Buildings

Highlights

Efficiency Opportunities

Residential and commercial energy consumption primarily occurs indoors. Buildings are main energy efficiency opportunities (e.g., building envelope, sourcing of construction materials, water efficiency, energy management systems, smart buildings) as well as the site of energy-consuming products (e.g. appliances, plug loads, HVAC systems).

Residential Building Energy Use

Residential energy use per household has fallen by roughly 16% from 2001 to 2018.

Commercial Building Energy Use

Commercial building energy consumption per square foot has been declining, in large part due to significant savings in lighting and space heating, which each fell by more than 600 trillion Btu from 2003 to 2012.

Energy Efficiency Gains for Appliances and Devices

The energy efficiency of appliances has increased dramatically since 1980, due to a combination of federal standards and the ENERGY STAR® product certification program. A typical household saves about $500 per year on utility bills due to minimum energy performance standards for appliances, and ENERGY STAR® has helped drive down energy use by refrigerators and clothes washers by 24% (since 1996) and 30% (since 2004), respectively.

Energy Efficiency Gains for Appliances and Devices

The U.S. has decreased its lighting energy consumption by 16% from 2001 to 2015 despite increasing its lamp inventory by 25% over that same period.

Tools to Understand and Enhance Building Efficiency

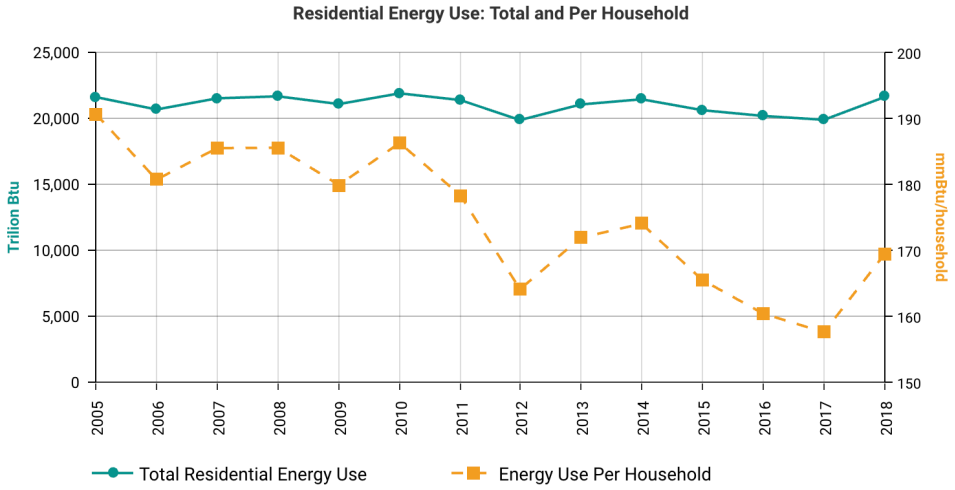
Benchmarking; energy rating, such as through the Home Energy Rating System or Home Energy Score; and certification (including ENERGY STAR® and LEED) can drive efficiency in buildings. Zero Net Energy Buildings and Smart Buildings are also growing rapidly.

Model Building Energy Codes

Model building energy codes are expected to save $126 billion in energy costs and 13 quads of primary energy over the 2010 to 2040 timeframe.

24 Energy Efficiency and Household Cost Reductions

Energy efficiency has driven down energy consumption per household by approximately 16%

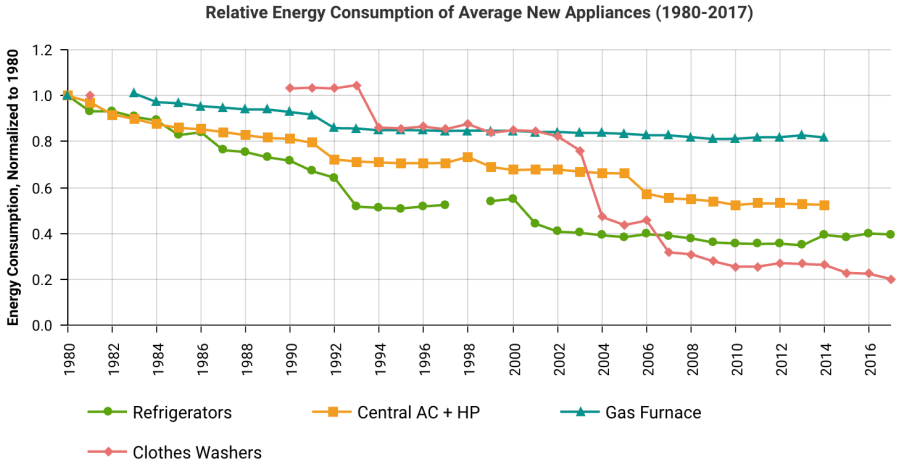


Sources: EIA (2019), Monthly Energy Review ; U.S. Census Bureau (2019), Current Population Survey

Energy consumption in residential buildings is responsible for approximately 20% of total primary energy use in the U.S.[1] Due to energy efficiency, total residential energy use has remained largely constant from 2005 to 2018, and per-household energy consumption has fallen by roughly 16% over the same period.[2] This is notable, given that the average U.S. resident lives in larger, better-acclimated homes with significantly more devices.

25 Appliance Energy Efficiency Improvements

Appliances and equipment have become more efficient across the board, using a fraction of the energy required in 1980



Source: ACEEE (2015), Energy Efficiency in the United States: 35 Years and Counting, analysis includes supplemental data from AHAM

