OFFICE OF ENERGY EFFICIENCY
AND RENEWABLE ENERGY

Lighting In the Library

Appendix

OFFICE OF BUILDING TECHNOLOGY,
STATE AND COMMUNITY PROGRAMS

High School Energy Inventory: Lighting Technology Primer

The amount and quality of light around us affects our health, safety, comfort, and productivity. Our country spends more than $37 billion each year on electricity for lighting, but technologies developed during the past 10 years can help us cut lighting costs by 30% to 60% while enhancing lighting quality and reducing environmental impacts. In a typical indoor lighting system, 50 percent or more of the energy supplied to the lamp can be wasted by obsolete equipment, poor maintenance, or inefficient use.

Lighting Principles and Terms

Some basic lighting terms are:

Lamp: a lighting industry term for an electric light bulb, tube, or other lighting device.

Illumination: the distribution of light on a horizontal surface. Illumination is measured in footcandles.

Lumen: a measurement of light output from a lamp (often called a bulb or tube). All lamps are rated in lumens. For example, a 100-watt incandescent lamp produces about 1750 lumens.

Footcandle: a lumen of light distributed over a 1-square-foot (0.09-square-meter) area.

Ideal Illumination: the minimum number of footcandles necessary to perform a task comfortably and proficiently without eyestrain. The Illuminating Engineering Society says that illumination of 30 to 50 footcandles is adequate for most home, office, and school work.

Efficacy: the ratio of light output from a lamp to the electric power it consumes. Efficacy is measured in lumens per watt (LPW).

Glare: excessive brightness from a direct light source. Types of glare include direct glare, reflected glare, and veiling reflections. Direct glare results from strong light from windows or bright. Reflected glare is caused by strong light from windows or lamps that is reflected off a shiny surface. Veiling reflection is a special type of reflected glare that can obscure contrasts and reduce task clarity. Veiling reflections occur when light is reflected from a work surface, a printed page or a computer screen.

Light Quality: a measurement of how well people in a lighted space can see to do visual tasks and how visually comfortable they feel in that space. Light quality is important to energy efficiency because spaces with higher quality lighting need less illumination. High-quality lighting is fairly uniform in brightness and has no glare.

Relamping: replacing an existing lamp and/or fixture to save energy.

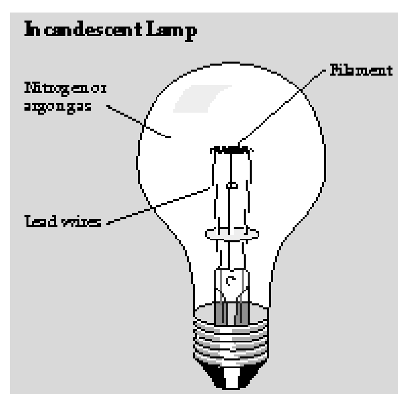
Types of Lighting

The four basic types of lighting are incandescent, fluorescent, high-intensity discharge, and low-pressure sodium.

Incandescent lighting is the most common type of lighting used in homes. Basic types of incandescent lights are standard household, tungsten halogen, and reflector lamps.

A standard incandescent lamp uses electric current to heat a tiny coil of tungsten wire inside a glass bulb to produce light. Compared with other types of lighting, Standard incandescent lamps, also known as the "A-type light bulb," have the shortest lives and convert most of the electricity used to power them into heat rather than light.

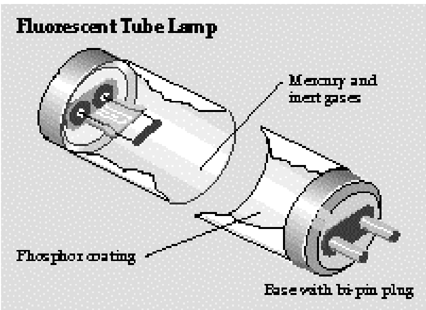
Tungsten halogen lamps are more energy-efficient than standard incandescent lamps. They have a gas filling and an inner coating that reflect heat. Together, the filling and coating recycle heat to keep the filament hot with less electricity. These lamps are much more expensive than standard incandescents and are primarily used in commercial applications: theater, store, and outdoor lighting systems.



Household incandescent lamps are the least expensive to buy, but they are the most expensive to operate.

Real life Math and Science Activities provided by U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy; Office of Building Technology, State and Community Programs

Fluorescent lighting is used primarily in commercial, institutional, and residential indoor lighting systems. Fluorescent lights are about 3 to 4 times as efficient as incandescent lighting and last about 10 times longer. A fluorescent tube produces light when electric current is conducted through mercury and inert (chemically unreactive) gases. Fluorescent lamps operate most efficiently when they are used for several hours at a time.

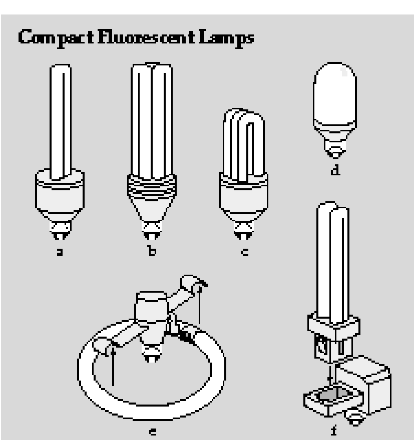


In fluorescent tubes, a very small amount of mercury mixes with inert gases to conduct the electrical current. This allows the phosphor coating on the glass tube to emit light.

Fluorescent lights require the use of devices called ballasts for starting and circuit protection. Ballasts control the electricity used by the lamp, and they typically consume 10 percent to 20 percent of the total energy used by light fixtures and lamps. One way to increase the energy savings of fluorescent lights replacing their ballasts.

Tube fluorescent lamps are the second most popular lamps after standard incandescent. The two most common types of fluorescent tubes are 40-watt, 4-foot (1.2-meter) lamps and 75-watt, 8-foot (2.4-meter) lamps. Tubular fluorescent fixtures and lamps are preferred for lighting in large indoor areas because their low brightness creates less direct glare than do incandescent bulbs.

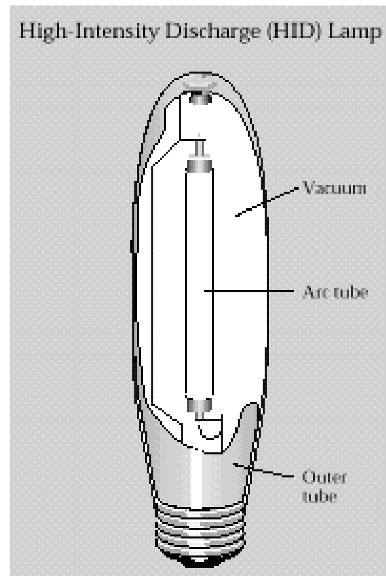
Compact fluorescent lamps are the most significant lighting advance in recent years. They combine the efficiency of fluorescent lighting with the convenience and popularity of incandescent fixtures. Compact fluorescent lamps can replace incandescent lamps that are roughly 3 to 4 times their wattage, which can save up to 75% of the initial lighting energy. Although they usually cost 10 to 20 times more than comparable incandescent bulbs, compact fluorescent lamps last 10 to 15 times as long. The energy saving and long life of compact fluorescent lamps make them one of the best energy efficiency investments available.



Compact fluorescent lamps come in a variety of sizes and shapes including (a) twin-tube integral (b and c) triple-tube integral, (d) integral model with casing that reduces glare, (e) modular circline and ballast, and (f) modular quad-tube and ballast. They can be installed in regular incandescent fixtures, and they consume less than one-third as much electricity as incandescent lamps do.

Early versions of compact fluorescent lamps introduced in the 1980s were bulky, heavy, and too big for many incandescent fixtures. However, newer models with less heavy electronic ballasts are only slightly larger than the incandescent lamps they replace. Some types of compact fluorescents include a ballast and a lamp in a single disposable unit. Other types feature separate ballasts that can handle about five lamp replacements before they wear out.

High-intensity discharge lighting is used in outdoor lighting applications such as large indoor arenas. These lamps use an electric arc to produce very bright light. High-intensity discharge lamps can save 75% to 90% of lighting energy when they replace incandescent lamps and fixtures. They provide the highest efficacy and longest service life any lighting type. Like fluorescent lamps, high-intensity discharge lamps use ballasts. They take a few seconds to produce light when first turned on because the ballast needs time to establish the electric arc to produce light.



In a high-intensity discharge lamp, electricity arcs between two electrodes, creating an intensely bright light. Mercury, sodium, or metal halide gases act as the conductor.

The three most common types of high-intensity discharge lamps are mercury vapor, metal halide, and high-pressure sodium. Metal halide lamps are similar in construction and appearance to mercury vapor lamps, but they use metal halide gases (along with mercury gas) in the lamp. Adding metal halide gases inside the lamp produces greater light output, more lumens per watt, and better color than mercury vapor lamps. Metal halide lamps are used to light large indoor areas such as gymnasiums, sports arenas, and anywhere that color rendering is important.

High-pressure sodium lighting is becoming the most common type of outdoor lighting. High-pressure sodium lamps are very efficient (90 to 150 lumens per watt). Their efficiency is exceeded only by low-pressure sodium lighting. High-pressure sodium lamps are also reliable and have long service lives, and they produce a warm white color.

Low-Pressure Sodium lamps are used where the color of light is not important, such as in outdoor security land highway lighting applications. Low-pressure sodium lamps work somewhat like fluorescent lamps. They are the most efficient form of artificial lighting available, have the longest service life, and maintain their light output better than any other type of lamp. A wide selection of low-pressure sodium lamps exists, and they vary in their construction, efficiency, color characteristics, and lamp life. Low-pressure sodium lamps produce colors as tones of yellow or gray.

Replacing Lamps and Fixtures

When relamping (substituting one lamp for another to save energy), a decision can be made to increase or decrease the level of illumination. When relamping a large space, the new lamps should first be tested in a small area to ensure adequate illumination, occupant satisfaction, and compatibility of the new lamp with the old fixture.

Matching replacement lamps to existing fixtures and ballasts can be tricky, especially with older fixtures. Buying new fixtures made for new lamps produces greater energy savings, reliability, and longevity compared to relamping alone.

