2018-2019

School Energy Experts
Student Guide

NEW!

NEED
National Energy Education Development Project

INTERMEDIATE

Introduction to Energy Use

The United States uses a lot of energy—over two million dollars' worth of energy per minute, 24 hours a day, 365 days a year. With a little more than 4.1 percent of the world's population, we consume about 17.8 percent of the world's energy resources. All of us use energy every day—for getting from one place to another, cooking, heating and cooling rooms, making products, lighting, heating water, and entertainment. We use a lot of energy to make our lives comfortable, productive, and enjoyable. Most of that energy is from nonrenewable energy sources. It is important that we use our energy resources wisely.

What Is Energy?

Energy allows us to do the things we do every day. Transportation, cooking, even the functioning of your body are all dependent upon energy. Energy changes forms, can be stored, and is almost always in flux.

Energy is defined as the ability to do work or produce change. Energy can be stored, and we refer to it as potential energy. When it is currently in use, it is called kinetic energy.

Forms of Energy

Energy is found in different forms, such as light, heat, sound, and motion. There are many forms of energy, but they can all be put into two categories: potential and kinetic.

POTENTIAL ENERGY

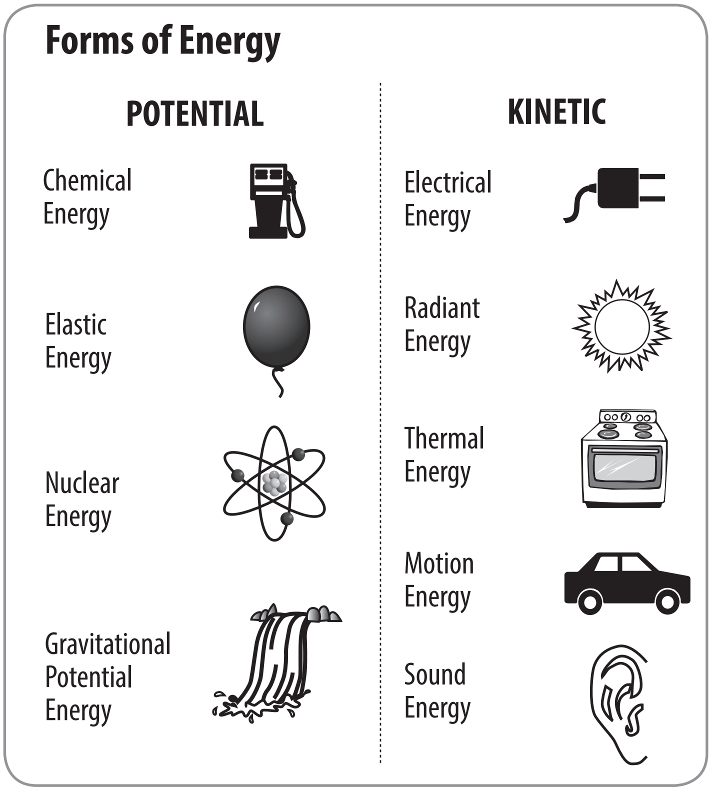
Potential energy is stored energy and the energy of position, or gravitational potential energy. There are several forms of potential energy.

- **Chemical energy** is energy stored in the bonds of **atoms** and **molecules**. It is the energy that holds these particles together. Biomass, petroleum, natural gas, propane, and the foods we eat are examples of stored chemical energy.
- **Elastic energy** is energy stored in objects by the application of a force. Compressed springs and stretched rubber bands are examples of elastic energy.
- **Nuclear energy** is energy stored in the nucleus of an atom; it is the energy that holds the nucleus together. The energy can be released when the nuclei are combined or split apart. Nuclear power plants split the nuclei of uranium atoms in a process called **fission**. The sun combines the nuclei of hydrogen atoms in a process called **fusion**.
- **Gravitational potential energy** is the energy of position or place. A rock resting at the top of a hill contains gravitational potential energy because of its position. Hydropower, such as water in a reservoir behind a dam, is an example of gravitational potential energy.

KINETIC ENERGY

Kinetic energy is motion; it is the motion of waves, **electrons**, atoms, molecules, substances, and objects.

- **Electrical energy** is the movement of electrons. Everything is made of tiny particles called atoms. Atoms are made of even smaller particles called electrons, protons, and neutrons. Applying a force can make some of the electrons move. Electrons moving through a wire are called **electricity**. Lightning is another example of electrical energy.



- **Radiant energy** is **electromagnetic** energy that travels in vertical (**transverse**) waves. Radiant energy includes visible light, x-rays, gamma rays, and radio waves. **Solar energy** is an example of radiant energy.
- **Thermal energy**, or heat, is the internal energy in substances; it is the vibration and movement of the atoms and molecules within a substance. The more thermal energy in a substance, the faster the atoms and molecules vibrate and move. **Geothermal** energy is an example of thermal energy.
- **Motion energy** is the movement of objects and substances from one place to another. Objects and substances move when an unbalanced force is applied according to **Newton's Laws of Motion**. Wind is an example of motion energy.
- **Sound energy** is the movement of energy through substances in **longitudinal** (compression/rarefaction) waves. Sound is produced when a force causes an object or substance to vibrate; the energy is transferred through the substance in a longitudinal wave.

Sources of Energy

We use many different energy sources to do work for us. They are classified into two groups—renewable and nonrenewable.

In the United States, most of our energy comes from **nonrenewable** energy sources. Coal, natural gas, petroleum, propane, and uranium are nonrenewable energy sources. They are used to make electricity, heat our homes, move our cars, and manufacture all kinds of products. These energy sources are called nonrenewable because their supplies are limited. Petroleum, a **fossil fuel**, for example, was formed hundreds of millions of years ago from the remains of ancient sea plants and animals. We can't make more petroleum deposits in a short time.

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

Conservation of Energy

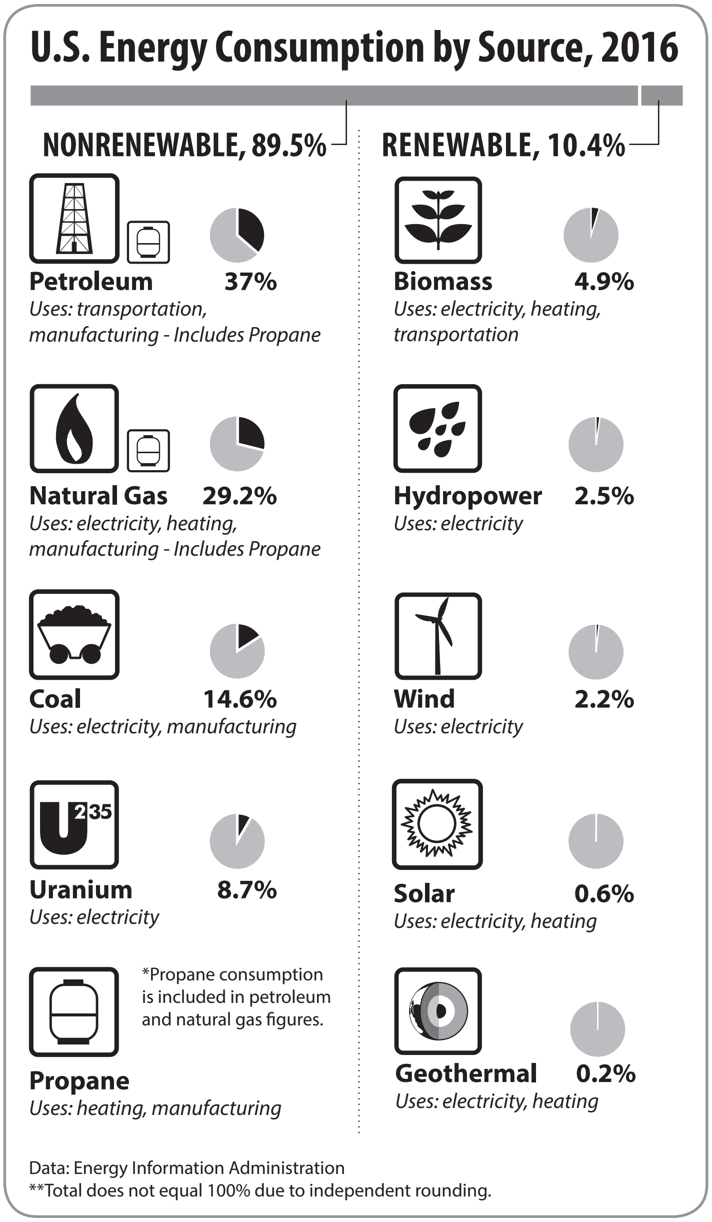
Your parents may tell you to conserve energy. "Turn off the lights," they say. To scientists, **energy conservation** is not just about saving energy. The **Law of Conservation of Energy** says that energy is neither created nor destroyed. When we use energy, it doesn't disappear. We change one form of energy into another.

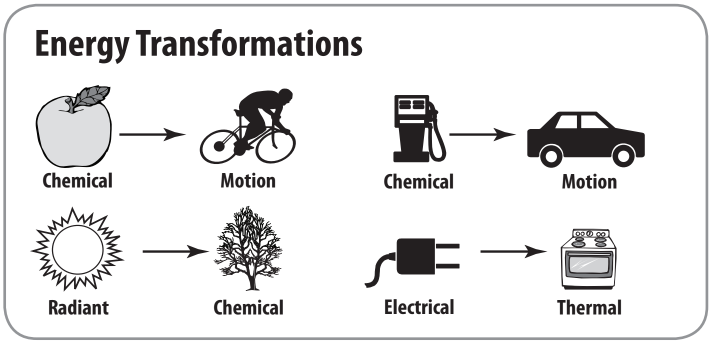
A car engine burns gasoline, converting the chemical energy in gasoline into motion energy. Solar cells change radiant energy into electrical energy. Energy changes form, but the total amount of energy in the universe stays the same.

Efficiency

Energy efficiency is the amount of useful energy you get from a system. A perfect, energy efficient machine would change all the energy put into it into useful work – a technological impossibility today. Converting one form of energy into another form always involves a loss of usable energy.

When we discuss energy efficiency, we really are talking about the machines or equipment we are using to complete a task. It might be a washing machine, a light bulb, or your family's vehicle, but they're all some kind of device that does work for us. If we say we are being more energy efficient, we are using devices that use less energy to perform the work. For example, a heavy duty pickup truck and a small sedan will both carry two people to work. However, the small sedan will use less fuel to do so, so it is more efficient. The ENERGY STAR® program identifies which devices are most efficient. We discuss this program further in Lesson 3.





Conservation

There are many ways the word conserve can be used. Some might use it in the context of keeping the natural environment as clean as possible. Scientists use conserve to refer to something that is kept constant. For example, in a chemical reaction, no mass is lost, it is all conserved. Others might be talking about water use or energy use.

When discussing energy use, energy conservation refers to the behaviors that we use to control our energy usage. Even the most efficient machines need people acting in conserving ways to make them of any use. An LED light is the most efficient lighting type available, but if the lights are left on all day every day, they're still using more energy than they should. The owners of that LED light need to turn it off and exhibit good energy conservation.

Who Uses Energy?

The U.S. Department of Energy uses categories to classify energy users—residential, commercial, industrial, transportation, and electric power generation. 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 graphic to the right shows that the electric power generation sector consumed the most primary energy in 2016. However, all of the other sectors, especially the residential, commercial, and industrial sectors, use electricity after it is generated. The other sectors are the end users of electric power. When the residential and commercial sectors of the economy are combined together and electricity consumption is included, the residential and commercial sectors consume more energy than any of the other sectors, with 38.2 total quads of energy. These two sectors actually account for nearly 40 percent of the total energy consumed by the U.S., when electricity is included. The residential portion of the sector consumed 20.2 quads of energy, with nearly 70 percent of this energy coming from electricity. The commercial portion of the sector consumed 18.0 quads of energy, of which 76% is electricity.

Residential/Commercial Sector

The residential sector includes houses, apartments, and other places where people live. The commercial sector includes schools, businesses, and hospitals. The residential and commercial sectors are put together because they use energy for similar tasks—for heating, air conditioning, water heating, lighting, and operating appliances. Schools use energy a little differently than the way energy is used in homes. By far, the greatest energy users in schools were space heating and cooling, making up almost half the energy used in schools. The other big energy users are ventilation, water heating, lighting, and computing.

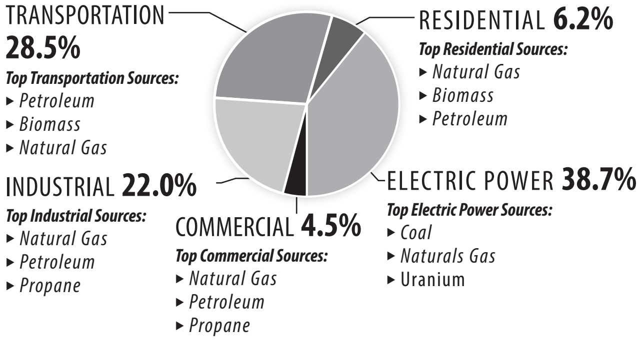
Transportation Sector

Americans make up about 4.3 percent of the world's population, yet we own nearly 16 percent of the world's automobiles. The transportation sector of the economy accounts for more than 28 percent of total energy use. America is a country on the move.

For model year 2016, the average motor vehicle uses 665 gallons of gasoline every year. You can achieve 10 percent fuel savings by improving your driving habits and keeping your car properly maintained. Over the life of a vehicle, your family can save a lot of money on gas by choosing a fuel-efficient model.

The corporate average fuel economy standard (regulated by the U.S. government, also known as CAFE) required for new passenger cars, light trucks, and SUVs, is 34.1 miles per gallon (combined city and highway mileage). There are some dedicated electric vehicles on the market today that can achieve the equivalent of over 100 mpg. If you buy a fuel-efficient vehicle, you can save a lot on fuel costs and reduce greenhouse gas emissions. Compare the fuel economy of vehicles you are considering, and make fuel economy a priority. All cars must display a fuel economy label that lists the estimated miles per gallon for both city and highway driving to help you compare.

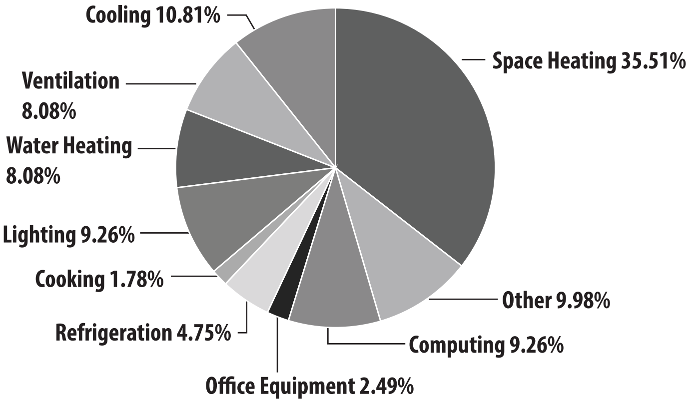
U.S. Energy Consumption by Sector, 2016



The residential, commercial, and industrial sectors use electricity. This graph depicts their energy source consumption outside of electricity.

Data: Energy Information Administration
*Total does not equal 100% due to independent rounding.

U.S. School Energy Consumption



Data: EIA Commercial Building Energy Survey

Industrial Sector

Manufacturing the goods we use every day consumes an enormous amount of energy. The industrial sector of the economy consumes about one-fifth of the nation's energy. In industry, energy efficiency and conservation are driven by economics—money. Manufacturers know that they must keep their product costs low so people will buy them.

Since energy is one of the biggest costs in many industries, manufacturers must use as little energy as possible. Their demand for energy efficient equipment has resulted in many new technologies in the last decades. Consumers can have an effect on industrial energy use through the product choices we make and what we do with the packaging and the products we no longer use.

A Word About Water

It might seem strange to talk about the water we use every day in the middle of a discussion about energy. However, fresh water and energy are inseparably linked to each other. We need energy to purify or treat our water for drinking and safe use. We also need water to generate electricity. For more information on water used for electricity generation, visit Lesson 3.

When water is extracted from the ground or a surface source such as a river or reservoir, it must be pumped from that site to the water treatment plant. Pumps are used to pull and convey the water to the treatment facility, and each pump uses energy to run.

At the treatment facility, pumps and other machinery are used to filter and clean the water so it is safe to drink. When water leaves the treatment facility, it is carried at a high pressure through pipes to your home or school. Pumps run to keep the water pressure elevated so you can always take a shower or wash your hands when you'd like.

As we use water, we have water softeners that further condition the water, filters that remove unpleasant tastes and odors from the water, heaters that heat the water, and pumps that move it in and out of the machines that use it. All of these devices use energy, too.

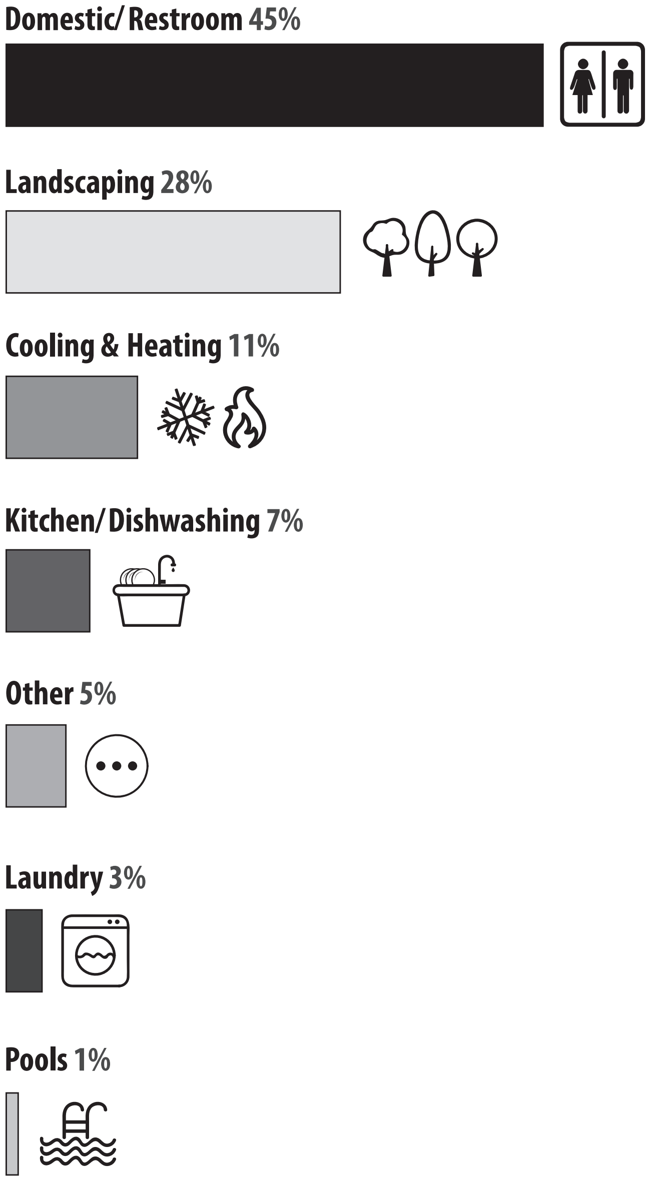
Finally, after you've finished a water-related task, it has to go somewhere. The drain in your school does not empty into a big hole in the ground. In most areas, water is sent through a series of sewer pipes to a wastewater treatment facility, where pumps and other machinery clean and filter it before releasing it back into the natural environment. Septic systems use gravity to pull water through a series of screens in a septic tank, where sediments are filtered out before the water is drained back into the ground water.

At each of the stages of our own water use listed above, significant amounts of energy are required to extract, clean, distribute, and treat the water we use every day. If you reduce the amount of water you use, you will also be reducing the amount of energy you use, saving your school money on the water bill and reducing the energy demand in your city or town.

