EFFICIENT USE AND CONSERVATION OF ENERGY IN BUILDINGS

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Summary

This topic describes energy efficiency measure in buildings. Buildings vary considerably across the globe: ranging from canvas tents to grass huts to “informal housing” made of cardboard, sheet metal, and wood sticks, to elaborate structures of synthetic materials.

There are however, a number of common attributes of buildings and their energy systems, which are captured here and in the articles within this topic.

1. Introduction

The construction and operation of buildings and their systems have an enormous impact on the worldwide use of materials, energy, and water resources. Globally, roughly 40% of the world’s energy and materials (including stone, gravel, and sand) are consumed by building construction and use.

In addition, more than half of the virgin wood procured for non-fuel purposes, and 16% of worldwide water, go to the building sector. Moreover, buildings contribute to environmental degradation by generating significant portions of waste materials and air pollutants.

To mitigate environmental abuses and to conserve natural resources, efforts to achieve sustainable, “green,” building practices are necessary. This topic and its sub-articles address a variety of measures to increase building energy efficiency. The efficiency of other resources and ways to control environmental pollution are addressed in other themes within this encyclopedia.

The main energy-using systems related to buildings are building structure elements (that is, the building envelope), heating, ventilation, and air conditioning equipment (HVAC), and energy-consuming devices and appliances, including lighting (see Figure 1). The efficiency of all these energy systems can be improved by implementing various measures and by switching to energy-efficient equipment.

Another way to improve energy efficiency is by implementing load management technologies. The following sections summarize the main energy efficiency measures for buildings. More detailed treatments for lighting, building envelope, and HVAC systems may be found in the sub-articles of this topic.

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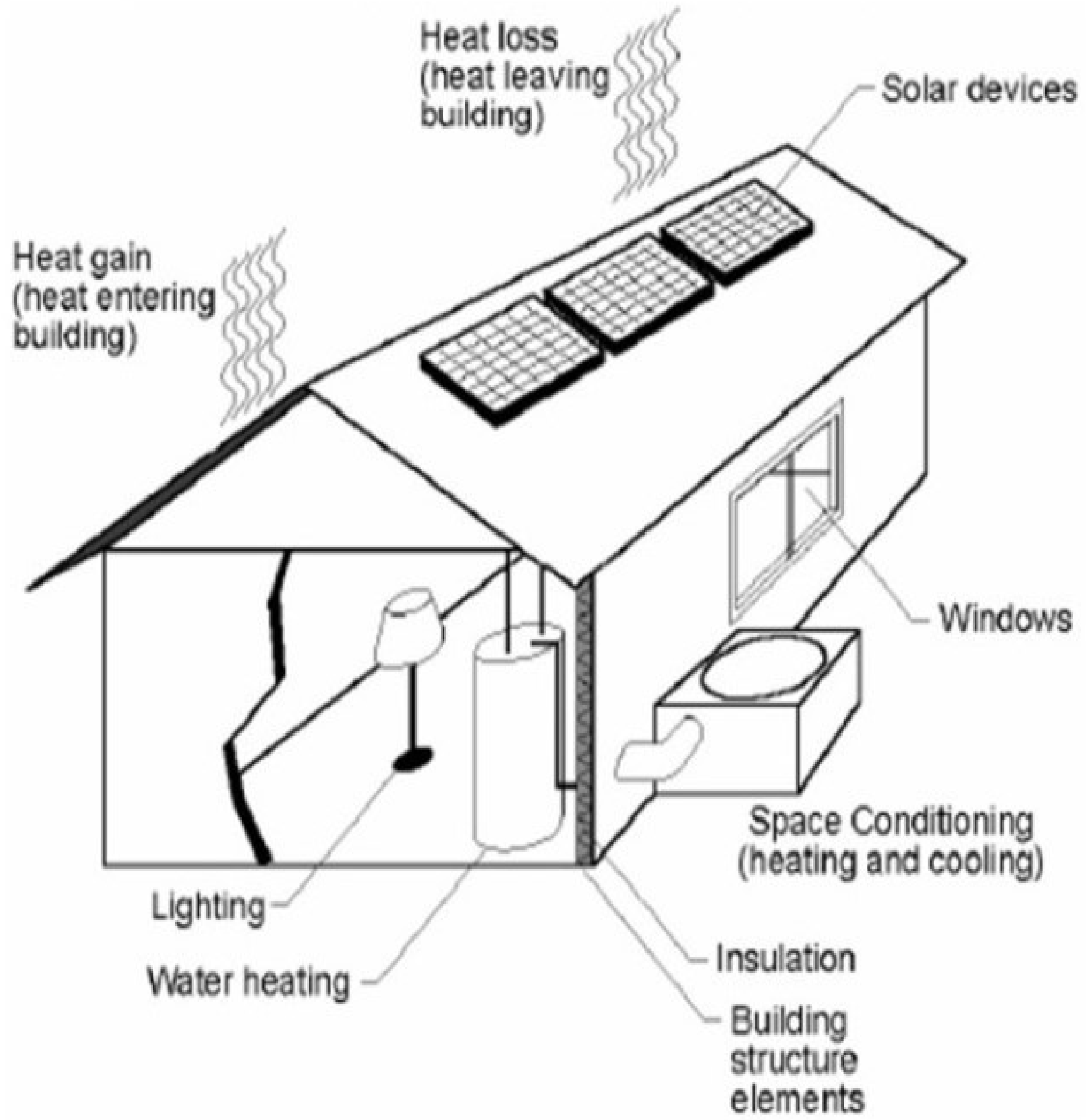

