Learning and Conserving

Student Guide

EFFICIENCY
CONSERVATION

NEED

National Energy Education Development Project

Student Backgrounder

The United States uses a lot of energy—nearly a million dollars worth of energy each minute, 24 hours a day, every day of the year. With less than five percent of the world's population, we consume about one-fifth (21 percent) of the world's energy resources. We are not alone among industrialized nations; 16 percent of the world's population consumes 80 percent of its natural resources.

The average American consumes five times the world average per capita consumption of energy. Every time we fill up our vehicles or open our utility bills, we are reminded of the economic impacts of energy.

Energy Efficiency and Conservation

Energy is more than numbers on a utility bill; it is the foundation of everything we do. All of us use energy every day—for transportation, cooking, heating and cooling rooms, manufacturing, lighting, water-use, and entertainment. We rely on energy to make our lives comfortable, productive, and enjoyable. Sustaining this quality of life requires that we use our energy resources wisely. The careful management of resources includes reducing total energy use and using energy more efficiently.

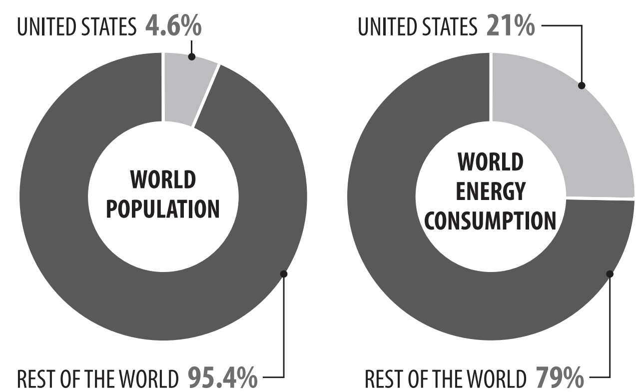
The choices we make about how we use energy—turning machines off when not in use or choosing to buy energy efficient appliances—will have increasing impacts on the quality of our environment and lives. There are many things we can do to use less energy and use it more wisely. These things involve energy conservation and energy efficiency. Many people use these terms interchangeably; however, they have different meanings.

Energy conservation includes any behavior that results in the use of less energy. Energy efficiency involves the use of technology that requires less energy to perform the same function. A compact fluorescent light bulb that uses less energy to produce the same amount of light as an incandescent light bulb is an example of energy efficiency. The decision to replace an incandescent light bulb with a compact fluorescent is an example of energy conservation.

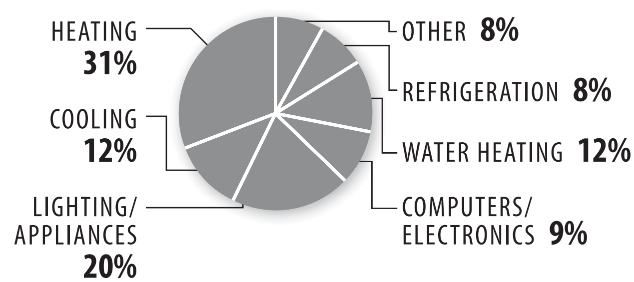
Energy Sustainability

Efficiency and conservation are key components of energy sustainability—the concept that every generation should meet its energy needs without compromising the needs of future generations. Sustainability focuses on long-term actions that make sure there is enough energy to meet today's needs as well as tomorrow's. Sustainability also includes the development of new technologies for using fossil fuels, promoting the use of renewable energy sources, and encouraging policies that protect the environment.

U.S. POPULATION AND ENERGY CONSUMPTION



HOME ENERGY USAGE



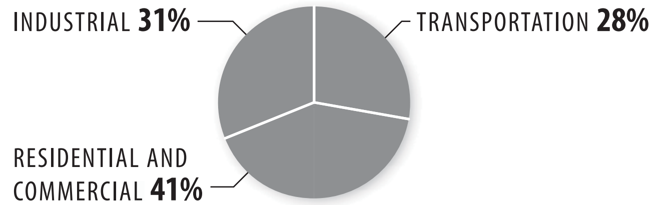
Sectors of the Economy

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

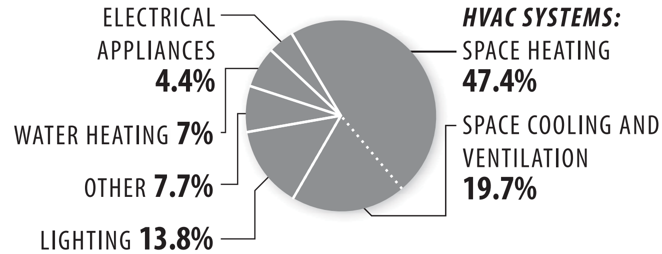
Residences are people's homes. Commercial buildings include office buildings, hospitals, stores, restaurants, and schools. Residential and commercial energy use are lumped together because homes and businesses use energy in the same ways—for heating, air conditioning, water heating, lighting, and operating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

The residential/commercial sectors of the economy consumed 40.5 percent of the total energy supply in 2008, more energy than either of the other sectors, with a total of 40.1 quads of energy. The residential sector consumed 21.6 quads and the commercial sector consumed 18.5 quads. Schools are included in the commercial sector of the economy.

ENERGY USAGE BY SECTOR OF THE ECONOMY



SCHOOL ENERGY USE



School Energy Consumption

A school building is an energy system made of many interrelated components. Some of these components are obvious, such as walls, roofs, lights, doors and windows. Occupants—students, teachers, and other building users—are also an important part of the system. The energy use of the system affects everything from the school budget to the global environment. It is important to understand how all of the system components can work together to create an environment in which everyone is comfortable and healthy.

A school building's energy system includes these components:

- **Building Shell:** This component includes everything that creates the boundaries between indoors and outdoors: walls, floors, roofs, windows, and doors.
- **Heating, Ventilation, and Air Conditioning (HVAC) Systems:** This component includes the equipment designed to provide heating, cooling, and fresh air. It also includes the devices that control the HVAC equipment, such as thermostats.
- **Lighting:** This component usually includes several types of fixtures that provide light for all of the activities in the school.
- **Electrical Appliances:** This component includes everything plugged into electrical outlets, such as refrigerators, copiers and computers, as well as appliances that are wired directly into the school's electrical system, such as ovens and refrigeration equipment in the cafeteria.