Relamping Incandescent Fixtures

Much is now known about fixture design. Many indoor fixtures waste energy by trapping a significant amount of light inside the fixture, while many outdoor fixtures tend to disperse much of the light they produce beyond an intended area.

New incandescent fixtures are designed to “push” all the light they produce out into the room. Advances in indoor fixture design include brighter reflectors and better reflecting geometry.

Many incandescent lamps are mismatched to their tasks. Some have high wattages which result in unnecessarily high illumination and energy waste. This can be corrected by using lamps with smaller wattages. Standard incandescent lamps can often be replaced with improved lamps. And, for energy savings of 60% to 75%, many incandescent lamps can be replaced with compact fluorescent lamps.

Standard incandescent lamps can be replace with compact fluorescent lamps in spaces where light is needed for long periods of time. New compact fluorescent lamp fixtures have built-in electronic ballasts and polished metal reflectors which improve light output and energy savings.

Relamping Fluorescent Fixtures

Although fluorescent lamps are generally energy efficient, there are new, more efficient fluorescent lamps that use better electrodes and coatings to produce about the same lumen output at a lower wattage. Common 40-watt and 75-watt lamps can be replaced with energy-saving lamps of 34 watts and 60 watts, respectively. Energy-saving lamps for less-common fluorescent fixtures are also available.

If the ballasts in fluorescent fixtures need to be replaced, improved electromagnetic ballasts and electronic ballasts can be used to raise the efficiency of the fixture 12 percent to 30 percent. Improved electromagnetic ballasts reduce energy loss, fixture temperature, and system wattage. Because they operate at cooler temperatures, they last longer than standard electromagnetic ballasts.

Electronic ballasts operate at a very high frequency that eliminates flickering and noise. They are even more efficient than improved electromagnetic ballasts. Some electronic ballasts even allow use of dimmer switches, which are usually not recommended with most fluorescent lamps.

Improving Lighting Controls

Lighting controls are devices for turning lights on and off or for dimming them. The simplest type is a standard snap switch. Other controls are photocells, timers, occupancy sensors, and dimmer switches.

Standard snap switches, located in numerous convenient areas, are made to turn off lights in unused areas. Photocells turn lights on and off in response to changes in natural light levels. For example, photocells turn outdoor lights on at dusk and off at dawn. Advanced photocells gradually raise and lower fluorescent light levels with changing levels of daylight.

Mechanical or electronic timers use clock settings to automatically turn on and off indoor or outdoor lights for security, safety, and tasks such as janitorial work. Crank timers limit lights to short durations where the need for light is brief.

Occupancy sensors detect motion to activate lights when a person is in the area and then turn off the lights after the person has left. They are popular for areas that are not regularly used and offer security advantages over continuous lighting: when lights suddenly come on, they startle intruders and alert residents and neighbors to motion in the area.

Dimmer switches reduce the wattage and output of incandescent and fluorescent lamps. Dimmers also increase the service life of incandescent lamps significantly. However, dimming incandescent lamps reduces their lumen output more than their wattage. This makes incandescent lamps less efficient as they are dimmed. Dimming fluorescent lamps requires special dimming ballasts and lamp holders, but does not reduce their efficiency.

Daylighting

Daylighting means using sunlight for indoor lighting. Modern buildings designed for daylighting typically use 40% to 60% less electricity for lighting needs than do conventional buildings.

Sunlight is free and can be easily used to daylight a building. However, using sunlight without causing glare and without overheating a building can be difficult. Glare can be avoided with the use of window sills, walls, louvers, reflective blinds, and other devices to reflect light deep into the building. Windows and skylights can be located away from the direct rays of the sun to avoid overheating. For example, placing skylights on the north slope of a roof rather than on the southern may reduce unwanted heat transfer. Windows are also available with selective coatings that transmit visible light from the sun while blocking heat transfer.

Lighting Maintenance

Maintenance of light fixtures is vital to lighting efficiency. Light levels decrease over time because of aging lamps and dirt on fixtures, lamps, and room surfaces. Together, these factors can reduce illumination by 50% or more, while lights continue drawing full power. The following basic maintenance activities can help prevent this:

Clean fixtures, lamps, and lenses every 6 to 24 months by wiping off the dust. However, never clean an incandescent bulb while it is turned on. The water's cooling effect will shatter the hot bulb.

Replace lenses if they appear yellow.

Clean or repaint small rooms every year and larger rooms every 2 to 3 years. Dirt collects on room surfaces, which reduces the amount of light they reflect.

Consider relamping entire rooms or systems at one time. Common lamps, especially incandescent and fluorescent lamps, lose 20 percent to 30 percent of their light output over time. Many lighting experts recommend replacing all the lamps in a lighting system at once. This saves labor, keeps illumination high, and avoids overworking any ballasts with dying lamps.

Conclusion

Saving lighting energy requires either reducing electricity consumed by lights or reducing the length of time the lights are turned on. This can be accomplished by:

- lowering wattage by replacing lamps or entire fixtures
- reducing the amount of time lights are on by installing improved lighting controls and educating people to turn off lights when they are not needed
- using daylight when possible to reduce energy consumption of electric lights
- performing simple maintenance to ensure adequate illumination and light quality and to lower required levels of illumination where possible.

Lighting Facts

A 100-Watt incandescent lamp typically lasts for about 750 hours, while a 28-Watt compact fluorescent lamp lasts for about 10,000 hours (13.3 times as long). At an average electricity cost of $0.08 per kWh, the cost of operating 13.3 incandescent lamps over 10,000 hours is $80. The cost of operating a single 28-Watt compact fluorescent lamp over 10,000 hours at $0.08 per kWh is $22.40. Assuming a cost of $1.00 for each 100-Watt incandescent lamp, the total life-cycle cost (product cost plus electricity cost) of using 13.33 incandescent lamps for 10,000 hours is $93.33. Assuming a cost of $20.00 for one 28-Watt compact fluorescent lamp, the life-cycle cost of using 1 compact fluorescent lamp is $42.40.

Replacing one 100-Watt incandescent lamp with a 28-Watt with compact fluorescent lamp can:

- save 496 pounds of coal used as fuel to generate electricity
- reduce carbon dioxide emissions from a coal-fired power plant by 850 pounds
- reduce sulfur dioxide emissions by four pounds
- reduce nitrous oxide emissions by three pounds
- reduce mercury emissions by 40 p

Unit Pre and Post Test

1 The energy in fossil fuels such as coal is stored as...

- a chemical energy
- b electrical energy
- c thermal energy
- d nuclear energy

2 Which energy source provides the nation with the most energy?

- a coal
- b natural gas
- c petroleum
- d electricity

3 Which residential task uses the most energy?

- a lighting
- b heating water
- c heating rooms
- d cooling rooms

4 Most energy conversions produce...

- a light
- b heat
- c motion
- d sound

5 The major use of coal in the U.S. is to...

- a fuel trains
- b heat homes and buildings
- c make chemicals
- d generate electricity

6 What percentage of the energy we use comes from renewable energy sources?

- a 4 percent
- b 8 percent
- c 16 percent
- d 25 percent

7 Compared to incandescent light bulbs, fluorescent bulbs...

- a use more energy
- b use less energy
- c use the same amount of energy

8 Which fuel provides most of the energy to commercial buildings?

- a electricity
- b natural gas
- c coal
- d petroleum

9 Which sector of the economy consumes the most energy?

- a transportation
- b commercial
- c industrial
- d residential

10 Which greenhouse gas is considered the most significant to global climate change?

- a sulfur dioxide
- b methane
- c ozone
- d carbon dioxide

11 Electricity is measured in...

- a amperes
- b volts
- c kilowatt-hours
- d current

12 Natural gas is transported mainly by...

- a barge
- b tanker
- c pipeline
- d truck

13 The average cost of a kilowatt-hour of electricity in the U.S. is...

- a 8 cents
- b 25 cents
- c 1 dollar
- d 5 dollars

14 Natural gas is measured by...

- a volume
- b weight
- c heat content
- d flammability

All About Energy

What Is Energy?

Energy does things for us. It moves cars along the road and boats on the water. It bakes a cake in the oven and keeps ice frozen in the freezer. It plays our favorite songs and lights our homes at night so we can read a good book.

Energy is defined as the ability to do work—to cause change-- and that work can be divided into five main tasks:

1. **Energy gives us light.**
2. **Energy gives us heat.**
3. **Energy makes things move.**
4. **Energy makes things grow.**
5. **Energy makes technology work.**

Forms of Energy

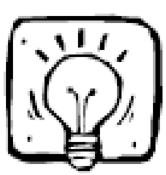
Energy takes many different forms. It can light our homes or heat them. There are six forms of energy.

Mechanical

Mechanical energy puts something in motion. It moves cars and lifts elevators. It pulls, pushes, twists, turns, and throws. A machine uses mechanical energy to do work and so do our bodies! We can throw a ball or move a pencil across a piece of paper. Sound is the energy of moving air molecules!

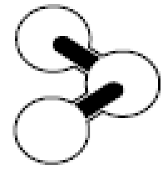
Kinetic energy is a kind of mechanical energy. It is the energy of a moving object. A moving car has kinetic energy. A stalled car does not; however, if it's poised at the top of a hill, it may have potential energy.

Potential energy is the energy an object has because of its position. Potential energy is resting or waiting energy. A spring is a good example of potential energy. Energy can be stored in the spring by stretching or compressing it. The sum of an object's kinetic and potential energy is the object's mechanical energy.



Radiant

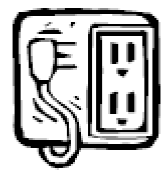
Radiant energy is commonly called light energy. But light energy is only one kind of radiant energy. All waves emit energy. Radio and television waves are other types of radiant energy. So are gamma rays and x-rays. Light waves do work by wiggling the receptors in back of our eyes.



Chemical

Chemical energy is the energy stored in food, wood, coal, petroleum, and other fuels. During photosynthesis, sunlight gives plants the energy they need to build complex chemical compounds. When these compounds are broken, the stored chemical energy is released in the form of heat or light.

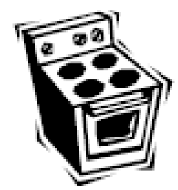
What happens to a wood log in a fireplace? Burning the wood breaks up the compounds, releasing the stored chemical energy in the forms of thermal and radiant energy.



