CENTER FOR SUSTAINABLE SYSTEMS
UNIVERSITY OF MICHIGAN

*factsheets*
**Built Environment**

# Residential Buildings

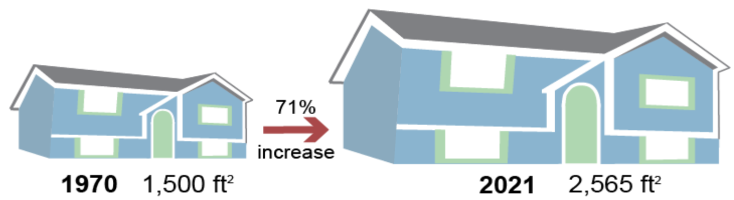
## Patterns of Use

Although climate-specific, resource-efficient house design strategies exist, per capita material use and energy consumption in the residential sector continue to increase. From 2000–2020, the U.S. population increased by 17.8%, while the number of housing units increased by 21.5%.[1,2,3] Between 2000 and 2010, urban land area increased by 15%.[1] The following trends demonstrate usage patterns in the residential building sector.

### Size and Occupancy

- Increased average area of U.S. houses:[4,5]
  1970s 1,767 $ft^2$; 1990s 2,185 $ft^2$; 2021 2,565 $ft^2$
  45% increase from 1970s
- Decreased average number of occupants in U.S. households:[7]
  1970s 2.96; 1990s 2.64; 2021 2.51
  15% decrease from the 1970s
- Increased average area per person in U.S. houses:
  1970s 597 $ft^2$; 1990s 828 $ft^2$; 2021 1022 $ft^2$
  71% increase from the 1970s
- A majority of Americans live in single-family houses. In 2019, 68% of the 124 million U.S. households were single family.[8]
- In 1950, 9% of housing units were occupied by only one person.[9] By 2021, this value had increased to 29%.[10]

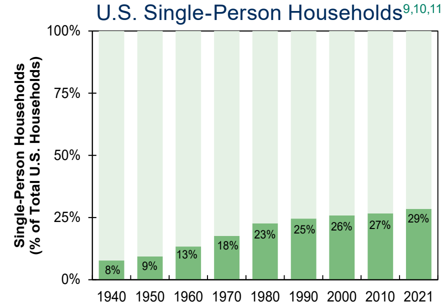
Average Size of a New U.S. Single-Family House, 1970 and 2021[5,6]



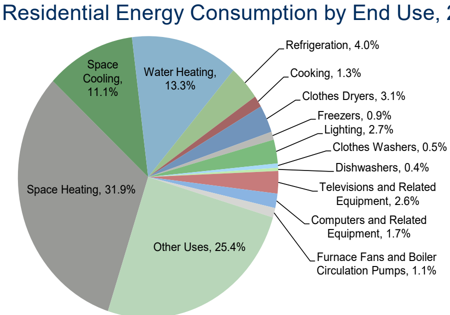

### Energy Use

- A University of Michigan study showed the average house in the U.S. consumed 147 $kWh/m^2$ annually in 2015.[13]
- Electricity consumption increased 13-fold from 1950 to 2021. In 2021, the residential sector used 3.79 trillion kWh of electricity, 96% of U.S. total electricity sales.[14]
- In 2021, the U.S. residential sector consumed 20.9 quadrillion Btu of primary energy, 22% of U.S. primary energy consumption.[15]
- Miscellaneous plug loads per household doubled from 1976 to 2006.[16] These are appliances and devices outside of a building's core functions (HVAC, lighting, etc.) such as computers, fitness equipment, computers, TVs, and security systems.[17] In 2021, miscellaneous loads consumed more electricity than any other residential end use (lighting, HVAC, water heating, and refrigeration), accounting for 37% of primary energy and 50% of electricity consumption.[12]
- Wasteful energy uses include heating and cooling of unoccupied homes and rooms, inefficient appliances, thermostat oversetting, and standby power loss.[18] Together, these uses account for at least 43% of the total energy use in the residential sector.[12]
- Building energy management systems display energy use via in-home monitor or mobile application and enable remote control of devices. Home energy management systems can reduce a house's energy use by an estimated 4-7%.[19]

U.S. Single-Person Households[9,10,11]




U.S. Residential Energy Consumption by End Use, 2021[12]




### Material Use

- The average U.S. single-family house built in 2000 required 19 tons of concrete, 13,837 board-feet of lumber, and 3,061 $ft^2$ of insulation.[20]
- From 1975 to 2000, the consumption of clay for housing and construction more than quadrupled, due to use in tiles and bathroom fixtures.[21]
- In 2012, around 24% of all wood products consumed in the U.S. were used for residential construction.[22]
- Approximately 10 million tons of waste were generated in the construction of new residential buildings in 2003—4.4 lbs per $ft^2$.[23]
- U.S. average recycling rate of waste from construction and demolition (C&D) is 20-30%.[24] Seattle recycled 66.3% of its C&D waste in 2020.[25]