INSULATION

Image courtesy of Owens Corning

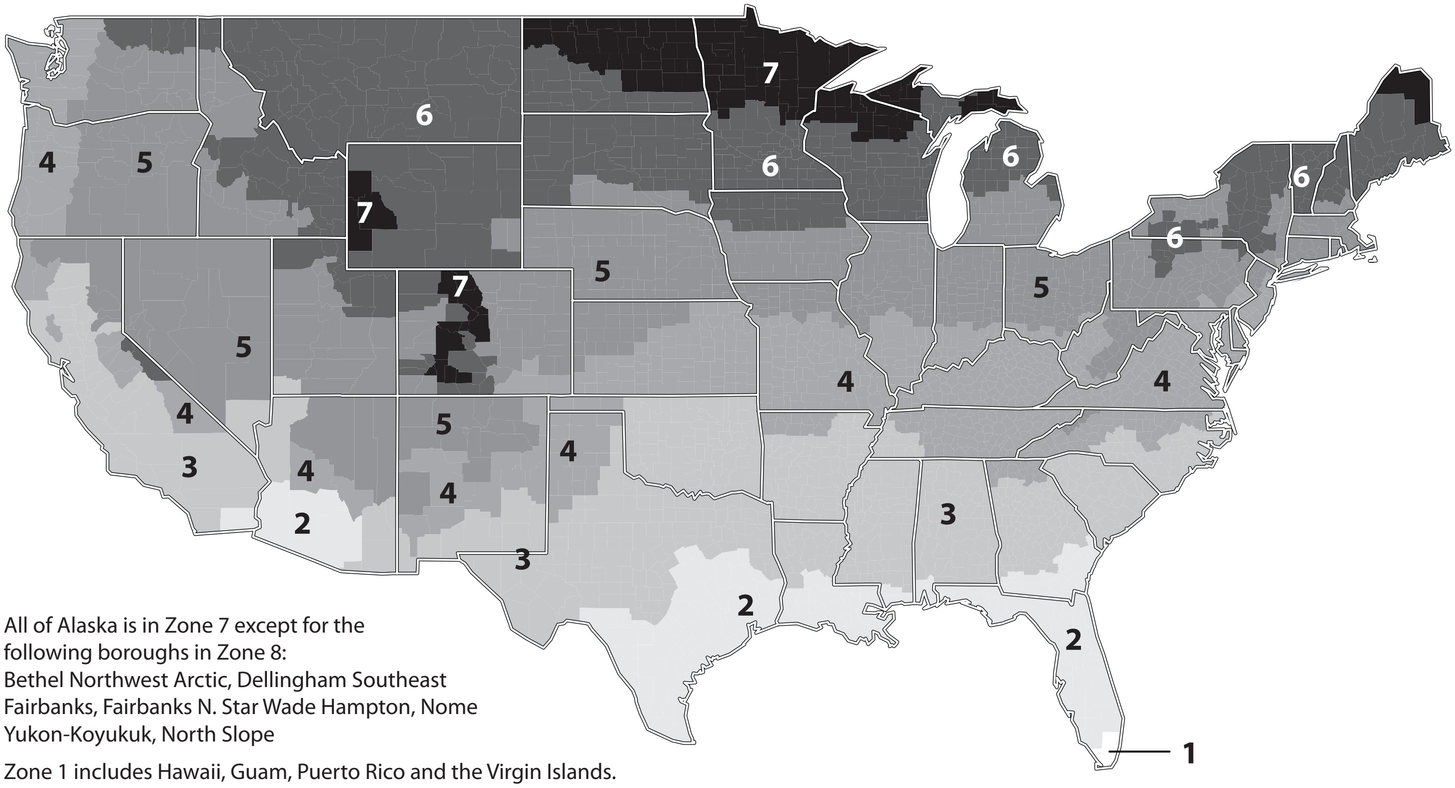
Building Shell

All parts of the building that create barriers between the inside and outside are components of the building shell. These parts include walls, floors, ceilings, windows, doors, and skylights. These components work together to reduce heat transfer. Any warm air that flows into the building during cooling season and out of the building during heating season wastes energy. The objective of the building shell is to allow as little heat transfer as possible.

One way to reduce heat transfer is with insulation. Roof systems on most schools include insulation. There may also be insulation in the walls of the building, depending on how it is constructed. Insulation is rated using an R-value that indicates the resistance of the material to heat transfer. The higher the R-value, the more effective the material is at reducing heat transfer. Insulation wraps the building in a blanket, slowing the transfer of heat through walls and roofs. This type of heat transfer is called conduction, the flow of thermal energy through a substance from a higher to a lower temperature area.

Even with insulation, air can still leak in or out through small cracks. Heat is carried along with the air through these cracks. Often the many small cracks in a building add up to a hole the size of a wide open door. Some of the cracks are obvious—those around doors and windows, for instance—but others are hidden behind walls and above ceilings. Sealing these cracks is a very effective way to stop another type of heat transfer—convection, the transfer of thermal energy through a gas or liquid by the circulation of currents from one area to another.

RECOMMENDED R-VALUES FOR NEW WOOD-FRAMED HOMES



All of Alaska is in Zone 7 except for the following boroughs in Zone 8:
Bethel Northwest Arctic, Dellingham Southeast Fairbanks, Fairbanks N. Star Wade Hampton, Nome Yukon-Koyukuk, North Slope

Zone 1 includes Hawaii, Guam, Puerto Rico and the Virgin Islands.

ZONE	ATTIC	CATHEDRAL CEILING	WALL INSULATION: CAVITY	WALL INSULATION: INSULATION SHEATHING	FLOOR
1	R30 to R49	R22 to R38	R13 to R15	None	R13
2	R30 to R60	R22 to R38	R13 to R15	None	R13, R19 to R25
3	R30 to R60	R22 to R38	R13 to R15	R2.5 to R5	R25
4	R38 to R60	R30 to R38	R13 to R15	R2.5 to R6	R25 to R30
5	R38 to R60	R30 to R60	R13 to R21	R2.5 to R6	R25 to R30
6	R49 to R60	R30 to R60	R13 to R21	R5 to R6	R25 to R30
7	R49 to R60	R30 to R60	R13 to R21	R5 to R6	R25 to R30
8	R49 to R60	R30 to R60	R13 to R21	R5 to R6	R25 to R30

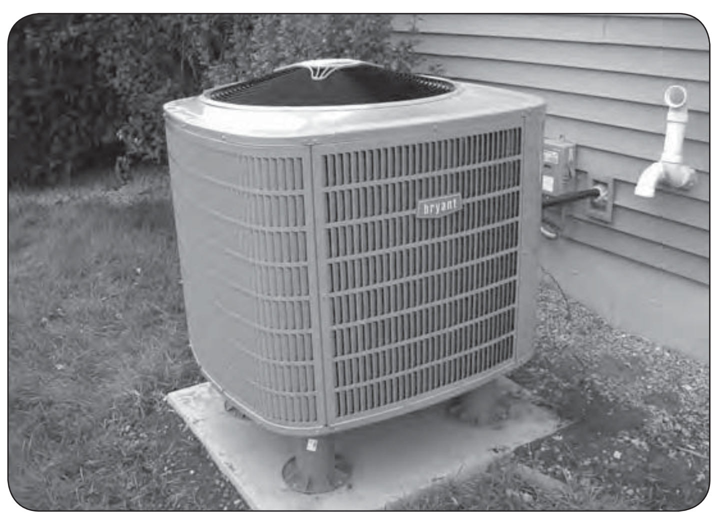
Data: U.S. Department of Energy

One of the easiest energy-saving measures to reduce heat transfer is to caulk, seal, and weatherstrip all cracks and openings to the outside, resulting in a 10 percent or more savings in energy costs. Even more savings are possible if a company that specializes in finding and sealing hidden leaks is employed.