Electrical

Electrical energy is a special kind of kinetic energy—the energy of moving electrons. Everything in the world is made up of tiny particles called atoms. Atoms are made up of even tinier particles called electrons, protons, and neutrons.

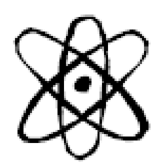
Electricity is produced when something upsets the balancing force between the electrons and protons in atoms and the electrons move from one atom to another. We can use electricity to perform work like lighting a bulb, heating a cooking element on a stove, or moving a motor.



Thermal

Thermal energy, or heat energy, is also a special kind of kinetic energy. It is the energy of moving or vibrating molecules. The faster the molecules move, the hotter an object becomes and the more thermal energy it possesses.

Thermal energy can do work for us or it can be the result of doing work. Do this. Rub your hands together quickly. What do you feel? You feel heat. When two objects slide against each other they produce friction heat.

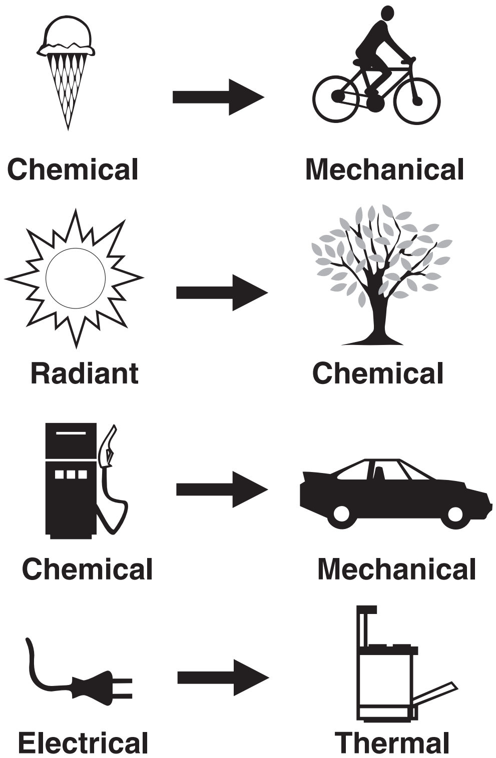


Nuclear

Nuclear energy is energy locked in the nucleus of the atom. It is the force that binds the nucleus of the atom together. The energy can be released when atoms are combined or split apart.

Nuclear power plants split atoms of uranium in a process called **fission**. The sun combines atoms of hydrogen to produce helium in a process called **fusion**. In both fission and fusion, mass is converted into energy, according to Einstein's Theory, $E + mc^2$.

Energy Transformations



Conservation of Energy

Your parents may tell you to conserve energy by turning off the lights. But, to scientists, conservation of energy means something else. The **law of conservation of energy** says energy is neither created nor destroyed.

Energy cannot be created or destroyed, but it can be transformed. That's really what we mean when we say we use energy. We change one form of energy into another. A car engine burns gasoline, converting its chemical energy into heat and mechanical energy that makes the car move. Wind mills change the kinetic energy of the wind into electrical energy. Solar cells change radiant energy into electrical energy.

Energy can change form, but the total quantity of energy in the universe remains the same. The only exception to this law is when mass is converted into energy during nuclear fusion and fission.

Energy Efficiency

Energy efficiency is how much useful energy you can get out of a system. In theory, a 100 percent energy-efficient machine would change all the energy put in it into useful work. Converting one form of energy into another form always involves a loss of usable energy, usually in the form of heat. In fact, most energy transformations are not very efficient.

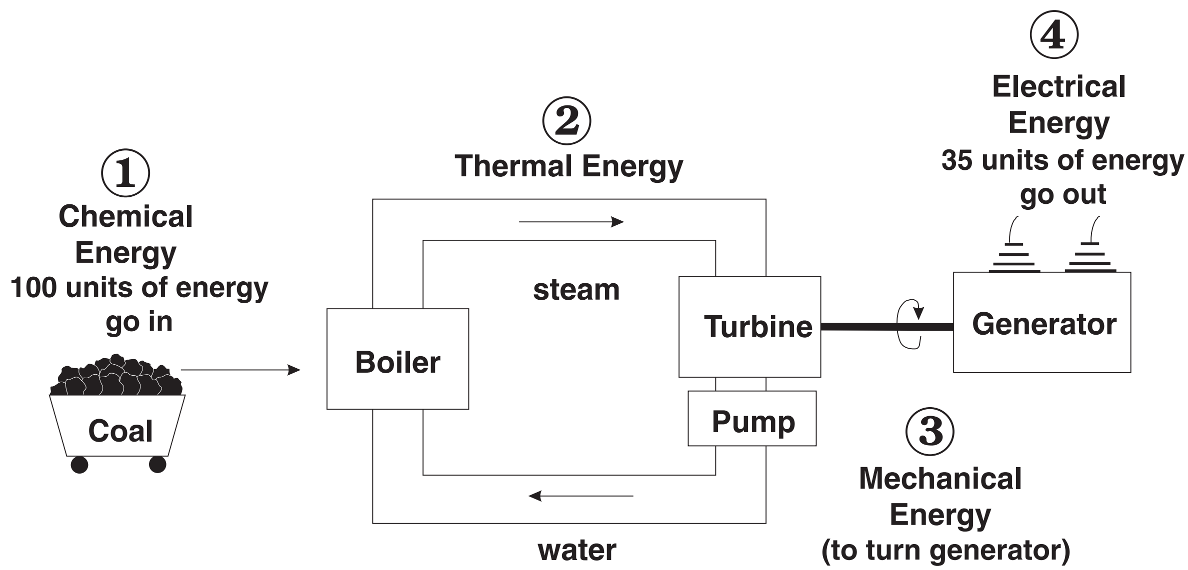
The human body is no exception. Your body is like a machine, and the fuel for your "machine" is food. Food gives us the energy to move, breathe, and think. But your body isn't very efficient at converting food into useful work. Your body is less than five percent efficient most of the time, and rarely better than 15 percent efficient. The rest of the energy is lost as heat. You can really feel the heat when you exercise!

An incandescent light bulb isn't efficient either. A light bulb converts ten percent of the electrical energy into light and the rest (90 percent) is converted into thermal energy (heat). That's why a light bulb is so hot to the touch.

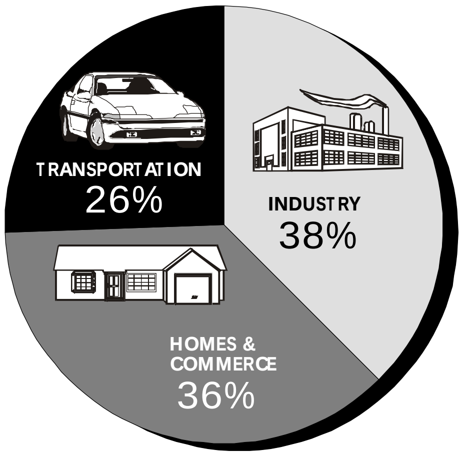
Most electric power plants are about 35 percent efficient. It takes three units of fuel to make one unit of electricity. Most of the other energy is lost as waste heat. The heat dissipates into the environment where we can no longer use it as a practical source of energy.

Energy Efficiency

Most power plants are about 35% efficient. That means for every 100 units of energy that go in a plant, 65 units are "lost" as one form of energy is converted to another form. Thirty-five units are left to do usable work.



Energy Use in 1997



SOURCE: ENERGY INFORMATION ADMINISTRATION

Energy Use

Imagine how much energy you use every day. You wake up to an electric alarm clock. You take a shower with water warmed by a hot water heater. You listen to music on the radio as you dress. You catch the bus to school. And that's just some of the energy you use to get you through the first part of your day!

Every day, the average American uses about as much energy as is stored in seven gallons of gasoline. That's every person, every day. Over a course of one year, the sum of this energy is roughly equal to 2,500 gallons of oil. Energy use is sometimes called **energy consumption**.

Who Uses Energy?

The U.S. Department of Energy uses three categories to classify energy users: residential and commercial; industrial; and transportation. These users are sometimes called sectors of the economy.

Residential & Commercial

Residences are people's homes. Commerce includes office buildings, hospitals, stores, restaurants, and schools. Residential and commercial are lumped together because homes and businesses use energy for much the same reasons—heating, air conditioning, water heating, lighting, and operating appliances.

The residential and commercial sector of the economy consumed about 34 quads of energy in 1997 (the residential sector consumed more than two-thirds of this energy.)

Industrial

The industrial sector includes manufacturing, construction, mining, farming, fishing, and forestry. This sector consumed 35 quads of energy in 1997—more energy than the residential and commercial sector.

Transportation

The transportation sector refers to energy use by cars, buses, trucks, trains, ships, and airplanes. In 1997, the United States used large amounts of energy for transportation, more than 24 quads. About 95 percent was supplied by petroleum products like gasoline, diesel fuel and jet fuel.

Energy Use and Prices

In 1973, when Americans faced their first oil price shock, people didn't know how the country would react. How would Americans adjust to skyrocketing energy prices? How would manufacturers and industries respond? We didn't know the answers.

Now we know that Americans tend to use less energy when energy prices are high. We have the statistics to prove it.

When energy prices increased sharply in 1973, energy use dropped, creating a gap between actual energy use and how much the experts had thought Americans would be using.

The same thing happened when energy prices shot up again in 1979 and 1980—people used less energy. In 1985 when prices started to drop, energy use began to increase.

We don't want to simplify energy demand too much. The price of energy is not the only factor in the equation. Other factors that affect how much energy we use include the public's concern for the environment and new technologies that can improve the efficiency and performance of automobiles and appliances.

Most energy savings in recent years have come from improved technologies in industry, vehicles, and appliances. Without these energy conservation and efficiency technologies, we would be using much more energy today.

In 1997, the United States used about 27 percent more energy than it did in 1993. That might sound like a lot, but the population increased by 27 percent and the nation's gross national product (the total value of all the goods and services produced by a nation in one year) was 77 percent higher! If we hadn't slowed down our energy use, that figure would have been twice as high!

MEASURING*energy*

"You can't compare apples and oranges," the old saying goes. And that holds true for energy sources. Just think. We buy gasoline in gallons, wood in cords, and natural gas in cubic feet. How can we compare them?

With British thermal units, that's how. The heat energy contained in gasoline, wood, or other energy sources can be measured by British thermal units or Btu's.