Here are some great ways you can reduce the amount of water you use:

1. Don't let the water run needlessly in the restroom or classroom. If you need hot water, consider heating it in a hot pot or on a hot plate instead of allowing the water to run several minutes.
2. Inform a teacher or other staff member if a faucet or drinking fountain does not turn off properly.
3. In the locker room, turn off the shower when finished, don't allow it to run for the next person.
4. Stomp or scrape your boots or shoes before entering the school to avoid the need to extensively clean the floors every evening.

Water Use in Schools



Data: EPA

Forms of Energy

All forms of energy fall under two categories:

POTENTIAL

Stored energy and the energy of position (gravitational).

CHEMICAL ENERGY is the energy stored in the bonds of atoms and molecules. Biomass, petroleum, natural gas, propane, and coal are examples.

NUCLEAR ENERGY is the energy stored in the nucleus of an atom – the energy that holds the nucleus together. The energy in the nucleus of a uranium atom is an example.

ELASTIC ENERGY is energy stored in objects by the application of force. Compressed springs and stretched rubber bands are examples.

GRAVITATIONAL POTENTIAL ENERGY is the energy of place or position. Water in a reservoir behind a hydropower dam is an example.

KINETIC

The motion of waves, electrons, atoms, molecules, and substances.

RADIANT ENERGY is electromagnetic energy that travels in transverse waves. Solar energy is an example.

THERMAL ENERGY or heat is the internal energy in substances – the vibration or movement of atoms and molecules in substances. Geothermal is an example.

MOTION is the movement of a substance from one place to another. Wind and hydropower are examples.

SOUND is the movement of energy through substances in longitudinal waves. Echoes and music are examples.

ELECTRICAL ENERGY is the movement of electrons. Lightning and electricity are examples.

Energy Source Matching

Write the number of the energy source on the line next to its definition.

1. Petroleum
2. Wind
3. Biomass
4. Uranium
5. Propane
6. Solar
7. Geothermal
8. Hydropower
9. Coal
10. Natural Gas

______ Black rock burned to make electricity.

______ Energy from heat inside the Earth.

______ Energy from flowing water.

______ Energy from wood, waste, and garbage.

______ Energy from moving air.

______ Energy from splitting atoms.

______ Portable fossil fuel used in grills.

______ Fossil fuel for cars, trucks, and jets.

______ Fossil fuel gas moved by pipeline.

______ Energy in waves from the sun.

Forms and Sources of Energy

In the United States we use a variety of resources to meet our energy needs. Use the information below to analyze how each energy source is stored and delivered.

1 Using the information from the *Forms of Energy* chart and the graphic below, determine how energy is stored or delivered in each of the sources of energy. Remember, if the source of energy must be burned, the energy is stored as chemical energy.

NONRENEWABLE

Petroleum ____________________

Coal ____________________

Natural Gas ____________________

Uranium ____________________

Propane ____________________

RENEWABLE

Biomass ____________________

Hydropower ____________________

Wind ____________________

Solar ____________________

Geothermal ____________________

2 Look at the U.S. Energy Consumption by Source graphic below and calculate the percentage of the nation's energy use that each form of energy provides.

What percentage of the nation's energy is provided by each form of energy?

Chemical _____

Nuclear _____

Motion_____

Thermal _____

Radiant _____

What percentage of the nation's energy is provided

By nonrenewables? ______

By renewables? ______

U.S. Energy Consumption by Source, 2016

NONRENEWABLE

PETROLEUM 37% *
Uses: transportation, manufacturing - includes propane

NATURAL GAS 29.2% *
Uses: heating, manufacturing, electricity - includes propane

COAL 14.6%
Uses: electricity, manufacturing

URANIUM 8.7%
Uses: electricity

PROPANE
Uses: heating, manufacturing

*Propane consumption is included in petroleum and natural gas totals.

RENEWABLE

BIOMASS 4.9%
Uses: heating, electricity, transportation

HYDROPOWER 2.5%
Uses: electricity

WIND 2.2%
Uses: electricity

SOLAR 0.6%
Uses: heating, electricity

GEOTHERMAL 0.2%
Uses: heating, electricity

**Total does not add up to 100% due to independent rounding.
Data: Energy Information Administration

Energy Definitions and Conversions

Definitions

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

Ccf: one hundred cubic feet; a unit used to measure natural gas usage

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

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

kWh: kilowatt-hour; one kilowatt of electricity expended 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; in 2016, the average cost of one kilowatt-hour of electricity for residential customers in the U.S. was about $0.126; the average cost for commercial customers, such as schools, was about $0.104

Mcf: one thousand cubic feet; a unit used to measure natural gas usage

MMBtu: 1,000,000 British thermal units (Btu)

Therm: a measure of thermal energy; one therm equals 100,000 Btu

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

Natural Gas Conversions and Cost, 2016

In 2016, the average heat content of natural gas for the residential, commercial, and industrial sectors was about 1,037 Btu per cubic foot.

1 cf = 1,037 Btu
1 Ccf = 103,700 Btu or 1.037 therms
1 Mcf = 1.037 MMBtu or 10.37 therms

1 kWh = 3,412 Btu
1 therm = 100,000 Btu

The cost of natural gas varies widely by sector of the economy. In 2016, one Mcf of natural gas cost $2.99 in the electric power generation sector, $3.52 in the industrial sector, $7.28 in the commercial sector, and $10.05 in the residential sector.

Efficiency vs. Conservation

	Efficiency	Conservation
Definition		
Examples		

Explain how energy efficiency and conservation work together:

Understanding Thermal Energy

Most Americans are very aware of how thermal energy impacts us. Many experience hot summers, cold winters, and all kinds of weather in between, and we go to great lengths to keep ourselves comfortable. Very little is worse than being hot and sweaty or cold and shivery. It's difficult to think about anything except how hot or cold we are in such circumstances.

What exactly is **thermal energy**? Thermal energy is the internal energy within a substance that causes its particles to move. The more thermal energy an object has, the faster its particles – its atoms and molecules – are moving. As you might expect, the molecules in a block of ice (solid) are just vibrating in place while the molecules in a glass of water (liquid) are moving around each other. The ice molecules have less thermal energy than the water molecules do, and they are held in place. If you boil water, the molecules in the steam (gas) have enough thermal energy to break free from each other and move around independently.

When we build schools, homes, and office buildings, significant thought is put into how the inside of the building will remain comfortable for the occupants – the people inside. The materials selected must be able to keep warm air from mixing with cool air; they must be good insulators, and limit the transfers of thermal energy.

Please Pass the Heat

Suppose you have a very large room, like a gym, and suppose it is a very cold, winter day. To keep everyone comfortable, you should try to heat the gym. But what is the best way to accomplish this? You will need to transfer thermal energy from a warm place to a cool place.

If you build a fire in a fire pit in the gym, the end of the room with the fire will get warm because thermal energy will spread out, or **radiate**, from it. This is great for getting the area immediately around the fire warm, but the other end of your gym will still be quite cold.

If you connect very long pieces of metal to the fire pit, and lay them across the room, they will carry the thermal energy from the fire throughout the pieces of metal. Metals are good at this because they **conduct** thermal energy well.

By now you may have decided that a fire on one end of the gym, even with long, conducting metal pieces extending from it, is not the best way to heat your large room. Another good way to warm this space is to place a large fan behind the fire and turn it on. The moving air will be warmed by the fire and then carried to the other side of the room on a **convection** current.

These three ways of warming the room, radiation, conduction, and convection, are the three ways thermal energy can be transferred. Radiation transfers thermal energy through waves that spread out from the heat source. Conduction transfers thermal energy by directly touching the heat source. Convection transfers thermal energy by warming a fluid such as air or water, then circulating the fluid. Regardless of which method is used, keep in mind that thermal energy always transfers from high temperature to low temperature, and stops when everything is the same temperature. In other words, you can't throw an ice cube into hot chocolate expecting the chocolate to get hotter and the ice cube to get colder.

Heat ≠ Temperature

Measuring the temperature of something does not directly tell you how much thermal energy that object has. However, it does give you an idea of how much thermal energy the atoms or molecules in that object might have. High temperatures tell us that the particles have more energy, on average. Low temperatures indicate that the particles have less energy.

Most heating or cooling systems use convection to transfer thermal energy. A forced air furnace will heat air, then use a fan to blow the warm air through duct work into the rooms of the building. Boiler systems heat water and then circulate water through piping systems in the rooms. Air conditioners remove thermal energy from air, then blow the cooled air into the warm room. The lower temperature air mixes with the higher temperature air in the room and reduces the overall temperature.

Heating and Cooling Systems

Heating and cooling systems use more energy than any other systems in residential and commercial buildings. Natural gas and electricity are usually used to heat, and electricity is used to cool. The energy sources that power these heating and cooling systems contribute carbon dioxide emissions to the atmosphere. Using these systems wisely can reduce environmental emissions.

With all heating and air conditioning systems, you can save energy and money too, by having proper **insulation**, sealing air leaks, maintaining the equipment, and practicing energy-saving behaviors.

AIR CONDITIONING SYSTEM

Programmable Thermostats

Programmable **thermostats** automatically control the temperature of buildings for time of day and can save energy and money. During heating seasons, for example, they lower the temperature of a building when no one is using it. When people are active in the building, the thermostat automatically raises the temperature. These controls are available for commercial buildings, from as simple as one programmable thermostat to a whole system of temperature sensors connected to a computer, depending on the building's size. Many newer schools and those that have been upgraded with new heating systems have a central computer that monitors the temperature in each room and adjusts the heating system accordingly.

Insulation and Weatherization

Air leaking into or out of a building wastes energy. Insulation prevents thermal energy transfer to keep the interior room comfortable and separated from the exterior air. Building owners can reduce heating and cooling costs by investing in proper insulation and weatherization products. Insulation is rated using an **R-value** that indicates the resistance of the material to thermal energy transfer. The R-value needed varies, depending on the climate, ceilings, walls, attics, and floors. In very cold climates, a higher R-value is recommended.

Insulation is like a blanket for buildings, but air can still leak in or out through small cracks. Often, the effect of many small leaks is the same as leaving a door wide open. One of the easiest energy-saving measures is to caulk, seal, and weather-strip cracks and openings to the outside. Building performance professionals can seal air leaks in attics and basements. Homeowners can typically save up to $200 a year in heating and cooling costs by air sealing their homes and adding insulation. Commercial buildings, which tend to be larger, can save even more by following the same procedures.

Doors and Windows

Some air leaks occur around and through the doors and windows. Doors should seal tightly and have door sweeps at the bottom to prevent air leaks. Insulated storm doors provide added barriers to leaking air. School entryways with two sets of doors are designed to keep cold air from blasting inside during the winter and outside during the summer. Both sets of doors should always be kept closed.

Most buildings have more windows than doors. The best windows shut tightly and are constructed of two or more pieces of glass. Caulk or seal any cracks around the windows and make sure they seal tightly. With older windows, install storm windows or sheets of clear plastic to create added air barriers. Insulated blinds also help to prevent air flow—during heating seasons, open them on sunny days and close them at night. During cooling seasons, close them during the day to keep out the sun.

PROGRAMMABLE THERMOSTAT

INSULATION

Image courtesy of Owens Corning

Moisture

Moisture is a term used to describe water in both liquid and vapor form. Like heat and air, it is important to have the right amount of moisture in a building. Most moisture indoors exists as water vapor. The amount of water vapor in the air plays an important role in determining our health and comfort.

Humidity is a measurement of the total amount of water vapor in the air. It is measured with a tool called a **hygrometer**. Relative humidity measures the amount of water vapor in the air compared to the amount of water vapor the air is able to hold. The relative humidity depends on the temperature of the air.

Air acts like a sponge and absorbs water through the process of evaporation. Warmer air, with greater energy, can support more water vapor than colder air, which has less energy. When cold air from outdoors is heated, it feels very dry and makes the occupants of the building uncomfortable. Furthermore, moisture in the air in a room will help it resist changes in temperature, which can reduce the number of times a heating or air conditioning system has to run.

The correct humidity level can also help promote a healthy indoor environment. Humidity levels should be kept between 30% and 60%. Using a dehumidifier in the summer and a humidifier in the winter can help condition the air to maintain appropriate humidity levels.

Ventilation

Something that is always taken into consideration in a school is ventilation. Each person in the building is a living, breathing carbon dioxide and heat machine, pumping both out at a constant rate. At home, this is handled by opening and closing doors as you enter and leave the house. Schools, though, are more tightly sealed, and have more people in them without opening a door for a long time. The buildup of stale, carbon dioxide-laden air is a problem.

Building code regulations require that the air inside a commercial building be exchanged with fresh air on a regular basis. The type of building use, room size, and number of people in the room determine how much fresh air must be brought in. For the average classroom with 25 students, the air in the room is changed about 2 ½ times every hour.

Bringing in fresh air from outdoors in winter puts more demand on the heating system to keep the interior space comfortable. That cold air must be warmed to a comfortable temperature.

Ventilation plays a very important role in controlling moisture in a building, too. When cold air from outside is warmed without moisture being added in, the air feels very dry. This not only causes us to have dry lips and skin, it can create some health problems when our sinuses are too dry. Additionally, dry air does not hold as much thermal energy as humidified air and the heating system must run more often as a result.

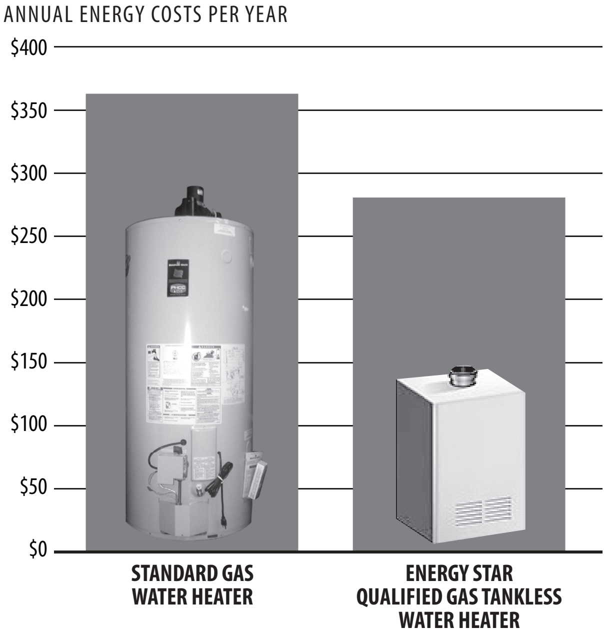
However, a more threatening situation occurs when there is too much moisture in a room, especially a room like a classroom where paper and books are found. As you know, paper is made from wood, and while our bodies are not designed to fully digest the fibers in paper and wood, other organisms do a great job. In fact, it is because of these other organisms that dead trees decompose into dirt on a forest floor. Fungi, including molds and mildew, thrive in warm, moist, dark places. When moisture is allowed to build up on a surface, mold and mildew also build up. As the molds prosper and grow, they release spores, which are carried in the air to other surfaces where they, in turn, may grow. These spores present a serious health hazard if people breathe them in.

A lack of fresh air combined with an excess of moisture spell disaster for schools because of the amount of paper products inside of them. Once a book begins to mildew it is very difficult to get it cleaned and acceptable for others to use; most mildewed books are thrown away. Thus it is important for schools in humid climates that run cooling systems on a regular basis to clean the ventilation and cooling equipment to make sure that mold and mildew are not building up in hidden areas where condensation may be accumulating. It is important for the people in a school as well as the books, papers, and other educational materials that the moisture levels inside be maintained properly.

Landscaping

Although you cannot control the weather, you can plant trees and bushes to block the wind and provide shade. Properly placed landscaping can reduce the energy needed to keep buildings comfortable. Deciduous trees, for example, are good to plant on the south side of a building in the Northern Hemisphere, since their leaves provide shade in summer and their bare branches allow sunlight through in the winter. Clusters of trees can be planted to reduce “heat islands” in areas like parking lots, and act as wind blocks during the winter. In tropical and warmer climates taller trees like palms and shades are used on a building’s exterior to block the sun while allowing a breeze to flow.

Water Heater Comparison



Data: ENERGY STAR®

Water Heating

You don’t think too much about the hot water you need at school, but it is definitely needed. At home you probably have a hot water heater that holds 40 or 50 gallons of hot water and is fueled by natural gas or electricity. When you turn the hot water tap on in the kitchen or bathroom, you have to let the water run a bit before it’s warm. However, having one hot water heater in one central location in a school would mean letting the water run for a very long time before it ran warm in rooms far from the heater. Most schools have one or more 100-gallon (or sometimes even bigger) hot water heaters, and the hot water supply is constantly circulating through the school with a pump. Thus, turning the hot water on in a distant classroom should provide hot water fairly quickly.

The temperature of the water at school is important. At home, you probably have your hot water heater set at 120-140 °F, and rarely any higher because of the danger of serious injury by scalding. This is true for the hot water at school except in the kitchen. To comply with health department regulations, the cafeteria workers must wash all dishes and serving equipment in water that is at least 160 °F. But at this temperature, scalding injuries happen very quickly. Very young or distracted students would easily get their hands burned if water came out of the faucet at this temperature.

Most building designs handle this dilemma in one of two ways. One is to have two separate water heating systems, one for the cafeteria and the other for the rest of the school. The cafeteria water supply is kept very hot while the rest of the school is kept at a safer, lower temperature. The other way is to keep the entire school supply at a safe temperature, but have a booster heating system in the cafeteria that heats the water to the necessary temperature for cleaning.

Radiation

Question

What is radiant transfer and how does it affect the heating and cooling of a building?

Hypothesis:

Materials

IR thermometer

Prediction

In the table below, list one or more components of the room (including walls, windows, doors, floor, ceiling, and any items in the room) that you believe will fall in the given temperature range.

Predicted Temperature Range	Component
40°-50°F	
50°-60°F	
60°-80°F	
80°-100°F	
100°-120°F	

✔ Procedure

Use the IR thermometer to check the actual temperature of each component from the table above.

Data

Component	Actual Temperature

⁂ Conclusion

1. Imagine that the space below is a map of the space you are in. Follow these steps:
    a. Draw and label the components from the data table on page 53 onto the map below. Indicate the temperature of each component.
    b. Draw an arrow from each component to at least one other component on the map, indicating the direction that heat is radiating.

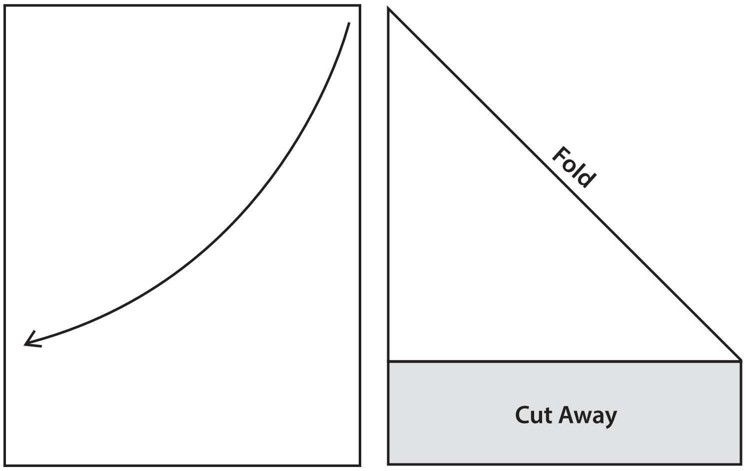
2. Based on your results, provide examples of how radiant heat transfer can affect the heating (or cooling) of your home or classroom.

3. Write a definition of radiant heat transfer.

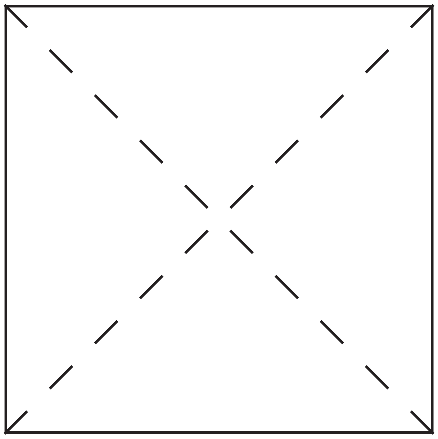
Thermal Energy Transfer Graphic Organizer

Now that you have been introduced to the transfer of thermal energy through conduction, convection, and radiation, make a graphic organizer that will help you remember them.