Doors should seal tightly and have door sweeps at the bottom to prevent air leaks. It is common to be able to see daylight through cracks around school doors. Most schools have more windows than doors. The best windows shut tightly and are constructed of two or more pieces of glass. Any cracks around the windows should be caulked and the windows checked often to make sure they seal tightly.

When we seal a building by minimizing air transfer, we must keep in mind the need for fresh air for the occupants. To provide fresh air and exhaust stale air, school buildings have mechanical ventilation systems. In buildings with effective ventilation systems, even the windows can be sealed. With a good ventilation system, there

AIR CONDITIONING SYSTEM



should be no concerns with sealing all the air leaks in a school building.

Landscaping

Although the weather cannot be controlled, trees can be planted around buildings to block the wind and provide shade. This is an excellent way to make the building shell more energy efficient. Deciduous trees planted on the south side of a building block the sun in warmer months and allow sun to shine on the building in winter, when the leaves are gone. Conifers planted on the north side of the building can block the north wind. Properly placed trees and bushes can reduce the energy needed to keep a building comfortable.

Heating Ventilation and Air Conditioning (HVAC)

Heating and cooling systems, along with ventilation systems, use more energy than any other systems in a school. Natural gas and heating oil, and sometimes electricity, are used to heat most buildings. Electricity is used to run cooling systems. Ventilation systems are necessary to provide fresh air and remove stale air and indoor air pollutants. About 67 percent of the average school district's energy bill is used to keep buildings at comfortable temperatures and provide fresh air for the buildings. The energy sources that power these heating and cooling systems (mostly fossil fuels) emit millions of tons of carbon dioxide into the atmosphere each year. They also generate sulfur dioxide and nitrogen oxides that cause acid rain.

Most school buildings are heated by boiler systems. These devices heat water to high temperatures, sometimes converting the water to steam, and then circulate it throughout the building via a system of pipes. Once the water in the pipes has given up its thermal energy to the air in the building, it is circulated back to the boiler to be reheated.

Many classrooms are provided with heat (and some with cooling) by unit ventilators. A unit ventilator is a metal cabinet, usually located underneath a window. Inside the unit are pipes with hot and sometimes cold water. A fan inside blows across the pipes and provides heated or cooled air to the classroom through a vent on the top. A vent at floor level pulls air into the unit from the room. Finally, a vent leads outside to bring fresh air into to the classroom. For a unit ventilator to work efficiently and effectively, the vents at the top and bottom must be kept clear of books and other items.

Thermostats often control heating and cooling systems in the building. Thermostats can be set for the desired temperature in the rooms. A thermostat is basically an "on-off' switch. In the heating season, when the temperature in a room falls below the setting, heat is delivered to the room. During cooling season, cool air is delivered when the temperature rises above the thermostat setting.

Many school districts control how high or low the temperatures can be set in different rooms. The most advanced systems use central computers to control heating, cooling, and ventilation. Temperature sensors in the rooms send information back to the computers, which adjust the temperature in the rooms to pre-programmed levels. They automatically control the temperature of buildings for time of day and can save energy and money. During heating seasons, for example, they can lower the temperature at night and weekends when no one is in the buildings. If requested, the building operator can adjust the program to provide heat and cooling outside of regular building hours for sporting events, community meetings, or concerts.

For HVAC equipment to operate at optimum efficiency, it is necessary to maintain the equipment. Regular maintenance of equipment ensures that all systems and controls are functioning as they should. Every school should have procedures in place that provide for regular maintenance of equipment.

Even if school buildings have energy efficient systems, a lot of energy can be wasted if the energy is not managed wisely. That is where students come in—learning about energy and how to save it.

Temperature Management

The best heating system in the world cannot do a good job if outside doors or windows are left open, or if the temperature is not controlled. The same is true for cooling systems. In classrooms and offices, it is recommended that the temperature be set at 68°F during the heating season and 78°F during the cooling season during the day. Windows and doors should be closed when the heating and cooling systems are operating.

Rooms and areas with windows in direct sunlight can be equipped with blinds that can help control temperature—closed in cooling months and opened in heating months when sunlight is focused on them.

If the temperature of rooms can be individually controlled, districts should have a policy on acceptable temperature settings. Temperature ranges can vary depending on the functions of the rooms. Gymnasiums, for example, do not need to be heated as much as classrooms. Auditoriums, hallways, storage rooms, and other little used rooms do not need to be heated and cooled as much either.

The relative humidity—the amount of moisture in the air—also affects comfort level. The more moisture, the warmer the air feels. The most comfortable relative humidity setting is between 40–60 percent. This range also minimizes the amount of bacteria, viruses, and molds in the air, and is healthy and comfortable for breathing.

With all heating and air conditioning systems, energy consumption can be minimized by making sure there is adequate insulation, maintaining the equipment, and practicing energy-saving behaviors. Teaching occupants how to dress practically for the season can help them stay comfortable without using too much heat in the winter or air conditioning in the summer.

PROGRAMMABLE THERMOSTAT

Water Heating

Water heating is the third largest energy expense in residential buildings; it typically accounts for about 14 percent of a utility bill. Water heating is usually a much smaller percentage of school energy use, but it is significant. Schools often heat water with the boiler that is used to heat the school building. The water is stored in a separate tank that has its own burner, controlled by a thermostat to keep the water at the desired temperature. Sometimes schools have large stand-alone water heaters, much like those used in residences. These are usually fueled by natural gas or electricity.

Heated water is used for showers, hand washing, dishwashing, and cleaning. There are five main ways to lower a school's water heating bills:

- use less hot water;
- make sure there are no water leaks or drips;
- turn down the thermostat on the water heater;
- insulate water heaters and water pipes; and
- buy energy efficient water heaters.

The easiest way to cut the cost of heating water is to reduce the amount of hot water consumed. This can be done with little cost and minor changes in lifestyle. Faucet aerators (which diffuse the flow of water from a faucet) can be installed in restrooms and classrooms. They limit the flow of water while providing adequate flow for washing. Many schools also utilize spring-loaded faucets that limit the amount of time the faucet runs. Other ways to conserve hot water include taking shorter showers, fixing leaks in faucets and pipes, and using the lowest temperature water necessary.