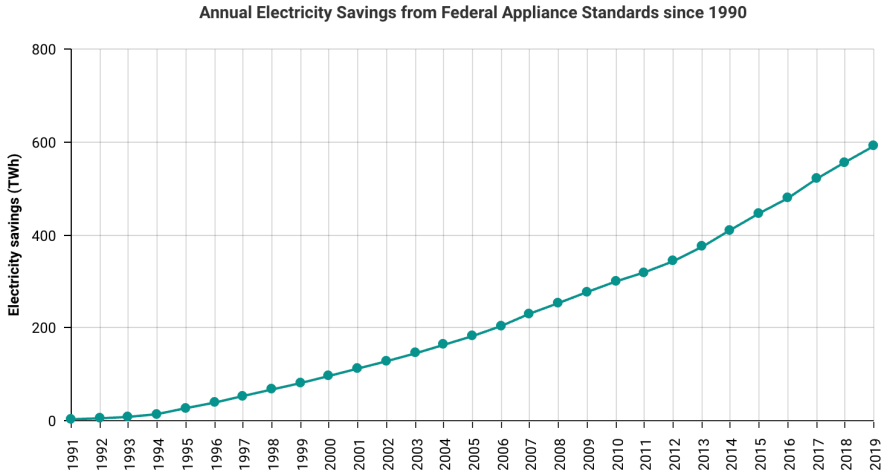
1 EIA (2019), Monthly Energy Review

2 Calculated based on a trendline from 2003-2018.

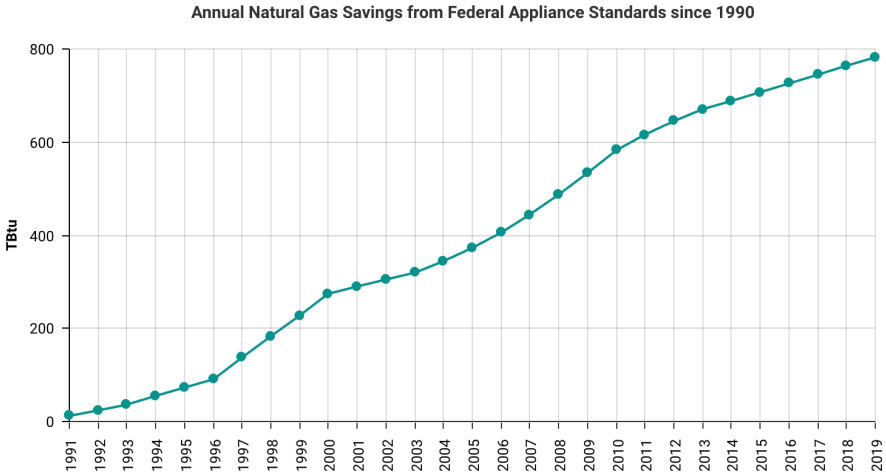
The efficiency of appliances has increased significantly in the last decades. The chart shows the relative average energy consumption of new appliances sold over the 1980–2017 period. Clothes washers and refrigerators showed the greatest improvements (80% and 60% reductions in energy consumption, respectively).[3] These gains were driven in large part by federal standards (indicator #26), ENERGY STAR® (indicator #27), tax credits, and utility rebates.

26 Policy Impact: Federal Appliance Standards

Policies for appliance efficiency are saving 14% of the total electricity generated in the U.S., and 6% of delivered natural gas



Source: ACEEE & ASAP (2019)



Source: ACEEE & ASAP (2019)

Federal appliance standards ensure a base-level efficiency for all appliances on the market, and have led to large-scale energy savings of both electricity and natural gas since 1990. These savings add to enormous benefits for U.S. households and businesses. A typical household saves about $500 per year on utility bills because new household appliances and heating, cooling, and lighting products comply with minimum standards.[4] Estimates suggest the federal appliance

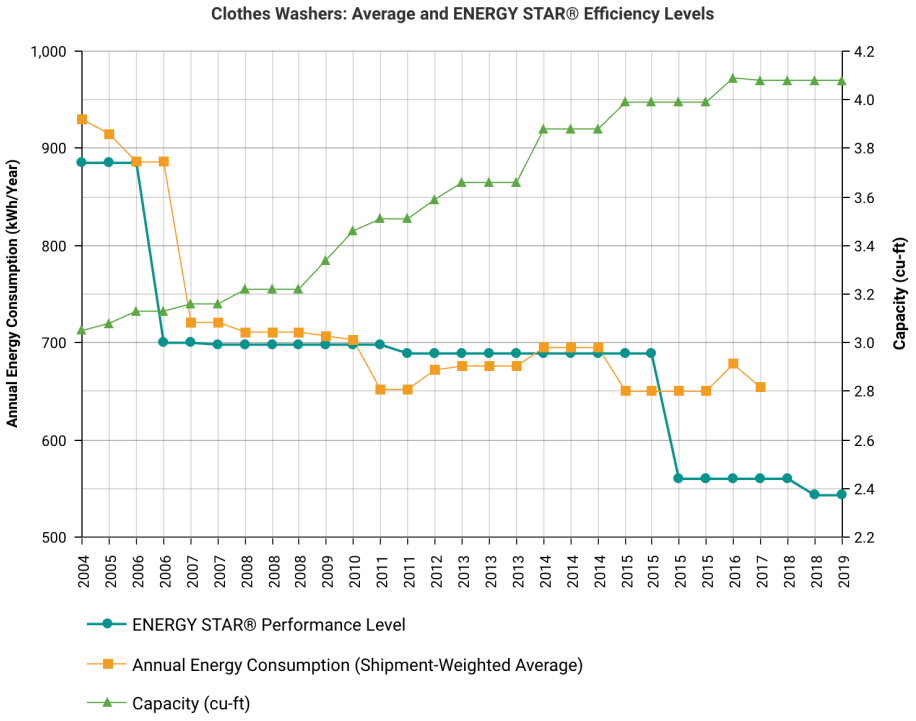
3 ASAP (2019), Refrigerators and Freezers

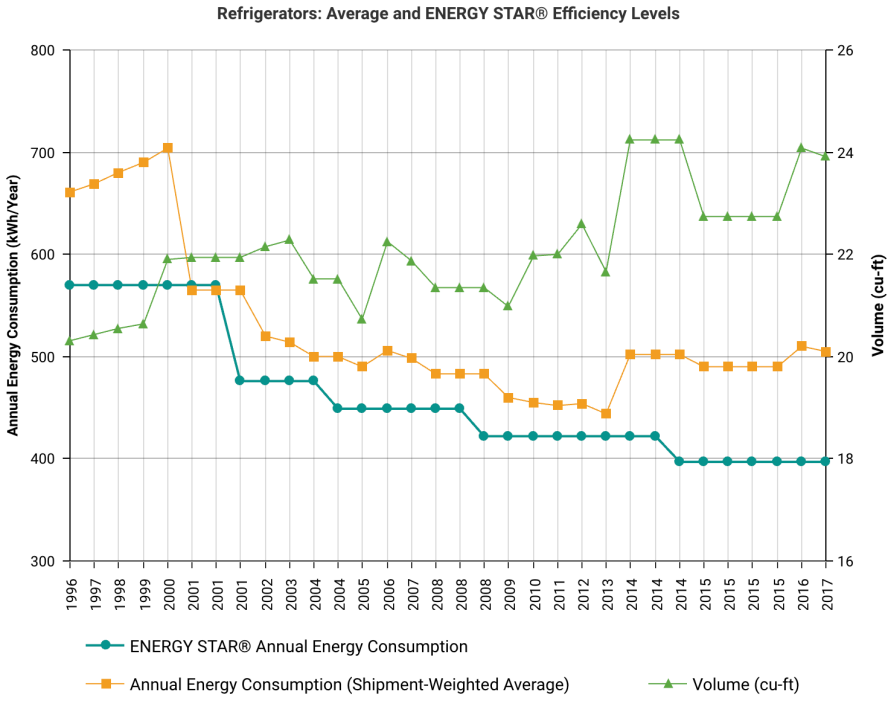
4 ACEEE (2017), Energy-Saving States of America: How Every State Benefits from National Appliance Standards

standards program saved nearly 600 TWh in 2019 relative to efficiency levels without standards, which is over 14% of the total electricity that was generated in the U.S. in 2018 (4,178 TWh).[5]

