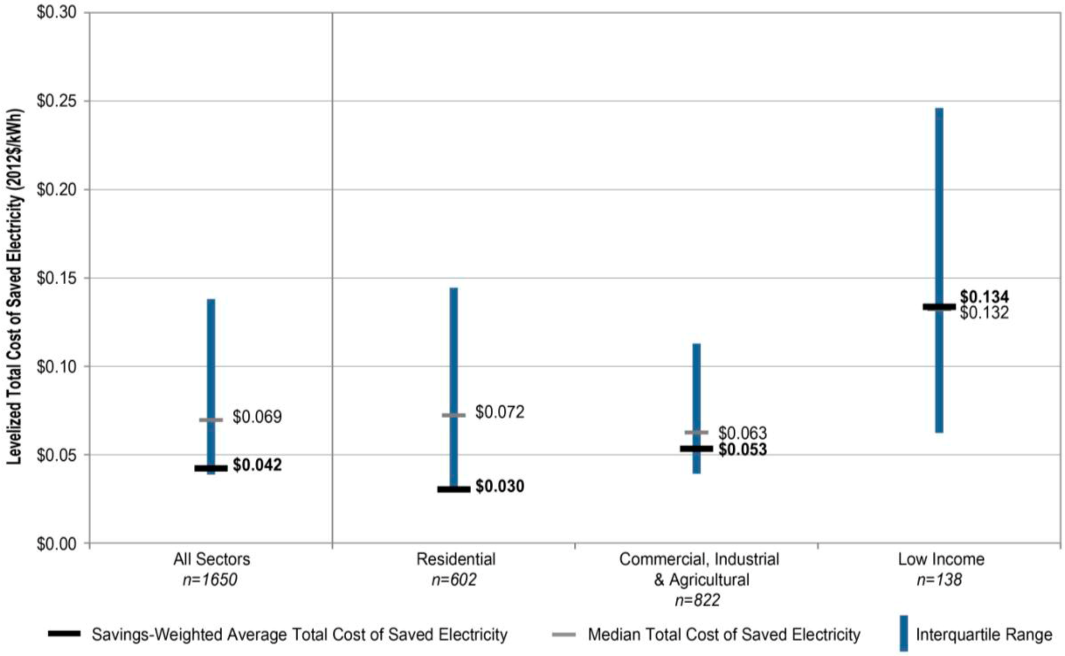
Low-income households have proven difficult and expensive to engage on efficiency upgrades. For example, one study showed that weatherization services from the Weatherization Assistance Program (which are free to low-income homeowners) were taken up by less than 1% of eligible households. With substantial additional marketing efforts, the participation level rose, but it was still less than 6%.[94] Utilities also run programs that target low-income households, and these programs cost substantially more per dollar saved than do other program types (Figure 2.22). In some cases, these higher costs may reflect non-efficiency measures that had to be addressed in the process of making efficiency improvements, such as required asbestos mitigation or gas-leak repair.

Low-income programs that work through community organizations that are trusted messengers have tended to elicit relatively strong participation.[95]

Utility programs support these federal and community efforts. One example is utility efficiency programs for manufactured housing. About three-quarters of manufactured home residents have an income below $40,000.[96] Among these programs, Tennessee Valley Authority, through its affiliated utilities, pays the incremental cost to upgrade to ENERGY STAR-qualified manufactured homes. More than half of the manufactured homes shipped to Tennessee in 2014 qualified for the program.[97]

Some utilities also offer direct-install programs that are free to all customers. These programs typically accompany energy audits and install low-cost, short-payback measures (at no cost to the customer). Typical measures include efficient lighting, water conservation measures, and air and duct sealing.

Figure 2.22. Energy efficiency program costs by market sector, 2009–2014[98]



Residential programs during this period had the lowest cost per kilowatt-hour saved, on a savings-weighted basis, of any market sector. Programs targeting the hard-to-reach, low-income market are more costly than other market sectors. Data include both direct program costs (e.g., the cost of rebates) and utility administrative and overhead expenses.[a]

2.6.4 Financing

Programs that offer financing for residential energy efficiency upgrades have grown substantially in recent years. Common offerings include the following:

- Conventional loans offered by utility, state, or third-party energy efficiency programs, generally unsecured loans
- On-bill loans that are repaid via a dedicated charge on an energy bill[99]
- Property assessed clean energy (PACE) programs that fund efficiency upgrades via an assessment on a property tax bill.[100]

Financing spreads the higher up-front cost of efficient products over time, in many cases allowing such measures to self-finance via energy bill savings that cover the loan or assessment payments. Depending on program design, on-bill loans and PACE assessments can potentially transfer with ownership of a home, eliminating a common split-incentive problem that deters homeowners from investing in longer-payback improvements.