One Btu is the heat energy needed to raise the temperature of one pound of water one degree Fahrenheit. A single Btu is quite small. A wooden kitchen match, if allowed to burn completely, would give off one Btu of energy. One ounce of gasoline contains almost 1,000 Btu's of energy. Every day the average American uses roughly 889,000 Btu's.

We use the quad to measure very large quantities of energy. A quad is equal to one quadrillion (1,000,000,000,000,000) Btu's. The United States uses about one quad of energy every 3.9 days. In 1997, Americans consumed 94.2 quads of energy, an all-time high.

ENERGY*sources*

1997*consumption*

Source	Consumption	Type	Uses
BIOMASS	2.9%	*renewable energy source*	Used for heating, electricity, transportation
GEOTHERMAL	0.4%	*renewable energy source*	Used for heating, electricity
HYDROPOWER	4.1%	*renewable energy source*	Used for electricity
SOLAR	0.15%	*renewable energy source*	Used for heating, electricity
WIND	0.05%	*renewable energy source*	Used for electricity
COAL	22.7%	*nonrenewable energy source*	Used for electricity, manufacturing
NATURAL GAS	23.1%	*nonrenewable energy source*	Used for heating, industrial production
URANIUM	7.1%	*nonrenewable energy source*	Used for electricity
PETROLEUM	37.7%	*nonrenewable energy source*	Used for transportation, manufacturing
PROPANE	1.7%	*nonrenewable energy source*	Used for heating, transportation

* Consumption of Other Energy Sources 0.1%

Sources of Energy

People have always used energy to do work for them. Thousands of years ago, cave men burned wood to heat their homes. Later people used the wind to sail ships. A hundred years ago, people used falling water to make electricity.

Today people are using more energy than ever before and our lives are undoubtedly better for it. We live longer, healthier lives. We can travel the world, or at least see it on television.

Before the 1970s, Americans didn't think about energy very much. It was just there. Things changed in 1973. The Organization for Petroleum Exporting Countries, better known as OPEC, placed an embargo on the United States and other countries.

The embargo meant they would not sell their oil to those countries. Suddenly, our supply of oil from the Middle East disappeared. The price of oil in the U.S. rose very quickly. Long lines formed at gas stations as people waited to fill their tanks with the amber-colored liquid they hadn't thought much about before.

Petroleum is just one of the many different sources of energy we use to do work for us. It is our major transportation fuel. We use coal and uranium to produce most of our electricity, and natural gas to heat our homes and cook our food.

There are ten major energy sources that we use in the United States today, and we classify those sources into two broad groups—renewable and nonrenewable.

Nonrenewables

Nonrenewable energy sources are the kind we use most in the United States. Coal, petroleum, natural gas, propane, and uranium are the major nonrenewable energy sources. They are used to make electricity, to heat our homes, to move our cars, and to manufacture all sorts of products from aspirin to CDs.

These energy sources are called nonrenewable because they cannot be replaced in a short period of time. Petroleum, for example, was formed millions of years ago from the remains of ancient sea life, so we can't make more petroleum in a short time. The supply of nonrenewable sources will become more limited in the future.

Renewables

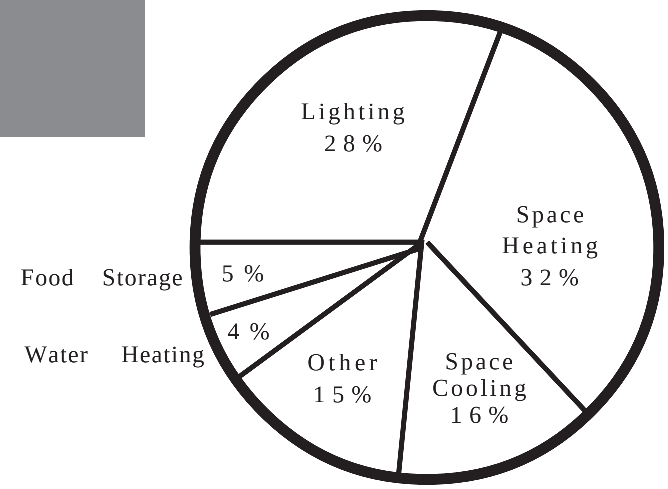
Renewable energy sources include biomass, geothermal energy, hydropower, solar energy and wind energy. They are called renewable energy sources because they can be replenished by nature in a relatively short period of time. Day after day, the sun shines, the wind blows, and the rivers flow. We mainly use renewable energy sources to make electricity.

Speaking of electricity, is it a renewable or nonrenewable source of energy? The answer is neither.

Electricity is different from the other energy sources because it is a **secondary** source of energy. That means we have to use another energy source to make it. In the United States, coal is the number one fuel for generating electricity.

Energy Consumption

Residential/Commercial Sector



COMMERCIAL ENERGY USE

The residential and commercial sectors–homes and buildings–consume 36 percent of the energy used in the United States today. We use that energy to heat and cool our homes and buildings, to light them, and to operate appliances and office machines.

In the last 25 years, Americans have significantly reduced the amount of energy we use to perform these tasks, mostly through technological improvements in the systems we use, as well as in the manufacturing processes to make those systems.

Heating & Cooling

The ability to maintain desired temperatures is one of the most important accomplishments of modern technology. Our ovens, freezers, and homes can be kept at any temperature we choose, a luxury that wasn't possible 100 years ago.

Keeping our living and working spaces at comfortable temperatures provides a healthier environment, and uses a lot of energy. Half of the average home's energy consumption is for heating and cooling rooms.

The three fuels used most often for heating are natural gas, electricity, and heating oil. Today, more than half of the nation's homes are heated by natural gas, a trend that will continue, at least in the near future. Natural gas is the heating fuel of choice for most consumers in the United States. It is a clean-burning, inexpensive fuel.

Most natural gas furnaces in the 1970s and 1980s were about 60 percent efficient - they converted 60 percent of the energy in the natural gas into usable heat. Many of these furnaces are still in use today, since they can last 20 or more years with proper maintenance.

New furnaces manufactrured today can reach efficiency ratings of 98 percent, since they are designed to capture heat that used to be lost up the chimney. These furnaces are more complex and costly, but they save significant amounts of energy.

The payback period for a new high-efficiency furnace is between four and five years, resulting in considerable savings over the life of the furnace.

Electricity is the second leading source of energy for home heating and provides almost all of the energy used for air conditioning. The efficiency of air conditioners and heat pumps has increased more than 50 percent in the last 25 years.

In 1973, air conditioners and heat pumps had an average Seasonal Energy Efficiency Rating, or SEER, of 7.0. Today, the average unit has a SEER of 10.7, and units are available with SEER ratings as high as 18.

These high-rated units are more expensive to buy, but their payback period is only three to five years. **Payback period** is the amount of time a consumer must use a system before beginning to benefit from the energy savings, because of the higher initial investment cost.

Heating oil is the third leading fuel for home heating, and is widely used in northeastern states. In 1973, the average home used 1,294 gallons of oil a year. Today, that figure is 833 gallons, a 35 percent decrease.

This decrease in consumption is a result of improvements in oil furnaces. Not only do today's burners operate more efficiently, they also burn more cleanly. According to the Environmental Protection Agency, new oil furnaces operate as cleanly as natural gas and propane burners.

A new technology under development would use PV cells to convert the bright, white oil burner flame into electricity.

Cost Management

The three most important things a consumer can do to reduce heating and cooling costs are:

Maintenance

Maintaining equipment in good working order is essential to reducing energy costs. Systems should be serviced annually by a certified technician, and filters should be cleaned or replaced frequently by the homeowner.

Programmable Thermostats

Programmable thermostats raise and lower the temperature automatically, adjusting for time of day and season. They also prevent people from adjusting the temperature They can lower energy usage appreciably.

Caulking & Weatherstripping

Preventing the exchange of inside air with outside air is very important. Weatherstripping and caulking around doors and windows can significantly reduce air leakage. Keeping windows and doors closed when systems are operating is also a necessity.

Building Design

The placement, design, and construction materials used can affect the energy efficiency of homes and buildings. Making optimum use of the light and heat from the sun is becoming more prevalent, especially in commercial buildings.

Many new buildings are situated with maximum exposure to the sun, incorporating large, south-facing windows to capture the energy in winter, and overhangs to shade the windows from the sun in summer. Windows are also strategically placed around the buildings to make use of natural light, reducing the need for artificial lighting during the day. Using materials that can absorb and store heat can also contribute to the energy efficiency of buildings.

For existing houses and buildings, there are many ways to increase efficiency. Adding insulation and replacing windows and doors with energy-efficient ones can significantly reduce energy costs. Adding insulated blinds, and using them wisely, can also result in savings. Even planting trees to provide shade in summer and allow light in during the winter can make a difference.

Lighting

Lighting is essential to a modern society. Lights have revolutionized the way we live, work, and play. Today, about five percent of the energy used in the nation is for lighting our homes, buildings, and streets.

Lighting accounts for about 10 percent of the average home's energy bill but, for stores, schools, and businesses, the figure is much higher. On average, the commercial sector uses about 28 percent of its energy consumption for lighting.

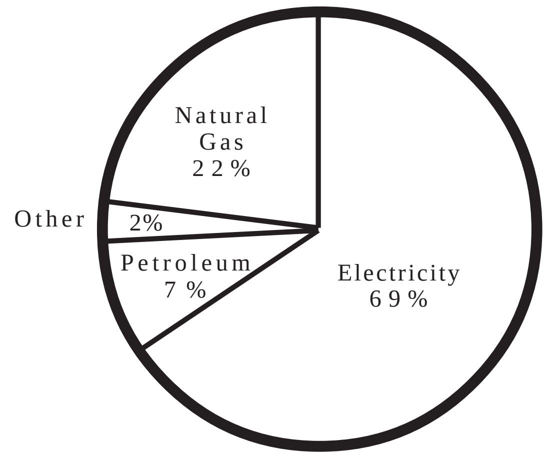
Most homes still use the traditional incandescent bulbs invented by Thomas Edison. These bulbs only convert about ten percent of the electricity they use to produce light; the other 90 percent is converted into heat. With new technologies, such as better filament designs and gas mixtures, these bulbs are still more efficient than they used to be. In 1879, the average bulb produced only 1.4 lumens per watt, compared to about 17 lumens per watt today. By adding halogen gases, this efficiency can be increased to 20 lumens per watt.

