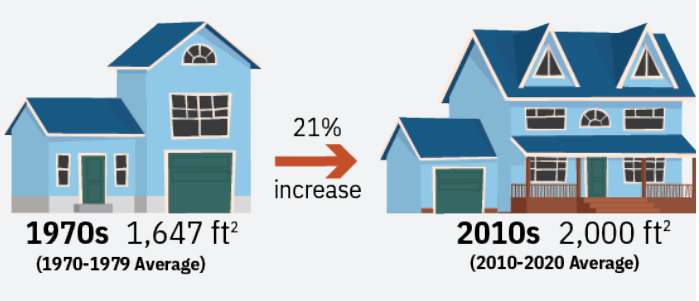
Residential Buildings

Despite the availability of climate-specific, resource-efficient housing design strategies, per capita material use and energy consumption in the residential sector continue to rise. From 2000–2024, the U.S. population increased by 21%, while the number of housing units increased by 27%.[1,2,3] Between 2000 and 2020, urban land area in the U.S. increased by 14%, reaching 3% of total U.S. land area.[1,4] The following trends illustrate use patterns in the residential building sector.

Size and Occupancy

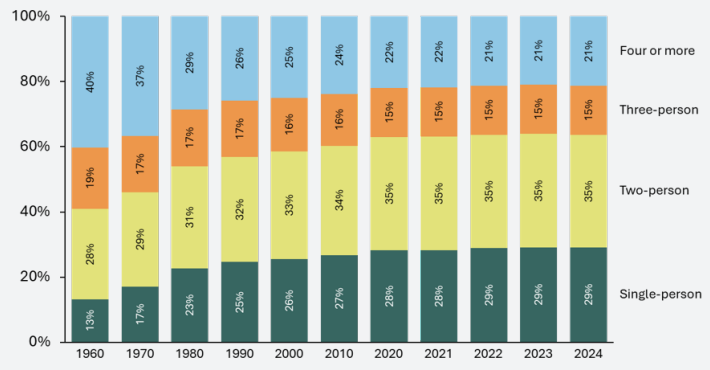
- Average U.S. house size grew from 1,647 ft² in the 1970s to 2,000 ft² in the 1990s, peaked at 2,131 ft² in the 2000s, and declined to 2,000 ft² by the 2010s, a 21% increase from 1970.[5]

Average Size of a New U.S. Single-Family House[5]



- The average number of occupants in U.S. households declined from 2.96 in the 1970s to 2.64 in the 1990s, 2.58 in the 2000s, and 2.55 by the 2010s, a 14% decrease from 1970.[6]
- Average area per person grew from 556 ft² in the 1970s to 758 ft² in the 1990s, peaked at 826 ft² in the 2000s, and declined to 784 ft² in the 2010s, a 41% increase from 1970.[5,6]
- Most Americans live in single-family houses. In 2023, 70% of the 133M U.S. households lived in single family units.[7]
- In 1950, 9% of housing units were occupied by only one person. By 2024, this value had increased to 29%.[8,9]
- In 2023, 14.8% of U.S. adults lived alone, nearly double the share in 1967, when only 7.6% lived alone.[49]

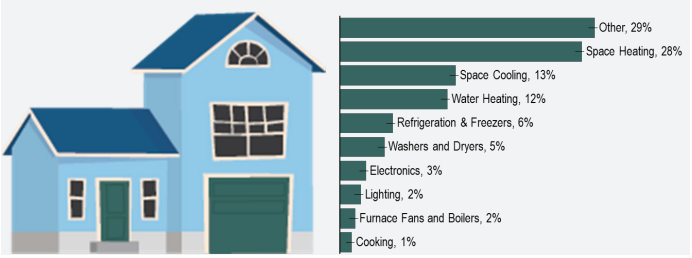
U.S. Historical Household Size[9]



Energy Use

- Electricity use increased 14-fold from 1950 to 2022. In 2022, the residential sector used 1.42T kWh of electricity, 35% of U.S. total electricity use,[11] and the average household used 10,791 kWh of electricity.[10]
- In 2024, the residential sector used 18.4 quads of energy, 19.6% of U.S. primary energy consumption.[13]
- Heating and cooling account for 45% of the total energy use in the residential sector.[12]

U.S. Residential Energy Use, 2024[12]



- Larger houses require more energy for heating, cooling, and lighting; a 3,000 ft² house uses twice the electricity of a 1,000 ft² one.[30] In 2015, the average U.S. house used 14 kWh/ft².[14]
- Miscellaneous electric loads (MEL) per household doubled from 1976 to 2006.[15] These are appliances and devices outside of a building's core functions (HVAC, lighting, etc.) such as computers, fitness equipment, and TVs.[16]
- In 2024, MEL used more electricity than any other residential end use, accounting for 40% of primary energy use and 52% of electricity use.[12]
- Energy is wasted by heating and cooling of unoccupied buildings and rooms, inefficient appliances, thermostat oversetting, and standby power loss.[17]
- Energy management systems display energy use through monitors or mobile apps and enable remote control of devices. They can reduce household energy use by 4-7%.[18]

