OFFICE OF ENERGY EFFICIENCY
AND RENEWABLE ENERGY

Lighting In the Library
A Student Energy Audit

OFFICE OF BUILDING TECHNOLOGY,
STATE AND COMMUNITY PROGRAMS

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OFFICE OF
BUILDING TECHNOLOGY, STATE AND COMMUNITY PROGRAMS

High School Energy Audit
and Teachers' Guide

Overview / School Energy Audit:

The U.S. Department of Energy's vision for Energy Smart Schools is to "form a national partnership to cut energy bills in schools and reinvest the savings in educating the nation's most valuable resource….our children". The plan is to invest in "books not BTUs". Some schools have taken the energy savings dollars and reinvested the funds into local education priorities. By reducing energy use, our schools could spend approximately $1.5 billion more on books, computers, and teachers each year by the year 2010. That amounts to almost $30 for each student, 40 million new textbooks, or 30,000 new teachers. In this activity, your students learn science and mathematical concepts in a hands-on, minds-on way. They become empowered to research their school environment and make recommendations for changes. They begin by focusing on the energy saving and pollution preventing opportunities that can be achieved by changing the light bulbs in your school library. They conclude their work by extending these findings to the opportunities in the entire school and preparing a presentation for the school board.

Level
Grades 8-12

Subject
Mathematics

Goals of the High School Energy Audit

- Provide students with tools and information they need to effectively monitor energy use within their school building
- Identify ways to save their schools money by using energy wisely
- Understand that the information that they learn may be used to help improve the environment
- Create in students and teachers an appreciation and passion for using energy efficiently and wisely
- Assist schools in using their school buildings as working laboratories for learning about energy
- Encourage schools to consider managing or retrofitting their buildings so that energy is used as efficiently and wisely as possible
- Link between energy use like lighting and electricity productions at power plant to CO_2 emissions at smokestack to Greenhouse gas/global warming

Introduction

We spend most of our time in buildings—homes, schools, offices, and stores. But most people hardly notice details about the buildings, such as how they are designed, how they are built, and how well they are maintained. The details have a strong effect on how comfortable a building is and how much it costs to operate.

An "energy-efficient" building is more comfortable than a wasteful building. It needs less fuel for heat and less electricity for cooling. A building that is badly designed and poorly maintained wastes money. This is because the building components are trying to heat and air-condition the outdoors as well as the indoors.

In a 1995 report, *School Facilities: Condition of America's Schools*, the General Accounting Office (GAO) estimated that the cost of bringing the Nation's 110,000 K-12 schools into good overall conditions was $112 billion.

The report revealed:
- 28,100 schools serving 15 million students have less-than-adequate heating, ventilation, and air-conditioning systems
- 23,100 schools serving 12 million students have less-than-adequate plumbing
- 21,100 schools serving 12 million students have less-than-adequate roofs

The National Center for Education Statistics projects that elementary and secondary enrollments will swell from 52.2 million in 1997 to 54.4 million in 2006. So as our nation grapples with modernizing older schools we will also need to build an additional 6,000 new schools to accommodate growing student enrollment over the next decade. We must take advantage of this building boom to introduce energy efficiency in the design, construction and operation of our nation's next generation of school buildings.

With the backlog for repairs and continued operation of older, inefficient, and often polluting equipment and school buses, our schools are wasting large amounts of energy and valuable taxpayer dollars that could be used to teach students. Our nation's schools spend over $6 billion a year on energy. Significant opportunities exist to lower energy bills with equipment upgrades and the use of widely available energy-efficient technologies such as energy-efficient lights, motors, energy management systems and alternatively fueled school buses.

As an added benefit, these improvements can result in better lighting conditions, better indoor and outdoor air quality, and better controlled classroom temperature – all of which can improve the productivity and general well-being of students and teachers.

Impact of Inadequate School Facilities on Student Learning

Businesses have spent millions of dollars on understanding the link between work environment and productivity. Yet, we generally view schools as separate public institutions the same way we view correctional facilities. Current research has linked student achievement and behavior to the physical building conditions and overcrowding.

High School Energy Audit

The High School Energy Audit Guide is a tool for you to use with your students to take an active role in making changes in the school environment. Contact your administration and find out if your school is on the school construction or retrofit schedule for your school district. If it is, an opportunity exists for your students to complete the energy audit and make a formal presentation to the school board and administration on their energy saving recommendations. The audit is designed to use the library, and eventually the whole building as a working and living laboratory for the students to learn about energy efficiency and renewable energy. The U.S. Department of Energy will make additional school energy audit activities available before the end of the school year for those who would like to extend this project into a more comprehensive audit. For the most update activities and information, please continue to check the following web page address: http:ww.eren.doe.gov/buildings/earthday/.

Decaying environmental conditions such as peeling paint, crumbling plaster, nonfunctioning toilets, poor lighting, inadequate ventilation, and inoperative heating and cooling systems can affect the learning as well as the health and the morale of staff and students. A school year is approximately 180 days. This is alot of time to spend in an atmosphere that is not conducive to learning or teaching.

National Science and Mathematics Content Standards and Benchmarks for Science Literacy

The content and associated activities are challenging and rigorous for high school students. The standards and benchmarks that are covered in these activities are noted in the individual teacher guides. The standards that are covered in the High School Energy Audit are as follows:

National Science Education Standards

PHYSICAL SCIENCE
Content Standard A
Science as Inquiry
As a result of their activities in grades 9-12, all students should develop:

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B
As a result of their activities in grades 9-12, all students should develop an understanding of:

- Conservation of energy and increase of disorder
- Interactions of energy and matter

SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES
Content Standard F
As a result of activities in grades 9-12, all students should develop understanding of:

- Natural resources
- Environmental quality
- Science and technology in local, national, and global challenges

Benchmarks for Science Literacy

Benchmark 4 –
The Physical Setting
4B – The Earth - Students will understand physical concepts and principles as energy, gravitation, conservation, and radiation.

Benchmark 5 –
The Living Environment
5E – Flow of Matter and Energy - Students will understand the conservation of matter with the flow of energy in living systems.

Benchmark 8 –
The Designed World
8C – Energy Sources and Use - Students can examine the consequences of the world's dependence on fossil fuels, explore a wide range of alternative energy resources and technologies, and consider trade-offs in each. They can propose policies for conserving and managing energy resources.

National Math Standards

Standard 1: Mathematics as Problem Solving

In grades 9-12, the mathematics curriculum should include the refinement and extension of methods of mathematical problem solving so that all students can:

- use, with increasing confidence, problem-solving approaches to investigate and understand mathematical content;
- apply integrated mathematical problem-solving strategies to solve problems from within and outside mathematics;
- recognize and formulate problems from situations within and outside mathematics;
- apply the process of mathematical modeling to real-world problem situations

Standard 2: Mathematics as Communication

In grades 9-12, the mathematics curriculum should include the continued development of language and symbolism to communicate mathematical ideas so that all students can:

- reflect upon and clarify their thinking about mathematical ideas and relationships;

Assessment/Rubric

An assessment is just one method of evaluating each student's grasp of the major concepts presented in the activities. Teachers are encouraged to use the assessments as-is or to develop their own assessments that meets the individual needs of the students. The assessments are used at the end of each activity. However, these assessments are provided as guidelines for the teacher to use in developing appropriate measurement packages. Many assessment techniques are available, including multiple-choice, short-answer, discussion, or open-ended questions; structured or open-ended interviews; homework; projects; journals; essays; dramatizations; and class presentations. Among these techniques are those appropriate for students working in whole-class settings, in small groups, or individually. The mode of assessment can be written, oral, or computer oriented. Please use these ideas and add or delete according to your needs. The tasks in this audit usually involve open-ended, problem-solving activities but some will require recall of content knowledge.

Included with the assessment is a standard, generic rubric. The rubric is established as guideline for performance. It is also a useful form of self-evaluation because it lets the student know what is expected for high quality work.