Most water heater thermostats are set much higher than necessary. Lowering the temperature setting on a water heater saves energy. Lowering the temperature 10 degrees can result in energy savings of five percent. Installing energy efficient water heaters in school buildings can save hundreds of dollars a year.

Indoor Air Quality (IAQ)

Students go to school to learn and, in order to make learning possible, the school building needs to be safe, healthy, and comfortable. One of the most important factors is making sure that the air in school buildings is healthy to breathe. A building with good indoor air quality has students, teachers, and staff who are healthy and alert. To ensure good indoor air quality, schools must eliminate air pollutants and introduce adequate clean, fresh air into the building. The amount of moisture in the building must be regulated as well.

Without efficient ventilation systems, indoor levels of air pollutants can be two to five times higher, and occasionally 100 times higher, than outdoor levels. Nearly 56 million people, approximately 20 percent of the U.S. population, spend their days inside elementary and secondary schools.

In 1999, the National Center for Education Statistics of the U.S. Department of Education reported that approximately 25 percent of public schools described unsatisfactory ventilation, while 20 percent of schools reported unsatisfactory indoor air quality. IAQ problems can cause discomfort and contribute to short and long term health problems for students and staff.

Classroom pets can contribute to poor indoor air quality.

Poor indoor air quality can increase the potential for short-term and long-term health problems such as asthma.

Contributors to Poor Indoor Air Quality

Several factors in schools contribute to poor indoor air quality. Some of the most common factors include:

- Excess moisture and mold
- Dry-erase markers and pens
- Dust and chalk
- Cleaning materials
- Personal care products
- Odors and volatile organic compounds from paint, caulk, and adhesives
- Insects and other pests
- Odors from trash
- Students and staff with communicable diseases
- Radon
- Classroom pets

All types of schools—new or old, big or small, elementary or secondary—can experience indoor air quality problems. Schools across the country have an array of indoor air problems. Biological problems, such as mold and mildew, are particularly pronounced in the Southeast where humidity levels are high. Schools across the country, however, even in desert areas, have experienced mold problems.

Effects of Poor Indoor Air Quality

Poor indoor air quality can significantly impede a school from achieving its core mission—educating its students. Failure to prevent or quickly resolve air quality problems can:

- Increase the potential for short-term and long-term health problems such as asthma, the number one cause of student absenteeism.
- Increase the absentee rate of students, teachers, and staff.
- Decrease the productivity and attitude of students, teachers, and staff.
- Strain relationships among school administrators, students, teachers, parents, and staff.

Ventilation

Since indoor air can be 2–5 times more polluted than outdoor air, most HVAC system designers understand that increased outdoor air supply is usually healthier. Yet, there are concerns over the implications that this added amount of outdoor air supply has on the energy used by the HVAC system, as well as humidity control. As a result, school designers often try to regulate the amount of outdoor air to equal the minimum requirement for school classrooms of 15 cubic feet per minute (cfm) of outside air per person. This standard has been established by the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE).

In some parts of the country, natural ventilation through operable windows can be an effective and energy efficient way to supplement HVAC systems to provide outside air ventilation, cooling, and thermal comfort when conditions permit (temperature, humidity, outdoor air pollution levels, precipitation). Windows that open and close can enhance occupants' sense of well-being and feeling of control over their environment. They can also provide supplemental exhaust ventilation during renovation activities that may introduce pollutants into the space.

On the other hand, sealed buildings with appropriately designed and operated HVAC systems usually provide better indoor air quality than buildings with operable windows. Uncontrolled ventilation with outdoor air can allow outdoor air contaminants to bypass filters, potentially disrupt the balance of the mechanical ventilation equipment, and permit the introduction of excess moisture.

Regulating Moisture and Relative Humidity

Humidity is a measurement of the total amount of water vapor in the air. Relative humidity measures the amount of water vapor in the air relative to the amount of water vapor the air can hold, which depends on the temperature of the air. Air acts like a sponge and absorbs water through the process of evaporation. Warm air is less dense and the molecules are further apart, which allows more moisture to be contained between them. Cooler air causes the air molecules to draw closer together, limiting the amount of water the air can hold.

It is important to control moisture and relative humidity in occupied spaces. Relative humidity levels that are too high can contribute to the growth and spread of unhealthy biological pollutants. This in turn can lead to a variety of health effects, ranging from more common allergic reactions, to asthma attacks and other health problems. Humidity levels that are too low, however, can contribute to irritated mucous membranes, dry eyes, and sinus discomfort. Maintaining the relative humidity between 40 and 60 percent also helps control mold. Maintaining relative humidity levels within recommended ranges is a way of ensuring that a building's occupants are both comfortable and healthy.

Lighting

Lighting is a major use of energy in a school. An average school uses 30 percent of the electricity it consumes to light buildings and outside areas. Schools are lit mainly with fluorescent lights.

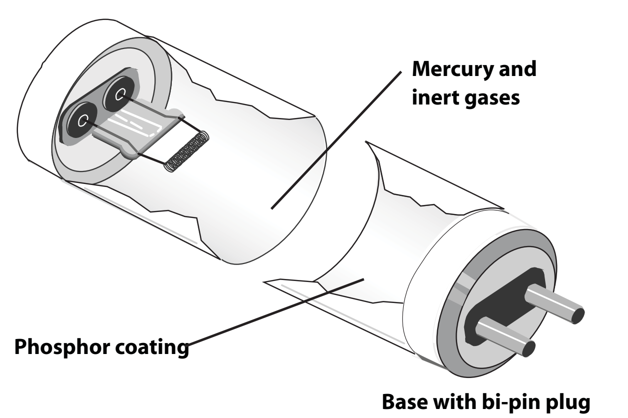
A fluorescent lamp is a glass tube, whose inner surface has a powdered, phosphor coating. The tube is filled with argon gas and a small amount of mercury vapor. At the ends of the tubes are electrodes that emit electrons when heated by an electric current. When electrons strike the mercury vapor, the mercury atoms emit rays of ultraviolet (UV) light. When these invisible UV rays strike the phosphor coating, the phosphor atoms emit visible light. The conversion of one type of light into another is called fluorescence.

Fluorescent lights have ballasts that help move the electricity through the gas inside the bulb. Ballasts are electromagnets that produce a large voltage between the ends of the bulbs so the electricity will flow between them. There are two types of ballasts, magnetic and electronic. Magnetic ballasts produce a frequency of 60 Hertz (Hz), which means the light is flickering on and off 60 times a second. Electronic ballasts produce a frequency of at least 20,000 Hz. Fluorescent lights with electronic ballasts are more energy efficient than those with magnetic ballasts.