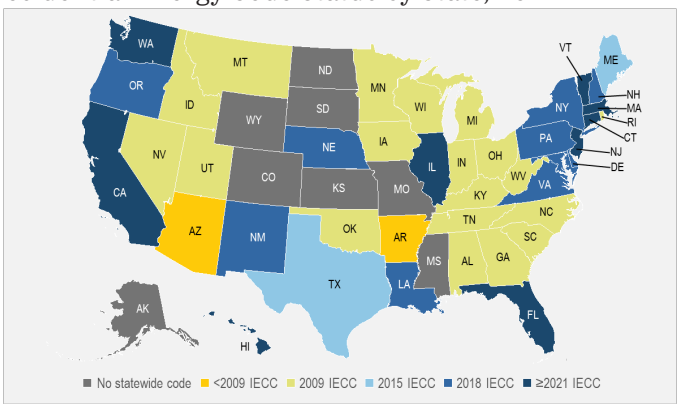
Material Use

- The average single-family house built in the U.S. in 2000 required 19 tons of concrete, 13,837 board-ft of lumber, and 3,061 ft² of insulation.[19]
- From 1975 to 2000, the use of clay for housing and construction more than quadrupled, due to its use in tiles and bathroom fixtures.[20]
- Historically, one-third of all wood products used in the U.S. were for new residential construction.[21]
- Constructing a 2,000 ft² house generates approximately 8,000 lbs of waste.[22] More than 75% of construction waste has a residual value but is not repurposed or recycled.[23]
- In 2018, 144M tons of waste from construction and demolition (C&D) was sent to the landfill.[47] In 2023, Seattle recycled over 81% of its C&D waste.[24]

Codes and Standards

- The International Energy Conservation Code (IECC) establishes minimum energy efficiency provisions for commercial and residential buildings, revised every three years.[48]
- The U.S. Department of Energy estimates the IECC will save 8.31 quads of energy from 2010–2040 in 41 states and D.C.[25] Cumulative energy savings would cut $182B (2021$) in costs and eliminate 466 Mt of CO_2.[25]
- The Energy Star program requires houses to be 10% more energy efficient than those built to code. On average, they are 20% more energy efficient than those built to 2009 IECC.[26]
- Florida's 2007 energy code saved 13% relative to pre-2007 energy use through reduction in heating, cooling, and hot water demand. Efficiency gains were offset by increasing house sizes and plug loads.[27]
- For most building types, energy efficient technology can reduce energy use by 20% relative to the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) 90.1-2004 standard.[28]

Residential Energy Code Status by State, 2024[29]



Life Cycle Impacts

- Between 1990 and 2022, residential GHG emissions increased less than 2%, reaching 973.5 Mt CO_2e.[31]
- A 1998 life cycle energy inventory of a 2,450 ft² single-family house in Ann Arbor, MI found that 90% of its energy consumption occurred during operation, while only 10% was attributed to construction and maintenance.[32]

  Energy efficiency measures reduced life-cycle energy use by 63%, while material selection cut embodied energy by 4%. GHG emissions dropped from 1,013 to 374 t CO_2e over the 50-year life of the house.[32]

  Major contributors to primary energy use included polyamide (carpet), concrete, asphalt shingles, and PVC (siding, windows, and pipes). An improved HVAC system and cellulose insulation were the most effective ways to reduce energy costs.[32]

  Substituting recycled plastic/wood fiber shingles for asphalt shingles reduced embodied energy by 98% over 50 years.[32]

- A 900 ft² house in Davis, CA, demonstrated 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 44% less than the standard house of the same size and location. Electricity generation from rooftop PV made the house energy net-positive.[33]

Solutions and Sustainable Actions

- Encouraging denser settlement and multifamily housing could decrease residential greenhouse gas (GHG) emissions.[14]

Reduce Operational Energy Demand

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

- Downsizing: Build smaller to reduce embodied and operating energy.[35]
- Operating energy can be reduced through passive space heating and cooling.[32]
- By adding ceiling fans, air conditioning can be comfortably set about 4 °F higher.[36] Adequate insulation can reduce heating and cooling costs.[38]
- Water heating accounts for 12% of residential energy consumption.[11] Install low-flow water fixtures to save both water and energy.[37]
- Save energy with a graywater heat recovery system.[39]
- Maximize natural lighting with south-facing windows. Properly shade windows to minimize summer heat gain.[40]
- Purchase energy efficient appliances and lighting. Appliances and lighting can account for 24% of household energy costs.[41]
- Replace incandescent lamps and halogen lamps with LEDs.[42]
- Pursue net-zero carbon/energy certifications including LEED, Living Building Challenge, GreenGlobes, BREEAM, and Passive House.[43] Federal rebates, tax credits, and financing strategies are available to homeowners and renters when purchasing new efficient appliances and electrification technologies.[44,45]
- Availability of these credits beyond 2025 is uncertain.[50]

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.