- formulate mathematical definitions and express generalizations discovered through investigations;
- express mathematical ideas orally and in writing;
- read written presentations of mathematics with understanding;
- ask clarifying and extending questions related to mathematics they have read or heard about;
- appreciate the economy, power, and elegance of mathematical notation and its role in the development of mathematical ideas.

Standard 3: Mathematics as Reasoning

In grades 9-12, the mathematics curriculum should include numerous and varied experiences that reinforce and extend logical reasoning skills so that all students can:
- make and test conjectures;
- formulate counterexamples;
- follow logical arguments;
- construct simple valid arguments;

and so that, in addition, college-intending students can:
- construct proofs for mathematical assertions, including indirect proofs and proofs by mathematical induction.

Standard 5: Algebra

In grades 9-12, the mathematics curriculum should include the continued study of algebraic concepts and methods so that all students can:
- represent situations that involve variable quantities with expression, equations, inequalities, and matrices;
- use tables and graphs as tools to interpret expressions, equations, and inequalities;
- operate on expressions and matrices, and solve equations and inequalities;
- appreciate the power of mathematical abstractions and symbolism—
and so that, in addition, college-intending students can:
- use matrices to solve linear systems;
- demonstrate technical facility with algebraic transformations, including techniques based on the theory of equations.

Standard 6: Functions

In grades 9-12, the mathematics curriculum should include the continued study of functions so that all students can:
- model real-world phenomena with a variety of functions;
- represent and analyze relationships using tables, verbal rules, equations, and graphs;
- translate among tabular, symbolic, and graphical representations of functions;
- recognize that a variety of problem situations can be modeled by the same type of function;
- analyze the effects of parameter changes on the graphs of functions;
and so that, in addition, college-intending students can understand operations on, and the general properties and behavior of, classes of functions.

Standard 10: Statistics

In grades 9-12, the mathematics curriculum should include the continued study of data analysis and statistics so that all students can:
- construct and draw inferences from charts, tables, and graphs that summarize data from real-world situations;
- use curve fitting to predict from data;
- understand and apply measures of central tendency, variability, and correlation;
- understand sampling and recognize its role in statistical claims;
- design a statistical experiment to study a problem, conduct the experiment, and interpret and communicate the outcomes;
- analyze the effects of data transformations on measures of central tendency and variability; and so that, in addition, college-intending students can:
- transform data to aid in data interpretation and prediction;
- test hypotheses using appropriate statistics.

Credits

The National Renewable Energy Laboratory would like to give credit to the following agencies for supplying information that used to prepare the ***High School Energy Audit***.

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Student Rubric

	Exceeds Expectations	Meets Expectations	Meets Some Expectations	Does Not Meet Expectations
Points Earned	6	4	2	0
Calculations of the activities and observations that were conducted	Calculations are complete, include clear writing, relevant examples, and contain very few errors	Calculations are complete, written clearly and have few errors	Calculations are incomplete, unclear, or contain several errors	No calculations of activities are included
Data showing potential sources of energy savings	Data is well done and includes useful information. Graphs and symbols are used	Data complete and includes a useful graph	Data is not clear or incomplete	No data is supplied
Description of how the team will validate the findings	Multiple validation techniques are used that produce accurate and conclusive results	Validation techniques are effective and produce conclusive results	Efforts are made to validate the information but is incomplete, irrelevant, or	There is no validation of the findings
Explanation of the potential relevance or importance of the findings	The relevance is clearly articulated and the explanation makes a compelling statement	The relevance of the findings is clearly articulated	The explanation or relevance is illogical or fails to communicate clearly	No explanation or relevance is offered
Use of the internet to research relevant information concerning building components and energy	Demonstrates the ability to research a topic without assistance using several tools	Demonstrates the ability to research a topic without assistance	Research topics with minimal assistance	Does not demonstrate the ability to research a topic
Cooperative group behavior	Team worked in a consistently positive mode; clear evidence of shared work and responsibility	Team worked mostly in a positive mode; effort made to include all members	Team members required careful monitoring; presentation component	Team members did not work as a team
Presentation delivery	Clear evidence of participation in some form by every team member; all parts well planned; strong portrayal of the teams'special suggestions	Evidence of participation by the majority of the team; good planning and execution; special interest of the team is evident	Participation by only 1 or 2 members; little evidence of group planning; special interest of team is not clearly presented	No participation by the team to prepare a presentation
Technology based presentation	Final project is enhanced through use of technology	Final project is partially technology based	Final project not technology based	No final project completed

Glossary

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

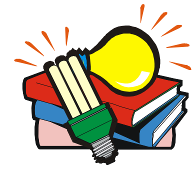
Efficiency. The ratio of the energy used for a desirable purpose, such as heating or lighting, compared with the total energy input, usually expressed in percent.

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

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

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

Glossary



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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Lighting in the Library

Overview

The purpose of the Lighting in the Library Activity is to calculate the electricity used to provide lighting in the school library and determine the feasibility of saving energy and money by using energy efficient lighting fixtures.

Your students will assume the role of an energy auditor assigned the task of assessing the current situation and making a recommendation for energy-efficient improvements. This activity requires a trip to the library, an examination of the school's energy bill, and a basic understanding of algebraic concepts as a problem solving strategy.

Level

Grades 8 - 12

Subject

Mathematics, Economics

Concepts

- Efficiency: getting a desired outcome lighting with the least effort and cost
- Energy-efficient lighting fixtures
- Energy conservation
- Cost of electricity

Applicable National Standards

National Math Standards:
- Standard 1: Mathematics as Problem Solving
- Standard 2: Mathematics as Communication
- Standard 3: Mathematics as Reasoning
- Standard 5: Algebra
- Standard 6: Functions

Skills

- Addition, subtraction, multiplication, and division
- Compiling lighting energy and cost data
- Drawing a plan of the library
- Critical thinking
- Problem solving
- Creating and giving presentations

Objective

Calculate the feasibility of replacing older, less efficient lighting in the library with new fixtures that are more efficient and cost less to operate.

(continued next page)

Getting Ready

The exercise is designed in two parts. The first part consists of determining the energy consumption, operating costs, and amount of "greenhouse gases" resulting from the existing lighting fixtures. The second part entails determining the economic feasibility of retrofitting the existing fixtures with three types of energy-efficient lights.

Two primers have been prepared to help you and your students ramp up your energy, environment, and lighting knowledge relatively quickly (see appendix). In addition, helpful hints and some examples specific to each step have also been provided. Before class, use the All About Energy Primer or download a copy of the secondary energy infobook located at: www.aep.com/environmental/renewables/solar/powerPie/pdf/second.pdf/). Each student in the class should have a copy of the following:

- All About Energy Primer or Infobook
- student pages 1-10
- Lighting technology primer
- glossary

Choosing the Room in the School for the Exercise

The exercise is designed for the school library; however it will work for almost any room in the school. If the school library is not available, choose a different common room, preferably one with different kinds of light fixtures with different on/off schedules. Ask the librarian or custodian to help the students determine the on/off schedule for the lights in the library. For example, there is typically one schedule for when school is in session and another for when it is out of session.

Additional Exercises for Advanced Students

Ask the students to see if there are any rooms in the area to be studied where lights are left on for long periods of time and are not occupied. Advanced students might determine the feasibility of installing motion detectors for those rooms as an extra credit exercise. Motion detectors will automatically turn lights on and off. Costs of motion sensors could be determined by calling a local electrical wholesale house and calculating labor at 1/2 hour per switch at a cost of $50 to $75 per hour for an electrician's time. The savings accrue from the number of hours the lights can be turned off. The payback period for the investment in motion detectors can be calculated in the same way as the ***Lighting in the Library*** exercise.

Background

Lighting typically accounts for 15 percent of the total energy bill of educational institutions nationwide. The majority of buildings built before the 1970s have high levels of illumination according to the design standards of the time. Most use older fluorescent fixtures with four tubes, the standard fixture used in schools and office buildings for many years. As a result, most schools spend too much on lighting bills.