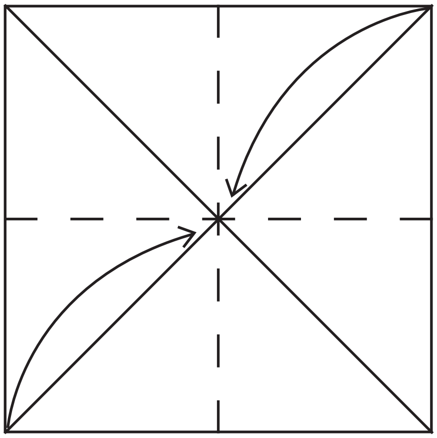
1. Holding your paper vertically, fold the short edge down to the long edge, as shown. Cut off the bottom edge to leave behind a perfect square.



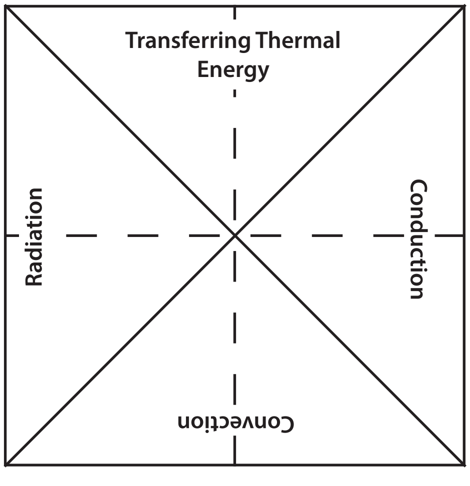
2. Fold the other corners together and open the square out, so you have a large folded "X" on the paper.



3. Fold the corners to the center of the square, making a smaller square with triangle-shaped flaps.



4. On the outside of one flap, write "Transferring thermal energy". Lift the flap, and beneath it, write the way thermal energy is transferred, either from low temperature to high temperature, or from high temperature to low temperature (there is only one right answer!). On the outside of the other three flaps, write "Conduction," "Convection," and "Radiation." Underneath the flaps, define each method of thermal energy transfer using words or pictures, and provide an example of each.



Tape, glue, or staple this organizer in your science notebook.

Thermometer

A thermometer measures temperature. The temperature of a substance is a measure of the average amount of kinetic energy in the substance.

This thermometer is a long, glass tube filled with colored alcohol. Alcohol is used in many thermometers because it expands in direct proportion to the increase in kinetic energy or temperature.

Temperature can be measured using many different scales.

The scales we use most are:

- **Celsius**

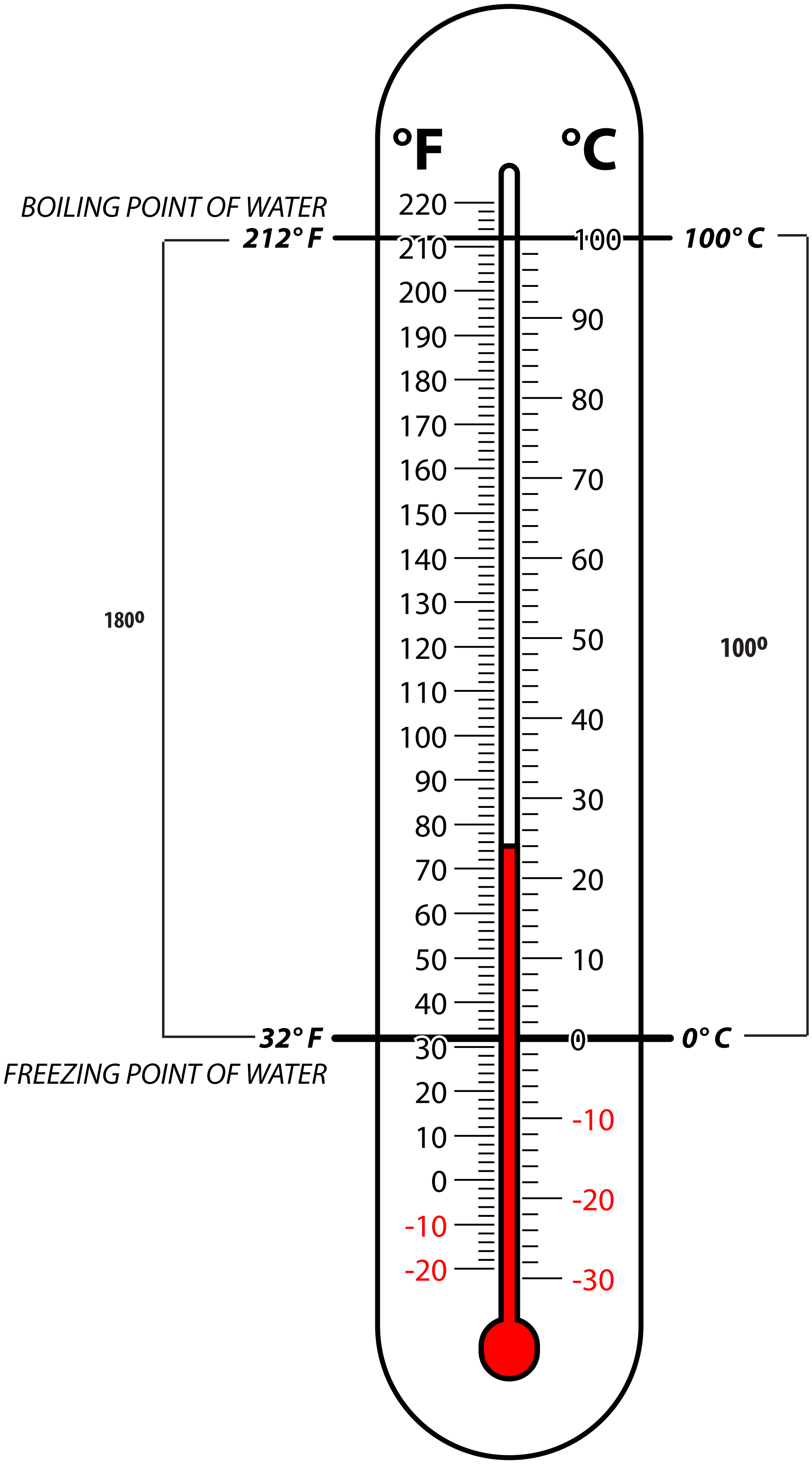
The **Celsius (C)** scale uses the freezing point of water as 0°C and the boiling point of water as 100°C.

- **Fahrenheit**

The **Fahrenheit (F)** scale uses the freezing point of water as 32°F and the boiling point of water as 212°F.

In the United States, we usually use the Fahrenheit scale in our daily lives, and the Celsius scale for scientific work. People in most countries use the Celsius scale in their daily lives as well as for scientific work.

Notice the numerical difference between the freezing and boiling points of water are different on the two scales. The difference on the Celsius scale is 100, while the difference on the Fahrenheit scale is 180. There are more increments on the Fahrenheit scale because it shows less of an energy change with each degree.



Fahrenheit/Celsius Conversion

On the Fahrenheit scale, the freezing point of water is 32° and the boiling point of water is 212°.

On the Celsius scale, the freezing point of water is 0° and the boiling point of water is 100°.

To convert from Celsius to Fahrenheit, multiply the C number by $\frac{180}{100}$ or $\frac{9}{5}$, then add 32, as shown in the formula below.

$$F = (C \times \frac{9}{5}) + 32$$

If C = 5

$$F = (5 \times \frac{9}{5}) + 32$$

$$F = 9 + 32$$

$$F = 41$$

To convert from Fahrenheit to Celsius, subtract 32 from the F number, then multiply by $\frac{100}{180}$ or $\frac{5}{9}$ as shown in the formula below.

$$C = (F - 32) \times \frac{5}{9}$$

If F = 50

$$C = (50 - 32) \times \frac{5}{9}$$

$$C = 18 \times \frac{5}{9}$$

$$C = 10$$

Insulation Investigation

Question

- Which materials are the best thermal insulators?

Materials

- 2 Radiation cans
- 2 Thermometers
- 2 Zipper seal sandwich bags
- 1 Set of insulation materials
- 1 Small box
- 2 Rubber bands
- Tape
- Hot water

Hypothesis

In your science notebook, write a statement to address which types of materials you think make the best thermal insulators.

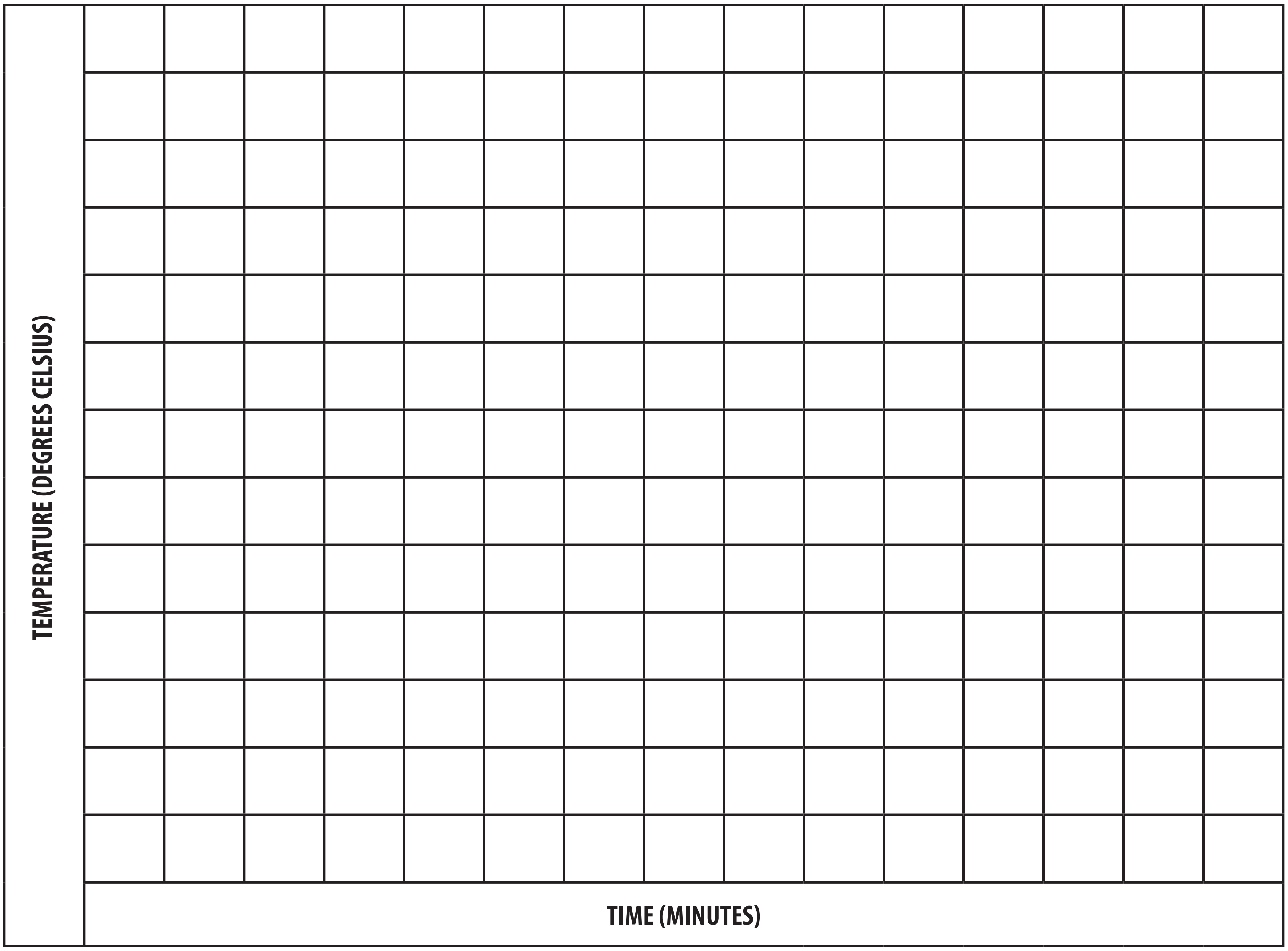
Procedure

1. Copy the data table into your science notebook, if necessary, and beneath it create a space for your graphing by either drawing axis lines or pasting a piece of graph paper into your notebook.
2. Remove the tops from the cans.
3. Set each can inside a sandwich bag and wrap a rubber band around the bag to hold it tightly against the can.
4. If you are collecting control data, skip to step 6.
5. Place both cans in the box, and if your teacher gave you some insulation, loosely pack it around the cans. Leave no empty spaces around the cans, but do not smash the insulation in the space either.
6. Place your cans, box, and insulation (as provided) on the desk top. Pour hot water into the cans.
7. Replace the tops on the cans. Insert a thermometer into each can so that the bulb is suspended in the hot water but not touching the bottom or side of the cans. Use tape to hold it in place if necessary.
8. Wait for the temperature to stabilize, then read the temperature in degrees Celsius (°C). This is your "time zero" measurement.
9. Record the temperature of the water every two minutes, making sure the same person reads the same thermometer to ensure consistency.
10. Calculate the overall change in temperature (ΔT) for both cans. Graph the results in the space provided or in your science notebook.
11. Using the space your teacher provides, record the data for your insulation type to compare with the other data collected by your classmates. Compare this data and discuss which material is the best thermal insulator. Also discuss the role the finish on the can, whether black or shiny, plays in the change in temperature.

Data

Type of Insulation (If none, write none, if control data, write control):

Time (min)	0	2	4	6	8	10	12	14	16	18	20	ΔT
Black Can												
Shiny Can												



Conclusion

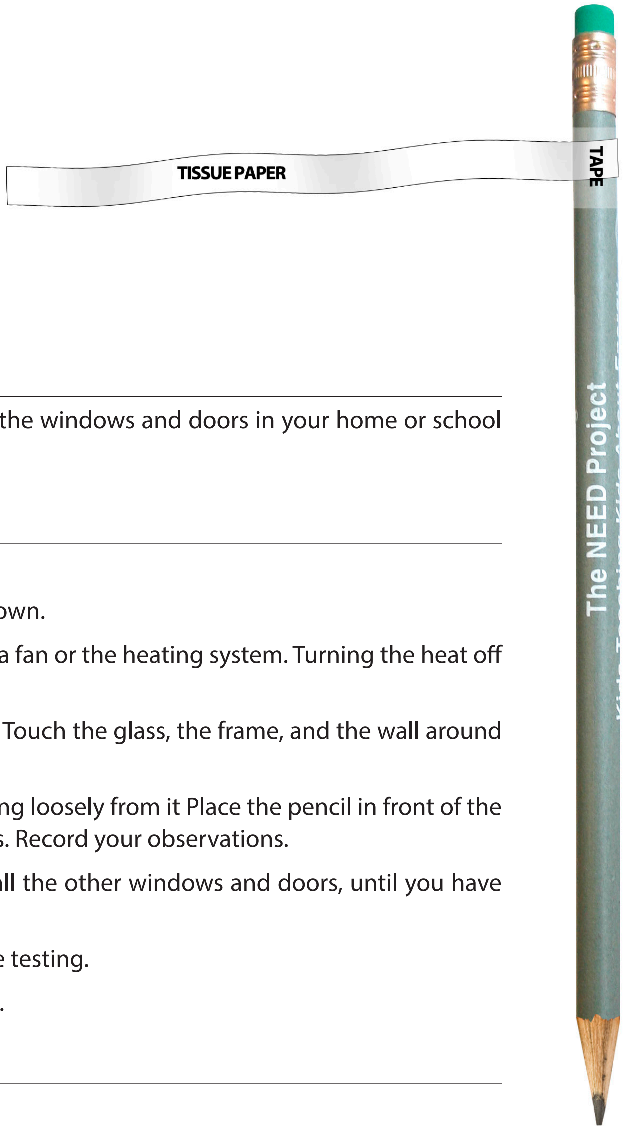
Copy the following questions into your notebook, leaving space after each for your answer. Answer the questions based on the data you and your classmates collected.

1. Explain why the control cans were enclosed in a sandwich bag.
2. Explain why one of the sets of data collected used cans in an empty box.
3. Which material was the best thermal insulator? Use evidence collected from your trial or your classmates to support your answer.
4. Did the black cans cool in the same way and at the same rate as the shiny cans? How could you further test the affect that can finish has on thermal insulation?
5. Which material would you choose to insulate your home? Why would you choose that material?

Air Infiltration Investigation

Question

How can you tell if the windows in your home or school seal tightly?



Materials

- 1 Pencil
- 1 Strip of tissue paper, 1” x 12”
- Tape

Hypothesis

In your science notebook, write a hypothesis stating how well you think the windows and doors in your home or school are sealed against air infiltration.

Procedure

1. Copy the data section into your science notebook if necessary.
2. Use a small piece of tape to attach the tissue paper to the pencil as shown.
3. Turn off anything that might cause an air current in the room, such as a fan or the heating system. Turning the heat off for a few minutes should not cause the room or building to get cold.
4. Stand in front of the window you are observing and record your data. Touch the glass, the frame, and the wall around the window.
5. Hold the pencil so it is parallel to the floor with the tissue paper hanging loosely from it Place the pencil in front of the lower edge of a closed window and observe whether the tissue moves. Record your observations.
6. Repeat the test around the other edges of the window, and around all the other windows and doors, until you have tested all the outside doors and windows of the room you are in.
7. If instructed, move to another room, copy the data table, and continue testing.
8. Answer the conclusion questions when you’re finished collecting data.

Data

Room in which you are testing: ____

Window you are testing: ______________________________

Which direction does the window face? North East South West

How many panes of glass are in the window? 1 2 3

What is the window frame made of? ____

Is the window latched closed? Yes No

Can you see any gaps around the window that should be filled with caulking or weatherstripping? ____________________________

How do the window panes and frame, and the wall around the window, feel to the touch? ________________________________

____

Results of tissue paper test: ____

⁂ Conclusion

Copy the following questions into your notebook, leaving space for your answer after each.

1. Based on your observations, are the windows well insulated, or do they conduct thermal energy too easily? Back up your answer with the data you recorded.
2. How well do the window frames block thermal energy transfer? Use evidence collected from the activity to support your answer.
3. Are the windows well sealed? What evidence that you collected supports your answer?
4. How warm or cool did the walls feel compared to the windows when you touched them?
5. Can you suggest anything, other than replacing the windows, to help prevent thermal energy loss?

Understanding Electrical Energy

Electricity: Unseen Power

Everything in the universe is made of **atoms**—every star, every tree, every animal. The human body is made of atoms. Air and water are, too. Atoms are the building blocks of the universe. There are over 100 different types of atoms found in the world around us that make up **elements**. Each element is identified and organized into the periodic table. Atoms of these elements are so small that millions of them would fit on the head of a pin.

Atoms are made of even smaller particles. The center of an atom is called the **nucleus**. It is made of particles called **protons** and **neutrons**. The protons and neutrons are very small, but **electrons** are much, much smaller. Electrons spin around the nucleus in energy levels a great distance from the nucleus. If the nucleus were the size of a tennis ball, the atom would be several kilometers in diameter.

Atoms are mostly empty space. If you could see an atom, it would look a little like a tiny center of spheres surrounded by giant invisible clouds. The electrons would be on the surface of the clouds, constantly spinning and moving to stay as far away from each other as possible on their **energy levels**. Electrons are held in their levels by an electrical force. The protons and electrons of an atom are attracted to each other. They both carry an **electric charge**. Protons have a positive charge (+) and electrons have a negative charge (-). The positive charge of the protons is equal to the negative charge of the electrons. Opposite charges attract each other. When an atom is in balance, it has an equal number of protons and electrons. Neutrons carry no charge, and their number can vary.

The number of protons in an atom determines the kind of atom, or **element**, it is. An element is a substance in which all of the atoms are identical. An atom of hydrogen, for example, has one proton and one electron, and almost always no neutrons. Every stable atom of carbon has six protons, six electrons, and typically six neutrons. The number of protons is also called the **atomic number**. The atomic number is used to identify an element.

