This chapter provides a general overview of residential energy use. It presents history, statistics, policy, energy-bill analysis, customer education, and energy-efficiency ratings.

## Energy – Past and Present

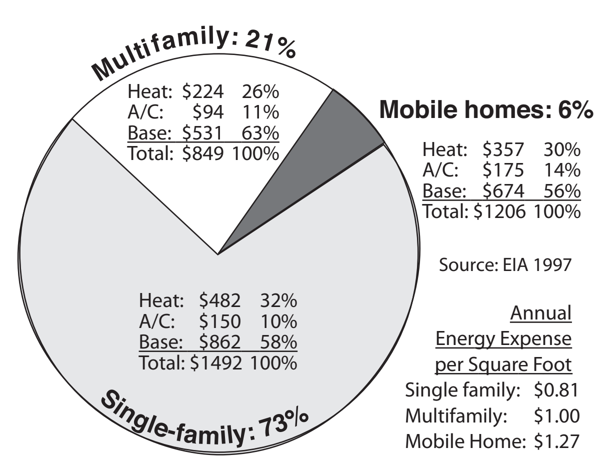
Cultures around the world have used energy conservation principles and passive solar technologies for centuries. For instance, some Native American communities maximized winter heating by orienting their dwellings and villages to the south. Middle East natives used wind chimneys, whitewashed walls and roofs, and window shading for cooling.

Before the industrial revolution, residential heat was provided by wood fires. Artificial light was provided by candles and oil or gas lamps.

A little over 100 years ago, things began to change rapidly. In the early 1880s, Thomas Edison invented the incandescent light and built the world's first power station. By 1908, 8% of American homes had electricity. By 1925, 53% of homes were connected to the country's expanding electrical grid. By the 1930s, natural gas began to compete with wood and coal as a heating fuel. Today, natural gas provides over 50% of the energy used in residential buildings.

Over the past 50 years, Americans have embraced air conditioning, replacing earlier attempts at low-energy cooling. Evaporative coolers appeared in the 1920s and window air conditioners in the 1940s. Central air conditioning followed in the 1950s. Today, around 70% of existing homes and 80% of new homes have air conditioners. Televisions, stereos, computers, swimming pools, spas, and all types of electric gadgets make American homes the most energy consumptive in the world.

Home Types and Average Energy Costs




Summary of EIA data for 105 million U.S. households.

### *The Energy Picture Today*

The United States represents about 5% of the world's population. Yet it consumes 25% of the world's energy supplies. The U.S. is the second behind China in total energy use and seventh in per capita energy use behind Canada and several smaller countries.

Buildings use about 40% of our total annual energy consumption. Energy is a principal commodity of our society, amounting to about 9% of the U.S. Gross National Product (GNP).

The benefits we receive from energy consumption are counterbalanced by environmental damage. With the exception of some renewable resources, energy consumption inevitably produces harmful by-products such as carbon dioxide, acid rain, and radioactive waste. Carbon dioxide is the most important cause of global warming, which is now an international problem and urgent priority.

**Annual Average Household Energy Cost by Region (1997)**

| | Northeast | | Midwest | | South | | West | |
|---|---|---|---|---|---|---|---|---|
| | $/yr | % | $/yr | % | $/yr | % | $/yr | % |
| **Space heating** | $689 | 39% | $575 | 39% | $329 | 23% | $253 | 22% |
| **Space cooling** | $78 | 4% | $85 | 6% | $211 | 15% | $134 | 12% |
| **Water heating** | $244 | 14% | $188 | 13% | $213 | 15% | $177 | 15% |
| **Appliances & other** | $752 | 43% | $645 | 42% | $662 | 47% | $590 | 51% |
| **Total cost** | **$1763** | **100%** | **$1492** | **100%** | **$1415** | **100%** | **$1155** | **100%** |

Energy Information Administration: *A Look at Residential Energy Consumption in 1997.*

**CO2 Emission for Energy Sources**

| Type of energy | Typical use | Typical $CO_2$ emission |
|---|---|---|
| Natural gas | 920 therms | 11,000 lbs. |
| Fuel oil | 660 gallons | 14,500 lbs. |
| Electricity | 10,800 kWh | 16,300 lbs |

From Energy Information Administration *A Look at Residential Consumption.*

Most scientists now agree that our unbridled energy use is warming the atmosphere through a process called the greenhouse effect. Gases, like carbon dioxide, that contribute to the greenhouse effect are called greenhouse gases. Recent climate changes, increasing forest fires, record droughts, melting polar ice, and other weather events, confirm that the earth is indeed warming. Unfortunately, U.S. greenhouse gas production increased by 17% between 1990 and 2007.