Since the late 1980s, many modern fluorescent fixtures have come equipped with the more efficient T8 lamp operated by an electronic ballast. Depending on the task being performed, there are situations where the old four light fixture can be coverted to a two light fixture and still provide the required amount of light. The electronic ballasts were developed to operate fluorescent tubes more efficiently

(continued)

Materials

- Pencil, paper, and a ruler
- Tape measure
- One copy per student of the ***Student Guide Primers:***
  - ***Energy Primer or Infobook***
  - ***High School Energy Inventory: Lighting Technology Overview***
- Student pages 1-10
- Glossary

Time

Two 55-minute classroom periods.

and consume less energy when the lights are on. Older, standard ballasts consume up to 20 percent of the total amount of electricity required to operate the lamp. Therefore, a 1.2 multiplier was added to the last equation in Step 5.

Light fixtures in this exercise are typical of those installed in schools built from the 1950s to the 1980s. During this period, the standard light fixture was the 4-tube fluorescent located in the ceiling. Incandescent lighting remains the standard fixture for task lighting. The majority of exit signs use incandescent bulbs. As students will see in this exercise, these fixtures can often be replaced with newer, more efficient types of lighting that cost much less to operate.

At the same time, there are a large variety of light fixtures in schools used across the country. Some schools have been designed to use natural lighting so effectively in common rooms, such as the library, that it will be extremely difficult to reduce their lighting bills. The best way to tell if there is an opportunity to improve the lighting efficiency of a room is to calculate the "lighting index" for the room as done in Steps 9, 14, and 19. If the index is above 1.3 (W/ft^2), there is likely an opportunity to economically reduce lighting energy consumption in the library. If the index is below 1.3, it will be more difficult to do so within a 3-year payback period but there are still many opportunities for savings and enhancing the visual environment that warrant serious consideration. Retrofitting the lighting system in older buildings, especially in institutional buildings that are illuminated above the current lighting design levels, has proven to be one of the most cost-effective energy conservation measures. The savings from lighting retrofits depend on the amount of time the lights are used during the year. For lights that are on a large percentage of the time, simple payback on the cost of replacing them is from one to three years.

Doing the Activity

Ideally, the students would read the primers first (perhaps as homework the night before beginning the activity), and then complete the exercises in subsequent classes. Steps 1-9 should be completed in the first class period. Steps 10-22 can be completed as a combination of in-class time and homework. When the students are done, they will have enough material to prepare a presentation for the school board about their energy-efficient proposal.

OFFICE OF ENERGY EFFICIENCY
AND RENEWABLE ENERGY

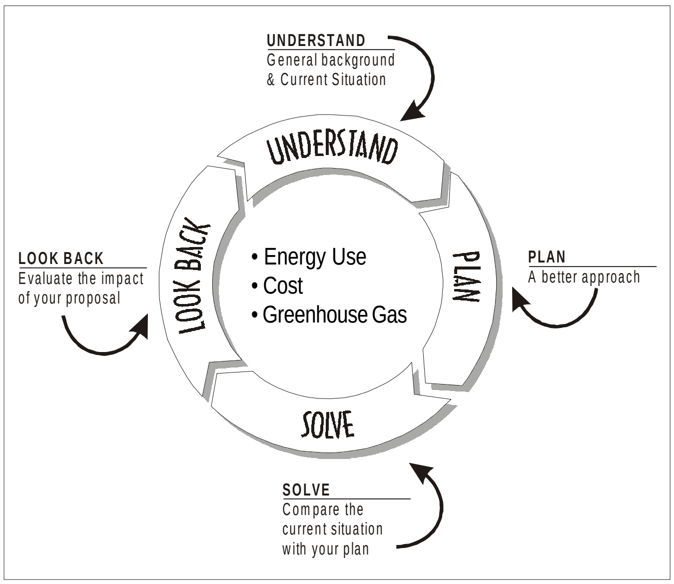
Lighting In the Library

Student Worksheets

OFFICE OF BUILDING TECHNOLOGY,
STATE AND COMMUNITY PROGRAMS

Lighting in the Library

The purpose of this exercise is to determine the amount of electricity used to provide lighting to the school library. During the course of these activities you will need to imagine that you are an energy auditor who needs to make recommendations to the school administration concerning the feasibility of saving energy and money by using energy-efficient lighting. To complete this task, an energy auditor would need to obtain the values of several variables about the location, the current situation, energy-efficient replacement options, and an evaluation of their impacts on the bottom line. This exercise is divided into several steps to help you determine the value of the variables necessary to evaluate the energy consumption, its cost and the resulting greenhouse gas from the lights in your library. We will use the following problem solving application strategy to achieve this objective:



- **UNDERSTAND** the current situation
- **PLAN** a new approach
- **SOLVE** equations to compare the current light design with your new plan
- **LOOK BACK** and compare the bottom line impact of your plan

Part 1 requires a visit to the library to *understand your current situation.* There, you will take an inventory of all of the lights in the room, estimate the schedule the lights are on and off, and using that information, calculate how much it costs to light the library for a year. You'll also estimate the amount of carbon dioxide (greenhouse gas) that is generated to make the electricity for these lights. While you work through the calculations, note the answers on the ***Variable Key on page10*** . This will help you keep track of your answers, and assist you in making accurate bottom line conclusions during the final *look back* steps.

HELPFUL HINTS:

This section will provide you with examples and addtional background which may be useful in completing Part 1.

Why is a sketch important to an energy auditor?

A sketch of the library is required that identifies the locations of the lighting fixtures. The sketch helps the energy auditor or engineer make sure the list of lights is complete, and thus they can accurately calculate energy savings. Furthermore, a sketch is essential for workers hired to make changes to the lighting equipment to be able to identify exactly where this equipment is located. On the sketch, list the type of light fixture with its electricity (power) rating, measured in Watts.

How do I draw a sketch to scale of my library and calculate the area?

Use the sketch paper on page 3 or use a ruler and a blank sheet of paper and draw the largest outline on the piece of paper that will fit within the margins. For example, if the room is 40 feet by 25 feet in size, use a quarter inch scale on the drawing: 0.25 inch on the drawing represents 1 foot of the library. In this case, the measurements of the drawing on the page will be 10 inches by 6.25 inches. Note the scale on the sketch, in this case: 0.25 inches = 1 foot, so you can interpret what you draw at a later date. Draw an arrow facing north so you'll be able to tell which wall is which when you look at the sketch again. The area of a rectangular room is its length times its width.

How do I find out how much my school pays for electricity?

In order to calculate savings from energy efficiency, it is first necessary to calculate how much the school is paying for energy. Electricity costs used for savings calculations are based on the average cost of electricity for the school. This number can be obtained from the school administration by checking the utility bill and equation four.

How do I determine the number of Watts of electric power the light bulbs in my library use?

The power consumption of different types of lighting can be determined by inspecting the lamps and ballasts in the fixtures. If it is impossible to inspect the fixtures themselves, try to determine the wattage of the lamps by asking the person responsible for changing them, such as the custodian. If this is not possible, assume the following watt ratings for the light bulbs below:

- Incandescent lights use lamps that you can examine to determine the rating (e.g. 100 Watts).

- Incandescent exit signs require power only for the lamp; assume they use 40-Watt bulbs.

- Fluorescent lights use either the old standard, 40-Watt F40 lamps or the newer 34 watt energy saver lamps. The ballast regulates current and voltage to ensure proper operation of the fluorescent lamps. All ballasts use a certain amount of energy while operating fluorescent lamps. This energy is called ballast loss and must be included in the calculation. A standard ballast consumes 20 percent of the total power of the fixture. The total power required to operate a fluorescent fixture is the wattage of the tube multiplied by the number of tubes times 20 percent (in other words, times 1.2). See example below. To help you remember to include the ballast loss inside the fluorescent fixture in your calculations, we have written this 1.2 multiplier in the last equation contained in step 5.

Example:

If a fluorescent fixture has four standard tubes, at 40 Watts each plus the ballast, the entire fixture is rated at:

$$\boxed{(4 \times 40) \times 1.2 = 192 \text{ Watts Fixture}}$$

How do I determine the number of hours per week that the lights are on in the library?