Figure 1. Types of energy use related to buildings

2. Building Structure Elements

These refer to the thermal integrity of the building and include the materials and type of construction of the building shell, its insulation, and the types of windows and doors. How these materials are utilized affects the degree to which heat loss or heat gain is realized.

Energy efficiency options related to building structure elements (or the building envelope) are summarized here and are discussed in greater detail in the article entitled *Building Envelope Efficiency Measures.*

The building structure elements most cited when energy efficiency is discussed include insulation, windows, doors, window treatments, and passive solar designs. Figure 2 illustrates some of these concepts.

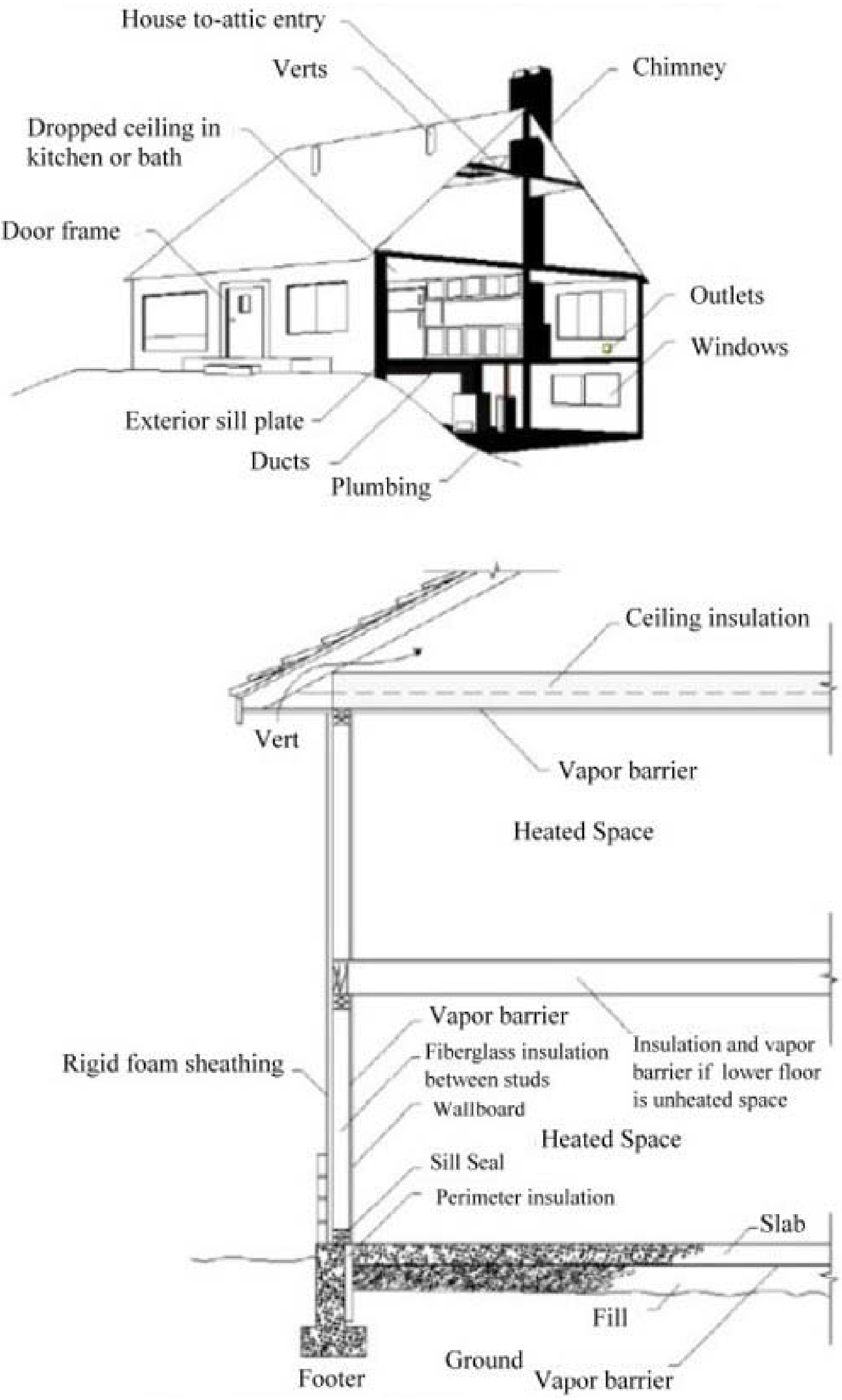

Figure 2. Examples of building structure elements

2.1. Insulation

Insulation made out of synthetic fibers reduces heating and cooling loads by resisting the transfer of heat through ceilings, walls, and floors. Insulation is available in batt, board, and loose-fill forms and is made of a number of materials with various heat-resistance, or R, values. Higher R-values indicate better insulating properties.

Insulation can be added to almost any building but is easiest to install in new buildings or spaces where structural framing is exposed. The R-value installed depends on the amount of insulation in place and the recommended R-values for the local climate. Insulation reduces both heating and cooling requirements, but reductions are usually proportionately higher for heating than for cooling because generally in winter there are larger indoor-to-outdoor temperature differences than there are in summer.

