Residential Buildings

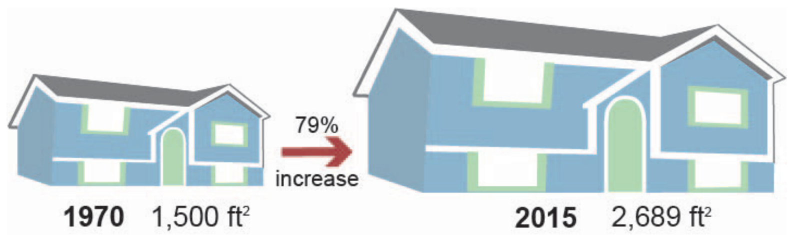
Patterns of Use

Although proven climate-specific, resource-efficient house design strategies exist, per capita material use and energy consumption in the residential sector continue to increase. From 2000 to 2010, the U.S. population increased by 9.7%, while the number of housing units increased by 13.6% and urban land area increased by 15%.[1] The following trends demonstrate the unsustainable nature of the residential building sector.

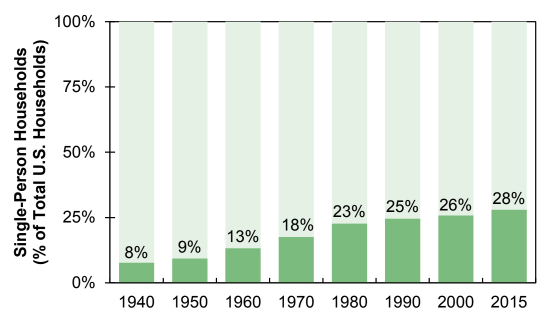
Size and Occupancy

- Increased average size of a new U.S. single-family house:[2,3,4]
  - 1950: 983 sq ft
  - 1970: 1,500 sq ft
  - 2000: 2,265 sq ft
  - 2015: 2,689 sq ft, a 174% increase from 1950.
- Increased average area per person in a new U.S. single-family house:[2,3,5]
  - 1950: 292 sq ft per person
  - 1970: 478 sq ft per person
  - 2000: 840 sq ft per person
  - 2015: 1,059 sq ft per person, a 263% increase from 1950.
- Decreased average number of occupants per U.S. household:[2,5]
  - 1950: 3.37 occupants
  - 1970: 3.14 occupants
  - 2000: 2.62 occupants
  - 2015: 2.54 occupants, a 25% decrease from 1950.
- A majority of Americans live in single-family houses. In 2013, 64% of the 116 million U.S. households were single family.[6]
- In 1950, 9% of housing units were occupied by only one person.[7] By 2015, this value had increased to 28%.[5]
- Americans spend, on average, 90% of their time indoors.[8]

Average Size of a New U.S. Single-Family House[3,4]



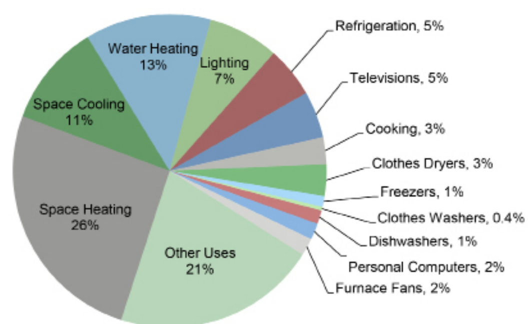
U.S. Single-Person Households[5,7]



Energy Use

- A 1998 study by the Center for Sustainable Systems of a single-family house in Michigan shows an annual energy consumption of 1.3 GJ per square meter.[10]
- A similar study of 3 houses in Sweden built in the 1990s shows annual energy consumption of 0.49–0.56 GJ per square meter, less than half the energy consumed by the Michigan house.[11]
- Between 1990 and 2014, total residential GHG emissions increased 20%, accounting for 17% of total U.S. GHG emissions in 2014.[12]
- The residential sector accounted for 22% of total primary energy consumption in the U.S. in 2015.[13]

Average U.S. Residential Energy Consumption, 2015[9]



Material Use

- The average U.S. single-family home built in 2000 required 19 tons of concrete, 13,837 board-feet of lumber, and 3,061 square feet of insulation.[14]
- From 1975 to 2000, the consumption of clay by the U.S. housing industry more than tripled, due to its use in tiles and bathroom fixtures.[15]
- In 2012, around 24% of all wood products consumed in the U.S. were used for residential construction.[16]
- Approximately 10 million tons of debris was generated in the construction of new residential buildings in 2003—4.4 pounds per square foot.[17]