Energy consumption also produces undesirable economic side effects. Even with increased domestic production, the U.S. imported 50% of the oil it used in 2010, making oil our largest import. Importing oil creates about 50% ($25 billion) of our annual balance-of-trade deficit of about $50 billion per year.

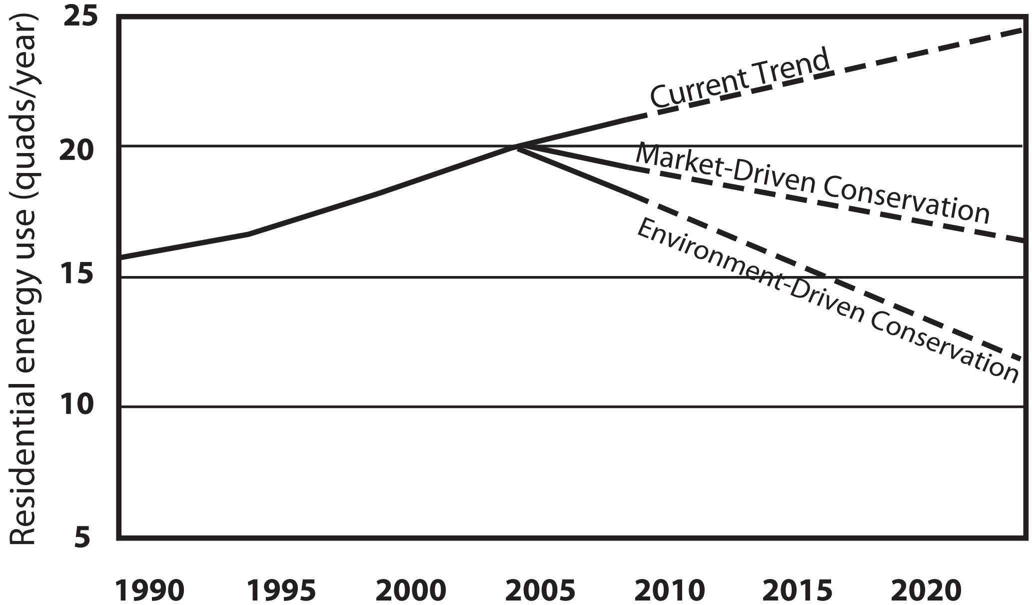
Our foreign-oil dependence dominates our foreign policy and has precipitated expensive military intervention. Energy conservation can help reduce this reliance on fossil fuels, especially if we eliminate federal subsidies for fossil fuels.

## *Energy Sources Compared*

Fossil energy is solar energy stored in ancient plant and animal remains. Fossil fuels, such as coal, oil, and natural gas, are very convenient to use and account for over 95% of energy used in homes. Supplies of fossil energy are limited and nonrenewable. Fossil fuels produce carbon dioxide—the main cause of global warming—and other air pollutants, which are a major worldwide cause of respiratory disease, environmental sensitivities, and neurological disorders.

Nuclear electricity harnesses energy released by the splitting of atoms and releases no carbon dioxide. At one time, experts predicted that nuclear electricity would become the world's cleanest and cheapest energy source—a prediction that has not yet materialized. Nuclear electricity is expensive, requiring large government subsidies. The nuclear industry's radioactive waste disposal process is a grave environmental, economic, socioeconomic, and political problem.

Past, Present, and Future Energy Consumption




From Energy Information Administration, DOE Energy Efficiency and Renewable Energy Division, and American Council for an Energy Efficient Economy

Each citizen helps make the decision about which energy path we will follow in the future. International standards favor returning to 1990 annual energy consumption levels, though environmental-driven conservation efforts could result in even lower energy consumption.