The appropriate insulation material is selected on a basis of climate, building type, and recommended R-value. In open ceilings, loose fill or blanket insulation is generally used. Installation of these types in open spaces requires no special equipment and is often done by the homeowner. For closed spaces such as existing walls, loose fill is generally used. Installation of loose fill in such spaces usually requires special equipment. Blanket insulation is normally used beneath floors.

2.2. Storm and Multipane Windows and Storm Doors

Storm windows and doors are installed over existing windows and doors to create an insulating air space that reduces heat loss through the glass. Multipane windows constructed with two (and sometimes three) panes of glass sealed in the frame have similar insulating qualities and are generally used in new construction or replacement applications.

Storm windows can be installed in most types of single-or-double-pane windows. Multipane windows are generally a better option than storm windows if existing windows are in poor condition. Vinyl and wood frames or aluminum frames with a thermal barrier provide the best insulation. Since the insulation value comes mainly from the air space, it must be large enough to inhibit heat transfer.

2.3. Window Treatments

Window treatments are those products installed on windows to help control winter heat losses and summer hear gains, thereby reducing space-conditioning loads. Several types of product are available.

Interior thermal shades and shutters can be installed to manually control heat gains and losses. They are typically made of heavy quilted materials, aluminized cardboard or rigid foam panels, flexible jointed wood tongue-and-groove slats, or foam fabric laminated slats formed into flexible roll-up shades. Most shutters and shades are permanently installed movable systems, but some panels are designed to be set into and out of the window opening as needed.

The more effective coverings include edge seals to minimize convection effects. Some motorized systems are available to automatically open and close the coverings, but these are generally very expensive, particularly for residential applications.