Life Cycle Impacts

- In 1998, the Center for Sustainable Systems conducted an inventory of the life cycle energy consumption from the materials manufacturing, construction, and operation of a 2,450 square foot, single-family house built in Ann Arbor, Michigan. The following energy efficiency strategies were then modeled to quantify the resulting life-cycle energy savings (note: insulation materials are measured in thermal resistance, R-values; the higher the R-value, the more effective the insulation):[10,18]
  - Wall and ceiling insulation increased from R-15 to R-35 and R-23 to R-49, respectively; building infiltration (leakage) reduced by half.
  - Concrete basement walls replaced with wood; basement thermal insulation increased from R-12 to R-39.
  - Double-glazed windows upgraded to include low-e treatment and argon fill.

- Energy-efficient appliances; electric stove & dryer switched to natural gas.
- Energy-efficient fluorescent lighting.
- Building-integrated shading (overhangs) created on south-facing windows.
- Hot-water heat recovery installed.
- Air-to-air heat recovery used with a ventilation system.
- Glass fiber thermal insulation replaced with recycled cellulose.
- Roofing shingles made from recycled materials (wood/plastic).

Single-Family House in Ann Arbor, Michigan[10]

- A 63% life-cycle energy reduction was achieved through the above measures, using readily available technology. Despite the additional material requirements, the total embodied energy was reduced by about 4%.[10]
- Life cycle greenhouse gas emissions were reduced from 1,013 to 374 metric tons CO_2-equivalent over the 50-year life of the house.[10]
- Only 10% of the life cycle energy consumption was attributed to construction and maintenance; 90% occurred during operation.[10]
- Top contributors to primary energy consumption were polyamide for carpet, concrete in foundation, asphalt roofing shingles, and PVC for siding, window frames, and pipes.[10]
- Installing a high-efficiency HVAC system and cellulose insulation ranked as the most effective strategies for reducing annual energy costs.[10]
- Many of the materials in the case study house are currently recyclable; however, the U.S. average recycling rate of building materials from demolition and construction is only 20-30%.[10,19]

Solutions and Sustainable Alternatives

Reduce Operational 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:

- Space heating and cooling make up 48% of residential energy consumption. Passive heating (e.g., passive solar, waste heat recovery from disposed hot water) and passive cooling (e.g., night-purge ventilation, shading) can help reduce household energy usage.[18]
- By adding ceiling fans, air conditioning can be comfortably set about 4°F higher.[20]
- Adequate insulation can reduce heating and cooling costs. R-value needs differ based on location, building design, and heating methods.[21]
- Maximize natural lighting with skylights and south facing windows.[22]
- Consider passive sanitary services, such as composting toilet, rainwater use for toilets, and greywater for gardening.
- Water heating accounts for 18% of residential energy consumption.[18] A drain water heat recovery system can save energy by capturing the heat from waste hot water and reusing it to preheat cold water.[23]
- Install low-flow water fixtures (less than 2.5 gallons-per-minute of flow) to save both water and energy.[24]
- Large appliances and lighting account, on average, for 25% of household energy costs. Purchasing energy efficient appliances and light bulbs can help reduce these costs.[25]
- Through the Taxpayer Relief Act, Congress offers tax credits up to $500 per 0.5 kW of power are available through the end of 2016 for geothermal heat pumps, small wind turbines, and solar energy systems.[26]

Select Durable and Renewable Materials

Durable building materials may have greater upfront cost, but long-term savings and reduced environmental impact are achieved by avoiding replacement. Renewable building materials also offer potential environmental advantages.

- Durables to consider: cork or hardwood vs. carpet, standing-seam roofing vs. asphalt shingles.
- Renewables to consider: cork, linoleum, wool carpet, certified wood and plywood, strawboard, cellulose insulation, straw-bale.
- Substituting asphalt shingle roofing with recycled plastic/wood fiber shingles can reduce embodied energy by 98% over 50 years.[10]

Renewable Materials Used in the Samuel T. Dana Building[27]
University of Michigan, Ann Arbor, Michigan

(Left to right: biocomposite countertops, 100% wool carpet, bamboo flooring)

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Cite as: Center for Sustainable Systems, University of Michigan. 2016. "Residential Buildings Factsheet." Pub. No. CSS01-08. **August 2016**