Renewable energy is the same as solar energy, and includes wind power, direct solar energy, and biomass energy. As fossil-fuel supplies dwindle, renewable energy is becoming more widely used. The advantages of renewable energy are safety, environmental quality, and sustainability.

Energy efficiency and energy conservation must bridge the gap between the present fossil-fuel era and the future renewable-energy era. If high standards of residential comfort and convenience are to endure, energy efficiency and energy conservation must precede and support the implementation of renewable energy systems.

## *Understanding Home Energy Usage*

Most of the energy statistics presented here come from the Department of Energy's Energy Information Administration (EIA). EIA reports energy consumption in dollars, millions of BTUs (MMBTU), or quads. A quad is one quadrillion British thermal units of energy—the equivalent of 40 million tons of coal or 182 million barrels of fuel oil.

The EIA recognizes three distinct housing types among the approximately 105 million American households: single-family, multifamily, and mobile homes. Householders in the U.S. spent about $150 billion for 20 quads of energy in 2000. By 2007, consumption rose to 22 quads, a 10% increase. Of this total energy in quads, 65% is electricity, 26% is natural gas, 7% is oil and propane, and the remaining 2% is renewable energy.

See "Calculating Energy Intensity" on page 24, for more information on energy intensity and energy indexes. See "Analyzing Annual Energy Costs" on page 277.

It's easy to get confused by percentages and pie charts unless you understand the relationship between electricity and natural gas—the leading energy sources. If you look at energy consumption, space heating consumes around half of the primary energy used in an average home. However, space heating is only about one-third of the $1400 average annual household energy cost, because natural gas, the main home-heating fuel, is less expensive than electricity.

**Energy Intensity by Housing Type (Btu/ft$^2$/yr)**

| Housing Type | Pre-1990 | Post-1990 |
|---|---|---|
| Single family | 60,900 | 45,100 |
| Multifamily (2–4 units) | 94,400 | 50,400 |
| Multifamily (> 4 units) | 58,000 | 41,500 |
| Mobile Home | 92,200 | 50,600 |

For total delivered energy per square foot of floor area. Energy Information Administration: 1997

Electricity's higher cost reflects the fact that its generation and transmission is only about 30% efficient. On the other hand, electricity is typically around 100% efficient at the point of use when it's converted into heat for home or water heating. Natural gas, oil, and propane are only 40% to 90% efficient at heating a home or its hot water, but the fossil fuels are cheaper than electricity because they don't experience the generation and transmission losses. This makes direct comparisons of homes heated by fossil fuels and electricity tricky. Electrically heated homes may use less energy on site, but the energy costs more. The EIA resolves this problem by using dollars as a unit for energy consumed, and their dollar-based statistics include both fossil fuels and electricity.

# Wise Energy Use

We know that our standard of living can endure with less energy, less money, and less environmental damage. For example, the year 2000 per capita energy consumption is about the same as it was in 1973, while per capita economic output has increased over 70% since 1973. Our increasing energy consumption has instead followed increasing population and increasing number of households.

From 1976 to about 1986, home-energy efficiency increased at an impressive rate, following the energy-price hikes of the mid-1970s. New buildings were more efficient than ever before. Owners of existing homes invested in insulation, storm windows, and better heating systems. Then around 1986, the cost of energy dropped, and the trend toward annual increases in energy efficiency stalled. From 1986 through 2005, energy concerns faded from public consciousness in the U.S. Then in 2008, energy shocks struck once more, caused by increasing worldwide energy demand and peaking oil supply. These shocks helped precipitate a worldwide financial crisis.

There are two major approaches to the wise use of energy in the future: energy efficiency and energy conservation. Although very similar, they aren't exactly the same. *Energy efficiency* is the more popular approach and focuses on maximizing the economic benefits of wise energy use. Energy efficiency often results in energy savings, as when you buy a new ENERGY STAR® qualified refrigerator to replace your inefficient old one.