27 Market Impact: ENERGY STAR®

The ENERGY STAR® voluntary certification program has enhanced the market value of efficiency and raised consumer awareness about its benefits





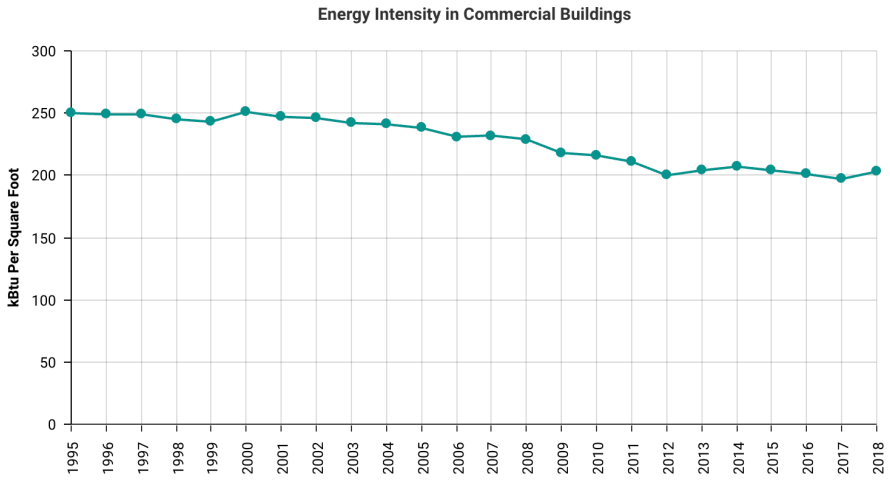
Source: EPA (2019)

5 EIA (2019), Frequently Asked Questions

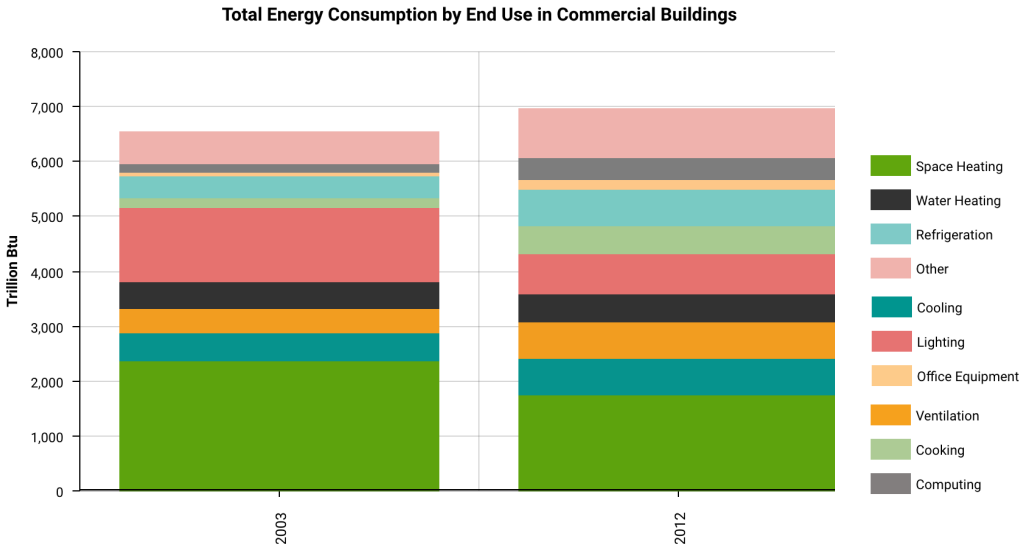
ENERGY STAR Products®, a part of the ENERGY STAR® program, has grown to cover more than 75 product categories and 60,000 product models, some of which have reached market penetrations as high as 90%.[6,7] For example, ENERGY STAR® specification for refrigerators was established in 1996 and has been revised and strengthened multiple times, helping to reduce the average energy consumption of refrigerators by 24% while the average volume increased 18% from 1996 to 2017. Established in 1997, ENERGY STAR® specifications for clothes washers were also strengthened multiple times, facilitating a 30% drop in energy consumption while the average capacity increased 34% from 2004 to 2017. Americans purchase more than 300 million ENERGY STAR® certified light bulbs annually, with an overall annual market value of more than $100 billion.

28 Commercial Building Energy Intensity

Gains in lighting and space heating efficiency have decreased energy intensity in commercial buildings, but demand in other areas is driving increased commercial energy use overall



Sources: EIA (2019), Monthly Energy Review ; EIA (1995–2012), CBECS (interpolation of square footage)



Sources: EIA (2003–2012), CBECS

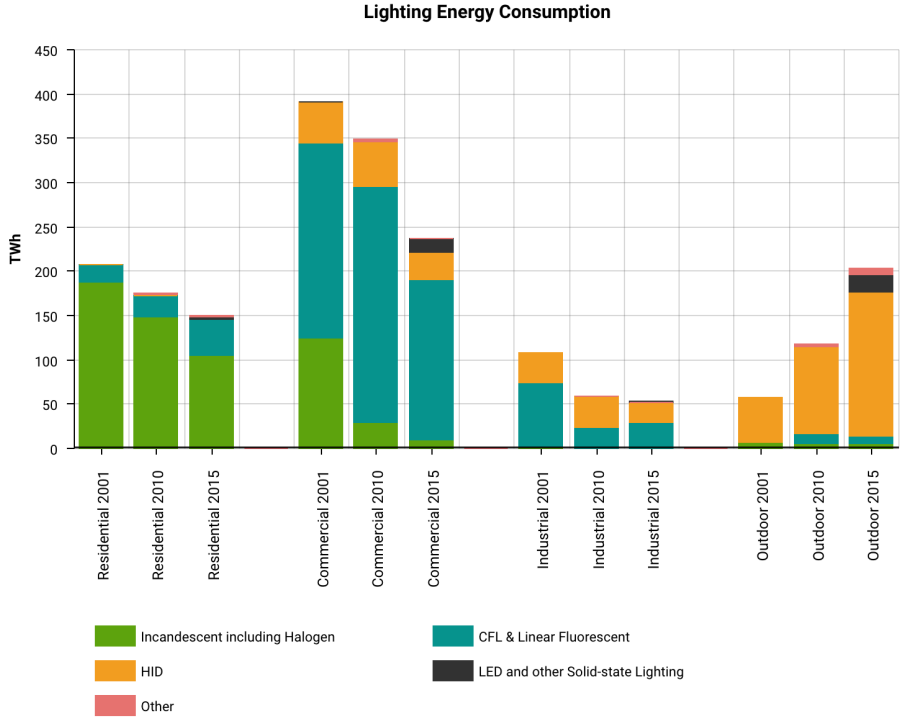
6 ENERGY STAR (2019), ENERGY STAR By the Numbers and About Products