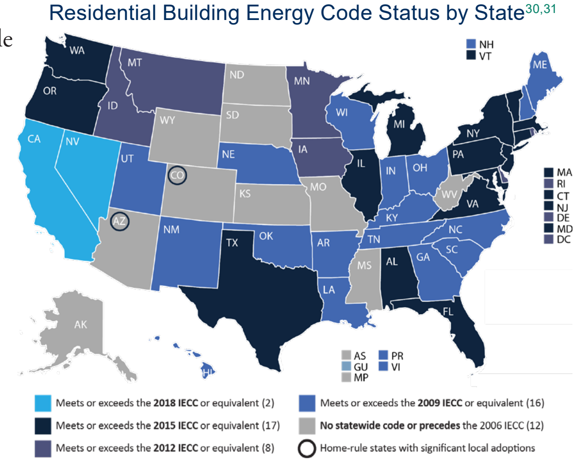
### Codes and Standards

- DOE Pacific Northwest National Laboratory estimated cumulative savings from the International Energy Conservation Code (IECC) for 42 states. From 2010–2030, the IECC would save 3.44 quads of primary energy, 17% of residential primary energy consumption in 2021.[15,26] Cumulative energy savings would generate $40.6 billion (2020 dollars) in cost savings and avoid 224.7 million metric tons of $CO_2$.[26]
- Houses built to Energy Star program requirements are 20% more energy efficient than houses built to 2009 IECC or better.[27]
- Florida's 2007 energy code saved 13% relative to pre-2007 energy consumption through the reduction in heating, cooling, and hot water demand. Efficiency gains were offset by increasing house sizes and plug loads.[28]
- For most building types, conventional energy efficiency technologies can achieve a 20% reduction in energy use relative to the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) 90.1-2004 standard.[29]
- Energy retrofits, reduced in-home fuel use, and encouraging denser settlement could decrease residential greenhouse gas (GHG) emissions.[13]

## Life Cycle Impacts

- Between 1990 and 2020, residential GHG emissions decreased by 3.6%, reaching 923 million metric tons $CO_2$-equivalent.[32]
- In 1998, CSS conducted a life cycle energy consumption inventory of a 2,450 square foot, single-family house built in Ann Arbor, Michigan.[33]
  - Only 10% of the house's life cycle energy consumption was attributed to construction and maintenance; 90% occurred during operation.[33]
  - Energy efficiency measures reduced life-cycle energy consumption by 63%. Careful selection of materials reduced embodied energy by 4%.[33]
  - Life cycle GHG emissions were reduced from 1,013 to 374 metric tons $CO_2$-equivalent over the 50-year life of the house.[33]
  - Top contributors to primary energy consumption were polyamide for carpet, concrete, asphalt roofing shingles, and PVC for siding, window frames, and pipes. Improved HVAC system and cellulose insulation were the most effective strategies to reduce energy costs.[33]
  - Substituting recycled plastic/wood fiber shingles for asphalt shingle roofing reduced embodied energy by 98% over 50 years.[33]
- A 900-$ft^2$ house in Davis, CA, modeled design and technologies to reduce energy consumption, such as LED lighting, efficient appliances, graywater heat recovery, and a radiant heating and cooling system. Annual energy consumption fell to 5,854 kWh, 44% less than a standard house of the same size and location. Electricity generation from rooftop PV made the house energy net-positive.[34]
- Operating energy accounts for 80-90% of a building's life cycle energy consumption and embodied energy accounts for 10-20%. As energy efficiency improves and operating energy decreases, embodied energy accounts for a larger fraction of life cycle energy. Design and materials selection are key ways to reduce embodied energy.[35]

Residential Building Energy Code Status by State[30,31]




## Solutions and Sustainable Alternatives

### Reduce Operational Energy Demand

Energy and water consumption during the life of a building contribute more to its environmental impact than do building materials. The following suggestions can significantly reduce operational energy demand:

- Downsizing: build smaller to reduce embodied and operating energy.[36] Tiny houses are designed for the efficient use of space.[37]
- Operating energy can be reduced through passive space heating and cooling.[33]
- By adding ceiling fans, air conditioning can be comfortably set about 4°F higher.[38]
- Install low-flow water fixtures to save both water and energy.[39]
- Adequate insulation can reduce heating and cooling costs. R-value needs differ based on location, building design, and heating methods.[40]
- Water heating accounts for 13% of residential energy consumption.[12] Save energy with a graywater heat recovery system.[41]
- Maximize natural lighting with south-facing windows. Properly shade windows to minimize summer heat gain.[42]
- Purchase energy efficient appliances and lighting. Appliances and lighting typically account for 24% of household energy costs.[43]
- Replace incandescent lamps and halogen lamps with LEDs to reduce energy costs and GHG emissions.[44]
- Pursue net-zero carbon/energy certifications including LEED, Living Building Challenge, GreenGlobes, BREEAM, Passive House.[45]

### Select Durable and Renewable Materials

As operational energy is reduced, the embodied energy of building materials becomes more significant to long-term energy conservation and GHG emission reduction.[46] Durable building materials last longer and require fewer replacements. Renewable materials generally have lower environmental burdens and many sequester carbon. As operational energy is reduced, the embodied energy of building materials becomes more significant to energy conservation and GHG emissions reduction.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