Residential PACE programs in California have grown dramatically in the past few years, financing nearly $1 billion of clean energy investments since 2009.[101] California PACE programs finance energy efficiency improvements and distributed renewable resource systems. Most of that investment has been delivered by the Home Energy Renovation Program, which operates in multiple California counties. The Federal

[a] In some cases, costs borne by third-party program administrators may not be fully reflected in these data.

Housing Finance Agency has directed Fannie Mae and Freddie Mac, the agencies that back most U.S. residential mortgages, not to purchase mortgages for homes with PACE assessments where these assessments are senior[a] to the mortgage lender. This action has stalled senior lien residential PACE programs, except in California. The California Alternative Energy and Advanced Transportation Financing Authority established a $10 million loan loss reserve to protect mortgage holders in the event of reduced recoveries from defaults on PACE-encumbered mortgages. To date, there have been no claims on the reserve.[102] States also can develop residential PACE programs using eligible subordinate lien structures under forthcoming guidelines from the Federal Housing Administration.[103] Residential PACE programs in Maine, Vermont, and Rhode Island subordinate PACE repayments to the mortgage lender; these programs have not delivered loan volumes on the scale of the California programs.

Some financing programs funded by utility customers and run by utilities or third-party administrators have also achieved significant lending volume. In 2014, these financing programs, including utility, on-bill, PACE, and state energy office programs, loaned more than $500 million for residential energy efficiency upgrades.[104]

2.6.5 Rate Design

Electric utility tariff structures may affect customer investments in energy efficiency. Improving rate design can encourage (or at least not discourage) such investments:[105]

- Tiered (inclining block) rates – Inclining block rate structures charge a higher rate for each incremental block of electricity consumption. They are common in the U.S. for residential customers and are based in part on the theory that higher usage typically is associated with consumption during times of peak demand, when generation and delivery costs are higher than non-peak periods.[106]
- Time-varying rates – The underlying costs of providing electricity vary hourly and seasonally. Tying rates more closely to the actual cost of providing electricity can give customers more economically efficient incentives to reduce usage during costly periods. Current penetration of time-varying rates is low in the residential sector, and many residential customers who have opted into these rates are EV owners who can take advantage of inexpensive nighttime rates for vehicle charging. However, these rates may become more prevalent in the future. For example, the California Public Utilities Commission is planning to introduce time-varying rates for residential customers as the default tariff in 2019, with the option for customers to opt out to a rate that does not vary by time of use.[107]
- Fixed and volumetric charges – Electric utilities in many states are proposing raising the fixed customer charge—a set dollar amount each billing period regardless of energy usage—and decreasing volumetric (per-kWh) rates. Such a change would lower incentives for electric efficiency. As of yet, few state public utility commissions have adopted significantly higher fixed charges.[108]
- Low-income rates and other assistance – Most utilities offer lower electricity rates for households that fall below defined income thresholds. Households on low-income rates consume less electricity; it is not clear whether the rate structure impacts their usage.[109]

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[a] Seniority refers to the order in which debt is repaid in the event of sale or bankruptcy.

2.7 Interactions with Other Sectors

This section briefly outlines several points of connection between the residential sector and the other sectors covered in this report.

Data servers – Residential computing usage drives electricity consumption in data servers that are part of the commercial sector. This means that residential demand will partly drive the growth of future commercial electricity-server consumption.

Electric vehicle charging – EVs displace petroleum fuel use in the transportation sector and increase electricity use in the residential sector (as well as the commercial sector), creating a potential conflict between energy efficiency and increasing load from plug-in electric vehicle (PEV) charging. While EV penetration is currently low, these vehicles are a significant electricity end use for those who own them. Assuming the need to recharge 30 vehicle miles per day and an EV that uses 0.3 kWh/mile (equivalent to a 2015 Nissan Leaf, the most common EV in the United States), an EV user would consume 9 kWh per day if all charging is done at home. This is equivalent to 29% of an average U.S. household's electricity usage. Therefore, as EV penetration increases, EVs may come to represent a significant source of residential electricity use.[a]

Telecommuting and e-commerce – Telecommuting and e-commerce redirect electricity consumption from the commercial sector to the residential sector. Telecommuting is on the rise: The percentage of workers who work at home at least 1 day per week increased from 7.0% to 9.5% from 1999 to 2010, and 4.3% of U.S. workers worked the majority of the week from home in 2010.[110] Telecommuting raises residential electricity usage for computing, lighting, and space conditioning. Telecommuting also may expand residential floor space to provide dedicated work space; the reverse is true of commercial impacts.[111] A study of telecommuting in Japan finds that telecommuting can reduce net energy usage in the buildings sector overall if commercial floor area is decreased through space sharing among telecommuters; however, it can increase net energy usage if commercial floor space is not reduced.[112]

R&D – Most of the technologies used in residential buildings—in building shells or products used within—are not unique to the sector. Innovations in technologies for residential and commercial sectors, in particular, readily spill over to each other, driving both improvements in electric efficiency and increases in demand for electricity-powered services.