7 As in the case for ENERGY STAR® dishwashers. ENERGY STAR Unit Shipment data

Total commercial building energy consumption per square foot in commercial buildings has been declining, in large part due to significant savings in lighting and space heating, which each fell by more than 600 trillion Btu from 2003 to 2012.[8] However, total energy consumption in this sector has been rising due to increased development, with square footage rising from 71 billion in 2003 to 87 billion in 2012, and increases in certain areas, such as the energy consumed by office equipment and computing, cooling, ventilation, and other loads. In contrast, plug loads account for about a third of commercial building electricity consumption, and could grow to nearly half by 2030.[9]

29 Market Impact: Efficient Lighting from 2001 to 2015

Rapid gains in more efficient lighting, including CFLs and LEDs, have reduced energy use in lighting by 16% in 14 years, while inventory grew 25%



Source: Navigant Consulting (2001, 2010, 2015), U.S. Lighting Market Characterization

A success story of bringing RD&D technologies to market, drastic efficiency gains in light bulbs have allowed the U.S. to decrease its energy use from lighting by 16% while increasing lamp inventory by 25% from 2001 to 2015.[10] Compared to a traditional 60W incandescent bulb,

8 EIA (2016), 2012 Commercial Buildings Energy Consumption Survey

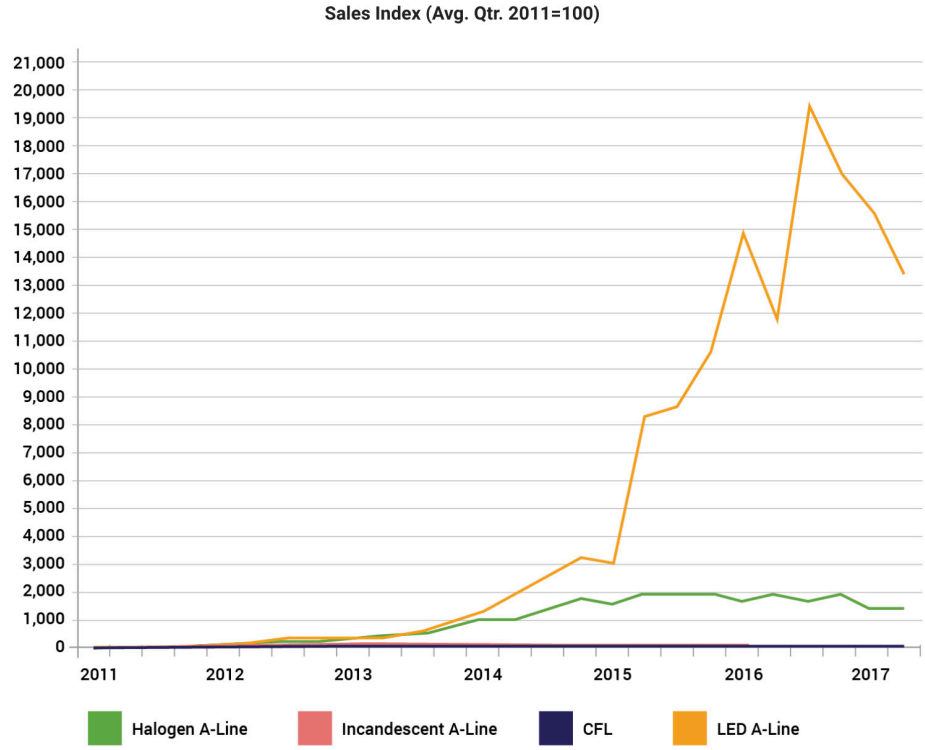
9 For electricity energy consumption, the "Other" category includes miscellaneous, process equipment, motors, and air compressors as defined by the Energy Information Administration (EIA). For fuel oil and natural gas, the model for other energy use is based on EIA's regression estimates. NREL (2013), Office Buildings

10 Navigant Consulting (2001, 2010, 2015), U.S. Lighting Market Characterization

an 8.5W light emitting diode (LEDs) consumes 85% less energy[11] and lasts from 10 to 25 times as long.[12] Furthermore, the price of LEDs per lumen has fallen by 75% from 2012 to 2016, and the market penetration has grown from less than one percent to 13.5% over that same time period. In contrast, energy use from high-intensity discharge lamps (HIDs), a less efficient high-output lamp used in street lighting, warehouses, and sports arenas, continues to grow for outdoor uses.[13] Nevertheless, DOE's September 2019 rule that rolls back energy efficiency standards for lightbulbs creates uncertainty in the future of the market.[14,15]

30 Growth in LED Sales After 2015

Sales of the most common pear-shaped LED lightbulbs have tripled from 2015 to 2018



Source: NEMA (2019)

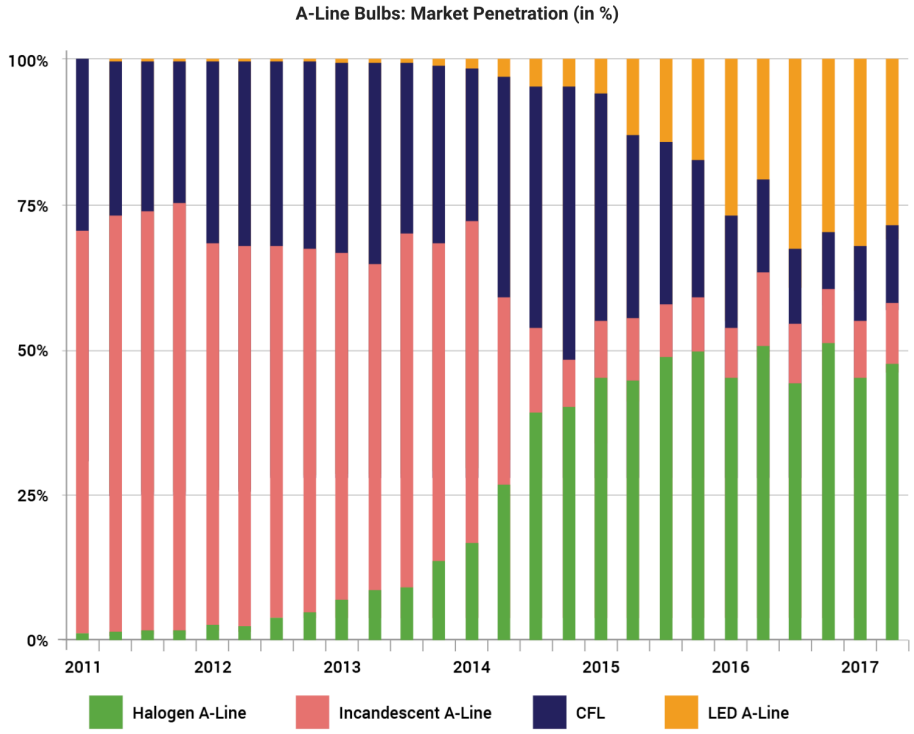
11 ASAP/ACEEE (2018), US Light Bulb Standards Save Billions for Consumers But Manufacturers Seek a Rollback