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Thermal curtain liners for installation on drapery rods are available as reversible quilts: one side is typically vinyl and helps to insulate windows in the winter, the other is aluminized polyester to reflect the sun in summer. Window blinds with low emissivity selective coatings applied to the slats are also available. These operate in the same manner as normal blinds, but are claimed to be more effective in blocking out light.

Exterior movable shutters and shades are typically constructed of polyvinylchloride, wood, or aluminum and can often be controlled from inside the building. Awnings, either fixed or retractable, can be installed on a permanent or seasonal basis to block sunlight.

Reflective window films and solar screens reduce window heat gains in summer by reflecting and blocking solar heat. Exterior films, usually made of plastic, attach directly to the windowpane with an adhesive. Polyester sheets with a transparent aluminized coating on one side are available for installation on inside panes; solar screens, which reflect solar radiation and look much like regular window screens, are available as weaves of vinyl coated fiberglass yarn and louvered aluminum and bronze alloys.

2.4. Infiltration and Indoor Air Quality Control

Air infiltration is the uncontrolled leakage of air into or out of a building, through cracks, ceilings, walls, floors, and so on. It results from temperature and pressure differences between the inside and outside of a building caused by wind, natural convection, and other forces. This exchange of indoor and outdoor air affects concentrations of indoor pollutants and contributes substantially to heat losses or gains. Recent estimates suggest that air infiltration can account for 15 to 30% of all heat transfer through a building's shell. As a result, reducing air exchange rates has become a principal target in residential energy conservation efforts.

Major sources of air leakage are attic bypasses (paths within walls that connect conditioned spaces with the attic), fireplaces without dampers, leaky ductwork, window and door frames, and holes drilled in framing members for plumbing, electrical, and heating, venting, and air conditioning (HVAC) equipment. Wall pathways typically account for 18 to 50% of total building air leakage; ceiling HVAC and fireplace paths can account for as much as 30% each; windows and doors can contribute 6 to 22%; and vents can add 2 to12% of total leakage.

In existing buildings, owners or contractors can take weatherization measures to reduce air exchange rates, such as sealing structural cracks and joints, weather-stripping windows and doors, installing gaskets to seal electrical outlet box holes, and taping leaky ducts. In new construction, structural and mechanical modifications can substantially reduce unwanted air exchange. Techniques include thoroughly sealing structural joints (such as those around door and window frames at intersections of floors and exterior walls), sealing holes made during construction for utilities and the like, and installing a continuous plastic film vapor barrier on the warm side of insulation.

Although lowering the air exchange rate improves the energy efficiency of a building, it also slows the transport of indoor-generated pollutants to the outside, effectively

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trapping them inside the building. Thus, control of air infiltration for conservation appears important to indoor air quality (pollutant source strength and location are also factors); in fact, many indoor air quality problems came to light only when people began noticing some pollution effects of reducing building air exchange rates.

Because indoor air quality has not been a priority research topic in the1990s, researchers know considerably less about harmful levels and combinations of indoor pollutants than they do about outdoor pollutants. However, existing research indicates that the most common residential indoor pollutants are radon, formaldehyde, and combustion products such as nitrogen dioxide, carbon monoxide, carbon dioxide, and particulates.

Radon is an inert but radioactive gas, commonly found in varying concentrations in rock and soil; its progeny, products of radioactive disintegration of radon, is suspected of causing lung cancer. Radon may escape from the soil under a building, from earth-derived building materials such as concrete, or from groundwater and natural gas, and enter a building through structural cracks and openings. Radon concentrations in buildings depend on ventilation rates. Halving the ventilation rate doubles the radon concentration from a fixed source. Thus, the air tightness of a building can affect radon concentrations. Present correlations between radon concentration and health effects are less certain, however.

Formaldehyde is a colorless, odorous gas generated indoors, primarily from artificial products that use formaldehyde polymer-based resins for bonding. Such products include building materials like urea-formaldehyde foam insulation, plywood, and particleboard, as well as furniture and carpets. Combustion processes such as natural gas-based cooking and heating can also produce some formaldehyde. Formaldehyde is an eye and respiratory irritant and may cause serious health effects in high concentrations over long periods of exposure. Decreased air infiltration can increase formaldehyde concentrations; both reduced air changes and increased humidity levels (often accompanying reductions in air exchange) can increase formaldehyde source emission rates.