Most commercial buildings have converted to fluorescent lighting, which costs more to install, but uses much less energy to produce the same amount of light. Buildings can lower their long-term lighting costs by as much as 50 percent with fluorescent systems.

Heating Water

In residential buildings, heating water uses more energy than any other task, except for heating and cooling. In commercial buildings, such as schools, heating water consumes about four percent of total energy consumption. Most water heaters use natural gas or electricity as fuel.

Water heaters today are much more energy efficient than earlier models. Many now have timers that can be set to the times when hot water is needed, so that energy is not used 24 hours a day.



FUELS USED BY COMMERCIAL BUILDINGS

New systems on the market combine high efficiency water heaters and furnaces into one unit to share heating responsibilities. Combination systems can produce a 90 percent efficiency rating.

In the future, expect to see water heaters that utilize heat from inside the building that is usually pumped outside as waste heat. Systems will collect the waste heat and direct it into the water heater, resulting in efficiency ratings three times those of conventional water heaters.

The temperature on most water heaters is set much higher than necessary. Lowering the temperature setting can result in significant energy savings. Limiting the amount of hot water usage with low-flow faucets and conservation behaviors also contributes to lower energy bills.

Energy Efficiency Ratings

We use many appliances every day. Some use less than 10 cents worth of electricity a year, while others use much more. Have you noticed that those appliances that produce or remove heat require the most energy?

In 1990, Congress passed the National Appliance Energy Conservation Act, which requires appliances to meet strict energy efficiency standards. All appliances must display a yellow label which tells how much energy the appliance uses.

When purchasing any appliance, consumers should define their needs and pay attention to the Energy Efficiency Rating (EER) included on the yellow label of every appliance. The EER allows consumers to compare not just purchase price, but operating cost as well, to determine which appliance is the best investment. Usually, more energy efficient appliances cost more to buy, but result in significant energy savings over the life of the appliance. Buying the cheapest appliance is rarely a bargain in the long run.

In the next few years, consumers will have the choice of many *smart* appliances that incorporate computer chip technology to operate more efficiently, accurately, and effectively.

Electricity

The Nature of Electricity

Electricity is a little different from the other sources of energy that we talk about. Unlike coal, petroleum, or solar energy, electricity is a **secondary** source of energy. That means we must use other sources of energy to make electricity. It also means we can't classify electricity as renewable or nonrenewable. The energy source we use to make electricity may be renewable or nonrenewable, but the electricity is neither.

Making Electricity

Almost all electricity made in the United States is generated by large, central power plants. These plants usually use coal, uranium, natural gas, or other energy sources to produce heat energy which superheats water into steam. The very high pressure of the steam turns the blades of a turbine.

The blades are connected to a generator which houses a large magnet surrounded by a coiled copper wire. The blades spin the magnet rapidly, rotating the magnet inside the coil and producing an electric current.

The steam, which is still very hot, goes to a condenser where it is cooled into water by passing it through pipes circulating over a large body of water or cooling tower. The water then returns to the boiler to be used again.

Moving Electricity

We are using more and more electricity every year. It is considered an efficient energy carrier––it can transport energy efficiently from one place to another. Electricity can be produced at a power plant and moved long distances before it is used.

Let's follow the path of electricity from power plant to a light bulb in your school.

First, the electricity is generated at the power plant. Next, it goes by wire to a transformer that "steps up" the voltage. A transformer steps up the voltage of electricity from the 2,300 to 22,000 volts produced by a generator to as much as 765,000 volts (345,000 volts is typical). Power companies step up the voltage because less electricity is lost along the lines when the voltage is high.

The electricity is then sent on a nationwide network of transmission lines made of aluminum. Transmission lines are the huge tower lines you may see when you're on a highway. The lines are interconnected, so should one line fail, another will take over the load.

Step-down transformers located at substations along the lines reduce the voltage to 12,000 volts. Substations are small buildings or fenced-in yards containing switches, transformers, and other electrical equipment.

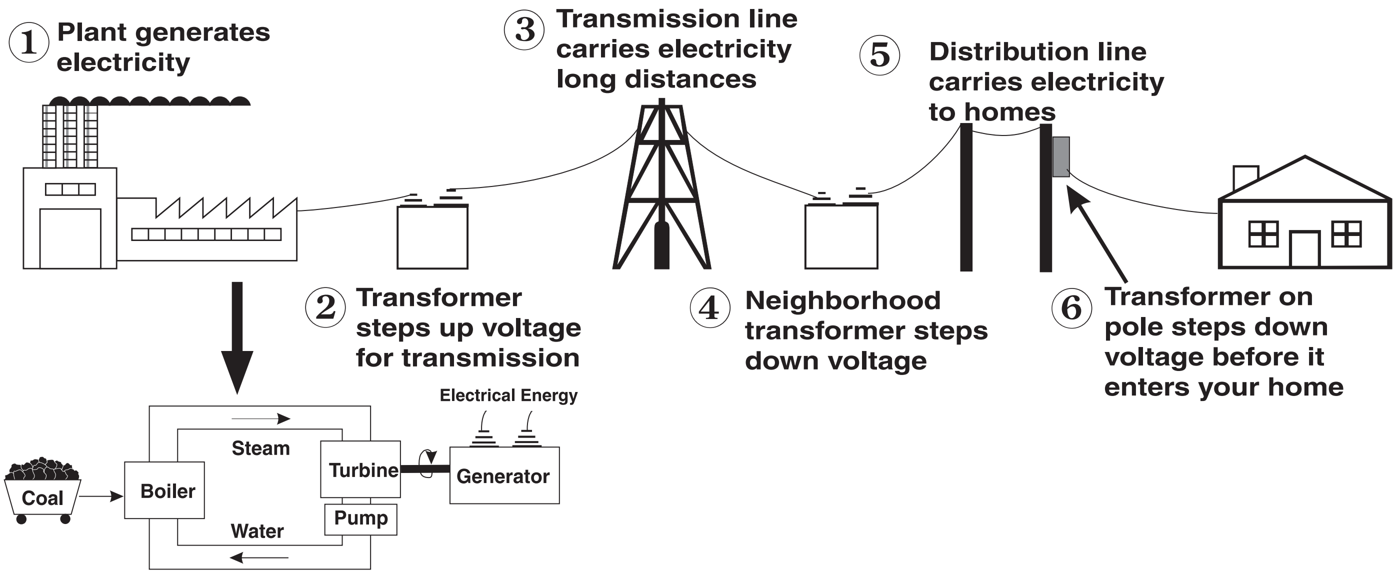
Electricity is then carried over distribution lines which bring electricity to your school. Distribution lines may either be overhead or underground. The overhead distribution lines are the electric lines that you see along streets.

Before electricity enters your school, the voltage is reduced again at another transformer, usually a large gray can mounted on an electric pole. This transformer reduces the electricity to the 120 volts that are needed to run the light bulb in your school.

Electricity enters your house through a three-wire cable. The "live wires" are then brought from the circuit breaker or fuse box to power outlets and wall switches in your home. An electric meter measures how much electricity you use so the utility company can bill you.

The time it takes for electricity to travel through these steps—from power plant to the light bulb in your home—is a tiny fraction of one second.

Transporting Electricity



Power to the People

Everyone knows how important electricity is to our lives. All it takes is a power failure to remind us how much we depend on it. Life would be very different without electricity—no more instant light from flicking a switch; no more television; no more refrigerators; or stereos; or video games; or hundreds of other conveniences we take for granted. We depend on it, business depends on it, and industry depends on it. You could almost say the American economy runs on electricity.

Reliability is the capability of a utility company to provide electricity to its customers 100 percent of the time. A reliable electric service is without blackouts or brownouts.

To ensure uninterrupted electric service, laws require most utility companies to have 15 to 20 percent more capacity than they need to meet peak demands. This means a utility company whose peak load is 12,000 MW, would need to have about 14,000 MW of installed electrical capacity. This helps ensure there will be enough electricity to go around even if equipment were to break down on a hot summer afternoon.

Capacity is the total quantity of electricity a utility company has on-line and ready to deliver when people need it. A large utility company may operate several power plants to generate electricity for its customers. A utility company that has seven 1,000-MW (megawatt) plants, eight 500-MW plants, and 30 100-MW plants has a total capacity of 14,000 MW.

Base-load power is the electricity generated by utility companies around-the-clock, using the most inexpensive energy sources—usually coal, nuclear, and hydropower. Base-load power stations usually run at full or near capacity.

When many people want electricity at the same time, there is a **peak demand**. Power companies must be ready for peak demands so there is enough power for everyone. During the day's peak, between 12:00 noon and 6:00 p.m., additional generating equipment has to be used to meet increased demand. This equipment is more expensive to operate. These peak load generators run on natural gas, diesel or hydro and can be running in seconds. The more this equipment is used, the higher our utility bills. By managing the use of electricity during peak hours, we can help keep costs down.

The use of **power pools** is another way electric companies make their systems more reliable. Power pools link electric utilities together so they can share power as needed.

A power failure in one system can be covered by a neighboring power company until the problem is corrected. There are nine regional power pool networks in North America. The key is to share power rather than lose it.

The reliability of U.S. electric service is excellent, usually better than 99 percent. In some countries, electric power may go out several times a day. Power outages in the United States are usually caused by such random occurrences as lightning, a tree limb falling on electric wires, or a car hitting a utility pole.

Demand-Side Management

Demand-side management is all the things a utility company does to affect how much people use electricity and when. It's one way electric companies manage those peak-load periods.

We can reduce the quantity of electricity we use by using better conservation measures and by using more efficient electrical appliances and equipment.