Electronic ballasts use up to 30 percent less energy than magnetic ballasts. Electronic ballasts operate at a very high frequency that eliminates flickering and noise. Some electronic ballasts even allow you to operate the fluorescent lamp on a dimmer switch, which usually is not recommended with most fluorescents.

Incandescent lighting is also used in schools. Only 10 percent of the energy consumed by an incandescent bulb produces light; the rest is given off as heat. Fluorescent lights produce very little heat and are much more energy efficient. Compact fluorescents (CFLs) use

FLUORESCENT TUBE LIGHT



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.

the same technology as overhead fluorescent lights, but they are designed to fit into lamps and other fixtures where incandescents are commonly used. CFLs can help cut lighting costs 60 to 75 percent and reduce environmental impacts. Although CFLs cost more to buy, they save money in the long run because they use only one-fourth the energy of incandescent bulbs and last 8–12 times longer. Each CFL installed can save $30 to $60 over the life of the bulb. One CFL can reduce carbon dioxide emissions by 260 pounds per year.

Although fluorescent tubes in ceiling fixtures are always more energy efficient than incandescents, there are new, even more efficient lamps that use better electrodes and coatings. They produce about the same amount of light with substantially lower wattage.

Most light fixtures in schools use four-foot long lamps, although three–foot lamps are common as well. Older fixtures often contain T12 lamps that are 1½″ in diameter and consume 34–40 watts. These lamps can be replaced with energy-saving T8 lamps that are 1″ in diameter and typically consume 28–32 watts. Some newer systems are now using T5 lamps that are ⅝″ in diameter and are even more efficient than the T8 lamps.

Lighting Controls

Lighting controls are devices that turn lights on and off or dim them. The simplest type is a standard snap switch. Other controls include photocells, timers, occupancy sensors, and dimmers. Snap switches, located in many convenient areas, make it easier for people in large, shared spaces to turn off lights in unused areas.

Photocells turn lights on and off in response to natural light levels. Photocells switch outdoor lights on at dusk and off at dawn, for example. Advanced designs gradually raise and lower fluorescent light levels with changing daylight levels.

Mechanical or electronic time clocks automatically turn indoor or outdoor lights on and off for security, safety, and tasks such as janitorial work. An occupancy sensor activates lights when a person is in the area and then turn off the lights after the person has left.

Dimmers reduce the wattage and output of incandescent and fluorescent lamps. Dimmers also significantly increase the service life of incandescent lamps; however, dimming incandescent lamps reduces their light output more than their wattage, making them less efficient as they are dimmed. Dimmers for fluorescents require special dimming ballasts, but do not reduce the efficiency of the lamps.

Even the best lighting system is not efficient if people do not use it wisely. In most schools, more light is used than needed and lights are often left on when no one is present. All lights that are not necessary for safety should be turned off when rooms are not in use. The same is true for outside lights. Using sunlight is a good idea whenever possible. Studies have shown that students learn better in natural light than in artificial light.

INCANDESCENT BULB | **CFL BULB** | **LED BULB**

Light Emitting Diodes (LEDs) offer better light quality than incandescent bulbs, last 25 times as long, and use even less energy than CFLs. Expect to see LEDs more widely used in the future as technology improves and costs come down.

FLUORESCENT LIGHTING EFFICIENCY

A T12 bulb consumes up to 40 watts of energy to produce a given amount of light. T8 and T5 bulbs use less energy to produce the same amount of light.

Electrical Appliances

A school building contains many electrical devices (called plug loads) that contribute to the learning process and help occupants stay comfortable and safe. It is estimated that up to 20 percent of the total electricity consumed by a school is used to power these electrical devices. Managing the use of such equipment can greatly reduce a school's electricity consumption.

Look around any classroom and you will see many appliances. A quick survey of the typical classroom and school building reveals many kinds of electrical appliances, such as:

- coffee makers
- fans
- microwaves
- televisions
- window air conditioners
- printers and scanners
- copiers
- overhead projectors
- vocational equipment
- drinking fountains
- computers/monitors
- desk and table lamps
- refrigerators
- VCRs/DVD players
- vending machines
- fax machines
- fish tanks
- ranges and stoves
- clocks
- pencil sharpeners

Many of these devices are important to the learning environment. In addition, there are appliances that teachers and school staff bring from home that are not related to teaching, but are routine devices found in any office. Many electrical appliances, such as computers, printers, and copiers, waste energy when they are left on 24 hours a day. Often they are left on as a matter of convenience because they have a long warm–up time. Turning these machines off at the end of the day, and turning other machines off when they are not being used, can save a lot of energy.

Once students, teachers, and staff are educated about the impacts of energy consumption, they are often willing to reduce their use

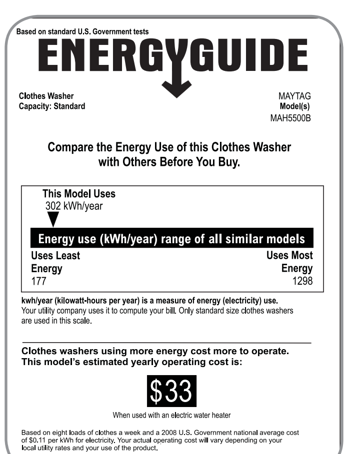
Roy Lee Walker Elementary School, McKinney, TX, incorporates a number of energy efficient and renewable design features to help lower energy bills, including daylighting, rainwater collection, solar water heating, wind energy, and high efficiency lighting.
Image courtesy of NREL

of these devices. By simply monitoring daily use of plug loads, students and staff can lower the school's utility bills, saving the school system money.

Many computers, TVs, VCRs, and other electrical devices use electricity even when they are turned off. This type of electricity consumption is known as phantom load, because it can easily go unnoticed. Phantom loads are also known as standby power or leaking electricity. Phantom loads exist in many electronic or electrical devices found in schools. Equipment with electronic clocks, timers, or remote controls, portable equipment, and office equipment with wall cubes (small box-shaped plugs that plug into AC outlets to power appliances) all have phantom loads and can consume 3–20 watts when turned off. These appliances should be plugged into surge protectors so that all of the power can be turned off when they are not in use, or at the end of the day.

Federal Government Guidelines for Appliances

When shopping for a new appliance, look for the Energy Star® label—your assurance that the product saves energy. Energy Star® appliances have been identified by the U.S. Environmental Protection Agency and Department of Energy as the most energy efficient products in their classes. If the average American equipped his/her home only with Energy Star® products, he/she would cut his/her energy bills, as well as greenhouse gas emissions, by about 30 percent. A list of these appliances can be found on the Energy Star® website at www.energystar.gov.



Another way to determine which appliance is more energy efficient is to compare energy usage using EnergyGuide labels. The federal government requires most appliances to display bright yellow and black EnergyGuide labels. Although these labels do not say which appliance is the most efficient, they provide the annual energy consumption and average operating cost of each appliance so you can compare them.