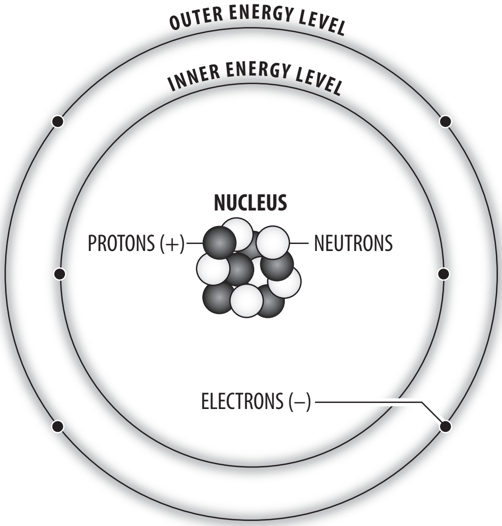
Electrons usually remain a relatively constant distance from the nucleus in well defined regions called energy levels. The electrons in the levels closest to the nucleus have a strong force of attraction to the protons. Sometimes, the electrons in the outermost levels do not. With enough energy, the electrons can move from one atom to another. These moving electrons are electricity.

Magnets

When charged particles, like electrons, move they create a magnetic field. In most objects the atoms have electrons that spin in random directions and are scattered evenly throughout the object. **Magnets** are different—they are made of atoms with aligned electron spins that create aligned magnetic fields. The molecules in a magnet are arranged so that most of the north seeking poles point in one direction and most of the south-seeking poles point in the other, creating what we call north and south poles of a magnet. The magnetic force in a magnet flows from the north pole to the south pole.

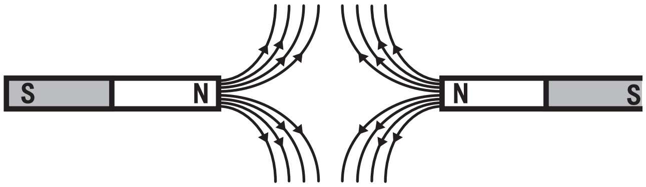
Carbon Atom

A carbon atom has six protons and six neutrons in the nucleus, two electrons in the inner energy level, and four electrons in the outer energy level.



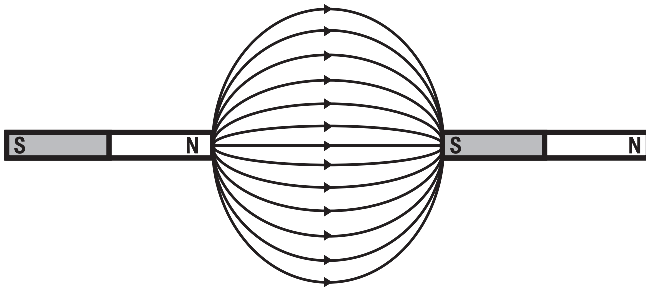
Like Poles

Like poles of magnets (N-N or S-S) repel each other.



Opposite Poles

Opposite poles of magnets (N-S) attract each other.



Have you ever held two magnets close to each other? They don't act like most objects. If you try to push the south poles together, they repel each other. The two north poles also repel each other. If you turn one magnet around, the north and the south poles are attracted to each other. The magnets come together with a strong force. Just like protons and electrons, opposites attract.

Magnets Can Produce Electricity

We can use magnets to make electricity. A magnetic field can move electrons. Some metals, like copper, have electrons that are loosely held; they are easily pushed from their levels.

Magnetism and electricity are related. Magnets can create electricity and electricity can produce magnetic fields. Every time a magnetic field changes, an electric field is created. Every time an electric field changes, a magnetic field is created. Magnetism and electricity are always linked together; you can't have one without the other. This phenomenon is called **electromagnetism**.

Power plants use huge turbine generators to make the electricity that we use in our homes and businesses. Power plants use many fuels to spin **turbines**. They can burn coal, oil, or natural gas to make steam to spin turbines. Or they can split uranium atoms to heat water into steam. They can also use the power of rushing water from a dam or the energy in the wind to spin the turbine.

The turbine is attached to a shaft in the generator. Inside the **generator** are magnets and coils of copper wire. The magnets and coils can be designed in two ways—the turbine can spin the magnets inside the coils or can spin coils inside the magnets. Either way, the electrons are pushed from one copper atom to another by the moving magnetic field.

Coils of copper wire are attached to the turbine shaft. The shaft spins the coils of wire inside two huge magnets. The magnet on one side has its north pole to the front. The magnet on the other side has its south pole to the front. The magnetic fields around these magnets push and pull the electrons in the copper wire as the wire spins. The electrons in the coil flow into transmission lines. These moving electrons are the electricity that flows to our houses. Electricity moves through the wire very quickly.

Generating Electricity

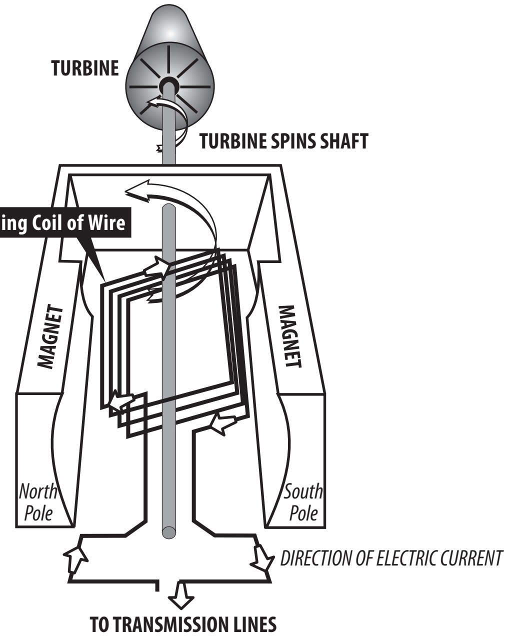
Most of the electricity we use in the United States is generated by large power plants. These plants use many fuels to produce electricity. Thermal power plants use coal, biomass, petroleum, or natural gas to superheat water into steam, which powers a generator to produce electricity. Nuclear power plants use the energy from nuclear **fission** to heat the water. Geothermal power plants use thermal energy from inside the Earth. Wind farms use the kinetic energy in the wind to generate electricity, while hydropower plants use the energy in moving water.

Another Word about Water

In Lesson 1 we discussed how using water around your home also uses a significant amount of energy. But the relationship between water and energy does not stop there.

Thermoelectrical power plants use water in the form of steam to turn a turbine, which generates electricity. In fact, all thermal power plants are the same from the steam turbine through to the distribution lines; the only difference is the manner in which the water is heated to steam. Coal plants burn coal, natural gas plants burn natural gas, nuclear plants use the thermal energy from uranium atoms splitting, and concentrated solar power plants use the sun's energy to heat water to steam. In each of these power plants, the goal is to boil water to high-pressure steam to turn a turbine. The water is condensed back to water, and the cycle repeats.

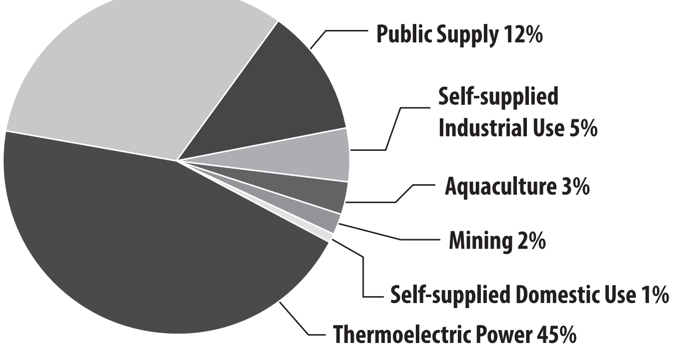
Turbine Generator



HYDROPOWER TURBINE GENERATORS

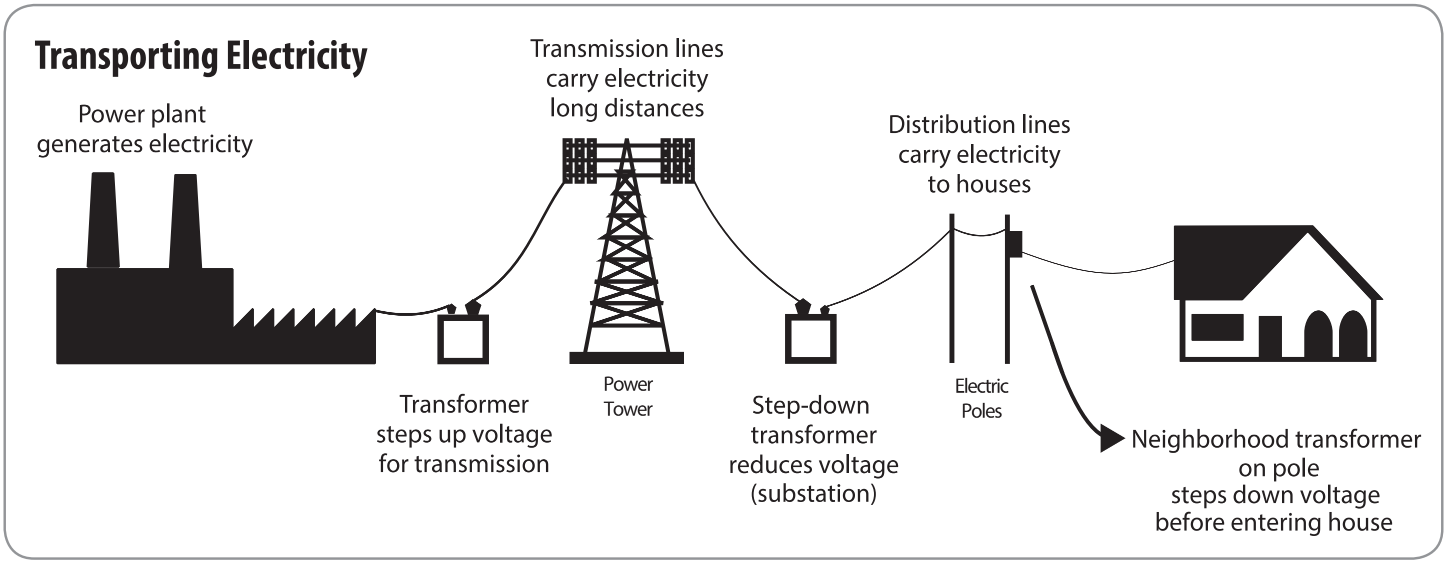
Photo of Safe Harbor Water Power Corporation on the Lower Susquehanna River in Pennsylvania.

U.S. Freshwater Withdrawals



Data: EPA
*Total does not equal 100% due to independent rounding.

Transporting Electricity



However, this is not a closed loop. Some water always evaporates, and must be replaced with more. According to the Environmental Protection Agency, the largest amount of water extracted, or pulled, by any single water using facility is electric power. Almost half of the water removed from fresh water supplies is used to generate electricity – on average, 25 gallons per kilowatt-hour! And on average, about two gallons of that water evaporates and cannot be recovered for further use. However, in drier climates, the evaporation rate is much higher. For example, in Arizona, almost 8 gallons of water evaporate, making water use for electrical generation a real concern. This is why being conscientious of the amount of electricity you use is important, and why some people are so eager to replace thermal power plants with methods that do not rely on water, such as solar photovoltaic and wind turbines, in dry climates.

Moving Electricity

We use more electricity every year. One reason we use so much electricity is that it's easy to move from one place to another. It can be made at a power plant and moved long distances before it is used. There is also a standard system in place so that all of our machines and appliances can operate on electricity. Electricity makes our lives simpler and easier.

Let's follow the path of electricity from a power plant to a light bulb in your home. First, the electricity is generated at a power plant. It travels through a wire to a **transformer** that steps up, or increases, the **voltage**. Power plants step up the voltage because less electricity is lost along the power lines when it is at a higher voltage.

The electricity is then sent to a nationwide network of **transmission lines**. This is called the electric **grid**. Transmission lines are the huge tower lines you see along the highway. The transmission lines are interconnected, so if one line fails, another can take over the load.

Step-down transformers, located at **substations** along the lines, reduce the voltage from 350,000 volts to 12,000 volts. Substations are small fenced-in buildings that contain transformers, switches, and other electrical equipment.

The electricity is then carried over **distribution lines** that deliver electricity to your home. These distribution lines can be located overhead or underground. The overhead distribution lines are the power lines you see along streets.

TRANSMISSION LINES

Before the electricity enters your house, the voltage is reduced again at another transformer, usually a large gray metal box mounted on an electric pole. This transformer reduces the electricity to the 120 or 240 volts that are used to operate the appliances in your home. Electricity enters your home through a three-wire cable. Wires are run from the circuit breaker or fuse box to outlets and wall switches in your home. An electric meter measures how much electricity you use so that the utility company can bill you.

What's a Watt?

We use electricity to perform many tasks. We use units called watts, kilowatts, and kilowatt-hours to measure the electricity that we use.

A **watt** is a measure of the electric power an appliance uses. Every appliance requires a certain number of watts to work correctly. Traditional light bulbs were rated by watts (60, 75, 100), as well as home appliances, such as a 1500-watt hairdryer. A **kilowatt** is 1,000 watts. It is used to measure larger amounts of electricity.

A **kilowatt-hour** (kWh) measures the amount of electricity used in one hour. Sometimes it's easier to understand these terms if you compare them to a car. A kilowatt is the rate of electric flow, or how much energy you are consuming at a specific instant. In a car, it would be similar to how fast you are driving at one instant. A kilowatt-hour is a quantity or amount of energy, or how much you consumed over a period of time. A kWh is like the distance traveled in a car.

We pay for the electricity we use in kilowatt-hours. Our power company sends us a bill for the number of kilowatt-hours we use every month. Most residential consumers in the United States pay about 12.6 cents per kilowatt-hour of electricity. In 2016, Louisiana residents paid the least for electricity: 9.3 cents per kilowatt-hour. Hawaii residents paid the most: between 20 to 30 cents per kilowatt-hour, depending on the island.

Electricity Measurement

Electricity makes our lives easier, but it can seem like a mysterious force. Measuring electricity is confusing because we cannot see it. We are familiar with terms such as watt, volt, and amp, but we may not have a clear understanding of these terms. We buy a 60-watt light bulb, a tool that needs 120 volts, or a vacuum cleaner that uses 8.8 amps, and we don't think about what those units mean.

Using the flow of water as an analogy can make electricity easier to understand. The flow of electrons in a circuit is similar to water flowing through a hose. If you could look into a hose at a given point, you would see a certain amount of water passing that point each second.

The amount of water depends on how much pressure is being applied—how hard the water is being pushed. It also depends on the diameter of the hose. The harder the pressure and the larger the diameter of the hose, the more water passes each second. The flow of electrons through a wire depends on the electrical pressure pushing the electrons and on the cross-sectional area of the wire.

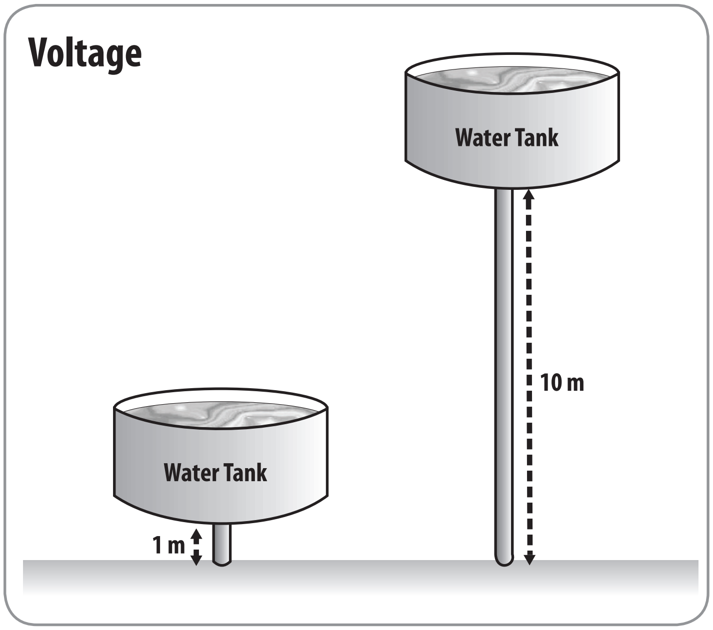
Voltage

The pressure that pushes electrons in a circuit is called **voltage (V)**. Using the water analogy, if a tank of water were suspended one meter above the ground with a 1-cm diameter pipe coming out of the bottom, the water pressure would be similar to the force of a shower. If the same water tank were suspended 10 meters above the ground, the force of the water would be much greater, possibly enough to hurt you.

Voltage is a measure of the pressure applied to electrons to make them move. It is a measure of the strength of the current in a circuit and is measured in **volts (V)**. Just as the 10-meter high tank applies greater pressure than the 1-meter high tank, a 10-volt power supply (such as a battery) would apply greater pressure than a 1-volt power supply.

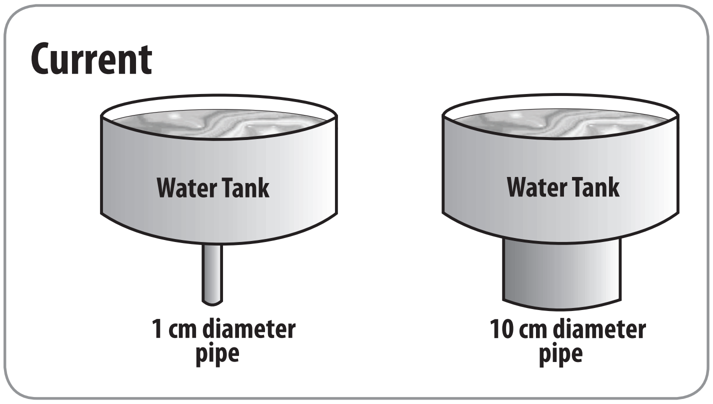
AA batteries are 1.5 volts; they apply a small amount of voltage or pressure for lighting small flashlight bulbs. A car usually has a 12-volt battery—it applies more voltage to push current through circuits to operate the radio or defroster.

The standard voltage of wall outlets is 120 volts—a dangerous amount of voltage. An electric clothes dryer is usually wired at 240 volts—a very dangerous voltage.



Current

The flow of electrons can be compared to the flow of water. The water current is the number of molecules flowing past a fixed point; **electric current** (I) is the number of electrons flowing past a fixed point. Electric current is defined as electrons flowing between two points having a difference in voltage. Current is measured in **amperes** or **amps (A)**. One ampere is 6.25 X 10^{18} electrons per second passing through a circuit.



With water, as the diameter of the pipe increases, so does the amount of water that can flow through it. With electricity, conducting wires take the place of the pipe. As the cross-sectional area of the wire increases, so does the amount of electric current (number of electrons) that can flow through it.

Resistance

Resistance (R) is a property that slows the flow of electrons. Using the water analogy, resistance is anything that slows water flow, a smaller pipe or fins on the inside of a pipe. In electrical terms, the resistance of a conducting wire depends on the metal the wire is made of and its diameter. Copper, aluminum, and silver—metals used in conducting wires—have different resistance.

Resistance is measured in units called **ohms (Ω)**. There are devices called resistors, with set resistances, that can be placed in circuits to reduce or control the current flow. Any device placed in a circuit to do work is called a **load**. The light bulb in a flashlight is a load. A television plugged into a wall outlet is also a load. Every load has resistance.

Ohm's Law

George Ohm, a German physicist, discovered that in many materials, especially metals, the current that flows through a material is proportional to the voltage. In the substances he tested, he found that if he doubled the voltage, the current also doubled. If he reduced the voltage by half, the current dropped by half. The resistance of the material remained the same.

This relationship is called **Ohm's Law**, and can be written in three simple formulas. If you know any two of the measurements, you can calculate the third, using the formulas to the right.

