Energy Conservation

An Online Continuing Education Course for Engineers

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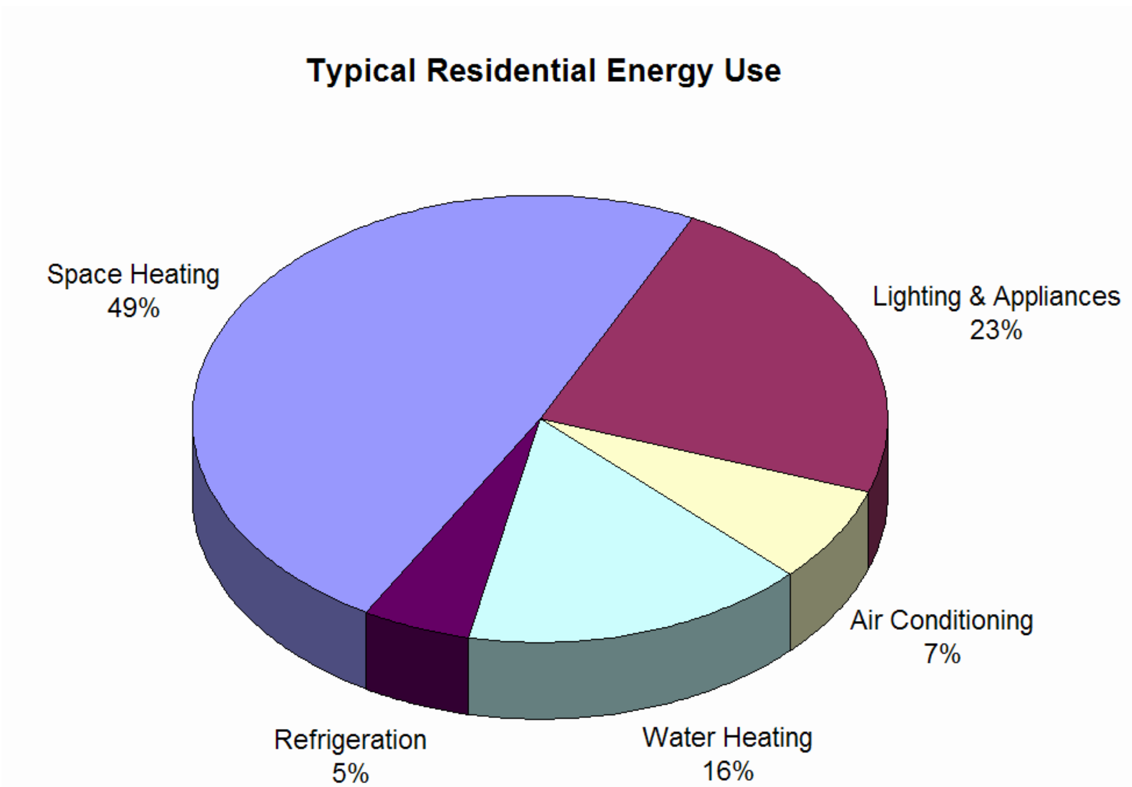
Introduction

Rising energy costs have created a renewed interest by facilities managers in the energy efficiency of their facilities. Whether it is a commercial building, an industrial plant, or even an individual residence, there are strategies that can improve the efficiency of the facility without reducing its comfort or operational effectiveness.



The above chart shows the typical energy use for a residential building. As you can see space heating is the largest consumer of energy at 49% of the total usage in a home, followed by lighting and appliances, which is 23% of the total. Water heating is the third largest consumer of energy at 16% of the total. These values vary based on the area of the country with air conditioning making up a larger percentage in the South and Southwest parts of the United States. Small commercial buildings will have similar usage patterns except that the water heating will be less and the air conditioning and lighting will be a larger percentage.

Strategies to improve the energy efficiency of facilities include, improving the building envelope, installing energy efficient heating, ventilation, and air-conditioning systems, using appropriate lighting, and managing the various appliances commonly found in commercial and residential buildings. The following information is divided into for sections: Building Envelope, Heating, Ventilation, & Air-Conditioning, Lighting, Equipment. The first section looks at factors affecting the building envelope such as infiltration and fenestration.

I. Building Envelope

The building envelope includes anything that encloses a building such as walls, ceilings, windows, foundations. Basically, the envelope is anything that separates the inside of a building from the outside environment. The foundation of a good energy conservation program begins with having a building envelope that efficiently minimizes heat loss.

From thermodynamics we know that there are three forms of heat transfer. Heat transfer occurs by conduction, convection, and radiation. We will look at how each of these forms of heat transfer work.

Conduction causes heat to flow by way of collisions between atoms and molecules, which causes a transfer in kinetic energy. Hot atoms move faster than cold atoms and when they come in contact the collisions slow down the "fast" atoms and speed up the "slow" atoms, which cause the transfer of some kinetic energy. Different materials transfer heat at different rates and the transfer capability of a material is known as its thermal conductivity. Some materials, such as steel and iron have high thermal conductivity and hence, transfer heat readily. Other materials, such as wood, and fiberglass are poor thermal conductors. Air is a poor thermal conductor so materials that have dead air space, such as fiberglass insulation and double pane windows are good insulators.