The School Building as a System

When managing the systems of a school to minimize energy consumption, it's important to maintain the health and comfort of the occupants. After all, the reason energy is being used in the first place is to provide a good learning environment. Human beings have specific requirements for temperature, relative humidity, and general air quality. They also have requirements for the quality and quantity of lighting. If light levels are too low, or of poor quality, they can cause eyestrain, headaches, and safety issues. Energy can be saved by turning off lights and lowering the heat in winter, but doing so thoughtlessly can cause unsafe or unhealthy conditions in the building. When the building is treated as a system, energy is saved while maintaining or improving the indoor environment. The school is not only a system in itself, but also a part of a global energy system that has finite energy resources.

Energy Definitions and Conversions

Definitions

Current: the flow of electrons—the number of electrons flowing past a fixed point (measured in amperes–A).

Energy: the ability to do work. Work involves a change in movement, temperature, energy level, or electrical charge. Energy is the ability to cause change.

Electricity: the energy of moving electrons (measured in kilowatt-hours–kWh).

Force: a push or pull that gives energy to an object, causing it to start moving, stop moving, or change direction.

Voltage: electric push or pressure—the energy available to move electrons (measured in volts–V).

Watt: the measure of electric power—the number of electrons moving past a fixed point in one second multiplied by the pressure or push of the electrons (W = A x V).

Conversions

1 Btu = British thermal unit—a measure of thermal energy (heat)—the amount of heat needed to raise the temperature of one pound of water by one degree Fahrenheit. One Btu is approximately the amount of energy released by the burning of one wooden kitchen match.

1 therm = 100,000 Btu—the amount of thermal energy in about one CCF of natural gas. One therm of natural gas costs between $1.00 and $2.00.

1 kWh = kilowatt-hour—one kilowatt of electricity over one hour. One kilowatt-hour of electricity is the amount of energy it takes to burn a 100-watt light bulb for 10 hours. The average cost of one kilowatt-hour of electricity for residential customers in the U.S. is about $0.11. The average cost for commercial customers, such as schools, is about $0.10.

1 kWh = 3,412 Btu

1 CF = one cubic foot—a measure of volume—one CF of natural gas contains about 1,020 Btu of thermal energy.

1 CCF = one hundred cubic feet—one CCF of natural gas contains about one therm of thermal energy. One CCF of natural gas costs between $1.00 and $2.00.

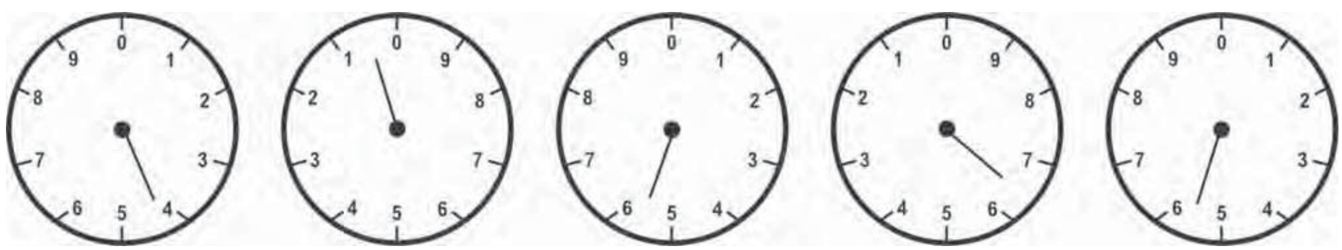
1 MCF = one thousand cubic feet—one MCF of natural gas costs between $10.00 and $20.00.

Reading an Electric Meter

An electric company sends electricity to your home or school through a power line. There is a meter at the school to measure the amount of electricity the school uses.

Reading an electric meter is easy. The face of the meter has five dials with the numbers 0 through 9 on each dial. The dials are not alike. On the first dial, the numbers are in a clock-wise direction. On the next meter, the numbers are in the opposite direction, in a counter clock-wise direction. The dials change from clock-wise to counter clock-wise, as shown below. If the pointer is between two numbers, you always record the smaller number. If the pointer is between 9 and 0, record 9, since 0 represents 10. Here are two examples with the correct numbers below the dials:

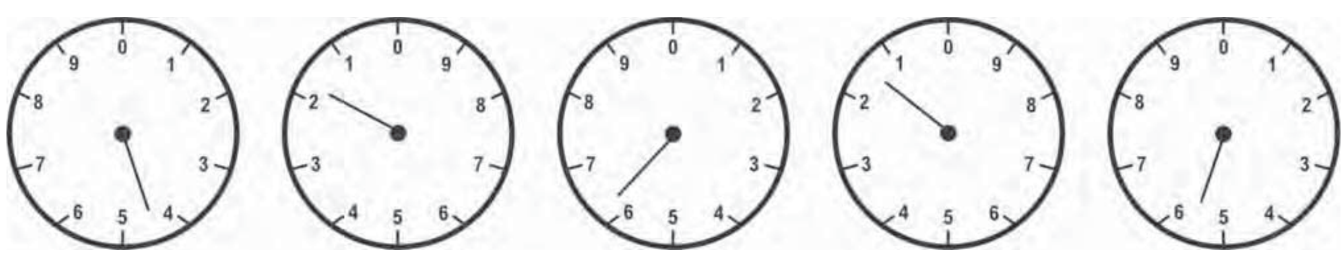
On Monday morning, this was the electric meter reading:



4 0 5 6 5

The total reading is 40,565

On Friday afternoon, this was the electric meter reading:



4 1 6 1 5

The total reading is 41,615

How much electricity was used this week? **Subtract Monday's reading from Friday's reading**:

Friday – Monday = Electricity used

41,615 – 40,565 = 1,050 kilowatt-hours

The electricity is measured in kilowatt-hours. If the power company charges a school ten cents ($0.10) for every kilowatt-hour (kWh) of electricity that is used, what is the cost of the electricity that was used during the week?

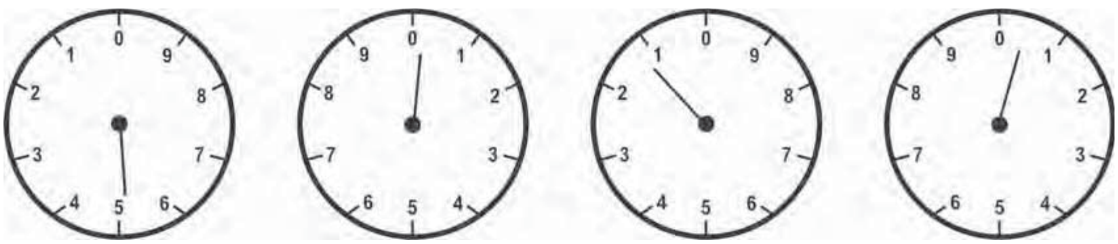
____________ **kWh X $0.10/kWh = $** ______________________

Reading a Natural Gas Meter

A gas company delivers natural gas to a school through an underground pipeline. There is a meter at the school to measure the volume of natural gas that the school uses.