Electric Power

Power (P) is a measure of the rate of doing work or the rate at which energy is converted. Electric power is the rate at which electricity is produced or consumed. Using the water analogy, electric power is the combination of the water pressure (voltage) and the rate of flow (current) that results in the ability to do work.

A large pipe carries more water (current) than a small pipe. Water at a height of 10 meters has much greater force (voltage) than at a height of one meter. The power of water flowing through a 1-centimeter pipe from a height of one meter is much less than water through a 10-centimeter pipe from 10 meters.

Electric power is defined as the amount of electric current flowing due to an applied voltage. It is the amount of electricity required to start or operate a load for one second. Electric power is measured in **watts (W)**.

Electrical Energy

Electrical energy introduces the concept of time to electric power. In the water analogy, it would be the amount of water falling through the pipe over a period of time, such as an hour. When we talk about using power over time, we are talking about using energy. Using our water example, we could look at how much work could be done by the water in the time that it takes for the tank to empty.

The electrical energy that an appliance or device consumes can be determined only if you know how long (time) it consumes electric power at a specific rate (power). To find the amount of energy consumed, you multiply the rate of energy consumption (measured in watts) by the amount of time (measured in hours) that it is being consumed. Electrical energy is measured in **watt-hours (Wh)**.

- **Energy (E) = Power (P) x Time (t)**
  E = P x t or E = W x h = Wh

Another way to think about power and energy is with an analogy to traveling. If a person travels in a car at a rate of 40 miles per hour (mph), to find the total distance traveled, you would multiply the rate of travel by the amount of time you traveled at that rate.

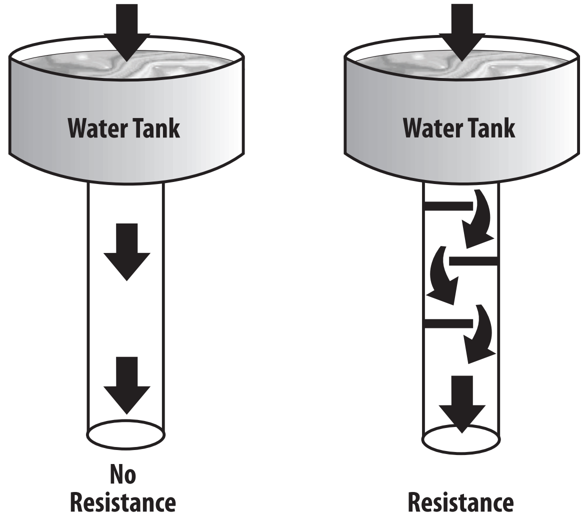
If a car travels for 1 hour at 40 miles per hour, it would travel 40 miles.

Distance = 40 mph x 1 hour = 40 miles

If a car travels for 3 hours at 40 miles per hour, it would travel 120 miles.

Distance = 40 mph x 3 hours = 120 miles

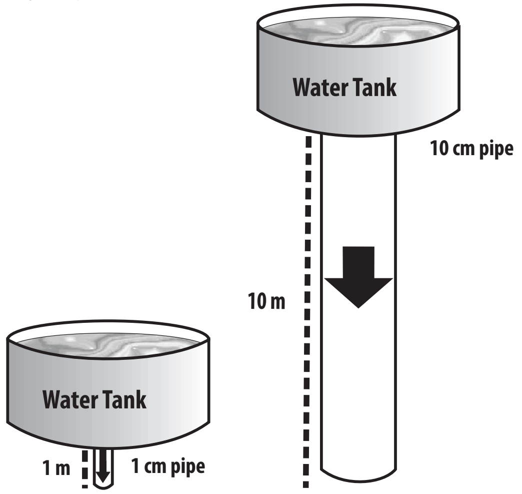
Resistance



OHM'S LAW

- **Voltage = current x resistance**
  V = I x R or V = A x Ω
- **Current = voltage / resistance**
  I = V / R or A = V / Ω
- **Resistance = voltage / current**
  R = V / I or Ω = V / A

Electric Power



ELECTRIC POWER FORMULA

- **Power = voltage x current**
  P= V x I or W = V x A

The distance traveled represents the work done by the car. When we look at power, we are talking about the rate that electrical energy is being produced or consumed. Energy is analogous to the distance traveled or the work done by the car.

A person wouldn't say he took a 40-mile per hour trip because that is the rate. The person would say he took a 40-mile trip or a 120-mile trip. We would describe the trip in terms of distance traveled, not rate traveled. The distance represents the amount of work done.

The same applies with electric power. You would not say you used 100 watts of light energy to read your book, because a watt represents the rate you use energy, not the total energy used. The amount of energy used would be calculated by multiplying the rate by the amount of time you read. If you read for five hours with a 100-W bulb, for example, you would use the following formula:

- **Energy = Power x Time**
  E = P x t

  Energy = 100 W x 5 hours = 500 Wh

One watt-hour is a very small amount of electrical energy. Usually, we measure electric power in larger units called **kilowatt-hours (kWh)** or 1,000 watt-hours (kilo = thousand). A kilowatt-hour is the unit that utilities use when billing most customers. The average cost of a kilowatt-hour of electricity for residential customers is about 12.6 cents.

To calculate the cost of reading with a 100-W bulb for 5 hours, you would change the watt-hours into kilowatt-hours, then multiply the kilowatt-hours used by the cost per kilowatt-hour, as shown below:

500 Wh x = 0.5 kWh

0.5 kWh x $0.126/kWh = $0.063

It would cost about six cents to read for five hours using a 100-W bulb.

Electricity-consuming Devices

Appliances, machines, and electronic devices use about 18 percent of a typical school's energy. Any appliance that is designed to change temperature uses a lot of energy. You can help save energy at school by:

- turning off appliances and machines when you aren't using them;
- keeping the doors closed as much as possible on refrigerators and freezers—know what you want before you open the doors; and
- being aware that many machines use energy even when turned off—save energy by unplugging them.

When schools are shopping for a new appliance or electronic device, there are two prices to consider. The first one covers the purchase price—the down payment. The second price tag is the cost of operating the appliance. The second price will be paid on the utility bill every month for the next 10 to 20 years. An energy efficient appliance will usually cost more to purchase, but it will save a lot of money in energy costs. An energy efficient model is almost always a better deal in the long run.

ENERGY STAR®

School leaders can save money by looking for the **ENERGY STAR®** label—it is a guarantee that the product saves energy. ENERGY STAR® qualified appliances and electronics incorporate advanced technologies that use less energy and water than standard models. A list of energy efficient appliances can be found on the ENERGY STAR® website at www.energystar.gov.

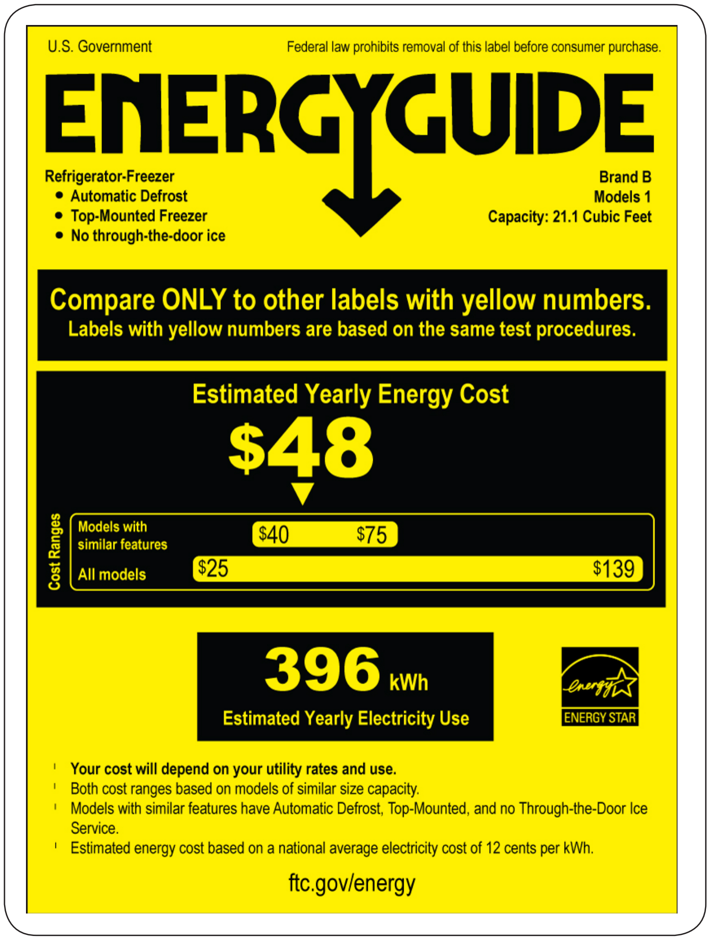
CHANGE FOR THE BETTER WITH ENERGY STAR

EnergyGuide Labels

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

All appliances and electronics will run most efficiently if they are maintained properly. Air vents should be vacuumed periodically to remove dust, and seals on refrigerators and freezers may need to be replaced if they do not seal tightly. A little bit of work will keep a machine running well and save energy costs.

ENERGYGUIDE LABEL



U.S. Government

Federal law prohibits removal of this label before consumer purchase.

ENERGYGUIDE

Refrigerator-Freezer
- Automatic Defrost
- Top-Mounted Freezer
- No through-the-door ice

Brand B
Models 1
Capacity: 21.1 Cubic Feet

Compare ONLY to other labels with yellow numbers.
Labels with yellow numbers are based on the same test procedures.

Estimated Yearly Energy Cost

$48

Cost Ranges

Models with similar features $40 $75

All models $25 $139

396 kWh

Estimated Yearly Electricity Use

ENERGY STAR

- Your cost will depend on your utility rates and use.
- Both cost ranges based on models of similar size capacity.
- Models with similar features have Automatic Defrost, Top-Mounted, and no Through-the-Door Ice Service.
- Estimated energy cost based on a national average electricity cost of 12 cents per kWh.

ftc.gov/energy

Environmental Implications

Generating, transporting, and using all this electricity to power our lives does not happen without impacting the environment. The vast majority of electricity is generated using nonrenewable sources – namely, coal, natural gas, and uranium. Locating, removing, transporting, and using those sources requires energy, too.

In Lesson 1 you learned that every time energy is transformed from one form into another, some of the energy is not transformed into a useable form. Think of all of the energy transformations that occur to generate electricity. Each step, from obtaining the resource to using the source, to turning the turbine, to sending the electrical energy out on the transmission lines to your school involves some losses of useful energy, usually as heat. Thermal power plants that use coal, natural gas, uranium, or biomass, are only 35 percent efficient. That means for every 100 units of energy that go into the plant, only 35 come out as useful electric power! And at that point we haven't even begun to transmit electricity through the lines to your neighborhood or school. That is why generating electricity uses such a large portion of our nation's energy.

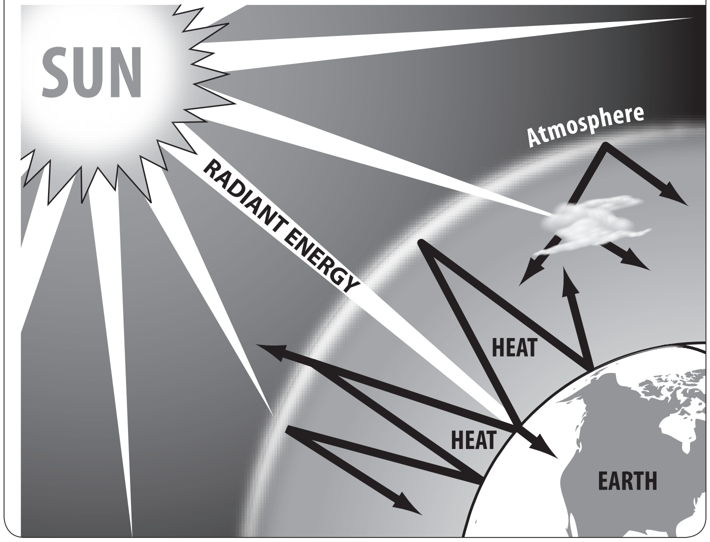
Burning coal and natural gas carry with them environmental consequences beyond using the resources themselves. When coal and natural gas are burned, carbon dioxide is released into the atmosphere. You've heard of carbon dioxide before – it is a waste product from living cells when they use their own energy sources. Carbon dioxide alone isn't a problem and is a necessary part of our natural cycles on Earth. However, when too much of it builds up in the atmosphere, it leads to **climate change**.

The atmosphere around the Earth works just like a blanket on your bed by trapping heat and holding it in. Water vapor, carbon dioxide, and other gases are called **greenhouse gases** because they absorb thermal energy and hold on to it. This is called the **greenhouse effect**, and it's what keeps us from freezing to death every night when we are beyond the sun's warming energy. But just like too much candy, too much of the greenhouse effect is not a good thing.

For thousands of years, carbon dioxide levels on Earth stayed fairly consistent. However, since the Industrial Revolution, when we as a society started using coal and petroleum for energy to run our large machines, the amount of carbon dioxide in the atmosphere has been increasing. This has led to temperature increases world-wide, and is causing large amounts of ice to melt, raising sea levels. Too much carbon dioxide is causing the atmosphere, and also the oceans, to get warmer than they should be.

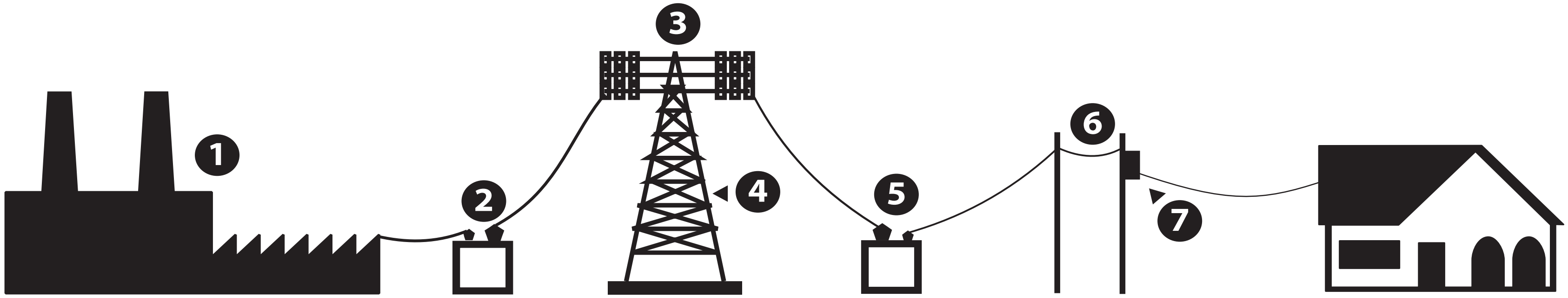
Every time we turn on the lights, or run an electric appliance, we are responsible for more carbon dioxide being released into the atmosphere. There are some things we really must use, like medical equipment and refrigeration to preserve our food. But other times, we can choose to leave something turned off and not contribute to climate change. Open a window instead of running the air conditioner. Read a book instead of watching TV. Eat cold pizza for a snack instead of using the microwave. Once you start thinking about the choices you can make, you will be surprised at how much you can do. Don't avoid typing your paper, however, unless your teacher approves it!

The Greenhouse Effect



Transporting Electricity

Explain what each of the components numbered below does to get electricity from the generator to the consumer.



1. Power plant: ____________________

2. Step-up transformer: ____________________

3. Transmission line: ____________________

4. Power tower: ____________________

5. Step-down transformer: ____________________

6. Distribution line: ____________________

7. Neighborhood transformer: ____________________

Kill A Watt® Meter

The Kill A Watt® meter allows users to measure and monitor the power consumption of any standard electrical device. You can obtain instantaneous readings of voltage (volts), current (amps), line frequency (Hz), and electric power being used (watts). You can also obtain the actual amount of power consumed in kilowatt-hours (kWh) by any electrical device over a period of time from one minute to 9,999 hours. A kilowatt is 1,000 watts.

Operating Instructions

1. Plug the Kill A Watt® meter into any standard grounded outlet or extension cord.
2. Plug the electrical device or appliance to be tested into the AC Power Outlet Receptacle of the Kill A Watt® meter.
3. The **LCD** displays all meter readings. The unit will begin to accumulate data and powered duration time as soon as the power is applied.
4. Press the **Volt** button to display the voltage (volts) reading.
5. Press the **Amp** button to display the current (amps) reading.
6. The **Watt** and **VA** button is a toggle function key. Press the button once to display the Watt reading; press the button again to display the VA (volts x amps) reading. The Watt reading, not the VA reading, is the value used to calculate kWh consumption.
7. The **Hz** and **PF** button is a toggle function key. Press the button once to display the Frequency (Hz) reading; press the button again to display the Power Factor (PF) reading.
8. The **KWH** and **Hour** button is a toggle function key. Press the button once to display the cumulative energy consumption. Press the button again to display the cumulative time elapsed since power was applied.

What is Power Factor?

The formula **Volts x Amps = Watts** is used to find the energy consumption of an electrical device. Many AC devices, however, such as motors and magnetic ballasts, do not use all of the power provided to them. The Power Factor (PF) has a value equal to or less than one, and is used to account for this phenomenon. To determine the actual power consumed by an AC device, the following formula is used:

Volts x Amps x PF = Watts Consumed

Measuring Electricity Use and its Cost

Question

Which devices cost the most to run? Which devices are the most efficient and environmentally-friendly?

Materials

- Assorted electrical appliances and electronic devices
- Kill A Watt® meter

Hypothesis

In your science notebook, write a statement outlining which devices used daily in your classroom or school you think use the most energy. Give reasons why you think they are the biggest energy users.

Procedure

1. Copy the data table into your science notebook if necessary. Leave plenty of room to write and list several devices.
2. Every machine that runs on electricity has an electric nameplate on it. The nameplate is usually on the back or bottom of the device and has the Underwriters Laboratory (UL) symbol on it. This nameplate gives specific information about the electric current and voltage or wattage of the device. It may include other information such as serial number or other specifications, too. The information you need is the current and voltage or the wattage.
3. If the device you wish to test no longer has its nameplate, or it is not easily located, you can use the Kill A Watt® meter. In fact, it might be interesting to look at the information listed on the nameplate and compare it to what the meter tells you the device is using. ***NOTE:** Do not unplug a device at school without making sure it's allowable to do so. Some devices like copiers require long start-up times, and you know what happens if a computer is unplugged before work is saved.
4. If you do not have the wattage from the nameplate and the Kill A Watt® meter is not available, you can use the formula Power (W) = current (Amps) x voltage (V) to calculate the watts the device uses.
5. If the device has multiple modes, such as a printer that can be actively printing, in stand-by mode, or power-saving mode, make sure you use the meter to test all three modes.
6. Phantom loads exist in devices that appear to be completely powered down but are still using a small amount of power. Examples of phantom loads are DVD players with clocks, microwaves with LED clocks, or anything that uses a remote control.
7. Once you have determined the wattage of the device, you will need to estimate the number of hours the device is actively running or engaged in one of its modes if applicable. For example, a refrigerator is not running all day long, every day of the week. Copiers and printers at school are not used overnight or on the weekend.
8. The rest of the data table is calculating the number of kilowatts, kilowatt-hours, cost, and pounds of carbon dioxide expelled into the atmosphere as a result of running the device. Keep in mind that one kilowatt is 1,000 Watts.
9. To calculate the weekly cost of running the device, you will need to know the rate your school is charged for electricity. If you cannot find this amount, use the average cost for schools in the United States of $0.104 per kilowatt-hour.
    a. Hours used x Kilowatts = Kilowatt-hours
    b. Kilowatt-hours x Cost of electricity = Cost to run the device
10. Each year, the U.S. Energy Information Administration (EIA) calculates how much carbon dioxide is released into the atmosphere for every kilowatt-hour of electricity used in the country. In 2016, the average was 1.60 pounds of carbon dioxide per kilowatt-hour consumed. Multiply the kilowatt-hours by 1.6 to calculate how much carbon dioxide is released by using this device.
11. Use the example shown as a guide to show you how the calculations are done.
12. Complete the conclusion questions.