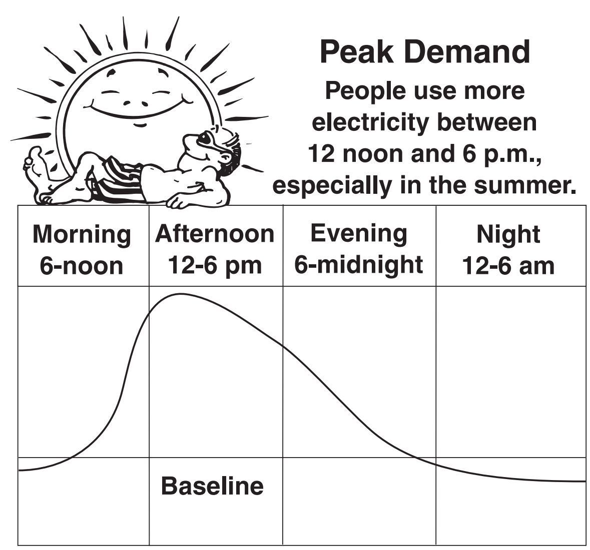
What's the difference between conservation and efficiency? Conserving electricity is like turning off the water in the shower while you shampoo your hair. Using electricity more efficiently is like installing a better shower head to decrease water flow.

Demand-side management can also affect the timing of electrical demand. Some utility companies give rebates to customers who allow the utility company to turn off their hot water heaters (via radio transmitters) during extreme peak demand periods, which occur perhaps 12 times a year. One East Coast power company gives participating customers a $4 per month rebate.

Economics of Electricity

How much does electricity cost? The answer depends on the cost to generate the power (50%), the cost of transmission (20%) and local distribution (30%).The average cost of electricity is 8.5 cents per kWh for residential customers. A major key to cost is the fuel used to generate electricity. For example, electricity produced from natural gas costs more than electricity produced from coal or nuclear power.

Another consideration is how much it costs to build a power plant. A plant may be very expensive to construct, but the cost of the fuel can make it competitive to other plants, or vice versa. For example, nuclear plants are very expensive to build, but their fuel—uranium—is very cheap. Coal-fired plants, on the other hand, are much less expensive to build than nuclear plants, but their fuel—coal—is more expensive.



When figuring costs, a plant's efficiency must be considered. In theory, a 100 percent energy-efficient machine would change all the energy put into the machine into useful work, not wasting a single unit of energy. But converting a primary energy source into electricity involves a loss of usable energy, usually in the form of heat. In general, it takes three units of fuel to produce one unit of electricity.

In 1900, electric power plants were only four percent efficient. That means they wasted 96 percent of the fuel used to generate electricity. Today's power plants are over eight times more efficient with efficiency ratings around 35 percent. Still, this means 65 percent of the initial heat energy used to make electricity is lost. (You can see this waste heat in the great clouds of steam pouring out of giant cooling towers on newer power plants.) A modern coal plant burns about 8,000 tons of coal each day, and about two-thirds of this is lost when the heat energy in coal is converted into electrical energy.

But that's not all. About two percent of the electricity generated at a power plant must be used to run equipment. And then, even after the electricity is sent over electrical lines, another 10 percent of the electrical energy is lost in transmission. Of course, consumers pay for all the electricity generated whether "lost" or not.

The cost of electricity is affected by what time of day it is used. During a hot summer afternoon from noon to 6 p.m., there is a peak of usage when air-conditioners are working harder to keep buildings cool. Electric companies charge their industrial and commercial customers more for electricity during these peak load periods because they must turn to more expensive ways to generate power.

Deregulation

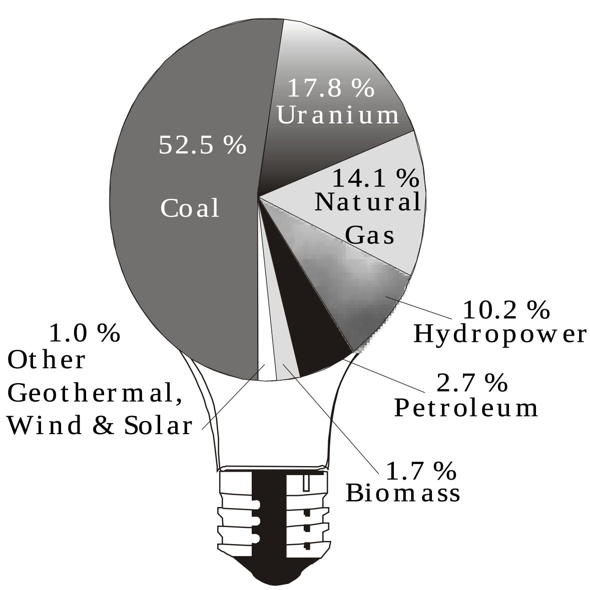
Since the 1930s, most electric utilities in the United States have operated under state and federal regulations in a defined geographical area. Only one utility provides service to any one area. People and businesses can not choose their electricity provider. In return, the utilities have to provide service to every consumer, regardless of the profitability.

Under this model, utilities generate the power, transmit it to the point of use, meter it, bill the customer, and provide information on efficiency and safety. The price is regulated by the state. As a result, the price of a kilowatt-hour of electricity to residential customers varies widely among the states and utilities, from a high of 16 cents to a low of four cents. The price for large industrial users varies, too.

MAKING*electricity*

Three kinds of power plants produce most of the electricity in the United States: fossil fuel; nuclear; and hydropower. There are also wind, geothermal, trash-to-energy, and solar power plants, but they generate less than three percent of the electricity produced in the U.S.

1997 U.S. ELECTRICITY PRODUCTION



SOURCE: ENERGY INFORMATION ADMINISTRATION

Fossil Fuel Power Plants

Fossil fuel plants burn coal, natural gas, or oil. These plants use the energy in fossil fuels to superheat water into steam, which drives a turbine generator. Fossil fuel plants are sometimes called thermal power plants because they use heat energy to make electricity. Coal is the fossil fuel of choice for most electric companies, producing 52.5 percent of the electricity. Natural gas plants produce 14.1 percent. Petroleum produces less than three percent of the electricity in the U.S.

Nuclear Power Plants

Nuclear plants produce electricity much as fossil fuel plants do except that the furnace is called a reactor and the fuel is uranium. In a nuclear plant, a reactor splits uranium atoms into smaller parts, producing heat energy. The heat energy superheats water into steam and the high pressure steam drives a turbine generator. Like fossil fuel plants, nuclear power plants are called thermal power plants because they use heat energy to make electricity. Nuclear energy produces 17.8 percent of the electricity in the U.S.

Hydropower Plants

Hydro (water) power plants use the force of falling water to generate electricity. Hydropower is the cheapest way to produce electricity in this country, but there are few places where new dams can be built. Hydropower is called a renewable energy source because it is renewed continuously by rainfall. Hydropower produces 10.2 percent of the electricity in the United States.

MEASURING*electricity*

Power is the rate (time) of doing work. A watt is a measure of the electric power an appliance uses. Appliances require a certain number of watts to work correctly. All light bulbs are rated by watts, (60, 75, 100 watts) as well as appliances (such as a 1500-watt hairdryer).

A kilowatt is 1,000 watts. A kilowatt-hour (kWh) is the amount of electricity used in one hour at a rate of 1,000 watts. Think of adding water to a pool. In this analogy, a kilowatt is the rate, or how fast water is added to the pool; and a kilowatt-hour is the amount, or how much water is added to the pool.

Just as we buy gasoline in gallons or wood in cords, we buy electricity in kilowatt-hours. Utility companies charge us for the kilowatt-hours we use during a month. If an average family of four uses 750 kilowatt-hours in one month, and a utility company charges 10 cents per kilowatt-hour, the family will receive a bill for $75. (750 x $0.10 = $75)

Power companies use megawatts and gigawatts to measure huge amounts of electrical power. Power plant capacity is measured in megawatts. One megawatt (MW) is equal to one million watts or one thousand kilowatts. Gigawatts are often used to measure the electrical energy produced in an entire state or in all the United States. One gigawatt is equal to one billion watts, one million kilowatts, or one thousand megawatts.

The types of generating plants, the cost of fuel, taxes, and environmental regulations are some of the factors contributing to the price variations.

In the 1970s, the energy business changed dramatically in the aftermath of the Arab Oil Embargo, the advent of nuclear power, and stricter environmental regulations. Independent power producers and co-generators began making a major impact on the industry. Large consumers began demanding more choice in providers.

In 1992, Congress passed the Energy Policy Act to encourage the development of a competitive electric market with open access to transmission facilities. It also reduced the requirements for new non-utility generators and independent power producers. The Federal Energy Regulatory Commission (FERC) began changing their rules to encourage competition at the wholesale level. Utilities and private producers could, for the first time, market electricity across state lines to other utilities.

Some state regulators are encouraging broker systems to provide a clearinghouse for low-cost electricity from under-utilized facilities. This power is sold to other utilities that need it, resulting in lower costs to both the buyer and seller. This wholesale marketing has already brought prices down in some areas.

Many states are now considering whether competition in the electric power industry is a good thing for their consumers. This competition can take many forms, including allowing large consumers to choose their provider and allowing smaller consumers to join together to buy power.

Eventually, individual consumers may have the option of choosing their electric utility, much like people can now choose their long-distance telephone carrier.

Their local utility would distribute the power to the consumer. Some experts say this could lower electric bills, but don't expect to see this happening on a large scale in the next few years.

It will take the industry and the states several years to decide if residential competition is a good thing and figure out how to implement the changes.

Future Demand

Home computers, answering machines, FAX machines, microwave ovens, and video games have invaded our homes and they are demanding electricity! New electronic devices are part of the reason why Americans are using more electricity every year.

The U. S. Department of Energy predicts the nation will need to increase its current generating capacity of 780,000 megawatts by a third in the next 20 years.

Some parts of the nation have experienced power shortages in the last few years. Some utilities resorted to rolling blackouts—planned power outages to one neighborhood at a time—during the 1995 blizzard. New England utility companies warn residents every summer to expect brownouts (decreases in power levels) whenever sweltering weather looms over the region.

Conserving electricity and using it more efficiently help, but experts say we will need more power plants. That's where the challenge begins. Should we use coal, natural gas, or nuclear power to generate electricity?

Can we produce more electricity from renewable energy sources such as wind or solar? And where should we build new power plants? No one wants a power plant in his backyard, but everyone wants the benefits of electricity.

Experts predict we will need 205 thousand more megawatts of generating capacity by the year 2010. Demand for electricity does not seem to be coming to an end.

We must make machines and appliances that use electricity much more energy efficient, or we will have to build the equivalent of 350 coal plants by the year 2010 to meet that demand.

Which energy sources will provide this additional electricity? Most new power generation will come from natural gas. Natural gas is a relatively clean fuel and is abundant in the United States.