The estimated schedule for each fixture is best determined by interviewing people who work in the library, such as the librarians or the custodian. This information combined with the equation in step 3 will help you determine the answer to this important variable.

Example:

School Sessions
For the purposes of illustrating how such a schedule might work, take a hypothetical school library where the lights are on from 7 a.m. to 7 p.m., Monday through Friday. During school sessions, the lights are on 12 hours a day for five days a week totaling 60 hours a week.

School Vacation
During school vacations, the library is open on weekdays from 9 a.m. to 3 p.m. This equals six hours a day for five days a week totaling 30 hours a week. If your school has eight weeks off during the summer, a three-week winter break, a week off for spring break, and a week off for holidays, vacations account for 13 weeks a year. The calculated "on times" for most of the lights in this case would be as follows:

$$\boxed{(w \times x) + (y \times z) = B}$$

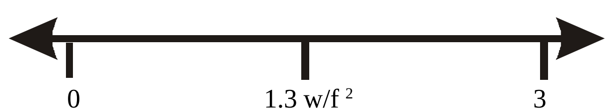
where:
w = hours per week that the lights are on when school **is in** session
x = weeks school **is in** session
y = hours per week lights are on when school **is not in** session
z = weeks during year when school **is not in** session

You would complete the equation as follows

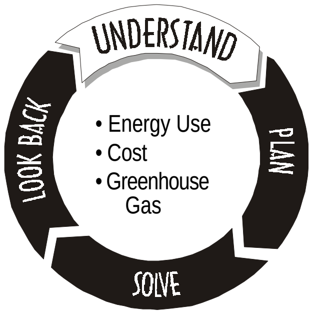
w = 60 x = 39 y =30 z = 13
(60 x 39) + (30 x13) = B
B=2730

What is a lighting efficiency index?

Energy engineers often use a lighting efficiency index such as the one below. When the index is higher than that for similar rooms or buildings, engineers can identify in advance where potential energy savings can be achieved. If the index is greater than 1.3 Watts/ft^2, it indicates that there are probably opportunities for savings. The index is calculated by dividing the total watts consumed by the area. This index is recorded as watts /ft^2. The equations in steps 9, 14, and 19 will help you see where you are and where you could be in relation to this standard.



If the lighting index, (Watts / ft^2) is greater than 1.3, there are probably opportunities for energy savings.

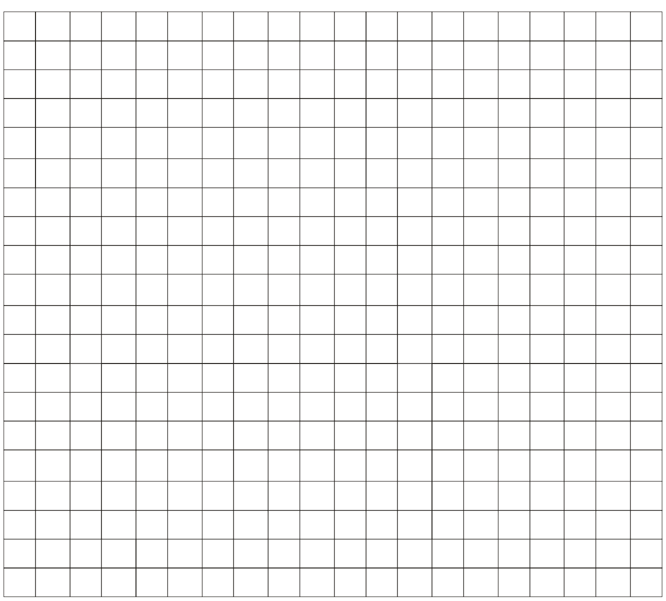


Data gathering and observation

INSTRUCTIONS: In order to get to the bottom line, the energy auditor must get general information about the specific location. The answers to the first four steps will help you complete the calculations necessary to understand your current situation, plan a better approach, solve issues concerning your new approach, and finally, look back at the difference you can make with energy efficiency. To begin, follow the directions for each step. Consult the background information as needed.

STEP 1

Measure the dimensions of the library floor and sketch it to scale below. Be sure to write the length and width on the sketch. Then draw the location and correct number of the incandescent light bulbs, fluorescent tube light bulbs, and incandescent exit sign light bulbs that you see.



STEP 2

Calculate the area (length x width) of the library and write your answer in the variable key next to **A** on page 10.

A= $\boxed{}$

STEP 3

Ask the people that work in the library how many hours per day the lights are on when school is in session and when school is not in session. Use this information and the key below to determine the total hours the lights are used in the library. Write your answer in the variable key next to **B** on page 10.

$$(w \times x) + (y \times z) = B \qquad B = \boxed{}$$

where:

w= hours per week that the lights are on when school **is in** session

x = weeks school **is in** session

y = hours per week lights are on when school **is not in** session

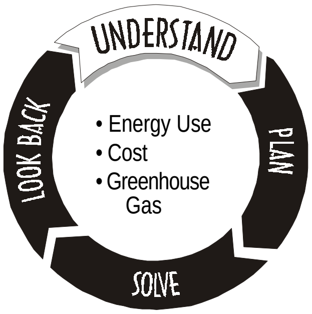
z = weeks during year when school **is not in** session

STEP 4

Use the equation below to calculate the average cost your school pays per kilowatt-hour. Write your answer in the variable key next to **C** on page10.

$$\frac{\textbf{Total monthly energy bill in \$}}{\textbf{Total kilowatt-hours from monthly bill}} = C$$

C= $\boxed{}$



What is the Current Situation?

Instructions: Energy auditors must learn the value of several variables about the current room in order to convince administrators that energy efficiency is a good idea. Steps 5-9 will help you find the value of the following variables about the light bulbs in your library: the number of watts (**D**); the number of kilowatt-hours (**E**); annual electricity cost (**F**); the carbon dioxide greenhouse gas created by the electricity produced (**G**); and the current lighting index (**H**). To begin, follow the directions below and complete the equations. Don't forget to transfer your answers to the variable key on page 10.

STEP 5

In Column 2, write the number of light bulbs you counted for each type listed in column one. Complete each equation. Then, add the answers in column 4 and enter this new watt total in answer block **D** and on page10.

Column 1	*Column 2*	*Column 3*	*Column 4*
Number of incandescent light bulbs with 40 watts	☐	x 40 watts =	☐
Number of incandescent light bulbs with 60 watts	☐	x 60 watts =	☐
Number of incandescent light bulbs with 75 watts	☐	x 75 watts =	☐
Number of incandescent light bulbs with 100 watts	☐	x 100 watts =	☐
Number of exit signs with 40 watt Incandescent light bulbs	☐	x 40 watts =	☐
Number of exit signs with 60 watt Incandescent light bulbs	☐	x 60 watts =	☐
Number of exit signs with 75 watt Incandescent light bulbs	☐	x 75 watts =	☐
Number of exit signs with 100 watt Incandescent light bulbs	☐	x 100 watts =	☐
Number of fluorescent light tubes	☐	x 40 watts x 1.2= (or 34)	☐
		D =	☐

STEP 6

Use the total watts you calculated in step 5 (D) and the total hours the lights are used in a year from step 2 (B) in the equation below to figure out how many kilowatt-hours are consumed by the lights in your library. Write your answer in the variable key next to **E** on page 10.

$$\frac{D \times B}{1000} = E \qquad E= \boxed{}$$

STEP 7

Refer to steps 4 and 6 for the value of the variables in the equation below. Then do the math to determine the current annual cost of operating the lights in your library. Write your answer in the variable key next to **F** on page10.

$$E \times C = F \qquad F= \boxed{}$$

STEP 8

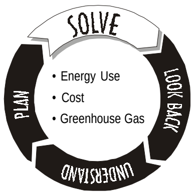
The amount of carbon dioxide greenhouse gas generated during electricity production ranges from 1.4lbs. to 2.8 lbs. per kilowatt-hour, depending on whether or not the electricity is produced from coal, nuclear power, or hydropower (see greenhouse gas article in the energy and environment primer). Use the equation below to estimate the amount of greenhouse gas created when the electricity is made to power the lights in your library. Write your answer in the variable key next to **G** on page10.