12 DOE (2019), How Energy-Efficient Light Bulbs Compare with Traditional Incandescents

13 BCSE & BloombergNEF (2019), 2019 Sustainable Energy in America Factbook

14 DOE (2019), Energy Conservation Program: Definition for General Service Lamps

15 ASAP (2019), Rollback of light bulb standards would cost consumers billions



Source: NEMA (2019)

Though they were only introduced in the 2000s, LED sales of A-line bulbs have grown quickly, with sales tripling between 2015 and 2018, resulting in a growth of market penetration from nearly zero to greater than 25% within a span of five years.[20]

The market share of LEDs has accelerated at a similar rate for tubular bulbs (primarily used in the commercial and industrial sectors), achieving more than 25% of the market share by 2018.[17] Their adoption has also been driven by their greater controllability, which leads to additional energy efficiency savings in commercial buildings; for example, LEDs are more easily paired with digital control systems, can feature both dimmable and color-changing features, and expel less waste heat.[18]

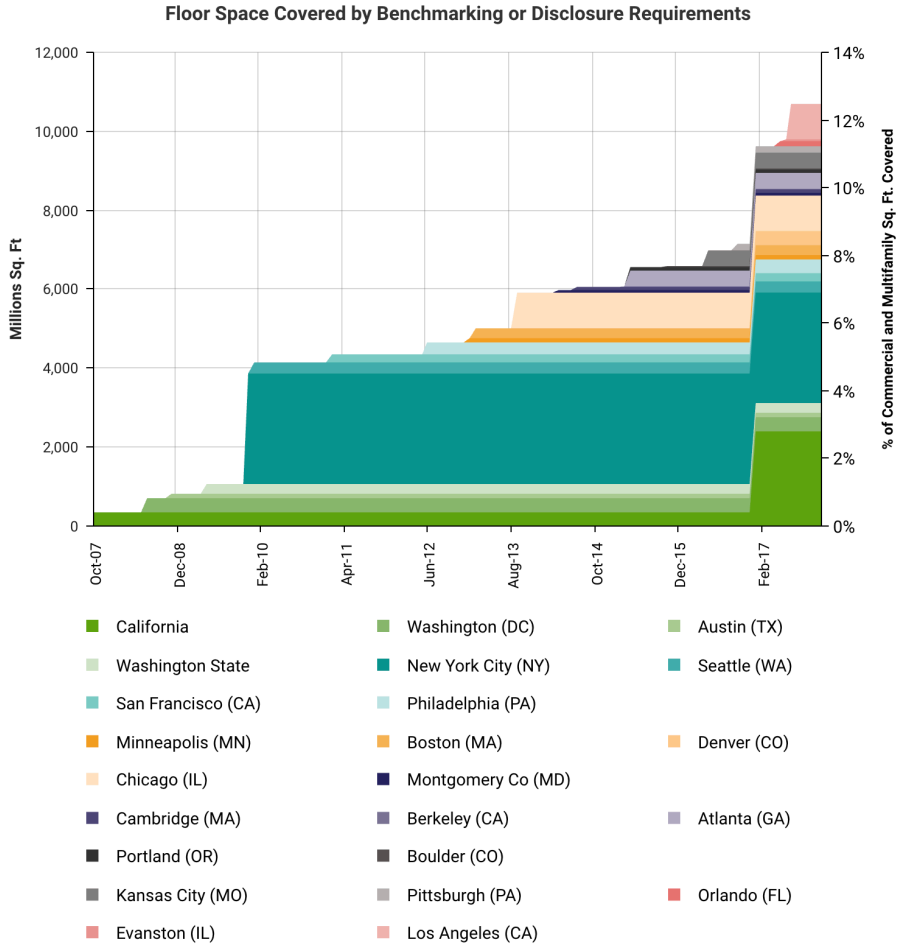
20 NEMA (2019), Second Quarter 2017 Year-Over-Year LED A-Line Lamp Shipments Up, Halogen, Incandescent and CFL Shipments Continue to Decline

17 NEMA (2019), Linear Fluorescent Lamp Indexes Continue Year-Over-Year Decline in First Quarter 2019 while T-LED Market Penetration Increases

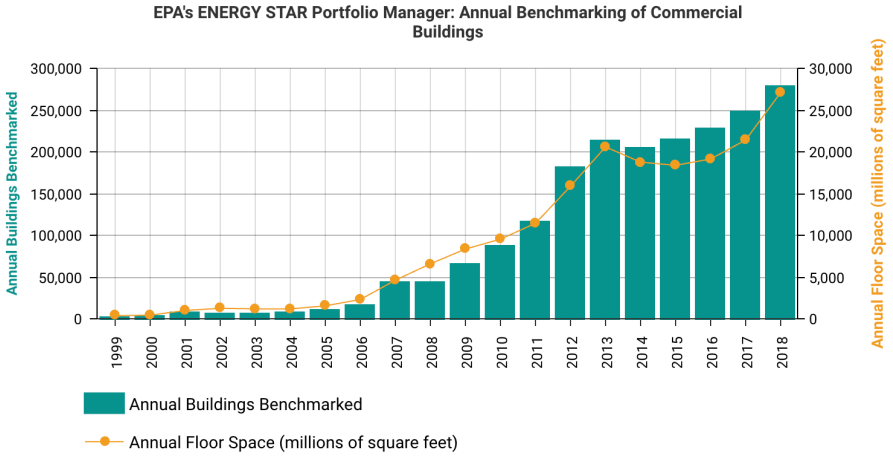
18 LCA (2016), Seven Trends in LED Lighting Control

31 Commercial Building Energy Performance Benchmarking

Commercial building energy performance benchmarking incentivizes energy efficiency and is increasingly required by cities and states



Source: BCSE & BloombergNEF (2019), 2019 Sustainable Energy in America Factbook



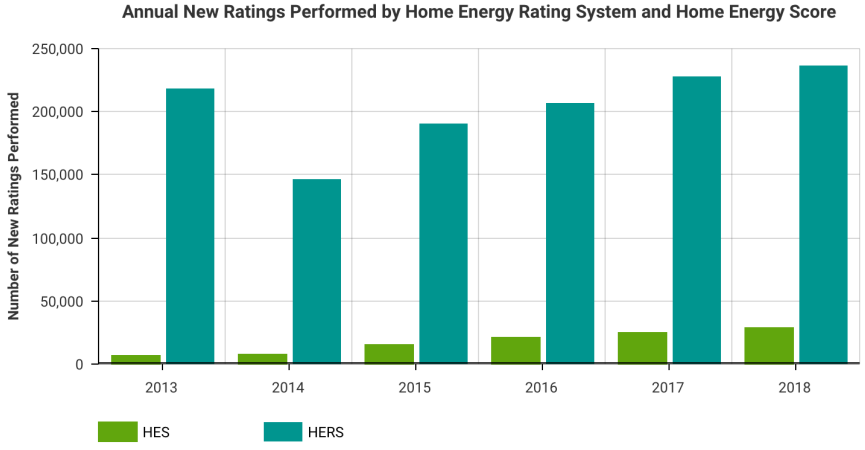
Source: EPA

Benchmarking can help facility managers set reasonable energy efficiency goals and assess the effectiveness of energy savings programs. The U.S. Environmental Protection Agency found that buildings that were consistently benchmarked reduced energy use by an average of 2.4% per year.