2.8 Research Gaps

Following are key research questions and research gaps related to electricity consumption and energy efficiency in the residential sector:

- What policies or methods of consumer engagement can be employed to increase the rate of household energy efficiency retrofits? Candidates include:
    - Financing products that motivate contractors to sell more energy efficiency projects
    - Ordinances requiring a home energy audit, rating, or label at time of sale and disclosure of results to prospective buyers
    - Building energy labels that enable home prices to reflect energy performance

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[a] From a grid-management perspective, however, EVs may be helpful as they add base load during off-peak hours, can provide grid services, and help to preserve utility revenues through additional kWh sales. See section 5.5.6 for more on these topics.

    - Training, outreach, and incentives to contractors and community groups on the benefits of efficiency for their consumers
    - Development of retrofit-friendly technologies to lower costs
- What policies or methods of consumer engagement can be employed to specifically reach low-income households who have proven challenging to engage, and for whom electric efficiency can ease budget pressures?
- How can policy best facilitate adoption and quality installation of efficient technologies while managing related moisture, comfort, and indoor air quality issues?
- What are the best methods to improve building energy code compliance?
- How can data be gathered and reported to eliminate confusion and competition between electricity usage reduction through efficiency and electricity usage increase for electric transportation?
- What technologies and policies can best control electricity usage from MELs?
- What are the potential electricity savings and relative cost-effectiveness of various innovative policy approaches, including
    - Home automation
    - Zero energy homes
    - Behavior-based programs
    - Innovative financing products
    - Building energy label

Residential Appendix

Air conditioning (AC) efficiency is measured by energy efficiency ratio (EER), which measures cooling output per electric energy input, and by two variants: seasonal energy efficiency ratio (SEER) for central air conditioners and heat pumps,[a] and combined energy efficiency ratio (CEER) for room air conditioners. Air source heat pump heating efficiency is measured by heating season performance factor (HSPF), which is conceptually analogous to SEER. Ground source heat pump heating efficiency is measured by coefficient of performance (COP), which is the ratio of the heating energy produced to the work required to produce it. As Table 7.3 shows, while current technology can attain much higher levels of performance than the installed stock (except in the case of room AC), typical installed units are expected to improve only marginally from those available today. A larger gap exists between today's performance levels and those of the installed stock, so equipment turnover will improve performance in the short run.

Table 7.3. Current and Projected Efficiency of Selected Electric Space-Conditioning Units[113]

Residential AC Type	2009 Installed	2013		2020		2030		2040	
		Typical	High	Typical	High	Typical	High	Typical	High
Room AC (CEER)	9.3	10.9	11.6	11	12	11	13	11.2	13
Central AC (SEER)	11.4	13/13.5 *	24	14/14.5 *	24	14.5	24	14.5	24
Air Source Heat Pump Cooling (SEER)	12	14	22	14.5	23	15.5	24	16	25
Air Source Heat Pump Heating (HSPF)	7	8.3	9	8.4	10.8	8.6	10.9	8.7	11
Ground Source Heat Pump Cooling (EER)	12.3	14.2	28	17.1	36	21	42	24	46
Ground Source Heat Pump Heating (COP)	3	3.2	4.5	3.6	4.9	3.8	5.2	4	5.4

Typical installed unit efficiency is projected to improve only slightly, though much higher performance levels are technologically possible. Asterisked values characterize typical efficiencies in the South, where high cooling loads and humidity place a premium on air conditioning performance relative to the rest of the United States. Note that CEER, SEER, EER, COP, and HSPF factors are not directly comparable to one another.

[a] Air-source heat pumps extract heat from the air, and ground-source heat pumps extract heat from the ground. A variety of air-source heat pump technologies are available, including ductless and ducted models and both single-room and multi-zone models. The vast majority of installed units are air source. Some rural electric cooperatives promote ground source heat pumps and give incentives for their installation. (Air-source heat pumps are also promoted, much more widely and especially in the South.)