The second form of heat transfer is *convection*. Convection is the flow of heat through the movement of a large mass of matter. Convection is most often associated with the movement of air masses. As an air mass heats up the molecules in the air spread out causing the air mass to be less dense than the surrounding air. Since the air is less dense than the surrounding air it will rise in relation to the surrounding air and force the more dense air downward. This is why cooler air is found closer to the floor in buildings and warmer air is found near the ceiling. This same effect is seen in the atmosphere as rising warm air creates low pressure and colder denser air descending creates high pressure. This process creates a "breeze" that attempts to equalize the pressures.

The third form of heat transfer is *radiation*. Radiation is the transfer of energy that does not require the movement of a material from one place to another. In fact, radiation can occur in a vacuum. For instance, the heat from sunlight travels through space to reach the earth, which is an example of radiation heating. Of course, sunlight is visible, but not all forms of radiation heating are visible. A microwave oven is another form of radiation heating.

A. Infiltration

Heat loss through gaps in the building envelope is called *infiltration* and is a form of convection. The most common energy conservation methods to reduce infiltration are caulking, using expanding foam around window and door frames, sealing electrical outlets, and using whole-house infiltration wraps. Some insulation types, such as cellulose, claim to offer significant reductions in infiltration, and it may be slightly better than fiberglass, but insulation alone is not sufficient to achieve acceptable levels of air infiltration.

Air barriers are intended to block random air movement through building cavities. Air barriers can be made of almost anything. A continuous air barrier is an important feature in energy-efficient design not only for the energy it can save but also because the water vapor carried by the air is the primary way moisture related damage gets started in structural cavities. As the water vapor cools it condenses and so promotes structural damage, rotting wood, other mold growth. Air barriers reduce this problem by stopping much of the air movement but still allowing what water vapor that does get in to diffuse back out again.

Some common materials used for this purpose are: "house wrap," plywood, drywall (gypsum) board and foam board. Many of these materials are also used for insulation, structural purposes, and finished surfaces. What to choose and how to use it depends mainly on where you are building and the climate.

The most common air barrier material is use today is "house wrap" such as Tyvek®. Some wraps have better weathering or water repelling abilities than others. All come in a variety of sizes for different purposes and are made of fibrous spun polyolefin plastic, matted into sheets and rolled up for shipping. Sometimes, they also have other materials woven or bonded to them for tear resistance.

House wraps are usually wrapped around the exterior of a house during construction. Sealing all of the joints with tape is a good practice that improves the wrap's performance by about 20%. All house wrap manufacturers have a special tape for this purpose.

An air/vapor retarder attempts to combine water vapor and the air movement control with one material. This method is most appropriate for wet Southern climates where keeping humid outdoor air from entering the building cavities is critical during the cooling season.

An air/vapor retarder is generally placed around the perimeter of the building just under the exterior finish, or it may actually be the exterior finish. In many cases it's constructed of one of the following: polyethylene plastic sheets, builder's foil, foam board insulation, and other exterior sheathings. The key to making this method work effectively is to permanently and carefully seal all of the seams and penetrations, including around windows, doors, electrical outlets, plumbing stacks, and vent fans.

Missed gaps of any size not only increase energy use, but also increase the risk of moisture damage to the house especially during the cooling season. An air/vapor retarder should also be carefully inspected after installation before other work covers it. Small holes can be repaired with caulk or polyethylene or foil tape. Areas with larger holes or tears should be removed and replaced. Patches should always be large enough to cover the damage and overlap any adjacent wood framing.

B. Insulation

Heat loss through the building structure is caused by conduction where heat moves through gypsum board, wood framing, exterior finish, window glass, and doors. Since heat flows naturally from a warmer to a cooler space, the purpose of insulation is to help slow the outflow of heat from the building structure during the winter. In the summer, insulation helps slow the inflow of heat into the building. Insulation is the most significant factor impacting the heat loss through a building envelope.

<u>1. Insulation Basics</u>

The purpose of insulation is to slow the flow of heat through a buildings walls, ceilings, and floors. Two important terms in energy conservation are “BTU’s” and “R-Values”.

A BTU is an abbreviation for British Thermal Units.

A *BTU* is the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit.

The effectiveness of thermal insulation is determined using "R-Values". A thermal insulator is any material that resists the conduction of heat energy. The official definition of R-Value is complex as you can see here,

> *R-Value* is the reciprocal of the BTU's of energy conducted times inches of thickness per hour of time per square foot of area per degree Fahrenheit of temperature difference between the two sides of the material. The units of R- Value are $hr*ft^2*F/BTU$.

What is important t … of the resistance of a material to heat flov … ating value. It is also important to remem … ethods of heat transfer – conduction.

Because insulation is … ing envelope it is often the first item that is cc … n. Adding insulation can be expensive, but i … conservation method. It is easy to determine … h the addition of insulation by using a pa …

The payback calculation … ew insulation, the efficiency of the heating … the structure, and the outside temperature wh … ually the temperature data is based on Heating Degree Day data … uilding location. The payback calculation is,

Payback = ($Cost_{Ins}$ * $R_{Existing}$ *R_{New} * Eff) / (Energy Cost * (R_{New} – $R_{Exising}$) * HDD * 24)

Where,
Payback = Expected payback, years.
$Cost_{Ins}$ = Installed cost of the insulation, $\$/ft^2$. $R_{Existing}$ = Areas existing R-Value.
R_{New} = New R-Value of area.
Eff = Efficiency of the heating system.
Energy Cost = Energy cost, \$/BTU. HDD = Heating Degree Days.

Note: The efficiency factor for natural gas, propane, and fuel oil systems is based on the Annual Fuel Utilization Efficiency (AFUE) factor. Typical values are 0.88 for propane systems and 0.92