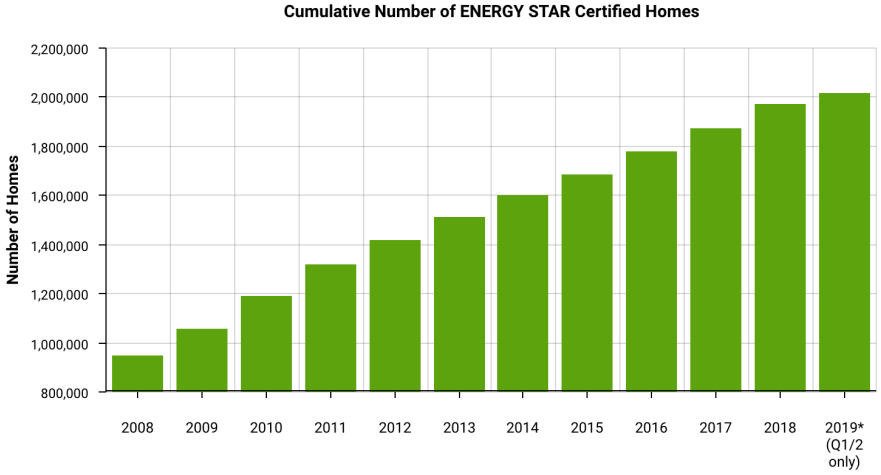
A number of states and localities have implemented benchmarking requirements using ENERGY STAR Portfolio Manager in the last decade, such that the square footage of floor area required to be benchmarked has increased dramatically – benchmarking through ENERGY STAR Portfolio Manager has grown to represent close to 25% of U.S. commercial floorspace.[19]

32 Residential Home Energy Use Rating and Certification Tools

Greater than 4 million energy performance ratings and certifications have been performed since 2012



Source: EPA (2019)



Source: EPA (2019)

19 ENERGY STAR (2019), Portfolio Manager DataTrends

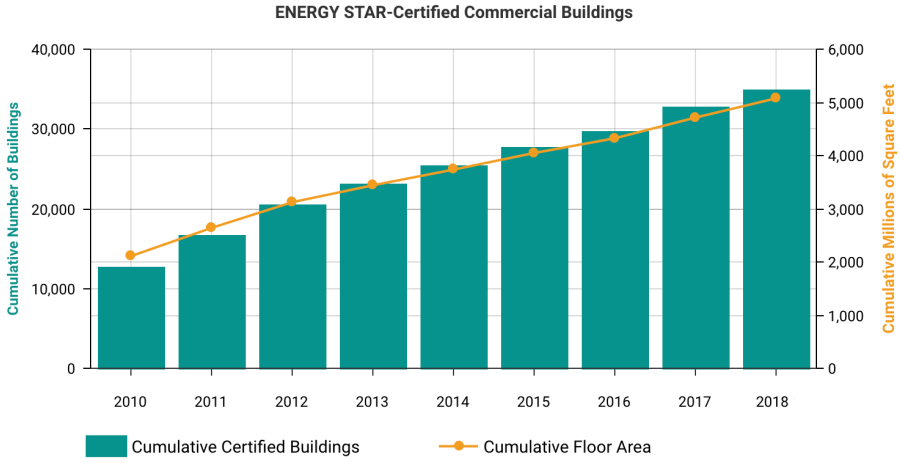
Ratings and certifications bring greater transparency to energy efficiency opportunities, and can result in a clearer understanding of utility bills and opportunities for savings, incentives to invest in energy-efficient construction, and help for homebuyers to qualify for loans.[20,21] Residential homeowners, builders, and property developers have several tools that can be used in different circumstances to achieve a deeper understanding of a home's energy performance, including the Home Energy Rating System (also known as a HERS rating), and Home Energy Score (HES rating).

HERS provides an estimate of energy performance in new homes, while HES ratings apply to existing homes. The first chart shows annual ratings performed by year, with increases in the use of both rating systems. Cumulatively, more than 2 million homes are estimated to have HERS ratings, or approximately one-fifth of new homes today.[22] More than 120,000 homes have received HES ratings.

While HERS and HES provide an energy efficiency rating regardless of the home's performance, ENERGY STAR® certifies new homes that have achieved higher levels of energy efficiency. The cumulative number of ENERGY STAR® certified homes reached more than 2 million in 2019 (Note that many homes receive more than one rating or certification).

33 Building Certification by ENERGY STAR® and LEED

ENERGY STAR® and LEED commercial building certifications have increased by nearly 3- and 6-fold since 2010

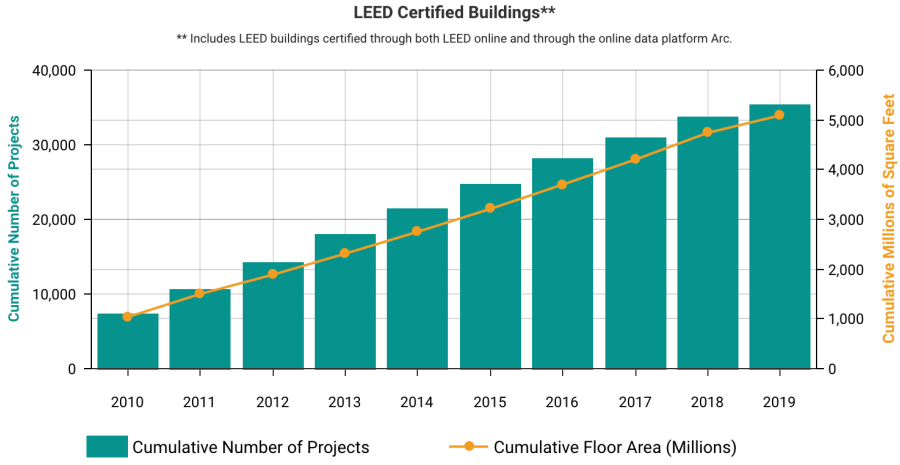


Source: EPA (2019), ENERGY STAR® Certified Building and Plant Locator (database)

20 While ENERGY STAR®, HERS, and HES are the most common certification and rating systems, there are also others, including Net Zero Energy Building Certification, Passive House Certification, Green Built Homes, and LEED Zero.