The *energy-conservation* approach focuses more narrowly on reducing non-renewable energy use and its resulting environmental damage. Proponents of this approach are more willing to ask consumers for changes in behavior than the energy-efficiency approach.

A quad of electricity costs more than a quad of natural gas because around 70% of the fuel energy, used to make electricity, is lost in the generation and transmission processes. About 105 MMBTUs of electrical energy are consumed at the average home annually. However, an additional 155 MMBTUs of energy are wasted annually by the electric generation and transmission facilities for every household served. Electricity's premium price reflects these losses.

For many years, analysts considered energy consumption and GNP to be causally linked. A rising GNP and rising energy consumption were considered signs of progress, although this view does not consider that a home's energy efficiency may increase, giving more comfort and services for less money. Some economists and world leaders may now be ready to challenge the necessity of economic growth to achieve prosperity.

Many American policy-makers believe "efficiency" is a more positive word than "conservation." Nevertheless, North Americans are using energy at an unsustainable rate. We must now reduce energy consumption to preserve our prosperity, security, and environment. Energy efficiency is a term that describes our efforts to use energy more efficiently. Energy conservation means reducing energy consumption by eliminating energy waste. Energy efficiency and energy conservation provide the following benefits.

**Efficiency of Use** - Efficient homes maximize comfort, service, and value for each unit of energy.

**Energy Security** - Wasting less energy makes individuals and communities less dependent on energy and less vulnerable to price and supply fluctuations.

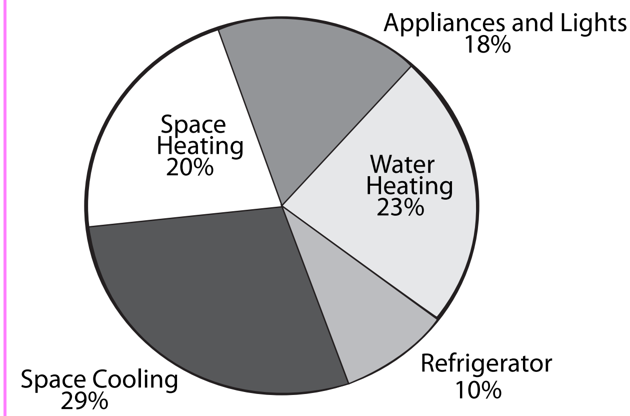
**Environmental Restoration** - Wasting less energy creates less environmental damage.

**Sustainable Prosperity** - Wasting less energy preserves fossil fuels for future generations and allows for diversity of energy generation options.

## Potential for Energy Conservation

The lack of insulation and inefficient heating and cooling systems, among other problems, drives typical residential buildings to use one-and-a-half to two times as much energy as necessary to achieve comfort and convenience. This excess energy usage costs about $45 billion annually.

**Home Energy Consumption in Hot Climates**




Space cooling often dominates the energy profile for homes in hot climates.

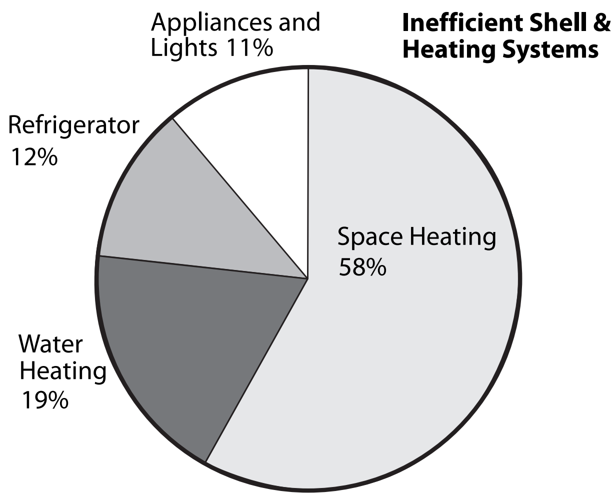
The Department of Energy's Weatherization Assistance Program typically saves 10% to 30% of total household energy consumption, according to nationwide studies.