Reading a natural gas meter is much like reading an electric meter. The face of the meter has four dials with the numbers 0 through 9 on each dial. Notice that the dials are not alike. On two dials the numbers are in a clock-wise direction. On the other two, the numbers are in a counter clock-wise direction. Each dial changes from clock-wise to counter clock-wise, as shown below. If the pointer is between two numbers, you always record the smaller number. If the pointer is between 9 and 0, record 9, since 0 represents 10. Here are two examples with the correct numbers below the dials:

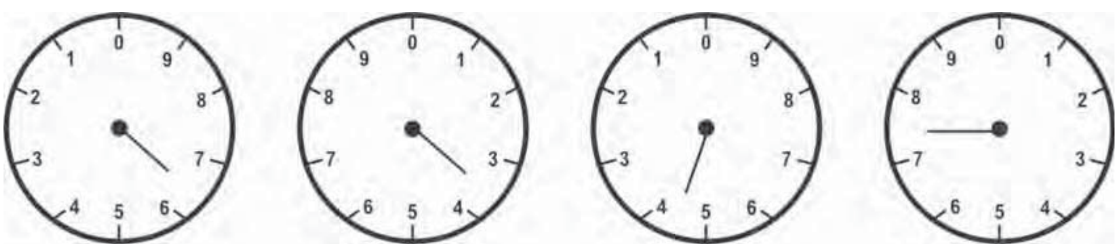
On December 1, this was the natural gas meter reading:



5 0 1 0

The total reading is 5,010

On January 1, this was the natural gas meter reading:



6 3 4 7

The total reading is 6,347

How much gas was used in December? Subtract the December 1st reading from the January 1st reading:

January 1 – December 1 = Electricity used

6,347 – 5,010 = 1,337 CCF

Natural gas is measured in CF or cubic feet—a measure of its volume. A cubic foot of natural gas is not much fuel, so most gas meters measure natural gas in hundreds of cubic feet—or CCF. The gas company measures the natural gas in CCF, but it charges by the amount of heat or thermal energy in the gas. The thermal energy is measured in therms.

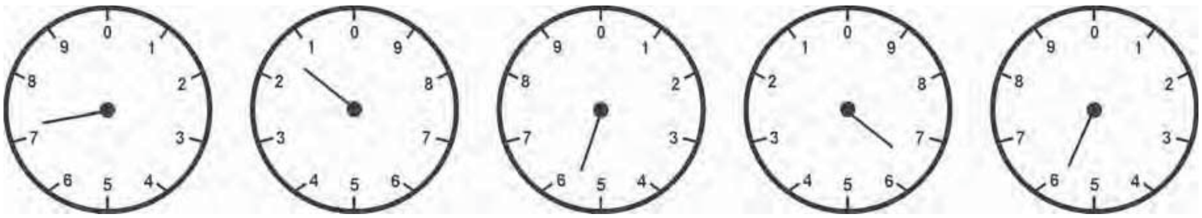
One CCF of natural gas contains about one therm of heat (1 CCF = 1 therm). If the gas company charges $1.37 for a therm of gas, how much did the gas cost in January?

Cost = ____________ therm X $1.37/therm = $ ______________

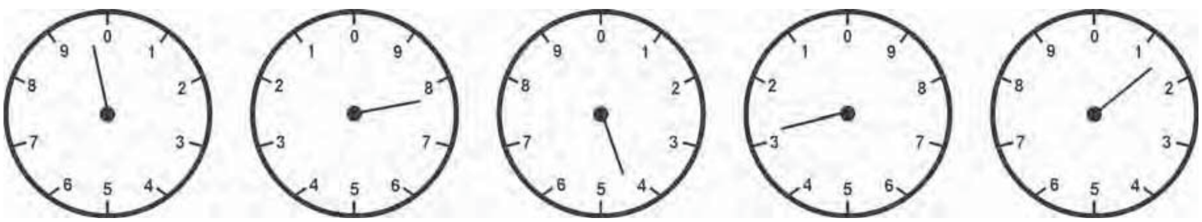
Reading Meters Worksheet

Electric Meter

On January 1, this was the electric meter reading:



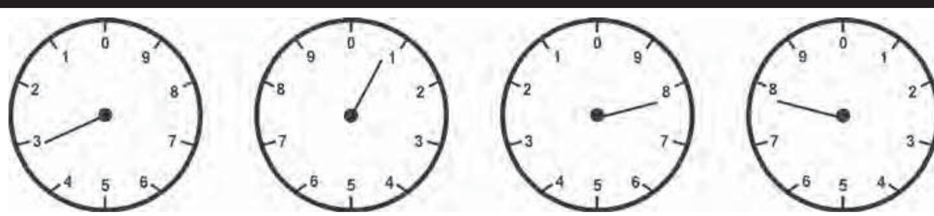
On December 1, this was the electric meter reading:



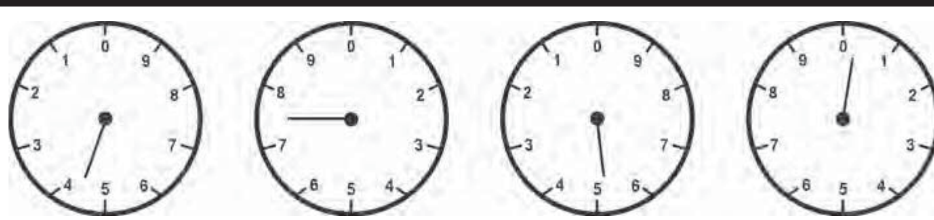
1. How many kilowatt-hours of electricity were used during January?
2. If the cost of electricity is $0.11 per kWh, how much did the electricity cost for January?
3. What was the average cost of electricity per day during January?

Natural Gas Meter

On January 1, this was the natural gas meter reading:



On December 1, this was the natural gas meter reading:



1. How many CCF of natural gas were used during January?
2. If the cost of natural gas is $1.37 per therm and there were 1.025 therms per CCF, what was the cost of natural gas during January?
3. What was the average cost of natural gas per week during January?

Facts of Light

We use a lot of energy to make light so that we can see. In schools, about 30 percent of the electricity is used for lighting and, in homes, about ten percent.

Most homes use incandescent light bulbs, the bulbs developed by Thomas Edison. These bulbs are not energy-savers. They change 90 percent of the electricity into heat instead of light. If everyone used new compact fluorescent light bulbs, we could lower our energy bill for lighting by 70 percent.