New natural gas combined-cycle turbines use the waste heat they generate to turn a second turbine. Using this waste heat increases efficiency to 50 or 60 percent, instead of the 35 percent efficiency of conventional power plants.

The Greenhouse Effect

Earth's Atmosphere

Our earth is surrounded by a blanket of gases called the atmosphere. Without this blanket, our earth would be so cold that almost nothing could live. It would be a frozen planet. Our atmosphere keeps us alive and warm.

The atmosphere is made up of many different gases. Most of the atmosphere (99 percent) is oxygen and nitrogen. The other one percent is a mixture of greenhouse gases. These greenhouse gases are mostly water vapor, mixed with carbon dioxide, methane, CFCs, ozone, and nitrous oxide.

Carbon dioxide is the gas we produce when we breathe and when we burn wood and fossil fuels. Methane is the main gas in natural gas. It is also produced when plants and animlas decay. The other greenhouse gases (ozone, CFCs and nitrous oxide) are produced by burning fuels and in other ways.

Sunlight and the Atmosphere

Rays of sunlight (radiant energy) shine down on the earth every day. Some of these rays bounce off molecules in the atmosphere and are reflected back into space. Some rays are absorbed by molecules in the atmosphere.

About half of the sunlight passes through the atmosphere and reaches the earth. When the sunlight hits the earth, most of it turns into heat (thermal energy). The earth absorbs some of this heat. The rest flows back out toward the atmosphere. This keeps the earth from getting too warm.

When this heat reaches the atmosphere, it stops. It can't pass through the atmosphere like sunlight. Most of the heat energy becomes trapped and flows back to the earth. We usually think it's the sunlight itself that warms the earth, but actually it's the heat energy produced when the sunlight is absorbed by the earth and air that gives us most of our warmth.

The Greenhouse Effect

We call this trapping of heat the greenhouse effect. A greenhouse is a building made of clear glass or plastic. In cold weather, we can grow plants in a greenhouse.

The glass lets the sunlight in. The sunlight turns into heat when it hits objects inside. The heat becomes trapped. The light energy can pass through the glass; the heat energy cannot.

THE GREENHOUSE EFFECT

Radiant energy (white arrows) from the sun travels through space and shines on the earth. Some radiant energy is reflected back into space by the atmosphere. Some radiant energy is absorbed by the atmosphere and turns into heat energy.

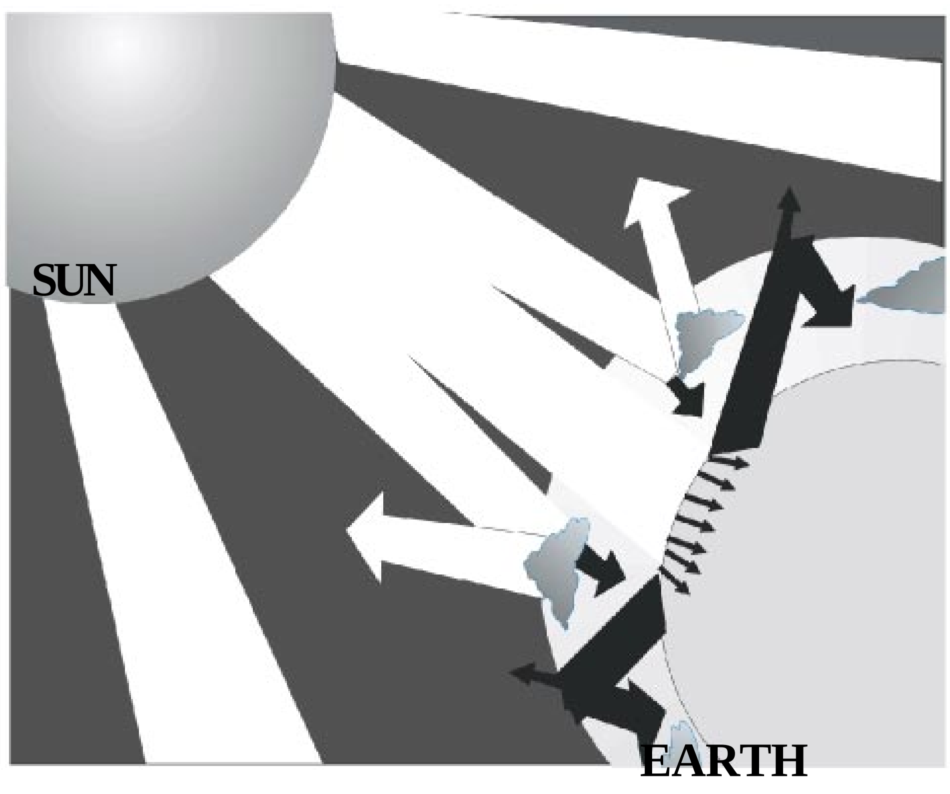
Half of the radiant energy passes through the atmosphere and reaches the earth, where it turns into heat (black arrows).

Some of this heat energy is absorbed by the earth.

Most of the heat energy flows back into the air where it is trapped by the atmosphere.

Very little heat energy passes through the atmosphere and escapes into space.

The trapped heat energy flows back toward the earth.



Greenhouse Gases

What is in the atmosphere that lets light through, but traps heat? It's the greenhouse gases, mostly carbon dioxide and methane. These gases are very good at absorbing heat energy and sending it back to earth.

In the last 50 years, the amount of some greenhouse gases––especially carbon dioxide and methane––has increased dramatically. We produce carbon dioxide when we breathe and when we burn wood and fossil fuels: coal, petroleum, natural gas, and propane.

Some methane escapes from coal mines and oil wells. Some is produced when plants and garbage decay. Some animals also produce methane gas. One cow can give off enough methane in a year to fill a hot air balloon!

Global Climate Change

Scientists around the world believe these greenhouse gases are trapping more heat in the atmosphere as their levels increase. They believe this trapped heat has begun to change the average temperature of the earth. They call this phenomenon **global warming**.

Many long–term studies indicate that the average temperature of the earth has been slowly rising in the last few decades. In fact, the last decade has seen two of the hottest years on record.

Scientists predict that if the temperature of the earth rises just a few degrees Fahrenheit, it will cause major changes in the world's climate. They predict there will be more flooding in some places and periods of drought in others. They think the level of the oceans will rise as the ice at the North and South Poles melts, causing low-lying coastal areas to disappear. They also predict more erratic weather––causing stronger storms and hurricanes.

Some scientists don't believe the world's temperature will rise as much as the predictions indicate. They think it is too soon to tell if there will be long-term changes in the global climate. They think slight warming could prove beneficial, producing longer growing seasons for crops, warmer nights, and milder winters.

Countries all over the world are concerned about the threat of global warming. They believe we need to act now to lower the amount of carbon dioxide we put into the atmosphere. They believe we should decrease the amount of fossil fuels that we burn.

Kyoto Protocol

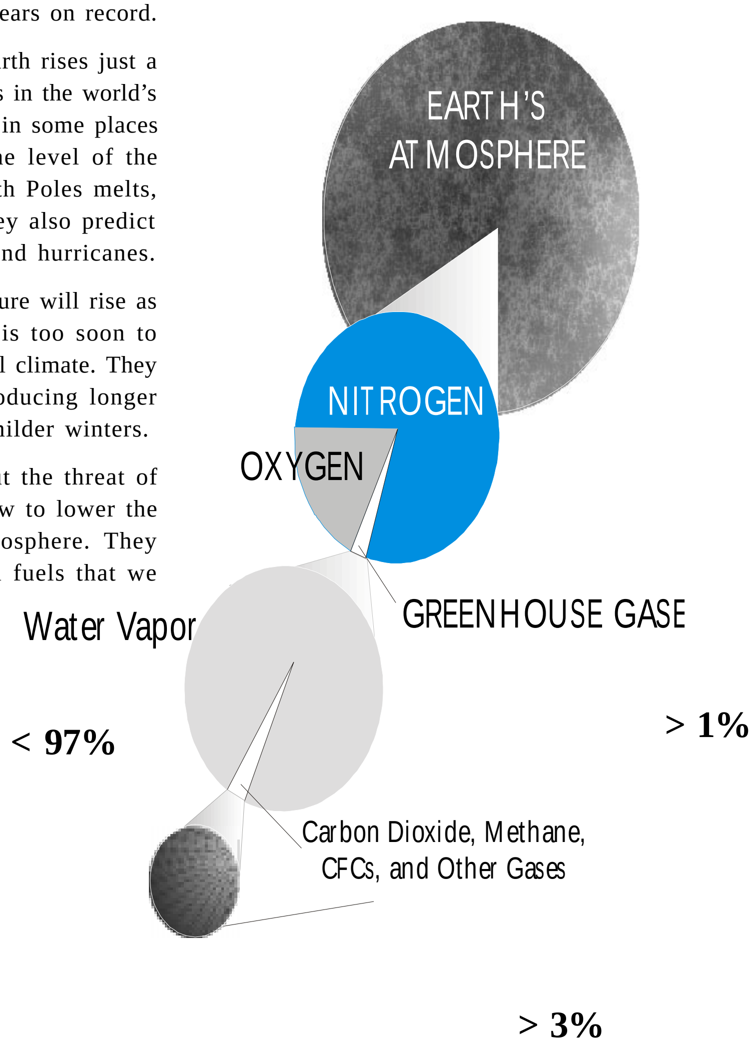
In December 1997, in Kyoto, Japan, representatives from countries around the world agreed upon a landmark treaty to reduce greenhouse gas emissions. The Kyoto Protocol requires 38 developed countries to reduce emissions below 1990 levels by the year 2012. The plan does not require commitments from developing countries.

The Kyoto Treaty was officially signed by the United States on November 12, 1998, but still must be ratified by the U.S. Senate before it becomes law. Most experts doubt that the Senate will approve the treaty in its present form, because it does not include limits for developing countries such as China, which will soon surpass the United States as the world's leading emitter of greenhouse gases.

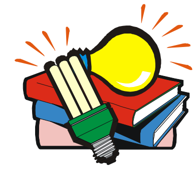
Another continuing dispute is the issue of emissions trading. Europeans want strict limits on trading to force countries to make domestic cuts. Unlimited emissions trading would allow rich countries––like the United States––to have higher domestic emissions in return for investing in clean technologies in developing countries.