Residential energy conservation programs use four main strategies to achieve energy savings in residential buildings:

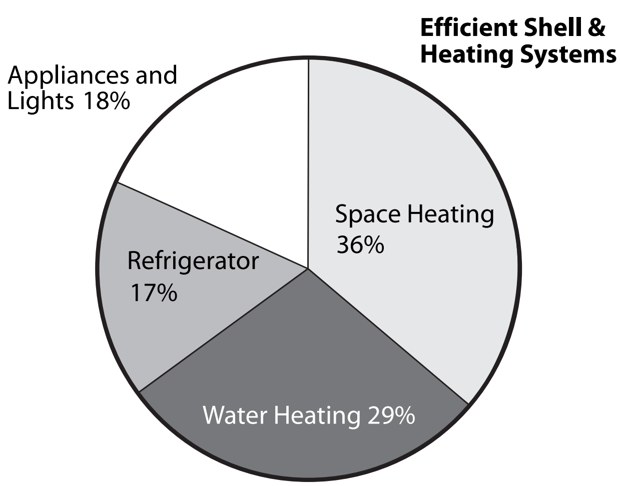
- Making thermal improvements to building shells.
- Replacing older heating systems, cooling systems, lighting, and other energy-using devices with new and efficient equipment.
- Repairing or adjusting existing energy-using equipment.
- Educating building occupants about energy-efficient practices.

The energy professional's most important challenge is to find the sources and causes of residential energy waste. These vary depending upon climatic conditions, building characteristics, and building operating procedures. For example, heating energy waste may dominate Minnesota single-family homes, while waste from cooling, water heating, and lighting may be the dominant problem in Texas high-rise residential buildings.

**Home Energy Consumption in Cold Climates**




Space heating dominates energy use in cold-climate homes with high air leakage, low insulation levels, and inefficient heating systems. Total annual energy cost: $2000.




After installing insulation, reducing air leakage, and installing an efficient heating system, the cold-climate home's appliances and water heater become a bigger piece of a smaller energy pie. Total annual energy cost: $1000.

Inefficiency can be divided into the following general categories:

- Heating—Seasonal efficiencies for fossil-fuel-heating systems range from 30% to 90%. Most older systems operate at the mid-to-lower end of this scale.
- Heat losses—Depending on the thermal resistance of building shells, heat moves from indoors to outdoors through the shell during the heating season.
- Air leakage—Infiltrating air must be heated or cooled to a comfortable temperature, and heated or cooled air is lost when air leaks out of the building.
- Water heating—Energy losses in heating and storage of hot water can amount to 40% or more of that system's energy consumption.
- Cooling systems—Many cooling systems suffer from infrequent or improper maintenance. Simple adjustments and cleaning can increase typically low cooling efficiencies. Due to technological advances, newer cooling systems are much more efficient than older systems.
- Heat gains—Many homes use excessive cooling energy because of inadequate shading, excessive radiant heat gains from dark colored building materials, excessive air leakage, inadequate insulation, and internally generated heat.
- Distribution systems—Heated or cooled air leaking from ducts and uninsulated pipes in unconditioned spaces wastes a portion of the energy consumed by furnaces, boilers, air conditioners, and water heaters.
- Appliances and lighting—Refrigerators, lights, entertainment systems, computers, and other appliances use considerable electrical energy because of obsolete design, careless operation, or just the sheer number of electrical devices in a home.
- Resident behavior—The awareness and conscientiousness of a building's residents and

managers has a significant influence on how much energy the building uses.

## Cost-Effectiveness of Retrofits

Most government and utility programs require a retrofit to repay its initial investment within 10 years. If a retrofit achieves this or some other standard, we say it is cost-effective.

The cost-effectiveness of energy-efficient retrofits for residences depends on the following factors:

- Fuel usage—The more energy a home uses, the greater the potential for savings. Fuel usage helps to determine the level of cost-effective investments for a particular residence.
- Fuel cost—The more expensive the fuel, the more cost-effective any retrofit will be.
- Climate—The farther the outdoor temperature varies from a comfortable indoor temperature, the more energy is used for heating and cooling.
- Retrofit selection—The more skillfully an auditor assembles the optimal combination of retrofits, the more cost-effective the retrofit package will be.
- Materials costs and quality—An energy retrofit's ratio of savings to cost is dependent on skillful selection and purchasing of materials.
- Labor efficiency—Management, organization, and training have a large impact on whether retrofits will be cost-effective.
- Systems approach—The coordination of financing, energy auditing, work-orders, scheduling, and quality workmanship affects cost-effectiveness in a big way.