$$E \times 2 = G \qquad G= \boxed{}$$

STEP 9

Use the following equation to calculate an overall lighting index for the library. This index is the Watts consumed per square foot. Write your answer in the variable key next to **H** on page10.

$$\frac{D}{A} = H \qquad H= \boxed{}$$



Summary of Variables Used in the Calculations

A = Area (Length times width) of library =

B = Total hours lights used in a year =

C = Average cost per kilowatt-hour =

D = Total watts consumed by your library lights =

E = Kilowatt-hours consumed by your library lights =

F = Annual cost of operating your library lights =

G = Estimated amount of carbon dioxide (CO_2) greenhouse gas generated during electricity production =

H = Current lighting index for your library =

I = Total watts consumed by your library lights with your new plan =

J = Kilowatt-hours consumed with your new library lighting plan =

K = Annual cost of electrity with your new library lighting plan =

L = Amount of carbon dioxide (CO_2) greenhouse gas with your new library lighting plan =

M = Lighting index with your new library lighting plan =

N = Energy saved in a year with your new library lighting plan =

P = the money saved in a year with your new library lighting plan =

Q= Greenhouse gas prevented in a year =

R = Initial cost of the compact lights you propose =

S = Number compact fluorescent =

T = Initial cost of the (LED) exit signs (chart 1) =

U = Number of (LED) exit signs you propose =

V = Initial cost of the T-8 electronic ballast fluorescent tubes =

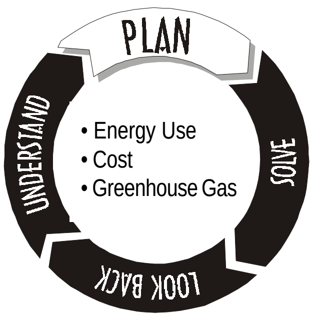
W= Number electronic ballast T-8 fluorescent tubes you propose changing =

Y = payback for your plan (years) =

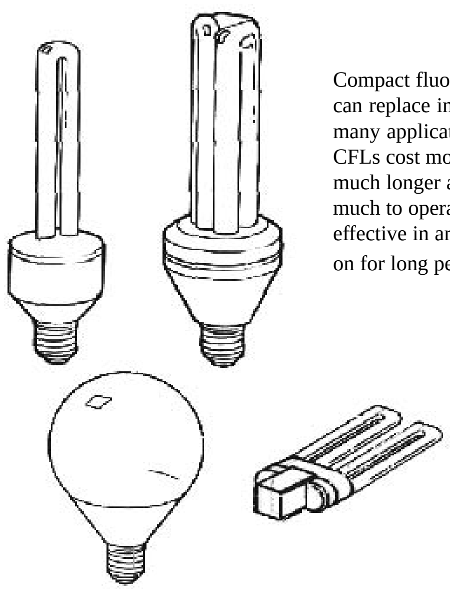
Summary of Abbreviations Used in the Calculations

A	area of a room measured in square feet
Btu	British thermal units
ft^2	square feet
h	hour
kW	kilowatt
kWh	kilowatt-hour
lm	lumen
L	length of a classroom wall
mmBtu	million British thermal units (Btu)
W	width of a classroom
wk	weeks
yr	year
$	U.S. dollars
x	multiplication (also *)
+	addition
-	subtraction
/	division (also "per," as in dollars per year; e.g. $ / yr)

Determine the Feasibility of Installing Energy Efficient Lighting



In this part of the exercise, you will plan a new approach to lighting your school library. This new plan will use less energy, cost less, and result in less greenhouse gas. Your plan will also include bottom line calculations and decision factors such as: identifying the costs and payback for buying and installing new lighting equipment and making a determination about whether or not the new, more efficient lighting will provide sufficient illumination to the library.



Compact fluorescent lamps (CFL) can replace incandescent lamps in many applications. Although the CFLs cost more initially, they last much longer and cost one fourth as much to operate. They are most effective in areas where the lights are on for long periods.

Background Information

The feasibility of replacing existing lighting with more efficient lighting depends on the cost of replacement versus the savings. The per year savings depend on the type of lighting and the number of hours per year the lights are on. Three types of efficient lighting will be examined here:

- replacing incandescent bulbs with compact fluorescent lamps
- replacing incandescent exit signs with those lit by light emitting diodes (LED)
- replacing the existing F40 lamps and 34 watt energy saver fluorescent fixtures with T8 lamps and electronic ballasts

Replacing incandescent bulbs with compact fluorescent lamps

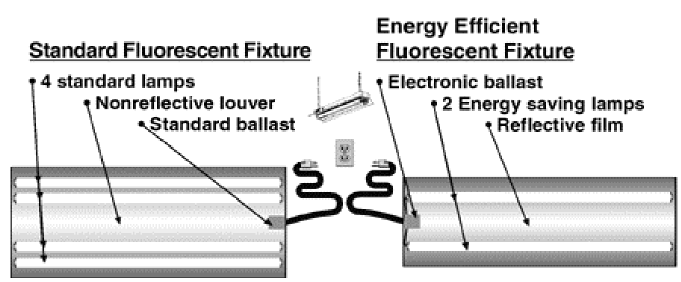
The savings result from increased efficiency: getting more light with less electricity. The efficiency of these fixtures can be measured in terms of lumens per Watt (lm / Watt), and the higher the lumens per Watt rating, the more efficient they are. Generally, fluorescent lamps are much more efficient than incandescent bulbs, producing as much as four times more light (and less heat) with the same electricity input. For example, a 27-Watt compact fluorescent lamp provides 1800 lumens, while a 100-Watt incandescent bulb produces 1750 lumens. The CFL produces almost four times the lumens per Watt of the incandescent bulb.

Replacing incandescent exit signs with those lit by light emitting diodes (LED)

Similar efficiencies can be obtained from exit signs using light emitting diodes (LED), also used in the display areas on a calculator. LEDs are very long lasting and require very little power. For this reason, they work very well in applications such as exit signs that must stay on all the time.

Replace F40 lamps and 34 watt energy saver lamps with T8 lamps and electronic ballasts (retrofit)

Replacing the existing 40w or 34w fluorescent lamps with the more efficient T8 lamp that is operated by an electronic ballast will provide excellent energy savings and also produce a superior quality of lighting which is important in a library environment. It is important that the existing fixtures be well cleaned before the new lighting is installed. Fixtures get dirty with age and are rarely cleaned. Up to 40% of a fixture's efficiency can be lost to dirt, so it is critical that all fixtures are well cleaned when being retrofitted. Replacing the old F40 lamps with the new efficient T8 lamps can save as much as 40% of the energy while providing equivalent or superior levels of illumination and a much better quality of lighting.



New fluorescent fixtures with energy-saver tubes, reflective louvers, and electronic ballasts provide almost as much light as the old, 4-tube fixtures while using less than half the electricity.

Chart 1.

Light Output for Several Types of Energy-Efficient Lamps

Lamp Type	Cost *replace	Lamp Life (h)	Watts	Lumens	Lumens per Watt
Replace incandescent bulbs with compact fluorescent lamps					
Compact fluorescent lamp (CFL)	$14	10,000	27	1800	67
Standard incandescent bulb	$.50	1,000	100	1750	17.5
Replace F40 or 34 watt energy saver tubes with with T8 lamps and electronic ballasts					
F40 or 34 watt fluorescent lamp	$ 5 per tube	20,000	192	11,960	62
T8 lamp and electronic ballast	$ 8.75 per tube	22,000+	106	10,620	
Replace incandescent exit signs with LED exit signs					
Incandescent exit signs		1,000	40		—
LED exit signs	$ 90	20,000	2		—

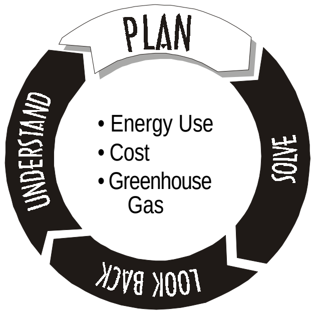
* Cost to replace fixtures in an existing building is higher than to install them in a new building because of higher labor costs to remove and replace fixtures. For example, costs for LED exit signs themselves are as low as $10. The estimates in this chart include labor costs and may vary by 30% or more, depending on location.

