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%. 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:\textsuperscript{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:\textsuperscript{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:\textsuperscript{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.\textsuperscript{6}
- In 1950, 9\% of housing units were occupied by only one person.\textsuperscript{7} By 2015, this value had increased to 28\%.\textsuperscript{5}
- Americans spend, on average, 90\% of their time indoors.\textsuperscript{8}

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.\textsuperscript{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.\textsuperscript{11}
- Between 1990 and 2014, total residential GHG emissions increased 20\%, accounting for 17\% of total U.S. GHG emissions in 2014.\textsuperscript{12}
- The residential sector accounted for 22\% of total primary energy consumption in the U.S. in 2015.\textsuperscript{13}

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.\textsuperscript{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.\textsuperscript{15}
- In 2012, around 2.4\% of all wood products consumed in the U.S. were used for residential construction.\textsuperscript{16}
- Approximately 10 million tons of debris was generated in the construction of new residential buildings in 2003—4.4 pounds per square foot.\textsuperscript{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):\textsuperscript{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.
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. Only 10% of the life cycle energy consumption was attributed to construction and maintenance; 90% occurred during operation. Top contributors to primary energy consumption were polyamide for carpet, concrete in foundation, asphalt roofing shingles, and PVC for siding, window frames, and pipes. Installing a high-efficiency HVAC system and cellulose insulation ranked as the most effective strategies for reducing annual energy costs. 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%. A 63% life-cycle energy reduction was achieved through the above measures, including energy-efficient appliances; electric stove & dryer switched to natural gas. Roofing shingles made from recycled materials (wood/plastic). Glass fiber thermal insulation replaced with recycled cellulose.

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. By adding ceiling fans, air circulation can be comfortably set about 4°F higher.
- Adequate insulation can reduce heating and cooling costs. R-value needs differ based on location, building design, and heating methods. Maximize natural lighting with skylights and south facing windows. 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. A drain water heat recovery system can save energy by capturing the heat from waste hot water and reusing it to preheat cold water.
- Install low-flow water fixtures (less than 2.5 gallons-per-minute of flow) to save both water and energy.
- 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.
- 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.

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.

27. Image courtesy of University of Michigan, School of Natural Resources and Environment.