## Priorities for Energy Efficiency

Energy retrofits employed without preliminary measurement or analysis can produce disappointing results. Therefore, energy professionals try to estimate a proposed retrofit's energy savings and prioritize the retrofits in descending order of their cost-effectiveness.

Comprehensive evaluations of government and utility energy-conservation programs have yielded surprising results. Some of the most important findings are listed below:

- Pre-retrofit fuel usage is a significant predictor of savings from energy retrofits; large users are large savers. Targeting large users increases average savings from the 10% to 20% range to the 20% to 30% range.
- Storm doors, storm windows, and window replacements are less cost-effective than insulation and air sealing because of their high cost per square foot.
- Thermal resistance of insulation is reduced by air flowing through and around the insulation.
- Densely packed, blown insulation can reduce air leakage when installed in building cavities.
- Leaky ducts can be a major source of energy waste, both by leaking conditioned air and by creating pressures that increase air leakage through the building shell.
- Preventable inefficiency in larger residential buildings is likely to be centered in the building's mechanical systems such as heating and cooling, water heating, and lighting.
- Winter heat loss and summer heat gain have somewhat different causes and require different retrofit strategies, although retrofits like attic and wall insulation reduce both heat loss and heat gain.
- Effective education and good quality management of energy specialists leads to more effective energy retrofits.
- Consumer education can produce measurable energy savings.
- Energy specialists who use equipment such as blower doors and heating-efficiency testers, produce more accurate assessments than those who don't use these testing devices.

## An Energy Audit's Purpose

Energy auditors visit residential buildings and talk to owners and residents. They inspect, test, and measure to decide what energy-efficient retrofits are practical and cost-effective.

Specific purposes of an energy audit are to:

- Identify the type, size, condition, and rate of energy consumption for each major energy-using device.
- Recommend appropriate energy conservation, operation, and maintenance procedures.
- Estimate labor and materials costs for energy retrofits.
- Project savings expected from energy retrofits.
- Note current and potential health and safety problems and how they may be affected by proposed changes.
- Explain behavioral changes that will reduce energy waste.
- Provide a written record of decision making.

Computerized energy audits help set retrofit priorities by rating the cost-effectiveness of each retrofit, as well as analyzing the entire building retrofit proposal.

## Quality Assurance Inspection

An energy professional's job doesn't end once priorities have been determined and retrofitting is authorized. Dollar savings and longevity of energy conservation measures are heavily dependent on proper installation. Inspecting every job helps ensure that the insulation, air sealing, space-conditioning, and baseload retrofits are done properly.

Changes are easier to implement if the job is still in progress. The best time for inspection is near project completion, while workers are still on the job.

The following are important elements of a quality-assurance inspection:

- Verifying compliance with specifications, job order, and energy audit.
- Providing feedback on performance of workers, both good and bad.
- Establishing procedures for correcting mistakes.
- Emphasizing the importance of maintenance procedures and conservation practices to residents.
- Arranging for future monitoring and evaluation, if appropriate.

## The Energy Professional's Mission

The major goals of an energy specialist's work are to:

- Conserve energy, increase energy efficiency, and save money.
- Protect the environment by reducing harmful energy by-products.
- Increase comfort in residential buildings.
- Enhance health and safety of the building's residents.
- Increase public awareness of energy-saving products and procedures.

To accomplish their mission, energy auditors and technicians must:

- Understand basic energy principles. Once understood in theory, these principles can better be applied in practice.
- Recognize all of a building's important energy-saving opportunities and choose the most promising.
- Translate energy savings into dollars and compare projected savings with each energy conservation measure's cost.
- Evaluate and measure building performance before and after energy improvements.
- Know about incentives, rebates, and tax benefits available to customers.