Data

Device	Mode			Hours/ week	Watts	Kilowatts	Kilowatt-hours / week	Rate ($/ kWh)	Weekly cost ($)	CO_2 Released per week (lbs)
	Running	Standby	Phantom							
Copier	x			10	1,265	1.265	12.65	$0.104	$1.32	20.24

Conclusion

Copy the following questions into your science notebook, leaving enough space after each to write your answer.

1. How many weeks per year is your school in full use? Are there any areas of the school that are used year-round?
2. Calculate how much the devices you tested will cost for one school year's use, multiplying the weekly cost by the number of weeks school is in session.
3. Which device is the most expensive to use? How does that compare to your prediction before you did the activity?
4. Which devices turned out to be much less expensive than you thought? Which devices were much more expensive than you had estimated? Does the data for the one device represent all of the devices of this type in the building? How will the cost differ if there are many of the device?
5. Schools need to use electricity to run devices. Simply sitting in the dark, doing nothing, is not an option. With this in mind, brainstorm three things you as students can do to reduce the amount of electricity your school uses, and calculate how much you can save if you do these three things.
6. Sometimes appliances like refrigerators and soda machines are left plugged in year-round. With permission, determine how much money can be saved for each week they are unplugged when school is not in session, such as during long breaks and over the summer. You will need to gather the same data about those machines as you did during this activity.

Sample School Electric Bill

Nov 27, 2016 ①

Customer Bill

ABC Elementary School
Anytown, USA

Your Electric Company

Billing and Payment Summary

Account # 000-1234 ② **Due Date: Jan 02,2017** ③

Total Amount Due: $ 7,462.61 ④

To avoid a Late Payment Charge of 1.5% please pay by Jan 02, 2017

Previous Amount Due:	$ 8,152.93
Payments as of Nov 27:	$ 8,152.93

Meter and Usage

Usage History

Current Billing Days: 34

Billable Usage

Schedule 130	*10/23 - 11/26* ⑫
Total kWh	12192
Dist Demand	61.0 ⑩
Demand	57.0
Schedule 130	*10/23 - 11/26*
Total kWh	69888
Dist Demand	272.0 ⑩
Demand	259.0

Measured Usage ⑤

Meter: 000-1234	*10/23 - 11/26*
Current Reading	4147
Previous Reading	4020
Total kWh	12192 ⑥
Current Reading	.60
Demand	57.60 ⑪
Multiplier: 96	
Meter: 111-4567	*10/23 - 11/26*
Current Reading	51746
Previous Reading	51382
Total kWh	69888 ⑥
Current Reading	1.35
Demand	259.20 ⑪
Multiplier: 192	

Explanation of Bill Detail

Your Electric Company		**1-800-123-4567**
Previous Balance	**8,152.93**	
Payment Received	**8,152.93**	
BALANCE FORWARD		**0**
Non-Residential Service (Schedule 130)	***10/23 - 11/26***	
Distribution Service		
Basic Customer Charge		**86.52**
Distribution Demand		**206.29**
⑬ **Electricity Supply Service (ESS)**		
ESS Adjustment Charge		**83.93 CR**
Electricity Supply kWh		**214.94**
ESS Demand Charge		**558.85** ⑦
Fuel Charge		**353.81**
Sales and Use Surcharge		**2.68** ⑧
Non-Residential Service (Schedule 130)	***10/23 - 11/26***	
⑭ **Distribution Service**		
Basic Customer Charge		**86.52**
Distribution Demand		**919.87**
Electricity Supply Service (ESS)		
ESS Adjustment Charge		**374.243 CR**
Electricity Supply kWh		**909.41**
ESS Demand Charge		**2,539.36** ⑦
Fuel Charge		**2,058.15**
Sales and Use Surcharge		**13.38** ⑧
TOTAL CURRENT CHARGES		**7,463.61** ⑨
TOTAL ACCOUNT BALANCE		**7,463.61** ④

For service emergencies and power outages, call 1-800-123-4567.

Mailed on Nov 28, 2016

Please detach and return this payment coupon with your check made payable to Your Electric Company.

Payment Coupon

Bill Date Nov 27, 2016 ①

Please Pay by 01/02/ 2017 ③
$ 7,463.54 ④

Amount Enclosed

Account # 000-1234 ②

Send payment to:

ABC Elementary School
123 Main Street
Anytown, USA 98765

Your Electric Company
PO BOX 123456
Anytown, USA 98765

01166005000 000000009368 6868686 0001234 11272007

Sample School Electric Bill Explanation and Discussion

Explanation

1. Bill mailing date
2. Customer account number
3. Payment due date
4. Total amount due
5. Meter readings by date in kilowatt-hours (note that there are two meters on this bill)
6. Actual kilowatt-hours consumed
7. Cost of the electricity consumed
8. Sales and use surcharge
9. Total current charges
10. Demand. This is a measurement of the rate at which electricity is used. The monthly demand is based on the 15 minutes during a billing period with the highest average kilowatt use. Demand charges are designed to collect some of the generation and transmission-related costs necessary to serve a particular group or class of customers.
11. Actual demand for the meter
12. Schedule 130. A rate class that determines how much is paid per kWh of usage and kW demand
13. Electricity supply service. Customers are billed for the electricity supply and the delivery of the electricity. The supply charge reflects the cost of generating the electricity at the power plant.
14. Distribution service. The delivery charge reflects the cost of delivering the electricity from the power plant to the customer.

Discussion

The appearance of utility bills will be different from one utility to the next, but they typically contain the same information. The rate that a school or other commercial building pays for electricity is determined by measuring two items: the electrical energy usage, in kilowatt-hours, and the electrical energy demand, measured in kilowatts.

The demand is the maximum amount of power that the building needed within a time frame. The higher the total amount of kilowatts being used at any given time by a building, the higher this charge is. Demand can be reduced by rescheduling when high energy devices are running, or scheduling them such that their use is spread out evenly throughout the day. For example, vacuum cleaners or other appliances with high energy motors can be run after school is over, when other devices are turned off. Professional energy managers can make recommendations about this scheduling, or some other changes that can help a building's occupants reduce the demand portion of their electric bill.

The energy use portion is how much electrical energy, in kilowatt-hours, is used in total during the billing period. The more devices turned on and running, the higher the energy use charge is. This portion of the utility bill can be reduced by turning off unnecessary items or installing more efficient equipment. For example, computer monitors in a school computer lab can be turned off at the end of the school day, or ENERGY STAR®appliances can be used in place of older, less efficient models.

Ask your teacher, principal, or building manager for a copy of the school's electric bill, and identify as many of the above items on it as you can. If you have more than one building in your school district, see if you can get bills for other buildings to compare. Talk about ways you as students can help reduce both the demand as well as the energy use portions of your school's utility costs.

Comparing Appliances

Comparing EnergyGuide Labels

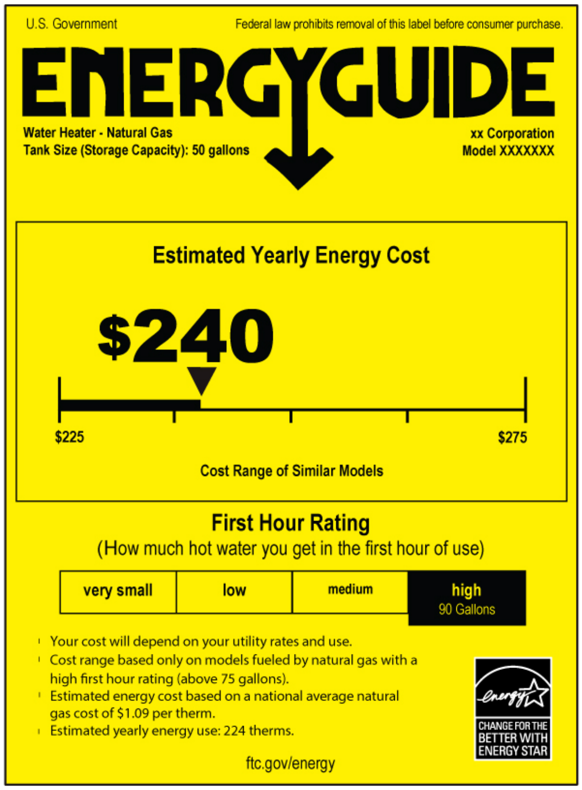
Your family needs to buy a new water heater. Water heaters usually last a long time—10 years or more—so you can save a lot of money using an energy-efficient one. Use the chart below to figure out which water heater to buy, comparing the information on the EnergyGuide labels.

Water Heater 1—Purchase Price: $750.00 **Water Heater 2— Purchase Price: $650.00**

WATER HEATER 1	EXPENSES	COST TO DATE	WATER HEATER 2	EXPENSES	COST TO DATE
Purchase Price			**Purchase Price**		
Year One			**Year One**		
Year Two			**Year Two**		
Year Three			**Year Three**		
Year Four			**Year Four**		
Year Five			**Year Five**		
Year Six			**Year Six**		
Year Seven			**Year Seven**		

How many years will it take before you begin to save money?______________________________

How much money will you have saved after seven years? ______________________________



U.S. Government
Federal law prohibits removal of this label before consumer purchase.

ENERGYGUIDE

Water Heater - Natural Gas
Tank Size (Storage Capacity): 50 gallons
xx Corporation
Model XXXXXXX

Estimated Yearly Energy Cost

$240

$225 $275

Cost Range of Similar Models

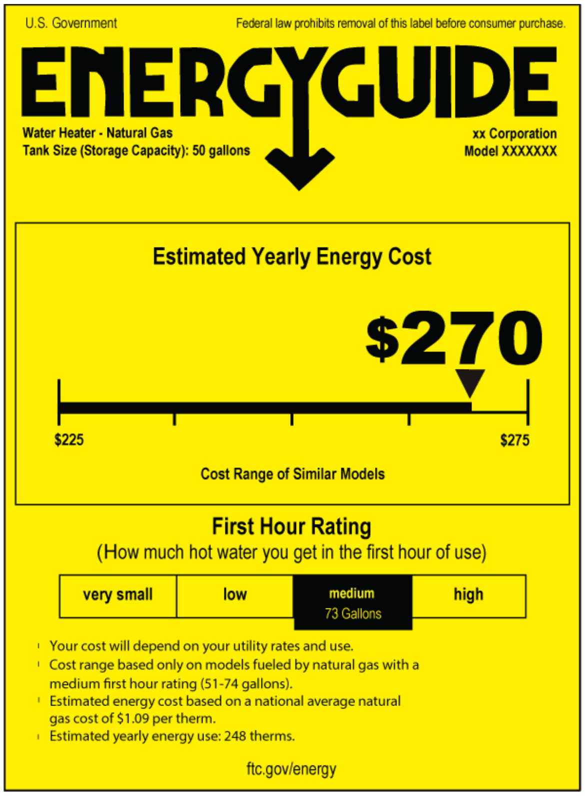
First Hour Rating
(How much hot water you get in the first hour of use)

very small | low | medium | high 90 Gallons

- Your cost will depend on your utility rates and use.
- Cost range based only on models fueled by natural gas with a high first hour rating (above 75 gallons).
- Estimated energy cost based on a national average natural gas cost of $1.09 per therm.
- Estimated yearly energy use: 224 therms.

CHANGE FOR THE BETTER WITH ENERGY STAR

ftc.gov/energy



U.S. Government
Federal law prohibits removal of this label before consumer purchase.

ENERGYGUIDE

Water Heater - Natural Gas
Tank Size (Storage Capacity): 50 gallons
xx Corporation
Model XXXXXXX

Estimated Yearly Energy Cost

$270

$225 $275

Cost Range of Similar Models

First Hour Rating
(How much hot water you get in the first hour of use)

very small | low | medium 73 Gallons | high

- Your cost will depend on your utility rates and use.
- Cost range based only on models fueled by natural gas with a medium first hour rating (51-74 gallons).
- Estimated energy cost based on a national average natural gas cost of $1.09 per therm.
- Estimated yearly energy use: 248 therms.

ftc.gov/energy

Understanding Lighting

Lighting

Legislation under the Energy Independence and Security Act put restrictions on how much energy light bulbs use. Traditional bulbs, called **incandescent** bulbs, have been replaced by more efficient bulbs like **halogens**, **compact fluorescents**, and **light emitting diodes** (LEDs) on store shelves.

Lighting accounts for nine percent of a school's energy use, which translates to about 17% of the school's electricity bill. Much of this can be the result of using inefficient lighting, while some can be attributed to wasteful lighting behaviors. Some schools may still use incandescent lighting in various lamps and fixtures in small spaces. Incandescent lighting is very inefficient, in that only 10 percent of the energy consumed actually produces light. The rest is given off as heat. There are other more efficient lighting choices on the market, including halogens, fluorescents, and LEDs. Halogens are sometimes called energy-saving incandescent bulbs because they last slightly longer, and use less energy than traditional incandescent bulbs, however they can burn hotter than incandescent lights do. Fluorescent lights produce very little heat and are even more efficient. Most schools use fluorescent tube lighting throughout the building, but may use incandescent bulbs in other spaces around the school.

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.

INCANDESCENT BULB

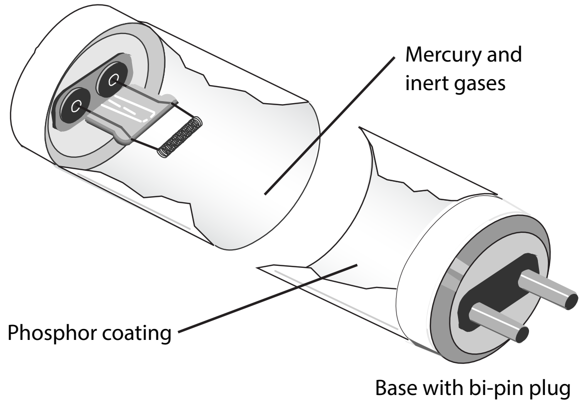
HALOGEN BULB

CFL BULB

LED BULB

LEDs offer better light quality than incandescent bulbs and halogens, last 25 times as long, and use even less energy than CFLs. LEDs now have a wide array of uses because technology has improved and costs have decreased. It is possible to see CFL use decrease as LED costs continue to improve.

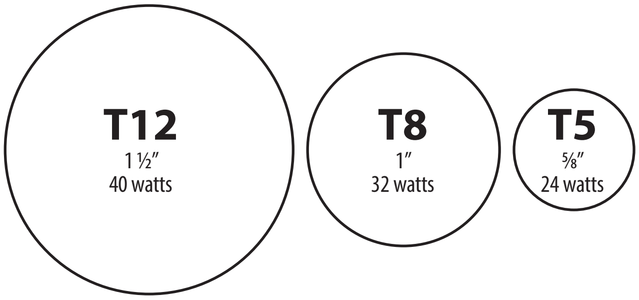
Fluorescent Tube Lamp



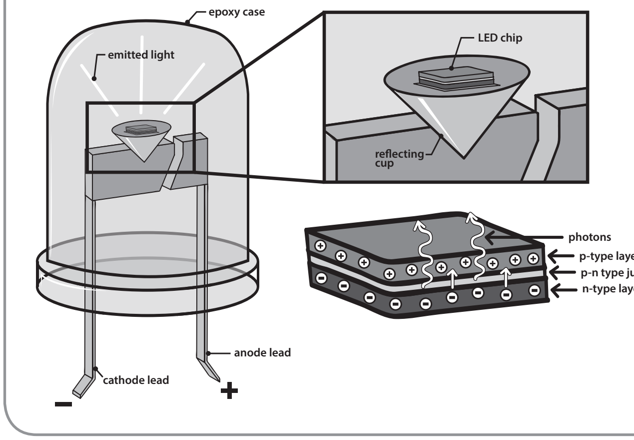
In fluorescent tubes, a very small amount of mercury mixes with inert gases to conduct the electric current. This allows the phosphor coating on the glass tube to emit light.

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.



Inside an LED



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.

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 11/2” 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 5/8” in diameter and are even more efficient than the T8 lamps.

LEDs have been commonly found in electronic devices and exit signs. Now they are offered as affordable options for lighting in homes and businesses. Light emitting diodes contain **semiconductors** like solar panels; the difference is in the way the electrical energy is used by the LED. Three layers within the LED – p-type, n-type, and a **depletion zone** – combine to produce light. A minimum voltage is needed to energize electrons and they move from the n-type layer to the p-type layer. When the electrons move back again, they emit light that we see. The section of text called “How Light Emitting Diodes Work” below explains this process in more detail.

One of the quickest and easiest ways to immediately decrease a school electricity bill is to install CFL or LED bulbs in the place of incandescent or halogen bulbs in individual fixtures. For every 100-watt incandescent bulb replaced, a savings of $30-$80 can be realized over the lifetime of the bulb. A CFL uses 75 percent less energy than an incandescent, and an LED bulb uses even less energy. CFL and LED bulbs last longer than incandescent bulbs, too. Each type of bulb has benefits as well as drawbacks. For example, a CFL is less expensive than an LED, but it is more fragile, contains mercury, and is not always dimmable. An LED is more durable than a CFL, but it is heavier and is sometimes more expensive. Both types are available in a wide variety of shapes and light colors. When shopping for a replacement bulb, look for ENERGY STAR® rated bulbs for the best quality and energy efficiency ratings, and make sure the bulb you buy produces the same brightness of light, as measured in lumens.

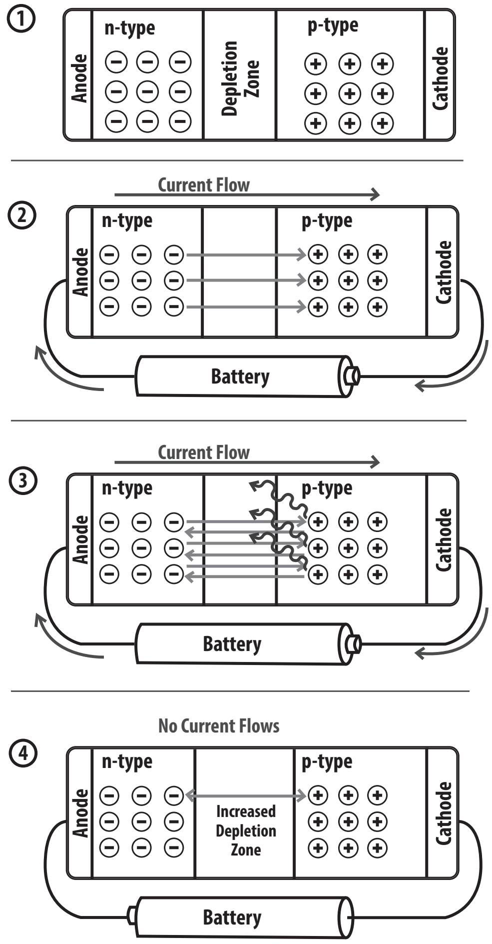
There are a few ways you can save energy on lighting in the school:

- switch incandescent bulbs to CFLs or LEDs;
- shut off lighting when exiting the room; and
- use natural light by opening blinds or curtains when possible.

How Light Emitting Diodes Work

1. Diodes are made of semiconductors and conducting materials that need to be added to the semiconductor. In an LED the most common conductor added is aluminum-gallium-arsenide (AlGaAs). The AlGaAs is “doped” by adding small amounts of another material. One material will have more valence electrons than AlGaAs, and another doping material will have fewer electrons. The two doped materials are put together in a crystal. The material with more electrons is the “n-type” (n for negative) and the material with fewer electrons is the “p-type” (p for positive). When these materials are sandwiched together, the electrons move to balance themselves out. The area between the materials, called the p-n junction, is also called the “depletion zone.”
2. Connecting a power source to the diode, such as a battery, provides electric current that carries electrical energy. The electrons in the n-type are repelled by the electric current, and move through the depletion zone to the p-type. They are energized, and will want to return to their original, unenergized state in the n-type.
3. When the electrons move back through the depletion zone to the n-type, they release energy as light. This is the light that we see from the LED. This process continues over and over again–electrons absorbing energy, moving, then moving back and releasing the energy, until the power supply is disconnected or depleted.
4. Connecting the power supply in the wrong orientation does not allow the LED to work. Instead, it merely increases the size of the depletion zone. Therefore, it is important that LED’s be wired to their power supply in the correct orientation.