21 DOE (2019), DOE's Home Energy Score and FHA Mortgages: New Tools to Help You Shop for and Buy an Energy Efficient House

22 RESNET (2019), Demand for HERS Continues to Grow



Source: USGBC (2019)

ENERGY STAR® certifies buildings that exhibit better energy performance than 75% of similar buildings nationwide, verified by a third-party.[23] On average, ENERGY STAR® certified buildings use 35% less energy and cost $0.50 less per square foot to operate than their peers.[24] In 2018 alone, more than 270,000 buildings, comprising 26 billion square feet of floorspace, used ENERGY STAR® Portfolio Manager to measure and track their energy use, water use, and waste and materials.[25]

LEED certifies the design, construction, and operations of a building. LEED requires the modeled design for its certified buildings to be better than a baseline building's performance by 5% for new construction and by 3% for major renovations, but most LEED buildings are much more efficient that the minimum requirement.[26,27] A 2014 study documented that the average design efficiency of LEED projects in the study was approximately 27% better than the reference code.[28] Post-occupancy studies have also borne out the energy performance of LEED buildings: a 2015 assessment of buildings in Washington, D.C., found that LEED-certified office buildings exhibited 13% less energy use intensity than their peers, and a 2016 report by the State of Washington found that by implementing green building practices, state agencies and higher educational facilities reduced their energy use by an overall average of 37%. And, a 2018 GSA latitudinal study examined 200 buildings over a three-year period, finding that compared to legacy buildings, GSA's high performing buildings show 23% less energy use.[29,30,31]

23 ENERGY STAR (2019), ENERGY STAR certification for your building

24 ENERGY STAR (2019), Ten reasons to pursue ENERGY STAR certification

25 ENERGY STAR certifications are also counted per building structure; multiple certifications of the same building are counted as a single certification in the above chart.

26 According to ANSI/ASHRAE/IESNA Standard 90.1–2010, Appendix G (Note: LEED's current system being tested includes update to Standard 90.1-2016, see USGBC (2019), LEED v4.1)

27 USGBC (2019), LEED BD+C: New Construction | v4 – LEED v4

28 USGBC (2014), The LEED Plaque Unpacked: What a Decade of LEED Project Data Reveals About the Green Building Market

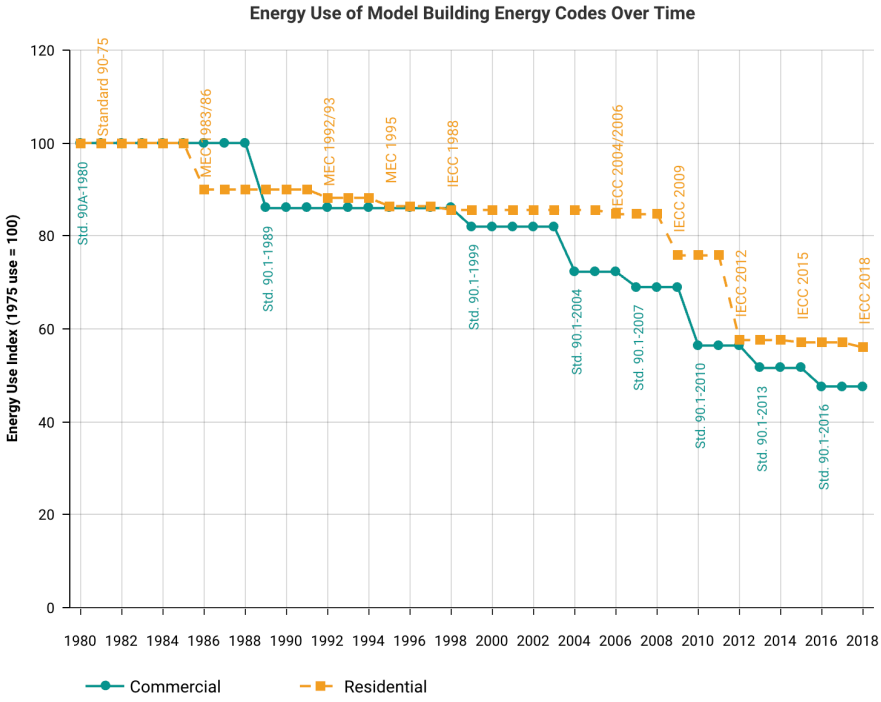
29 USGBC (2015), LEED buildings outperform market peers according to research

30 Washington State Department of Enterprise Services (2016), High Performance Public Green Buildings

31 U.S. General Services Administration (2018), The Impact of High Performing Buildings

34 Model Building Energy Codes

Building energy codes have reduced covered energy use in buildings by more than 40% over four decades



Source: ACEEE & PNNL (2019)

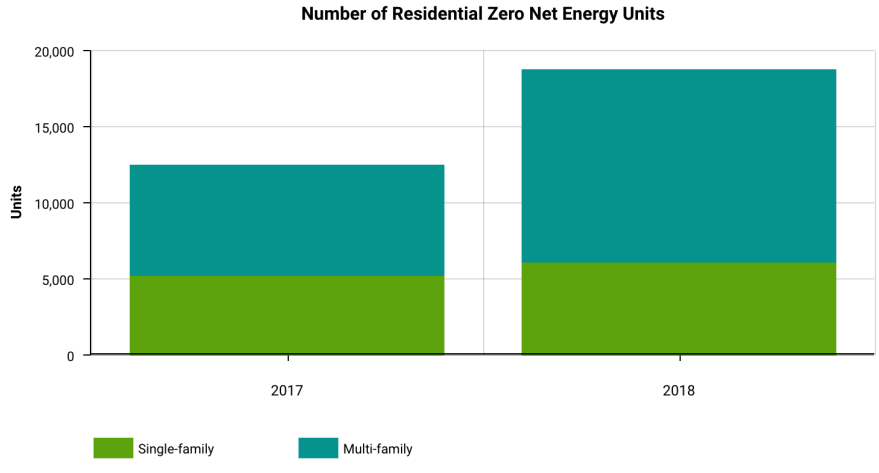
Building energy codes set minimum efficiency requirements for renovated or new buildings, locking in savings through the building's lifespan (which can reach over 100 years in the case of new constructions).[32] Model energy codes are expected to save $126 billion in energy costs and 13 quads of primary energy over the 2010 to 2040 timeframe.[33] A home built to the specifications of the International Energy Conservation Code of 2018 would use 40% less code-covered energy than if it had been built using standard practices in 1975.