PAY BACK

While commercial establishments require a 3-year payback or less for investing in lighting, schools and institutional facilities will generally accept a much longer payback period ranging up to six years. Some of the reasons these longer payback periods are acceptable include:

- The savings will continue many years after the initial investment is recovered since most schools are intended to be in use for 50 years or more
- Educators are concerned both with immediate savings from a new system and lighting quality

Occasionally, the first cost of a new, efficient system will require a simple return of investment that exceeds 5 years; however, the long-term benefits actually prove that the new, more efficient system with the higher first cost is the better investment. Steps 18-22 will provide you with first hand information about the economics for your school.



Plan a New Approach

Instructions: When energy auditors plan a new approach to lighting the library, they consider many factors, including when and how to use daylight, time controls on some lights and which energy-efficient light bulbs will deliver the same or better light but use less energy. In this activity we will concentrate on three common energy-efficient light replacement options. They are compact fluorescent lights, LED exit signs, T8 Fluorescents. In steps 10-14 you will recommend energy-efficient light bulb replacements, and then work to find the answer to the following variables about your new plan: the number of watts **(I)**; the number of kilowatt-hours **(J)**; its annual electricity cost **(K)**; the carbon dioxide greenhouse gas created by the electricity produced **(L)**; and the new lighting index **(M)**. To begin, follow the directions to write and solve the equations below. Then complete the calculations and transfer the value of these variables to your key on page10.

STEP 10

Refer to your library sketch and the equations you completed in step 5 to determine the number of inefficient light bulbs you could replace with the energy-efficient options you read about on your background sheet. Complete the equations below. Then add up the answers to each equation and write this total in the variable key next to **I** on page 10.

_______________ **X 27 watts =** _______________
Number of incandescent light bulbs replaced by compact fluorescent lights

_______________ **X 2 watts =** _______________
Number of exit signs with incandescent light bulbs replaced LED exit signs

_______________ **X 34 watts =** _______________
Number of fluorescent light tubes you can replace with T8

I= ☐

STEP 11

Use the total watts you calculated in step 10 **(I)** and the total hours the lights are used in a year from step 2 **(B)** in the equation below to figure out how many kilowatt-hours are consumed by the new approach you planned. Write your answer in the variable key next to **J** on page10.

$$\frac{\mathbf{I \times B}}{\mathbf{1000}} = \mathbf{J} \qquad J= \square$$

STEP 12

Refer to steps 4 and 11 for the value of the variables in the equation below. Then do the math to determine the current annual cost of operating the lights in your library. Write your answer in the variable key next to **K** on page10.

$$\mathbf{J \times C = K} \qquad K= \square$$

STEP 13

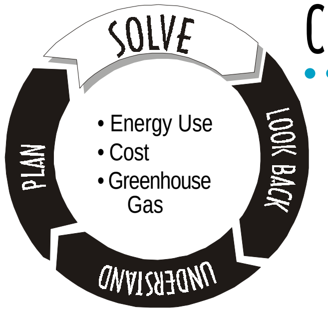
The amount of carbon dioxide greenhouse gas generated during electricity production ranges from 1.4lbs. to 2.8 lbs. per kilowatt-hour (depending on whether or not the electricity is produced from coal, nuclear power, or hydropower). Use the equation below to estimate the amount of carbon dioxide greenhouse gas created when the electricity is made to power the lights in your library with your new approach. Write your answer in the variable key next to **L** on page10.

$$\mathbf{J \times 2 = L} \qquad L= \square$$

STEP 14

Use the following equation to calculate an overall lighting index for the library. This index is the watts consumed per square feet. Write your answer in the variable key next to **M** on page 10.

$$\frac{\mathbf{I}}{\mathbf{A}} = \mathbf{M} \qquad M= \square$$



Compare Your New Approach with the Current Situation

Instructions: Finally, the energy auditor must compare the current approach and the new plan. If you have not transfered the values of the variables you calculated from the previous pages onto the variable key on page 10, go back and do it now. Then write the equations with the values concerning your school library and do the math.

STEP 15

Calculate the energy savings between the current lights in your library and the new lights you recommended in your plan.

N= $\boxed{}$ **E - J = N**

Where N = the energy saved in a year

STEP 16

Calculate the energy cost savings between the current lights in your library and the new lights you recommended.

P= $\boxed{}$ **F -K = P**

Where P = the money saved in a year

STEP 17

Calculate the greenhouse gas emissions prevented by replacing your current lights in your library and the new lights you recommended.

Q= $\boxed{}$ **G - L = Q**

Where Q = lbs. of carbon dioxide prevented in a year

STEP 18

This exercise is designed to help you identify the payback possible from your proposed lighting changes. Simple payback is defined as the initial cost divided by the first-year dollar savings. To determine the simple payback that would occur if your school adopted your proposed lighting changes, use the equation below. Note: Financial decision-makers usually use a 3-year payback.

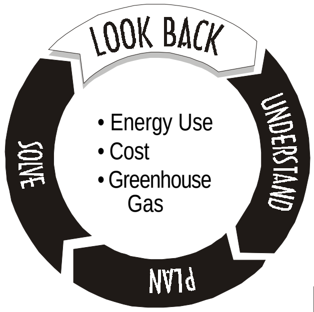
$$\frac{(R \times S) + (T \times U) + (V \times W)}{P} = \underline{\hspace{3cm}} = y$$

year payback

Where:
P= the money saved in a year
R= Initial cost of the compact fluorescent lights (See Chart 1, page 6)
S =Number compact fluorescent lights you propose
T= Initial cost of the (LED) exit signs
U =Number of (LED) you propose
V =Initial cost of the electronic ballast T-8 fluorescent tubes
W=Number electronic ballast T-8 fluorescent tubes you propose

STEP 19

Now compare the index between your current situation, your proposed new lighting plan and the 1.3 w/ft ^{2} standard used by auditors to determine the probability of energy savings. Plot the values for H and M below.



What's The Bottom Line?

Instructions: Use your variable key on page10 to fill in the chart below. Then consider proposing that the school accept your plan for a more energy-efficient, cost-effective, environmentally friendly library. Use the table in step 20 and the results of your work in steps 21-22 in your proposal.

STEP 20

	Energy	**Cost**	**Greenhouse Gas**
Current lights in the Library (variables E,F,G)			
Proposed new plan for the lights in your library (variables J,K,L)			
Savings from your proposal (variables N,P,Q)			

What difference can this make in your school?

STEP 21

If you get the total square footage of your school and complete the equations below you will have a good idea about the impact you can make on your school.

$\frac{N}{A}$ x sq. footage of school = estimated energy saved by applying your plan to the whole school

$\frac{P}{A}$ x sq. footage of school = estimated money saved by applying your plan to the whole school

$\frac{Q}{A}$ x sq. footage of school = estimated CO_2 greenhouse gas prevented by applying your plan to the whole school

Make an Energy Smart Schools presentation.

STEP 22

Discuss your idea and findings with your classmates and teachers and make one combined proposal to your school board and administration team. Research the Energy Smart Schools program offered by the U.S. Department of Energy (www.eren.doe.gov/energysmartschools) and include the many benefits of this program and your findings from this activity as support for making your school or library more energy-efficient.

Unit Pre and Post Test

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

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

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

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

3 **Which residential task uses the most energy?**

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

4 **Most energy conversions produce...**

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

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

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

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

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

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

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

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

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

9 **Which sector of the economy consumes the most energy?**

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

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

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

11 **Electricity is measured in...**

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

12 **Natural gas is transported mainly by...**

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

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

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

14 **Natural gas is measured by...**

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

All About Energy

What Is Energy?