Greenhouse gases make up less than one percent of the atmosphere.

Greenhouse gases are more than 97 percent water vapor.



Glossary



Annual Energy Index. The ratio of the total annual energy consumption of a building or plant in millions of Btu divided by the total building area in thousands of square feet. The AEI is computed in thousands of Btu per square foot of building per annum as a way of characterizing energy usage in the building.

Air Changes per Hour. A measure of how rapidly air is replaced in a room over a period of time, usually referring to that replaced by outside air.

Air Conditioning. The process of treating air to meet the requirements of the conditioned space by controlling simultaneously its temperature, humidity, cleanliness and distribution.

Air Conditioners. Systems that control the temperature and humidity of air using electricity to power fans and pumps called compressors. Air conditioners use a refrigeration cycle to extract heat from indoor air and expel the heat outside.

Air Handler. Mechanical ventilation systems contained inside large sheet metal boxes. Air handlers have fans inside that supply air to rooms through ducts connected to them. Air handlers recirculate air inside buildings and provide fresh air from outside. They usually contain coils of copper tubing with hot or cold water inside the tubing. When fans blow air across the tubes containing hot water, heat is transferred to the air blown through the ducts for heating. When fans blow air across the tubes containing cold water, heat is removed from the air blown through the ducts for cooling.

Air Infiltration. The process by which outdoor air leaks into a building by natural forces (pressure driven) through cracks in walls and around doors and windows.

Ballast. Devices for starting and controlling the electricity used by a lamp. Ballasts also protect electrical circuits in lighting systems. A ballast typically consumes 10 percent to 20 percent of the total energy used by a light fixture and lamp.

Boilers. Heating systems that burn natural gas, oil, coal, or sometimes wood or waste paper as fuel to heat water or produce steam. The heated water or steam is then circulated in pipes to devices called radiators and convectors. Radiators are made of a series of large iron grids or coils, while convectors are usually made of networks of non-iron metal tubes with steel fins surrounding the tubes. Hot water or steam can be circulated in a boiler system by pressure and gravity, but pumps are typically used to control the circulation more efficiently. Boilers sometimes also provide hot water for showers, cleaning, or other uses in schools.

British Thermal Unit (Btu). The amount of energy required to raise one pound of water one degree Fahrenheit.

British Units. A unit of measure of energy and other scientific phenomena based on the British Engineering System. For example, temperature is measured in degrees Fahrenheit in British units.

Caulking. A flexible material made of latex or silicone rubber used to seal up cracks in a wall or between window frames and door frames and walls. Caulking reduces the infiltration of outside air into a building and makes it more energy efficient and reduces maintenance due to wear from rain, sun, and other weather related stress on a building.

Celsius or Centigrade. The SI temperature scale on which the freezing point of water is zero degrees and the boiling point is 100 degrees at sea level.

Chillers. Refrigeration machines used in some schools to provide cool air. They use a refrigeration cycle that extracts heat from water and rejects it to outdoor water. Chillers produce cold water that is fed through coils of copper tubing contained in *air handlers*. Air handlers contain fans that blow air across the copper tubes containing cold water. This cools the air, which is then delivered to rooms through ducts.

Controls. Devices, usually consisting of electronic components, used for regulating machines; for example, a thermostat is a control that regulates the heating and cooling equipment in a building.

Cooling Load. Calculated on a monthly, yearly or seasonal basis by multiplying the overall thermal transmittance (U-value) of a building (in Btu per hour per degree F per square foot) times total building surface area times 24 hours/day times the number of cooling degree days per time period desired.

Degree Days, Cooling. A method of estimating the cost of cooling a residential home based on the local climate, and is usually expressed in the average number for an entire year. The degree day value for any given day is the difference between the mean daily temperature and 65 F when the temperature is greater than 65 F. The total for the year is the sum of the average daily value for 365 days a year.

Degree Days, Heating. A method of estimating the cost of heating a residential home based on local climate. Like cooling degree days, heating degree days are usually expressed in an average number for a year. The degree day value for any given day is the difference between 65°F and the mean daily temperature when the temperature is less than 65 F. Degree days are a measure of the severity of the heating season and are directly proportional to fuel consumption.

Ducts. An enclosed tube or channel, usually made of sheet metal or flexible plastic, for delivering air to rooms in a building. Supply ducts bring treated air from air handlers, consisting of warm air in the winter to warm the rooms and cool air in the summer for air conditioning. Old ducts that lie in unconditioned areas of a building often leak significant quantities of air and can result in large energy losses in a building.

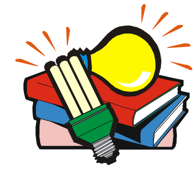
Efficiency. The ratio of the energy used for a desirable purpose, such as heating or lighting, compared with the total energy input, usually expressed in percent.

Electricity, or Electric Energy. A basic form of energy measure as kilowatt-hours (kWh). For conversion, one kWh of electricity is 3413 Btu's. Electricity is generated in electric power plants, most of which burn fossil fuels to produce heat, which is converted to electricity in a generator. The process is not 100% efficient, and it takes, on average, about 11,600 Btu of heat energy from fossil fuels to generate 1 kWh of electricity.

Envelope, or Building Envelope. The external surfaces of a building, including as walls, doors, windows, roof and floors in contact with the ground.

Fahrenheit: The temperature scale in "English" units used in the United States and England on which the freezing point of

Glossary



water is 32 degrees and the boiling point of water is 212 degrees at sea level.

Foot-candle. A unit of measure of the intensity of light. A foot-candle is a lumen of light distributed over a 1-square-foot (0.09-square-meter) area.

Fossil Fuels. Fuels consisting of coal, oil, natural gas, propane, and those derived from petroleum such as gasoline that are derived from prehistoric plants having been "fossilized" by remaining for eons under pressure underground. These fuels are called hydrocarbons because the hydrogen and carbon in the fuels combines with oxygen in the air to release heat energy.

Global Warming: Possible accelerated increase in the Earth's temperature caused by excess production of greenhouse gases due, in large part, to the depletion of forests, air pollution from automobiles, making electricity via fossil fuels and burning fossils fuels for other needs.

Greenhouse Effect: The trapping of the sun's heat. In houses and cars it can be caused by glass. In the Earth's atmosphere it is a naturally occurring phenomenon resulting from the interaction of sunlight with greenhouse gases (such as CO_2 and CFCs). This interaction helps maintain the delicate balance of temperature and breathable air necessary for life as we know it.

Heat Capacity (rc_p) per unit volume of air. As used in this document, heat capacity is the amount of heat energy it takes to increase the temperature of one cubic foot of air by one degree Fahrenheit.

Heat Pumps. Energy-efficient heating and cooling systems that use the refrigeration cycle to move heat from one source (air, water, or the Earth) to another.

Heat Transfer. The movement of heat energy always flowing in the direction from hotter to colder through materials such as walls or windows in a building. The flow of heat energy is usually measured in terms of Btu/h, and is equal to the area times the temperature difference divided by the thermal resistance (R-value).

Heating, Ventilating, and Air-Conditioning (HVAC). Systems that provide heating, ventilation and/or air-conditioning within with buildings.

Humidity. The amount of water vapor in the air, and usually expressed in terms of percent relative humidity. This figure represents the amount of moisture the air actually contains divided by the total amount of moisture that it is physically possible for the air to hold at a particular temperature. In other words, at 100% relative humidity condensation will occur, and if outdoors, it will start raining.

Insulation. Material used to increase the resistance to heat flow. In buildings, three types of insulations are most common: batts usually made from fiberglass that fit between wall studs or roof joists; loose-fill usually made from shredded newspaper (treated cellulose) that is blow into wall cavities or attics; and rigid foam boards usually made from petrochemicals (polyisocyanurate) that are nailed into walls, under roofs, or just below outside wall coverings like siding or sheathing.

Kilowatt (kW). A unit of electric power equal to one thousand watts.

Kilowatt Hour (kWh). A unit of electric energy equal to one thousand watts over a period of one hour.

Lamp. A generic term for a non-natural source of light. In fluorescent fixtures, lamps also refer to the part of the glass tubes that light up when electricity is turned on.

Lumen. An SI unit of light output from a source such as a lamp or light fixture. Commonly, the efficacy of electrical lighting is gauged by the number of "lumens per watt" of light output per unit of electric power input listed on the lamp manufacturers' label.

Occupied Hours. The time when a building such as a school is normally occupied with people working or attending classes.

Power. The time rate of doing work, which in SI units is measured in Watts, and in British units, is measured in British thermal units per hour (Btu/h). In the United States, we usually refer to electric power in terms of Watts and heat flow in terms of Btu/h.

Simple Payback Period. The length of time required for an investment to pay for itself in energy savings.

SI Units. Units of measuring energy and other scientific phenomena based on the International System (or SI for Systme Internationale d'Unites). For example, temperature is measured in degrees Celsius in SI units.

Therm. A unit of gas fuel containing 100,000 Btu's. Most natural gas bills are charged according to the number of therms consumed.

Thermal Resistance (R-value). A term used to measure an insulating material's resistance to the flow of heat, and usually measured in units of square feet x hour x degrees F per Btu. Thermal resistance is the reciprocal of thermal conductance (U-value). R-values can be added together to obtain an overall value for an insulated wall or ceiling.

Thermostats. Heating and cooling systems' controls that monitor the temperatures of buildings and allow temperatures to be maintained or changed automatically or manually.

U-value (Thermal Transmittance): Overall coefficient of heat expressed in British units as Btu's per square foot per hour per degree F. The lower the U-value, the less heat is transferred. Numerically, it is equivalent to the reciprocal of the sum of the thermal resistance of materials measured in their R-values.

Unoccupied Hours. The time when a commercial, industrial, or institutional building is normally empty of people, except maintenance people such as janitors.

Ventilation. Air supplied to buildings from outdoors plus air recirculated from indoors that has been filtered and treated by heating, cooling, and/or air handling equipment.

Watt. An SI unit of measurement for power. In the United States, a watt almost always refers to electric power, and is equal to the amount of power (energy per second) supplied when one ampere of electric current flows at a potential difference of one volt. For conversion to British units, 1,000 watts equals 3,413 Btu's.

Weatherstripping. Materials such as metal, plastic, or felt strips designed to seal spaces between windows and doorframes to prevent infiltration of outside air into a building.