Table 7.4. Status of Consumer Product and Lighting Standards that Impact Residential Electricity Use[114]

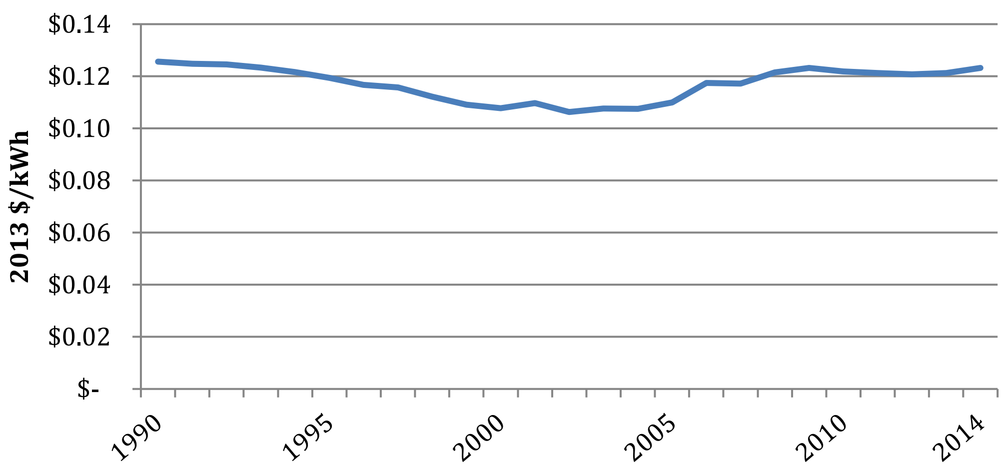
Product Covered	Last Standard Issued	Effective Date	Updated Standard Expected	Potential Effective Date	States with Standard
Consumer Products					
Battery Chargers	None	None	2016	2017	CA, OR
Boilers	2015	2021	2022	2027	
Ceiling Fans	2005	2007	2016	2019	
Central Air Conditioners and Heat Pumps	2011	2015	2016	2021	
Clothes Dryers	2011	2015	2017	2021	
Clothes Washers	2012	2015	2018	2021	
Compact Audio Equipment					CA, OR, CT
Dehumidifiers	2007	2012	2016	2019	
Dishwashers	2012	2013	2016	2019	
DVD Players and Recorders					CA, OR, CT
External Power Supplies	2014	2016	2016	2018	CA
Furnace Fans	2014	2019	2020	2025	
Microwave Ovens	2013	2016	2019	2022	
Miscellaneous Refrigeration Products			2016	2019	CA
Pool Heaters	2010	2013	2016	2021	
Pool Pumps			2016	2021	AZ, WA, CA, CT
Portable Air Conditioners	None	None	2016	2019	
Portable Electric Spas					AZ, OR, WA, CA, CT
Refrigerators and Freezers	2011	2014	2018	2021	
Room Air Conditioners	2011	2014	2017	2020	
Televisions	None	None	None	None	CA, CT, OR
Water Heaters	2010	2015	2016	2021	
Lighting					
Candelabra & Intermediate Base Incandescent Lamps	2007	2012	2016	2019	
Ceiling Fan Light Kits	2015	2016	None	None	
Compact Fluorescent Lamps	2005	2006	2017	2020	
General Service Lamps	2007	2012	2017	2020	
Incandescent Reflector Lamps	2015	None*	2023	2026	D.C., OR
Incandescent Reflector Lamps (includes certain BR and Other Exempted IRLs)	None	None	2016	2019	
Luminaires	None	None	None	None	CA
Torchiere Lighting Fixtures	2005	2006	None	None	

New federal standards for a number of significant products—AC, heat pumps, washers and dryers, refrigerators and freezers, and ceiling fan light kits—went into effect in 2014 and 2015. In addition, many states set standards for appliances and equipment that are not covered by federal standards.

** There is no effective date for this standard because the 2015 rule found that "amending energy conservation standards for incandescent reflector lamps (IRLs) would not be economically justified.*[115]

Between 1990 and 2014, electricity prices in the residential sector decreased by about 2% in real terms (constant 2013 dollars), from 12.6 cents/kWh to 12.3 cents/kWh. Residential electricity prices are higher than any other market sector (Figure 7.16).

Figure 7.16. Electricity prices for the residential sector, 1990 to 2014[116]



Electricity prices in the residential sector decreased by about 2% in real terms (constant 2013 dollars) between 1990 and 2014.

Table 7.5. Example Residential and Commercial Sector Miscellaneous Electric Loads[117]

Example Residential MELs	Example Commercial MELs
Audio Equipment	Distribution Transformers
Ceiling Fans	Data Center Servers
Dehumidifiers	IT Equipment (non-data center)
DVD/Media Players	Video Displays
External Power Supplies	Large-Format Video Boards
Modems & Routers	Water Treatment/Distribution
Monitors (i.e. desktop PC monitors)	Monitors (i.e. desktop PC monitors)
Non-Computer Rechargeable Electronics	Kitchen Ventilation (Exhaust Hoods)
Pools/Pool Pumps	Lab Refrigerators/Freezers
Portable Electric Spas	Security Systems, Commercial
Security Systems, Home	Medical Imaging Equipment
Set-top Boxes, All	
Televisions	

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