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

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

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

Forms of Energy

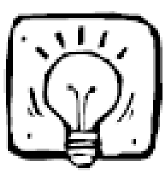
Energy takes many different forms. It can light our homes or heat them. There are six forms of energy.

Mechanical

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

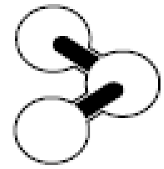
Kinetic energy is a kind of mechanical energy. It is the energy of a moving object. A moving car has kinetic energy. A stalled car does not; however, if it's poised at the top of a hill, it may have potential energy.

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



Radiant

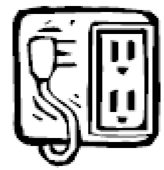
Radiant energy is commonly called light energy. But light energy is only one kind of radiant energy. All waves emit energy. Radio and television waves are other types of radiant energy. So are gamma rays and x-rays. Light waves do work by wiggling the receptors in back of our eyes.



Chemical

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

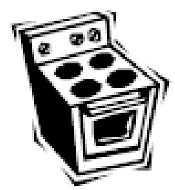
What happens to a wood log in a fireplace? Burning the wood breaks up the compounds, releasing the stored chemical energy in the forms of thermal and radiant energy.



Electrical

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

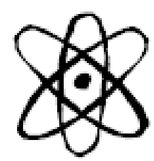
Electricity is produced when something upsets the balancing force between the electrons and protons in atoms and the electrons move from one atom to another. We can use electricity to perform work like lighting a bulb, heating a cooking element on a stove, or moving a motor.



Thermal

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

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

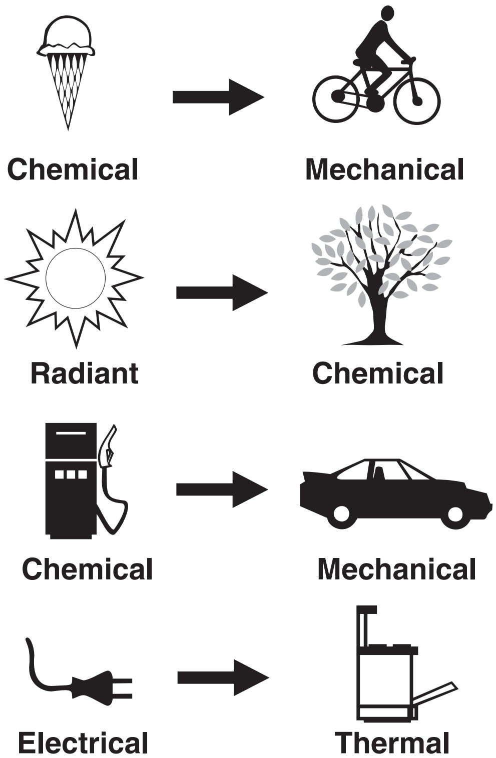


Nuclear

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

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

Energy Transformations



Conservation of Energy

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

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

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

Energy Efficiency

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

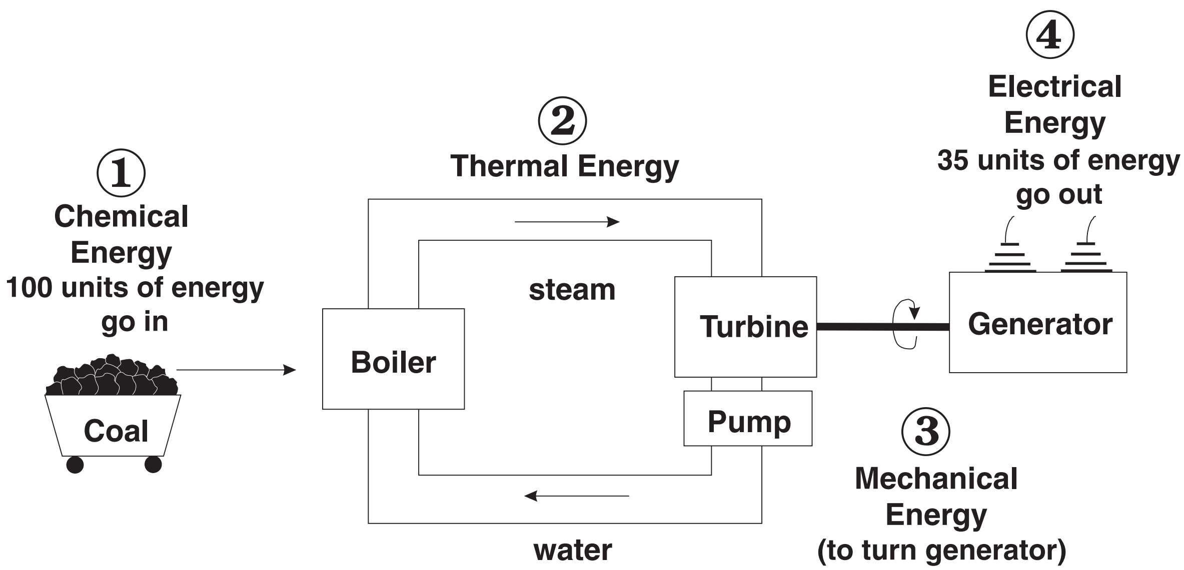
The human body is no exception. Your body is like a machine, and the fuel for your "machine" is food. Food gives us the energy to move, breathe, and think. But your body isn't very efficient at converting food into useful work. Your body is less than five percent efficient most of the time, and rarely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

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

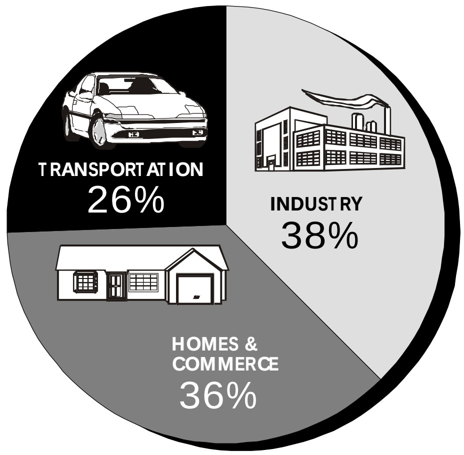
Most electric power plants are about 35 percent efficient. It takes three units of fuel to make one unit of electricity. Most of the other energy is lost as waste heat. The heat dissipates into the environment where we can no longer use it as a practical source of energy.

Energy Efficiency

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



Modern Energy Use



SOURCE: ENERGY INFORMATION ADMINISTRATION

Energy Use

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

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

Who Uses Energy?

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

Residential & Commercial

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

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

Industrial

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

Transportation

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

Energy Use and Prices

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

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

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

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

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

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

In 2000 and 2001 deregulation of power utilites and years of population increases without the building of new power plants, caused an energy crisis in California. Energy prices tripled in the state in one year. power companies could not keep up with energy demand. This added to the problem as power providers began to go bankrupt, leading to rolling blackouts and further price increases.

MEASURING*energy*

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

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

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

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

ENERGY*sources*

Modern Consumption

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

* Consumption of Other Energy Sources 0.1%

Sources of Energy

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

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

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

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

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

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

Nonrenewables

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

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

Renewables

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

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

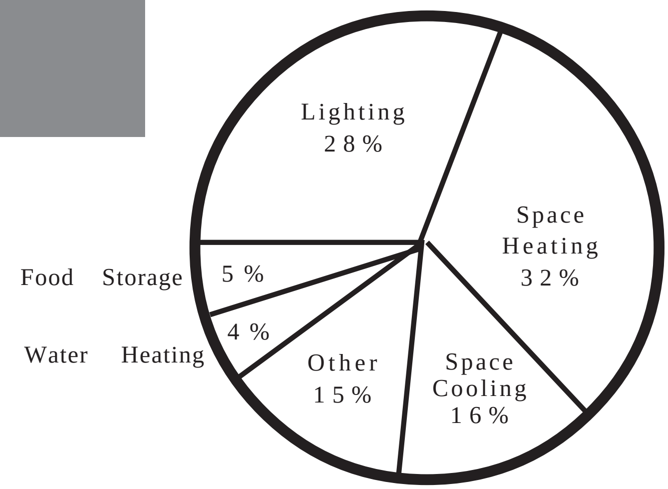
Electricity is different from the other energy sources because it is a **secondary** source of energy. That means we have to use another energy source to make it. In the United States, coal is the number one fuel for generating electricity.