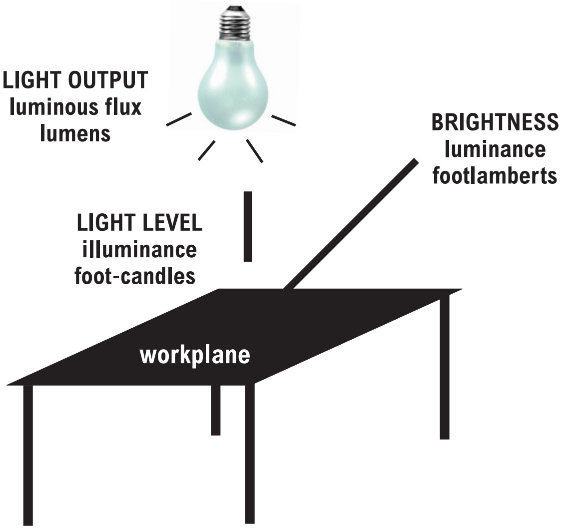
How Light Emitting Diodes Work



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).

Light Bulb Investigations

Questions

What is the difference in thermal energy output of different light bulbs?

What is the difference in light output of different light bulbs?

How do light bulbs compare in the amount of energy used?

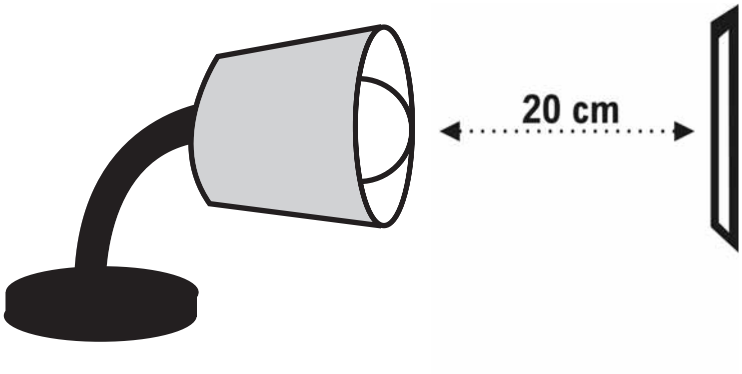
Materials

- 3 Lamps
- 1 Incandescent or halogen incandescent light bulb and its packaging
- 1 Compact fluorescent light bulb (CFL) and its packaging
- 1 Light emitting diode bulb (LED) and its packaging
- 3 Thermometers
- Tape
- Kill A Watt® meter
- Light meter
- Ruler or meter stick

Hypothesis

In your science notebook, write hypotheses stating which bulbs you think will be the hottest, brightest, and use the most energy.

✔ Procedure



1. Copy the data table into your science notebook, if necessary, leaving plenty of room to record your observations.
2. Place the incandescent bulb in one lamp, the CFL in another lamp, and the LED bulb in the third lamp. If you do not have three lamps, conduct three trials, one for each bulb.
3. Place the lamps on a table about 20 cm away from a blank wall. The light should face the wall.
4. Tape the thermometers to the wall so the lamps shine directly on them, as shown in the diagram.
5. Record the thermometer readings every two minutes.
6. Calculate and record the change in temperature (ΔT) for each bulb.
7. Turn on the light meter and remove the cover from the sensor. Place the sensor on the wall in front of the thermometer and record the foot-candles for each bulb.
8. Turn off each lamp and unplug them. Plug one into the Kill A Watt® meter and plug the meter into the wall. Push the Watts button and turn on the lamp. Record the power used by the lamp. Repeat for the other two lamps.
9. Answer the conclusion questions.

Data

Bulb type	Package stated Wattage	Package stated Lumens	Temperature (Celsius)							Light meter reading	Kill-a-Watt meter reading
			0 min	2 min	4 min	6 min	8 min	10 min	ΔT		
Incandescent											
CFL											
LED											

⁂ Conclusion

Copy the following questions into your science notebook, leaving plenty of room for answers.

1. Rank the bulbs in order of brightness, the first being the brightest. Does this ranking reflect the ranking of the bulbs according to the lumens listed on the package? Explain why you think this is.
2. The three bulbs emit light using three different methods. Based on your observations of temperature change, which bulb do you think is most efficient at producing light? Does this agree with the watts recorded on the Kill A Watt® meter?

Comparing Light Bulbs

The graphic on the previous page shows four light bulbs that produce the same amount of light. You might use bulbs like these as a bright overhead light. One bulb is an incandescent light bulb (IL), one is a halogen, one is a compact fluorescent light (CFL), and another is a light emitting diode (LED). Which one is the better bargain? Let's do the math and compare the four light bulbs using the residential cost of electricity at $0.126/kWh.

1. Determine how many bulbs you will need to produce 25,000 hours of light by dividing 25,000 by the number of hours each bulb produces light.
2. Multiply the number of bulbs you will need to produce 25,000 hours of light by the price of each bulb. The cost of each bulb has been given to you in the chart below.
3. Multiply the wattage of the bulbs (using the kW number given) by 25,000 hours to determine kilowatt-hours (kWh) consumed.
4. Multiply the number of kilowatt-hours by the cost per kilowatt-hour to determine the cost of electricity to produce 25,000 hours of light.
5. Add the cost of the bulbs plus the cost of electricity to determine the life cycle cost for each bulb. Which one is the better bargain?
6. Compare the environmental impact of using each type of bulb. Multiply the total kWh consumption by the average amount of carbon dioxide produced by a power plant. This will give you the pounds of carbon dioxide produced over the life of each bulb. Which one has the least environmental impact?

All bulbs provide about 850 lumens of light.

	COST OF BULB	**INCANDESCENT BULB**	**HALOGEN**	**COMPACT FLUORESCENT (CFL)**	**LIGHT EMITTING DIODE (LED)**
	Life of bulb (how long it will light)	1,000 hours	3,000 hours	10,000 hours	25,000 hours
	Number of bulbs to get 25,000 hours				
x	Price per bulb	$0.50	$1.5	$1.5	$1.33
=	**Cost of bulbs for 25,000 hours of light**				
	COST OF ELECTRICITY	**INCANDESCENT BULB**	**HALOGEN**	**COMPACT FLUORESCENT (CFL)**	**LIGHT EMITTING DIODE (LED)**
	Total Hours	25,000 hours	25,000 hours	25,000 hours	25,000 hours
x	Wattage	60 watts = 0.060 kW	43 watts = 0.043 kW	13 watts = 0.013 kW	12 watts = 0.012 kW
=	Total kWh consumption				
x	Price of electricity per kWh	$0.126	$0.126	$0.126	$0.126
=	**Cost of Electricity**				
	LIFE CYCLE COST	**INCANDESCENT BULB**	**HALOGEN**	**COMPACT FLUORESCENT (CFL)**	**LIGHT EMITTING DIODE (LED)**
	Cost of bulbs				
+	Cost of electricity				
=	**Life cycle cost**				
	ENVIRONMENTAL IMPACT	**INCANDESCENT BULB**	**HALOGEN**	**COMPACT FLUORESCENT (CFL)**	**LIGHT EMITTING DIODE (LED)**
	Total kWh consumption				
x	Pounds (lbs) of carbon dioxide per kWh	1.6 lb/kWh	1.6 lb/kWh	1.6 lb/kWh	1.6 lb/kWh
=	**Pounds of carbon dioxide produced**				

Energy Systems Working Together

At this point we have investigated energy use one form at a time. However, the overall energy consumption picture of a school is much more complicated than isolating one classroom or one facet of the building. The lights, heating, and electrical systems throughout the building work with the insulation and building envelope to keep us comfortable while we learn.

The heating, ventilation, and air conditioning system (HVAC) in your school is a good example. If your school has a central boiler system, it probably uses natural gas or fuel oil to heat water. Some boiler systems heat the water into steam, and others simply heat the water to near-boiling. Regardless of which fuel is used, and whether it distributes hot water or steam, the heating system needs pumps that run on electricity to send the hot water or steam out into the school. In the event of an electric power failure, those pumps will not be able to distribute water or steam and the building will get cold.

Most schools have two boiler systems that each could heat the building on its own. The reason for duplicating equipment is two-fold. First, if one system should break down, there is a second already in place to heat the school. Second, if the outdoor weather is exceptionally cold, the maintenance staff can turn on the second system to supplement the first and keep the school at a reasonable temperature. However, even two systems are useless if the power goes out and the pumps cannot run to distribute the water or steam.

During hot weather, instead of heating the building, a cooling system is used. Instead of circulating warm water to heat the rooms, a cooling system uses refrigeration to cool air, then blow the cool air into rooms. The compression unit of the cooling system uses a lot of electricity, as do all the fans to distribute the cold air.

Heating and cooling a large building like a school is a complex process, and needs to account for the mobile heating units that fill it throughout the day – the people. The human body is constantly radiating thermal energy, and adjusting the temperature of the room needs to be done while it is full of students, not when it is empty. Otherwise, the room will be too hot to be comfortable. Thus, you are an important part of your school's energy use system!

There are many other systems that work together in other ways in your school, but the most important part of those systems is the people who use them. People are the brains of the energy use and they are the part of the system that will have the most impact on how much energy they use.

The Energy Efficient School: A Cautionary Tale

Washington School is an imaginary K-8 school somewhere in the U.S. where winters are cold and summers are warm. It was built in the 1950s, but the principal, Mrs. Johnson, recently applied for and won a grant to give the school an energy efficiency overhaul. Over the course of two years, maintenance crews worked with special companies to replace the lights, light switches, thermostats, and HVAC system to new, efficient, computer-controlled equipment. The walls were given additional insulation, and windows were replaced with high-efficiency, triple-pane windows.

Before the work was done, Mrs. Johnson was careful to instruct the teachers and students to please turn off lights when leaving a room empty, and adjust the temperature a little bit at the end of each school day – cooler in winter and warmer in summer – to help save energy. The students and staff at Washington School really like Mrs. Johnson and they wanted to save energy, keep costs down, and keep their carbon footprint as small as possible, so they were very cooperative. However, as is always the case, someone would forget to turn off the lights or adjust the thermostat, and the night custodian would have to do it long after school was over. That was what prompted Mrs. Johnson to apply for the grant.

Now that the work is done, the school looks almost brand-new. The old boilers have been replaced with smaller, 90% efficient models, and they are controlled through a computer that is in the maintenance office. Here, the maintenance staff can look any time to see what systems are operating and what the temperature is in any room. There is even a smart phone app that can be used remotely! The building manager has set the heating system to come on October 1 and turn off April 1. The temperature is set higher during the school day and cooler at 4:00 and on weekends, when nobody is there. The air conditioner turns on April 1, turns off October 1, and is set in a similar fashion as the heating system, to use less energy in the evenings and on the weekend.

The old, fluorescent light fixtures have been replaced with smaller LED lights that direct the light directly on the work surface. The students like the light better because it's not as bright, and some corners of the classroom can be a little darker for computer or tablet use, or even sneaking in a nap. All of the lights are controlled by motion-detecting light switches, which automatically turn the lights off in a room that has been empty after 20 minutes, but allow students and staff to immediately turn the lights off, too.

Mrs. Johnson was very excited about all the upgrades throughout her school, and she could tell that her students and staff were, too. However, when the next utility bills came, she did not see the savings that she thought she would. She couldn't understand why all this new equipment hadn't made much difference. Mrs. Johnson asked the superintendent for some help, and the school board agreed to hire an energy manager to evaluate what was going on.

The energy manager, Terry, first walked through the building in the evening when no one was there. Walking into room after room, the lights would pop on, and Terry noticed that the lights were staying on for 20 minutes in rooms that the custodian had been in for only a few minutes. Terry wrote some notes in a small notebook.

Terry checked the rest of the building: Water heaters, locker room showers, cafeteria equipment, athletic equipment, administrative offices, and the library. Terry found that the water temperature was 160 °F throughout the building and that some of the showers in the boys' locker room were dripping. Terry also counted three full-size refrigerators in the teachers' lounge that were less than 1/3 full, and ten additional mini-fridges throughout the building. Again, Terry made some notes.

Next, Terry evaluated the school's utility bills, and compared the computer control system for the HVAC to the school calendar. Terry saw several days when the school was not as full as it should be. There were a few half-days for students, when teachers left for professional development. Some classes took field trips. And of course, there were single holidays and longer breaks scattered throughout the year when school was not in session. And yet, the computer-controlled system had been set to the same setting, Monday through Friday, week after week. Terry made some more notes.

Spot the Energy Wasters

What do you think of Washington School's energy efficiency overhaul? Read through the story as many times as necessary, noting things that you think the students and staff should be doing to save energy.

Next, work in a small group, with 2 or 3 other students, and compare your notes. Make a complete list of things Washington School needs to do, or stop doing, to save energy. Then, as a group, write an Action Plan for Washington School.

Washington School Saving Energy List

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Washington School Energy Action Plan!

Evaluating Energy Use in a Building

Before moving on, let's stop and reflect on everything you have learned. In Lesson 1 you learned about energy use – where we get it, who uses it, how much of it is used by which systems in a school, and so on. Lessons 2, 3, and 4 focused on thermal energy, electricity, and lighting, and Lesson 5 discussed how all the energy systems in a school work together to create the whole energy consumption snapshot of the school. Now you're ready to take the next step, and conduct a student energy audit.

If you ask your parents about audits, they might tense up a little and talk about taxes. A tax audit is usually very stressful. Energy audits are not intended to be stressful; in fact, they should be positive, because you and your audit team are working to help your school use less energy, and by doing so save money and help the environment.

Professional energy audits, such as the one that Terry conducted in Washington School in Lesson 5, are conducted over several days and involve recommendations with specific amounts of money that will be saved by the school if implemented. Your audit will not be that detailed, but can be almost as helpful. You will be assigned a work area to monitor, and you and your audit team of 3 or 4 students will look at that area, make some notes, take some data, and make some recommendations.

Work Area

Your teacher will assign a room or group of rooms for you to audit. Ideally, you will make observations at two different times, when the class is empty, and when it is full of students who are working. However, that is up to the teacher whose classroom you are auditing. If you enter a room that is in use, remember to be as quiet as you can, and quickly and efficiently take your measurements.

Most classrooms in your building will have similar data with few differences from one room to the next. However, you have some spaces, such as computer labs, science labs, gymnasiums, and the library, that use energy differently from a typical classroom, so you should expect to need to make different notes and record somewhat different data in those rooms.

Auditing Tools

There are several important auditing tools that you will use, but the two most important are tools you have with you all the time, even at home. You are using one of those tools right now, as you read – your eyes. The other important tool is your ears. Many observations are seeing what is happening in a room, and listening for things that are running. You will see more and hear best if you are quiet and not talking to your audit teammates.

The other auditing tools that you will use are a thermometer, hygrometer, light meter, and maybe a Kill A Watt® meter. Make sure you know how to use each of these tools. Take good care of them because other audit teams will have to use them, too. Instructions for using each of the tools are on pages 31, 39, 48, and 49. Additionally, your teacher may have you conduct the tissue paper test from Lesson 2 on the windows in your work area.

Making Notes

There is much more to an audit than temperature, relative humidity, and light level. You need to know what is turned on and running, and whether that is an appropriate device to be running at the time. You need to know if there are many windows or few, and how well they keep outside air outside. Be consistent with the way you take notes. If you cannot explain to a team member why you think something is important to note, then it probably is not necessary.

Note anything unusual, such as fish or reptile tanks, and what electrical devices they have, fans, lamps, and other devices that are not part of a standard classroom, and anything else being used in the classroom. Do not note things that are not plugged in and running. Use the Kill A Watt® meter to determine the phantom load of devices like projectors and DVD players. Also, do not neglect unusual things like vending machines and drinking fountains. If the cooling unit of a drinking fountain is not running properly, the water will come out warm. That is something that should definitely be noted in your report.

Recording Data

The measurements you take need to be taken in a consistent way. Don't carry the thermometer by the probe; otherwise, it is only measuring how well your hands warm the thermometer, not the temperature of the room. The same is true about the hygrometer. You aren't interested in how sweaty your palms are, just how much moisture is in the air in the room. When measuring light levels, place the sensor on the desktop or table top and don't lean over it. Rather, lean back and read the meter. It might be helpful to have one person hold the sensor in place while you read the meter. If you are measuring light in a room without tables, like the gym or hallway, hold the sensor at waist or chest height in front of you, and make sure you are not casting a shadow on it.

If you notice significant temperature differences from one area of the room to another, record several temperatures and then take the average, and record the average. The same principle applies to light levels. Measure light levels at different parts of the room and average.

Making Recommendations

After you have taken measurements and made notes in your entire work area, it's time to evaluate the data you have collected and make some recommendations that will save energy. Keep in mind there are some things that cannot change, like leaving lights on in the hallways or using computers during the day. It is not practical for teachers to turn copy machines off after using them because they require a lengthy amount of time to start up again. As you evaluate your data, think of things that can be done right away to save energy, and which things might need to be put off for the future.

In our imaginary school example, Terry found several things that could be done right away. First, instead of waiting for the motion sensors to turn off the lights, teachers and students are still able to turn lights off right away when leaving a room. Second, instead of having several mini fridges scattered throughout the school and large refrigerators that are mostly empty, teachers could store their beverages and lunches in the teachers' lounge. A full refrigerator uses less energy than a mostly empty one, and the mini fridges won't use any if they aren't plugged in. Third, the hot water temperature was much too high, and hot water was being wasted in the dripping showers. All of these suggestions cost no money to employ, and can save the school a lot of money in reduced energy costs.

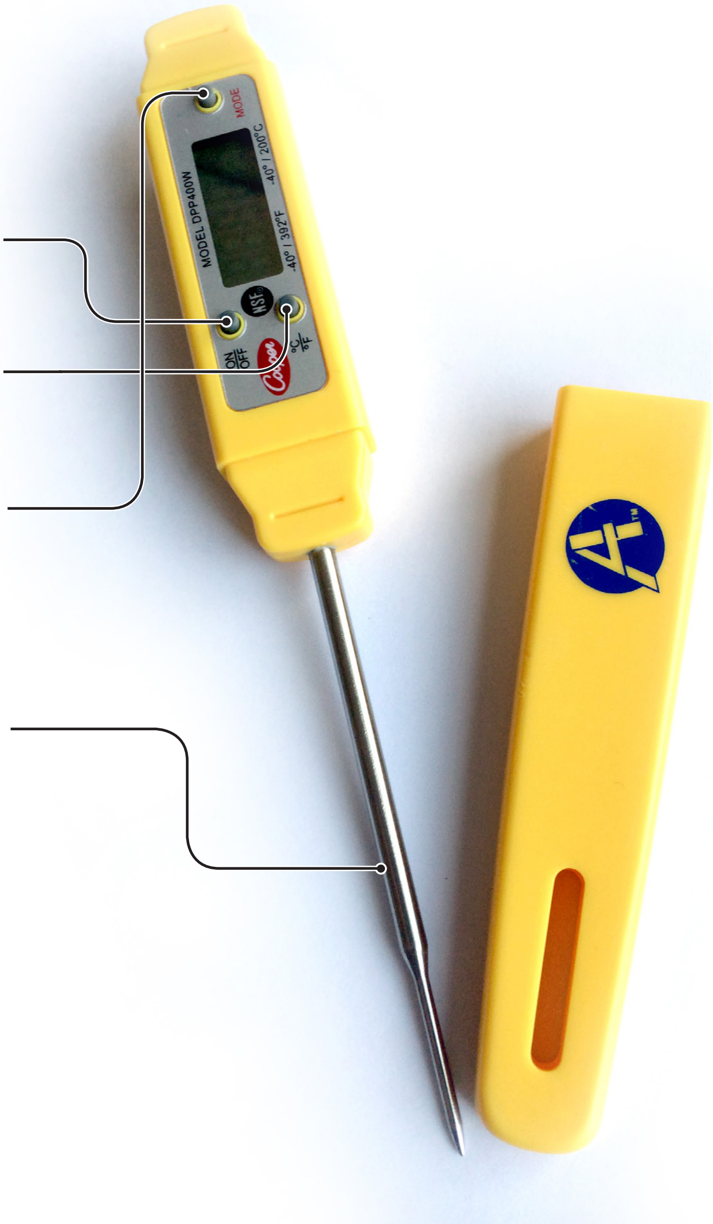
When you make your recommendations and present your findings, back up your claims with the evidence you collected in your audit. If you found six lights left on that total 100 watts of power, calculate the cost per month or year based on your school's electrical use rate and explain how that much money could be saved by turning those lights off. Be respectful and stick to the evidence you collected. It's difficult to argue with data because numbers don't lie. Don't make judgments about how much energy is being used; instead, focus on how much money can be saved. Keep your recommendations positive.