32 Energy-Efficient Codes Coalition (2019), The IECC: A Life-Safety Code That Pays 100 Years of Dividends to Occupants & Our Nation

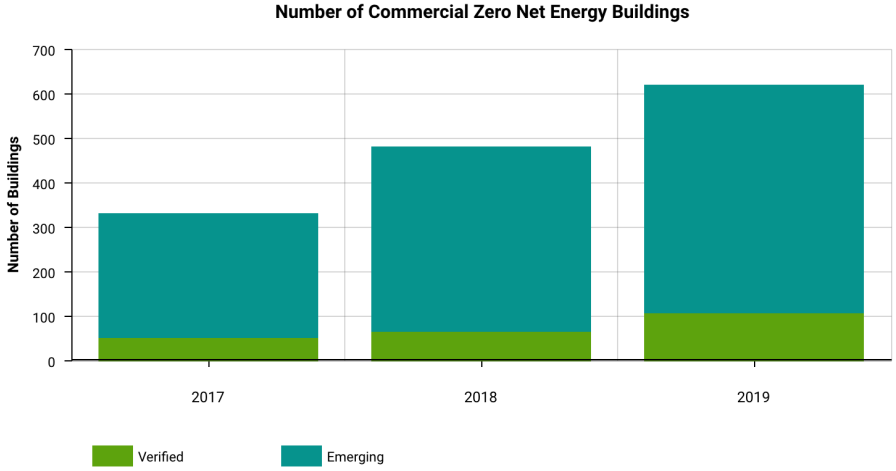
33 DOE (2016), Why Building Energy Codes?

35 Zero Net Energy Buildings

The U.S. market for zero net energy buildings is growing rapidly



Sources: Team Zero (2017, 2018), Inventory



Sources: New Buildings Institute (2019), Number of Zero Energy Buildings Chart & Getting to Zero Buildings Database

The construction of zero net energy and zero energy ready buildings is a very recent trend that still constitutes a small fraction of the building market, but is growing rapidly.[34] From 2017 to 2018, the total number of residential units has grown by 50%. In 2019, the number of verified commercial buildings has reached 108, the number of emerging commercial buildings striving for zero net energy has grown by over 270 since 2017.[35] Certifications such as LEED Zero may help drive more net zero energy projects by facilitating recognition and incentives. States and cities are also beginning to incorporate net zero energy into codes and stretch codes.[36]

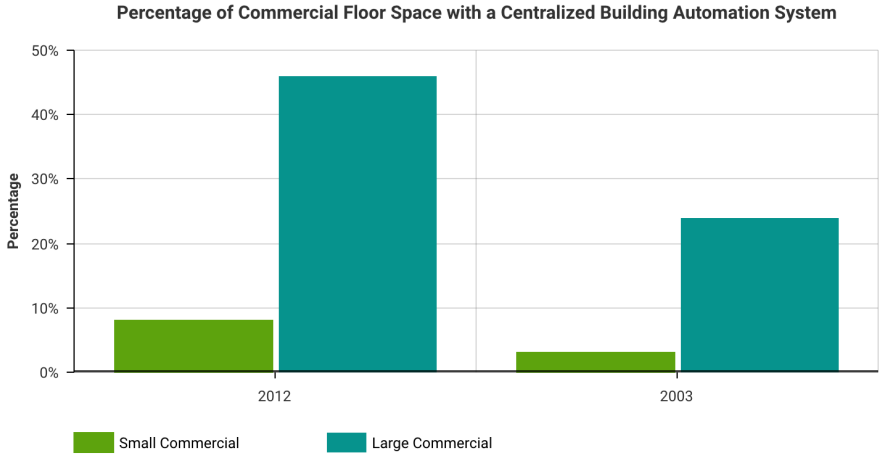
34 840,000 single-family homes and 345,000 multifamily units were completed in 2018. Census Bureau (2019), Characteristics of New Housing

35 New Buildings Institute (2019), Getting to Zero Buildings Database

36 See, e.g., Washington D.C. proposed code update, Appendix Z.

36 Smart Buildings

Nearly half of large commercial buildings have centralized building automation systems



Source: DOE (2019), Sensors and Controls RD&D Overview

Smart Technology Examples	Energy Savings Potential
Smart thermostat	5–10% of HVAC energy
Web-based lighting management system	20–30% above controls savings
Automated shade system	10–20% of cooling energy
Traditional building automation system	10–25% of whole building energy

Source: ACEEE (2017), Smart Buildings: Using Smart Technology to Save Energy in Existing Buildings; Lutron (2014), Lutron Energy Savings Claims

Building controls, sensors, and submeters work together to make up smart building systems, and their deployment is growing rapidly.[37] This growth in investment coincides with a growth in the adoption of smart technologies – 46% of large commercial buildings have a centralized building automation system and 41% of homes have a programmable thermostat.[38] However, the market has significant growth potential. For example, in spite of the energy savings potential shown in the table above, only 3% of homes currently use smart thermostats to control HVAC systems, and only 8% of small commercial floor space currently has a building automation system.

37 In the 2018 Energy Efficiency Indicator Survey conducted by Johnson Controls, participants were asked whether they planned to invest in building controls in the next 12 months: whereas only a third of respondents in 2016 planned to do so, 68% reported plans in 2018 to invest in building controls in the following year, while 74% of respondents in 2018 reported that they did invest in building controls in the past year.

38 DOE (2019), Sensors and Controls (S&C) RD&D Overview at BTO Peer Review

37 State-Level Appliance Efficiency Standards

Thirteen states and the District of Columbia have established appliance efficiency standards

Product	# of states with Standards	Product	# of states with Standards
Battery chargers	2	Lawn spray sprinklers	4
Commercial dishwashers	3	Mercury vapor ballasts	1
Commercial fryers	3	Metal halide lamp fixtures	1
Commercial steam cookers	3	Miscellaneous refrigeration products	1
Compact audio equipment	3	Pool pumps	4
Compressors	4	Portable air conditioners	4
Computers & computer systems	5	Portable electric spas	7
Deep-dimming fluorescent ballasts	1	Residential ventilating fans	3
DVD players & recorders	3	Showerheads	5
External power supplies	1	Small-diameter directional lamps	1
Faucets	5	Televisions	3
General service lamps	5	Toilets	5
High light output double-ended quartz halogen lamps	1	Uniterruptible power supplies	3
High-CRI linear fluorescent lamps	4	Urinals	5
Hot food holding cabinets	10	Water Dispensers	10

Source: ASAP (2019), State Adoption of Energy Efficiency Standards

Thirteen states and the District of Columbia have established appliance efficiency standards across a range of 30 different product types that are either allowed to exceed or are not covered by the U.S. Department of Energy's minimum energy performance standards.[39]

For products that are not yet covered nationally, state standards can build momentum around efficiency for new types of equipment. For instance, California was the first state to adopt a commercial clothes washers efficiency standard in 2002, shortly followed by eight more states, and then the first federal standard for clothes washers was adopted by Congress in 2005.[40]

39 ASAP (2019), States

40 ASAP (2019), Clothes Washers, Commercial