Gas-fired appliances (for instance, ranges, ovens, furnaces, domestic water heaters), wood- or coal-fired stoves and fireplaces, and cigarette smoking all emit combustion products. Concentrations depend strongly on ventilation rates; thus, increasing the air tightness of a building can increase the concentrations of these pollutants.

Several methods are available, or under development, for reducing indoors pollutants while obtaining the energy efficiency benefits of reduced air infiltration. Passive measures, such as installing a ground cover in the crawl space of a home, can lessen earth sources; however, eliminating the sources themselves is difficult, especially for retrofitting, because alternative materials or appliances may be uneconomical and difficult to install. In new construction, however, it is often possible to mitigate earth-derived sources and to use non-formaldehyde-based materials, electric appliances, and so forth to minimize potential sources.

Several indoor air treatment techniques are available. In many cases, mechanical ventilation that brings in a controlled amount of fresh air can significantly reduce

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pollutant concentrations in tightly sealed buildings. Heat exchangers are available, often as part of the fan assembly, to recover most of the useful energy in the exhaust air by preheating or precooling the entering air.

European applications have used heat exchangers with heat pumps to recover energy from the outgoing air and transfer this energy either to the domestic hot water supply or to the incoming air.

Another technique is spot ventilation, such as that provided by range hoods over gas stoves and exhaust fans in bathrooms, to remove specific pollutants at the source. The use of heat exchangers in range hoods is possible, but is generally impractical and not cost-effective for residential applications.

Other techniques include air cleaning (especially to remove particulates), using filters, electrostatics precipitators, and so forth, and dehumidification, especially for reducing formaldehyde concentrations. In most cases, a combination of techniques can provide acceptable indoor air quality while minimizing building heating and cooling loads.

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2.5. Passive Solar Design

A passive solar design consists of an assembly of primarily non-mechanically driven architectural components that convert solar energy into usable heat. In winter, heat gained through windows and walls when the sun is shining is stored in masonry and/or water for nightime release.

In summer, roof overhangs and landscape features limit heat gain, and vents dissipate unwanted heat. An optimal solar design maximizes heat gain in the winter and minimizes heat gain in the summer and so minimizes the total cost of providing heating and cooling of a building during its lifetime.

The assembly of components used in a passive solar design is site specific, varying with climate, building orientation, and building design. The following components are used in different combinations:

- double-glazed, south-facing windows
- masonry or water heat storage walls
- sunspace or greenhouse
- overhanging roof
- earth berm
- movable insulation (window blankets)
- sunshades
- vents
- exhaust fans (occasionally).

High levels of weatherization are necessary in order for passive solar systems to be effective.

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Biographical Sketch

Clark Gellings' 30-year career in energy spans from hands-on wiring in factories and homes to the design of lighting and energy systems to his invention of "demand-side management" (DSM). Mr. Gellings coined the term DSM and developed the accompanying DSM framework, guidebooks, and models now in use throughout the world. He provides leadership in EPRI, an organization that is second in the world only to the US Department of Energy (in dollars) in the development of energy efficiency technologies. Mr. Gellings has demonstrated a unique ability to understand what energy customers want and need and then implement systems to develop and deliver a set of R&D programs to meet the challenge. Among Mr. Gellings' most significant accomplishments is his success in leading a team with an outstanding track record in forging tailored collaborations—alliances among utilities, industry associations, government agencies, and academia—to leverage R&D dollars for the maximum benefit. Mr. Gellings has published 10 books, more than 400 articles, and has presented papers at numerous conferences. Some of his many honors include seven awards in lighting design and the Bernard Price Memorial Lecture Award of the South African Institute of Electrical Engineers. He has been elected a fellow in the Institute of Electrical and Electronics Engineers and the Illuminating Engineering Society of North America. He won the 1992 DSM Achiever of the Year Award of the Association of Energy Engineers for having invented DSM. He has served as an advisor to the US Congress Office of Technical Assessment panel on energy efficiency, and currently serves as a member of the Board of Directors for the California Institute for Energy Efficiency.

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