Audit Tools and Instructions

You have already used the light meter and the Kill A Watt® meter in other activities. Review those instructions now, and then study the following pages to familiarize yourself with the digital thermometer and hygrometer. Remember, if you don't know, ask.

Digital Thermometer

A digital thermometer measures the temperature of a substance and displays the temperature reading on its face. It has a battery for power. Sometimes they are waterproof for measuring the temperature of a liquid.



This digital thermometer can measure the temperature in Fahrenheit or Celsius. It shows the temperature range of the thermometer. It can read temperatures from -40° to 392°F and -40° to 200°C.

It has three buttons. The button on the bottom left is the **ON/OFF** switch. If the thermometer is not used for a few minutes, it turns itself off.

The **C/F** button on the bottom right switches from the Celsius scale to the Fahrenheit scale. The face of the thermometer will show a C or an F to indicate which scale is being used.

The **mode** button on the top holds the temperature reading when it is pushed. If you need the exact temperature of a liquid, you push the hold button while the thermometer is in the liquid, then remove the thermometer to read it. This button will also allow you to view the maximum and minimum temperatures measured when pushed two or three times.

The **metal stem** of the thermometer can measure the temperature of the air or the temperature of a liquid. The stem should be placed about halfway into a liquid to measure the temperature.

Hygrometer

HUMIDITY/TEMPERATURE PEN

Scientists measure the amount of water vapor in the air in terms of relative humidity—the amount of water vapor in the air relative to (compared to) the maximum amount it can hold at that temperature. Relative humidity changes as air temperature changes. The warmer the air is, the more water vapor it can hold.

Air acts like a sponge and absorbs water through the process of evaporation. Warm air is less dense and the molecules are further apart, allowing more moisture 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 humidity in occupied spaces. Humidity levels that are too high can contribute to the growth and spread of unhealthy biological pollutants. This can lead to a variety of health effects, from common allergic reactions to asthma attacks and other health problems. Humidity levels that are too low can contribute to irritated mucous membranes, dry eyes, and sinus discomfort.

This digital humidity/temperature pen measures relative humidity and temperature and displays the readings on its face. It has a battery for power. It can display the temperature in Fahrenheit or Celsius. The reading shown on the right is 68.5°F. Devices that measure humidity are also called hygrometers.

The hygrometer displays relative humidity in terms of percentage. The hygrometer shown reads 35%. This means that the air contains 35 percent of the water vapor it can hold at the given air temperature. When the air contains a lot of water vapor, the weather is described as humid. If the air cannot carry any more water vapor, the humidity is 100 percent. At this point, the water vapor condenses into liquid water.

Maintaining relative humidity between 40 and 60 percent 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. High humidity is uncomfortable for many people. It is difficult for the body to cool down in high humidity because sweat cannot evaporate into the air.

Directions

ON/OFF KEY

Press the ON/OFF key to turn the power on or off.

°F/°C

Press the °F/°C key to select the temperature unit you want to use, Fahrenheit or Celsius.

MAX/MIN

Press the MAX/MIN key once to display the stored maximum readings for temperature and humidity.

An up arrow will appear on the left side of the display to indicate the unit is in the maximum recording mode.

Press the MAX/MIN key a second time to display the stored minimum readings for temperature and humidity. A down arrow will appear on the left side of the display to indicate the unit is in the minimum recording mode.

Press the MAX/MIN key a third time to return to normal operation.

CLEAR

If an up or down arrow is displayed, press the CLEAR key until - - - appears on the display. The memory is cleared. New maximum or minimum values will be recorded within 3 seconds.

Recommended Light Levels

Below is a list of recommended illumination levels for school locations in foot-candles. These illumination levels align with the recommendations from the Illumination Engineering Society of North America.

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	20-30
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

School Building Survey

General Information

1. When was the school built?
2. What changes have been made since the school was built? When were they made?
3. What things use energy on the school grounds? Lighted fields? Outdoor lighting?
4. What fuels are used in the school? For heating, cooling, water heating, lighting, other?
5. How much does the school pay each year for energy? How much for electricity? How much for heat?
6. Are there other energy costs that the school pays for, like buses?
7. How many hours is the school in use each week?
8. Do other groups that use the school pay for the energy they use?
9. Who is in charge of controlling energy use in the school?
10. Who is in charge of maintaining energy-use equipment? Is there a maintenance schedule for all energy-using systems?

Building Envelope

1. What is the building made of? Is it in good condition?
2. In which direction does the building face?
3. How many windows are on each side of the building? Are any windows cracked or broken?
4. Are the windows single or double-paned? Can they be opened? Do the windows have adjustable blinds?
5. How many outside doors are there? Are they insulated? Are there windows in the doors? Are any cracked or broken?
6. Does the building have insulation in the walls and ceiling?
7. Are inside stairwells open or enclosed?
8. Do windows and doors seal tightly, or do they leak air?
9. Are trees placed around the building to provide shade in warm months?
10. Are there awnings or overhangs over the windows to shade windows from the overhead direct sun in warm weather, yet allow the slanted rays in winter to enter?
11. What kind of surfaces surround the buildings and classrooms (grass, asphalt, concrete, etc.)?

Heating/Cooling Systems

1. What kind of heating system is used in the school? What fuel does it use?
2. How old is the heating system?
3. Does the heating system have a programmable thermostat to control temperature? What are the settings?
4. What kind of cooling system is used in the school? What fuel does it use?
5. How old is the cooling system?
6. Does the cooling system have a programmable thermostat to control temperature? What are the settings?
7. Is there an air exchange system to provide fresh air when the heating and cooling systems are not operating?
8. Are the boilers, pipes, and ducts sealed and insulated?
9. Are the heating and cooling systems maintained on a regular basis?
10. Does your school make use of passive solar heating?
11. Does the air exiting the system(s) match the thermostat or desired temperature?

Water Heating

1. What fuel is used to heat water in the school?
2. Is there more than one water heater? How many?
3. How old are they?
4. Do the water heaters have timers?
5. At what temperatures are the water heaters set?
6. Are the water heaters and water pipes insulated?
7. Are there leaks in the hot water system?
8. Are flow restrictions used?

Lighting

1. What kind of lighting is used in the school? Outside the school? Exit lights?
2. Can the lights be controlled with dimmer switches? In which areas or rooms?
3. Does the school make use of skylights and natural lighting?
4. Are there timers for the outside lights so they go off automatically?
5. Are there automatic timers for any of the indoor lights?

Student Audit Recording Form

Date: ____________________ Time: ______________________ Outdoor Temperature: ______________

Outdoor Relative Humidity: _______Weather: ____

Is the heating system in use? yes no Is the cooling system in use? yes no

Temperature of air exiting system vent ______________________________

Work Area Description: ____

Who is in the room? ____

Can you feel any air currents in the room? If so, describe where: ____

____

Are there any vents that can be opened to the outdoors? yes no

If yes, are they currently open? yes no Temperature of vent ______________

Number of Outside Windows: __________ Open __________ Closed

Results of Tissue Paper Test: ____

Indoor Temperature of Room: __________ Thermostat setting: ________

Relative Humidity: _________

Landscaping and surfaces outside of room ____

Turn on the water, and start timing until hot water is delivered.

Hot Water Temperature: ___________ Length of Time for Hot Water: ___________

Are there any dripping faucets? _____________________

Lighting Types Present: _______________

Light Meter Reading: ______________

Can the lights be dimmed? yes no

Can some lights be turned on, and some left off? yes no

Were the lights on when you entered the room? yes no

Were the blinds closed when you entered the room? All Some None N/A

Are doors leading outside tightly closed? yes no N/A

Are doors leading inside tightly closed? yes no

Fill in the table below for every electrical device (plug-in) in the room:

Device	Plugged In	Running	Stand-by	In Use	Watts Used if Running	Watts of Phantom Load

Other notes and comments:

Findings and Recommendations

Engineers study building systems, then report the results of their investigations and recommend ways to use less energy. Use this form to organize the data you gathered on the *Student Audit Recording Forms* to prepare a presentation on your findings and recommendations. In your presentation, include an introduction and conclusion that explain your findings and recommendations.

Building Envelope

What We Learned:

Our Recommendations To Save Energy:

Room Temperature and Thermostat Settings

What We Learned:

Our Recommendations To Save Energy:

Windows and Doors

What We Learned:

Our Recommendations To Save Energy:

Lighting

What We Learned:

Our Recommendations To Save Energy:

Electrical Appliances

What We Learned:

Our Recommendations To Save Energy:

Water Heating

What We Learned:

Our Recommendations To Save Energy:

Glossary

amperes (amps)	a unit of measure for an electric current; the amount of current that flows in a circuit at an electromotive force of one volt and at a resistance of one ohm; abbreviated as amp
appliance	any piece of equipment, usually powered by electricity, that is used to perform a particular function; examples of common appliances are refrigerators, clothes washers, microwaves, and dishwashers
atomic number	the number of protons within an atom of one element
atoms	a tiny unit of matter made up of protons and neutrons in a small, dense core, or nucleus, with a cloud of electrons surrounding the core
chemical energy	energy stored in the chemical bonds of a substance and released during a chemical reaction such as burning wood, coal, or oil
climate change	a term used to refer to all forms of climatic inconsistency, but especially to significant change from one prevailing climatic condition to another
compact fluorescent	a light bulb consisting of a gas-filled tube and a magnetic or electronic ballast; electricity flows from the ballast through the gas, causing it to give off ultraviolet light; the ultraviolet light excites a white phosphor coating on the inside of the tube, which emits visible light; compact fluorescent light bulbs use less energy and produce less heat than a comparable incandescent bulb
conduction	the transfer of thermal energy from one particle to another through vibrations in a solid
convection	the transfer of thermal energy from one particle to another by movement in a fluid
depletion zone	a barrier region in a semiconductor that interferes with electron movement because it lacks excess electrons and spaces or holes for electrons (see semiconductor)
distribution lines	power lines that carry electricity at a safer voltage to consumers
elastic energy	energy stored through the application of a force to stretch or compress an item
electric charge	either positive or negative, based on proton and electron interaction; electric charge determines the interaction of atoms with other atoms and produces electromagnetic fields
electric power	see *power*; the part of the economy related to generation of electricity
electrical energy	the energy associated with electric charges and their movements
electricity	a form of energy characterized by the presence and motion of elementary charged particles generated by friction, induction, or chemical change; electricity is electrons in motion
electromagnetic	having to do with magnetism produced by an electric current
electromagnetism	the interaction of forces occuring between electrically charged particles that can create an electric field or magnetic field
electrons	a subatomic particle with a negative electric charge; electrons form part of an atom and move around its nucleus
elements	the most pure form of matter; all matter is made of elements
energy	the ability to do work or make a change
energy conservation	saving energy through behavior changes and installing energy efficient devices
energy efficiency	the ratio of the energy delivered by a machine to the energy supplied for its operation; often refers to reducing energy consumption by using technologically advanced equipment without affecting the service provided
energy levels	area where electrons can be found; describes the probable amount of energy in the atom

ENERGY STAR®	a program that tests and certifies products based on efficiency features; labels help consumers save money
EnergyGuide labels	the label on an appliance that shows how much energy the appliance uses in comparison to similar appliances
fission	the splitting of atomic nuclei; this splitting releases large amounts of energy and one or more neutrons; nuclear power plants split the nuclei of uranium atoms
fossil fuel	fuels (coal, oil, etc.) that result from the compression of ancient plant and animal life formed over hundreds of millions of years
fusion	when the nuclei of atoms are combined or "fused" together; the sun combines the nuclei of hydrogen atoms into helium atoms in a process called fusion; energy from the nuclei of atoms, called "nuclear energy," is released from fusion
generator	a device that turns motion energy into electrical energy; the motion energy is sometimes provided by an engine or turbine
geothermal	the heat energy that is produced by natural processes inside the Earth; it can be taken from hot springs, reservoirs of hot water deep below the ground, or by breaking open the rock itself
gravitational potential energy	energy of position or place
greenhouse effect	the trapping of heat from the sun by the atmosphere, due to the presence of certain gases; the atmosphere acts like a greenhouse
greenhouse gases	gases that trap the heat of the sun in the Earth's atmosphere, producing the greenhouse effect; the two major greenhouse gases are water vapor and carbon dioxide; lesser greenhouse gases include methane, ozone, chlorofluorocarbons, and nitrogen oxides
grid	the layout of an electrical distribution system
halogen	element that will glow in certain combinations, often used in light bulbs or lamps
hygrometer	a tool used to measure humidity
incandescent	a type of electric light in which light is produced by a filament heated by electric current; the most common example is the type you find in table and floor lamps
insulation	a material used to separate surfaces to prevent the transfer of electricity, heat, or sound
kilowatt	a unit of power, used to measure electric power or consumption; a kilowatt equals 1,000 watts
kilowatt-hour	a measure of electricity, measured as one kilowatt (1,000 watts) of power expended over one hour
kinetic energy	the energy of motion
Law of Conservation of Energy	the law governing energy transformations and thermodynamics; energy may not be created or destroyed, it simply changes form, and thus the sum of all energies in the system remains constant
light emitting diodes	energy saving bulb that generates light through the use of a semiconductor
load	the power and energy requirements of users on the electric power system in a certain area or the amount of power delivered to a certain location or item
longitudinal	describing motion that is lengthwise
magnets	any piece of iron, steel, etc., that has the property of attracting iron or steel
molecules	particles that normally consist of two or more atoms joined together; an example is a water molecule that is made up of two hydrogen atoms and one oxygen atom
motion energy	the displacement of objects and substances from one place to another
neutrons	neutrally charged particle within the nucleus of an atom
Newton's Laws of Motion	three physical laws that govern the force and motion interaction of all bodies, for example, the Law of Inertia

nonrenewable	fuels that cannot be renewed or made again in a short period of time, such as petroleum, natural gas, coal, propane, and uranium
nuclear energy	energy stored in the nucleus of an atom that is released by the joining or splitting of the nuclei
nucleus	the core of the atom that houses positively charged protons and neutrally charged neutrons
ohm (Ω)	the unit of resistance to the flow of an electric current
Ohm's Law	a mathematical relationship between voltage (V), current (I), and resistance (R) in a circuit; Ohm's Law states the voltage across a load is equal to the current flowing through the load times the resistance of the load (V = I x R)
potential energy	the energy stored within a body
power	the rate at which energy is transferred; electrical energy is usually measured in watts; also used for a measurement of capacity
protons	positively charged particle within the nucleus of the atom
radiant energy	any form of energy radiating from a source in electromagnetic waves
radiate	to emit energy in waves of rays away from a central point
renewable	fuels that can be made or used again in a short period of time, such as solar, wind, biomass, geothermal, and hydropower
R-value	a measure of a material's resistance to heat flow in units of Fahrenheit degrees x hours x square feet per Btu; the higher the R-value of a material, the greater its insulating capability
semiconductor	a material that has a conductivity level between an insulator and a conductor
solar energy	the radiant energy of the sun, which can be converted into other forms of energy, such as thermal energy or electricity
sound energy	energy that travels in longitudinal waves
substations	equipment located along transmission lines that lowers voltage
thermal energy	the total potential and kinetic energy associated with the random motions of the atoms and molecules of a material; the more the molecules move and vibrate the more energy they possess
thermostats	a device that adjusts the amount of heating and cooling produced and/or distributed by automatically responding to the temperature in the environment
transformer	a device that converts the generator's low-voltage electricity to higher-voltage levels for transmission to the load center, such as a city or factory
transmission lines	a set of conductors, insulators, supporting structures, and associated equipment used to move large quantities of power at high voltage, usually over long distances between a generating or receiving point and major substations or delivery points
transverse	to extend across, motion moving across in a wave-like fashion
turbines	a device with blades, which is turned by a force, e.g., that of wind, water, or high pressure steam; the motion energy of the spinning turbine is converted into electricity by a generator
voltage	the difference in electric potential between any two conductors or between a conductor and the ground; it is a measure of the electrical energy per electron that electrons can acquire and/or give up as they move between the two conductors
volt (V)	the International System of Units (SI) measure of electric potential or electric force
watt	a unit of measure of power
watt-hours	a measure of electrical energy consumed

NEED's Online Resources

NEED'S SMUGMUG GALLERY

http://need-media.smugmug.com/

On NEED's SmugMug page, you'll find pictures of NEED students learning and teaching about energy. Would you like to submit images or videos to NEED's gallery? E-mail info@NEED.org for more information.
Also use SmugMug to find these visual resources:

Videos

Need a refresher on how to use Science of Energy? Watch the Science of Energy videos. Also check out our Energy Chants videos! Find videos produced by NEED students teaching their peers and community members about energy.

Online Graphics Library

Would you like to use NEED's graphics in your own presentations? Download graphics for easy use in your classroom.

AWESOME EXTRAS

Looking for more resources? Our awesome extras page contains PowerPoints, animations, and other great resources! This page is available under the Educators tab at www.NEED.org.

THE BLOG

We feature new curriculum, teacher news, upcoming programs, and exciting resources regularly. To read the latest from the NEED network, visit www.NEED.org/blog_home.asp.

E-PUBLICATIONS

The NEED Project offers e-publication versions of various guides for in-classroom use. Guides that are currently available as an e-publication can be found at www.issuu.com/theneedproject.

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NEED ENERGY BOOKLIST

Looking for cross-curricular connections, or extra background reading? NEED's booklist provides an extensive list of fiction and nonfiction titles for all grade levels to support energy units in the science, social studies, or language arts setting. Check it out at www.NEED.org/booklist.asp.

U.S. ENERGY GEOGRAPHY

Go to www.need.org/energyinsocietymaterials to see energy production, consumption, and reserves all over the country!

The NEED Project @NEED_Project · 3h
Be sure to keep an eye on our Event Calendar! Lots of great hands-on energy education workshops coming up!
need.org/calendar_list...

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Louisville Gas and Electric Company
Midwest Wind and Solar
Minneapolis Public Schools
Mississippi Development Authority–Energy Division
Mississippi Gulf Coast Community Foundation
Mojave Environmental Education Consortium
National Fuel
National Grid
National Hydropower Association
National Ocean Industries Association
National Renewable Energy Laboratory
NC Green Power
Nebraskans for Solar
New Mexico Oil Corporation
New Mexico Landman's Association
NextEra Energy Resources
NEXTracker
Nicor Gas
Nisource Charitable Foundation
Noble Energy
Nolin Rural Electric Cooperative
Northern Rivers Family Services
North Carolina Department of Environmental Quality
North Shore Gas
Offshore Technology Conference
Ohio Energy Project
Oklahoma Gas and Electric Energy Corportation
Opterra Energy
Pacific Gas and Electric Company
PECO
Pecos Valley Energy Committee
Peoples Gas
Pepco
Performance Services, Inc.
Petroleum Equipment and Services Association
Phillips 66
PNM
PowerSouth Energy Cooperative
Providence Public Schools
Quarto Publishing Group
Read & Stevens, Inc.
Renewable Energy Alaska Project
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