Compact fluorescent lights (CFLs) use less energy than incandescent bulbs and last much longer. Over the life of the bulbs, CFLs cost less to produce the same amount of light. CFLs also produce very little heat. The chart below shows how using CFLs can save money. Even though the bulbs cost more, they last much longer and use less energy. Life cycle cost is the cost of the bulb plus the cost of the energy to operate it over its useful life.

Most schools and businesses use fluorescent tube lights. New tube lights are very energy efficient. They provide a lot of light without using a lot of energy. Many schools are saving a lot of money by changing their old lights to new energy efficient fluorescent tube lights.

Incandescent

Cost: $0.50 each

Light Output: 1600 Lumens

Energy Used: 100 Watts

Life: 1,000 hours

Compact Fluorescent

Cost: $3.00 each

Light Output: 1600 Lumens

Energy Used: 23 Watts

Life: 10,000 hours

Comparing Light Bulbs

How Much Can You Save With CFLs?

The graphic on the previous page shows two light bulbs that produce the same amount of light. You might put bulbs like these into a bright overhead light. One bulb is an incandescent light bulb (IL); the other is a compact fluorescent light bulb (CFL). Which one is the better bargain? Let's do the math and compare the two light bulbs using the residential cost of electricity at $0.11/kWh.

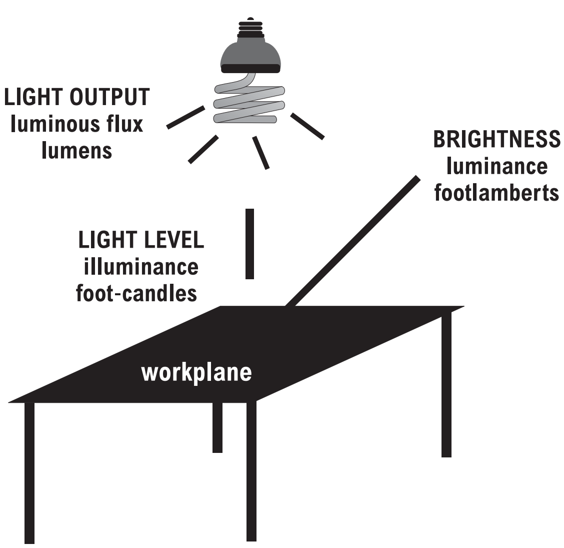
1. Determine how many bulbs you will need to produce 10,000 hours of light by dividing 10,000 by the number of hours each bulb produces light.
2. Determine the cost of each bulb by dividing the cost of a package of bulbs by the number of bulbs in the package.
3. Multiply the number of bulbs you will need by the cost of each bulb to determine the cost of bulbs to produce 10,000 hours of light.
4. Multiply the wattage of the bulbs by 10,000 hours to determine watt-hours (Wh), then divide by 1,000 to determine the number of kilowatt-hours (kWh).
5. Multiply the number of kilowatt-hours by the cost per kilowatt-hour to determine the cost of electricity to produce 10,000 hours of light.

COST OF BULB		**INCANDESCENT BULB**	**COMPACT FLUORESCENT (CFL)**
	Life of Bulb (how long it will light)	1,000 hours	10,000 hours
	Number of bulbs to get 10,000 hours	10 bulbs	1 bulb
x	Price per bulb	$0.50	$3.00
=	**Cost of bulbs for 10,000 hours of light**	________	________
COST OF ELECTRICITY		**INCANDESCENT BULB**	**COMPACT FLUORESCENT (CFL)**
	Total Hours	10,000 hours	10,000 hours
x	Wattage	100 watts = 0.10 kW	23 watts = 0.023 kW
=	Total kWh consumption	1,000 kWh	230 kWh
x	Price of electricity per kWh	$0.11	$0.11
=	**Cost of Electricity**	________	________
LIFE CYCLE COST		**INCANDESCENT BULB**	**COMPACT FLUORESCENT (CFL)**
	Cost of bulbs	________	________
+	Cost of electricity	________	________
=	**Life Cycle Cost**	________	________
ENVIRONMENTAL IMPACT		**INCANDESCENT BULB**	**COMPACT FLUORESCENT (CFL)**
	Total kWh consumption	1,000 kWh	230kWh
x	Pounds (lb) of carbon dioxide per kWh	1.6 lb/kWh	1.6 lb/kWh
=	**Pounds of carbon dioxide produced**	________	________

The Light Meter

Operating Instructions

1. Insert the battery into the battery compartment in the back of the meter.
2. Slide the ON/OFF Switch to the ON position.
3. Slide the Range Switch to the B position.
4. On the back of the meter, pull out the meter's tilt stand and place the meter on a flat surface in the area you plan to measure.
5. Hold the Light Sensor so that the white lens faces the light source to be measured or place the Light Sensor on a flat surface facing the direction of the light source.
6. Read the measurement on the LCD Display.
7. If the reading is less than 200 fc, slide the Range Switch to the A position and measure again.



Light Output or Luminous Flux

A lumen (lm) is a measure of the light output (or luminous flux) of a light source (bulb or tube). Light sources are labeled with output ratings in lumens. A T12 40-watt fluorescent tube light, for example, may have a rating of 3050 lumens.

Light Level or Illuminance

A foot-candle (fc) is a measure of the quantity of light (illuminance) that actually reaches the work plane on which the light meter is placed. Foot-candles are work plane lumens per square foot. The light meter can measure the quantity of light from 0 to 1000 fc.

Brightness or Luminance

Another measure of light is its brightness or luminance. Brightness is a measure of the light that is reflected from a surface in a particular direction. Brightness is measured in footlamberts (fL).

Recommended Light Levels

Below is a list of recommended illumination levels for school locations in foot-candles.

AREA	FOOT-CANDLES
Classrooms (Reading and Writing)	50
Classrooms (Drafting)	75
Computer Labs (Keyboarding)	30
Computer Labs (Reading Print Materials)	50
Computer Labs (Monitors)	3
Labs-General	50
Labs-Demonstrations	100
Auditorium (Seated Activities)	10
Auditorium (Reading Activities)	50
Kitchens	50
Dining Areas	30
Hallways	30
Stairwells	15
Gymnasiums (Exercising and Recreation)	30
Gymnasiums (Basketball Games)	75
Locker Rooms	10
Libraries and Media Centers (Study Areas)	50
Libraries and Media Centers (Other Areas)	30
Shops (Rough Work)	30
Shops (Medium Work)	50
Shops (Fine Work)	75
Offices (Reading Tasks)	50
Offices (Non-Reading Tasks)	30
Teacher Workrooms	30
Conference Rooms	30
Washrooms (Grooming Areas)	30
Washrooms (Lavatories)	15
Maintenance Rooms	30
Building Exteriors and Parking Lots	1-5