Energy Consumption

Residential/Commercial Sector

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

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



COMMERCIAL ENERGY USE

Heating & Cooling

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

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

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

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

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

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

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

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

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

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

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

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

Cost Management

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

Maintenance

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

Programmable Thermostats

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

Caulking & Weatherstripping

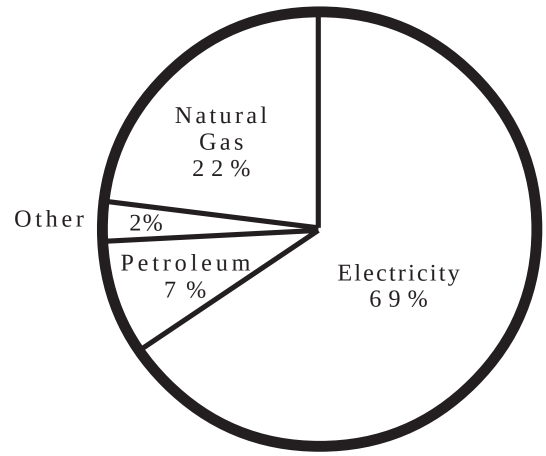
Preventing the exchange of inside air with outside air is very important. Weatherstripping and caulking around doors and windows can significantly reduce air leakage. Keeping windows and doors closed when systems are operating is also a necessity.

Building Design

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

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

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



FUELS USED BY COMMERCIAL BUILDINGS

Lighting

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

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

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

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

Heating Water

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

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

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

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

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

Energy Efficiency Ratings

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

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

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

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

Electricity

The Nature of Electricity

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

Making Electricity

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

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

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

Moving Electricity

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

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

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

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

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

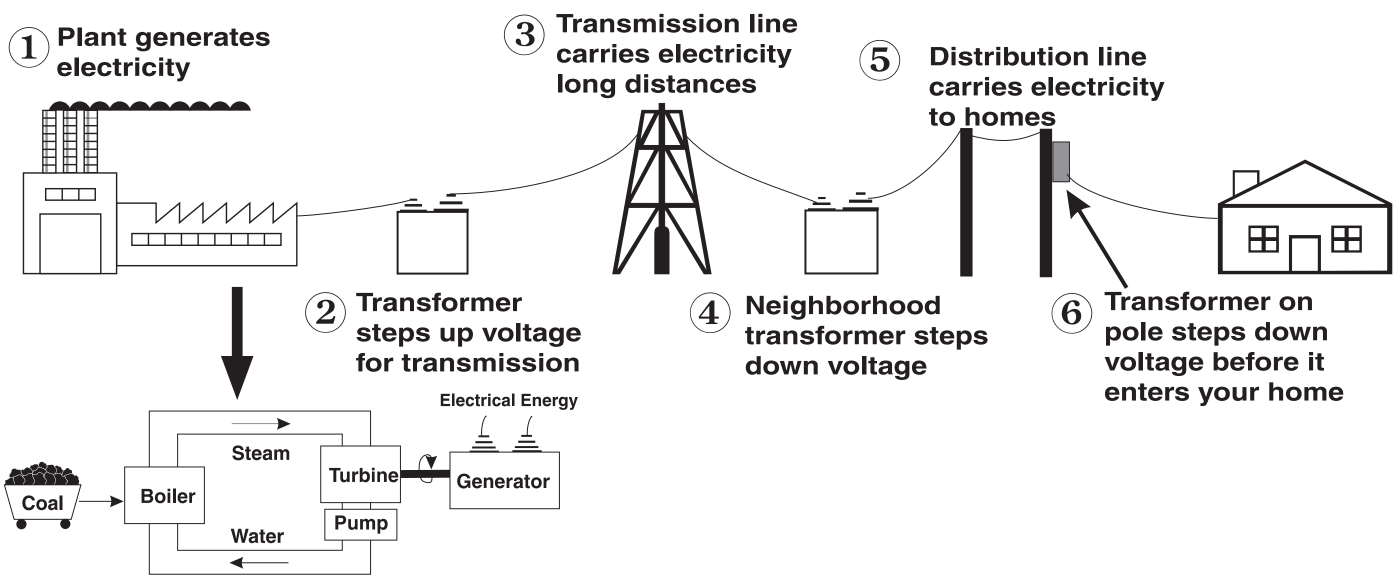
Electricity is then carried over distribution lines which bring electricity to your school. Distribution lines may either be overhead or underground. The overhead distribution lines are the electric lines that you see along streets.

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

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

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

Transporting Electricity



Power to the People

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

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

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

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

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

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

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

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

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

Demand-Side Management

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

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

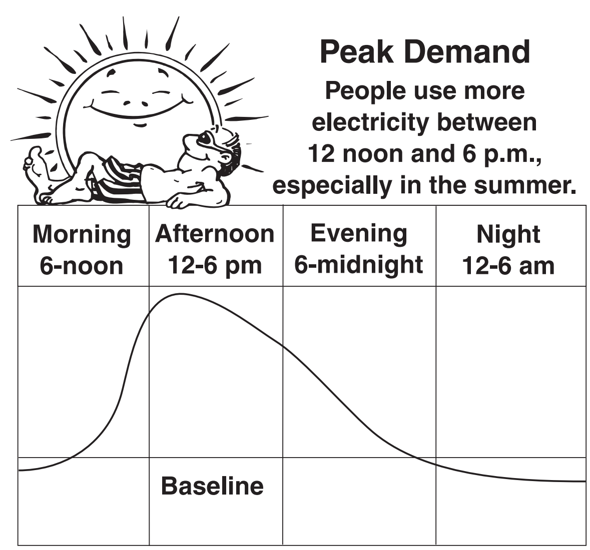
What's the difference between conservation and efficiency? Conserving electricity is like turning off the water in the shower while you shampoo your hair. Using electricity more efficiently is like installing a better shower head to decrease water flow.

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

Economics of Electricity

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

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



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

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

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

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

Deregulation

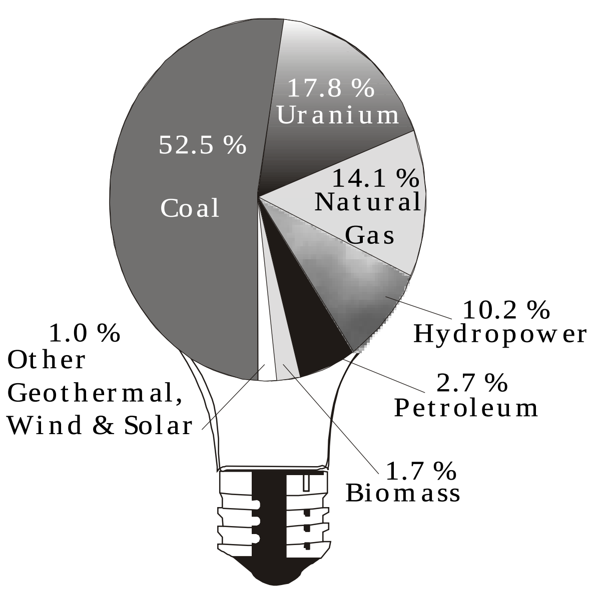
Since the 1930s, most electric utilities in the United States have operated under state and federal regulations in a defined geographical area. Only one utility provides service to any one area. People and businesses can not choose their electricity provider. In return, the utilities have to provide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

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

MAKING *electricity*

Three kinds of power plants produce most of the electricity in the United States: fossil fuel; nuclear; and hydropower. There are also wind, geothermal, trash-to-energy, and solar power plants, but they generate less than 3% of the electricity produced in the U.S.

U.S. ELECTRICITY PRODUCTION



SOURCE: ENERGY INFORMATION ADMINISTRATION

Fossil Fuel Power Plants

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

Nuclear Power Plants

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

Hydropower Plants

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

MEASURING *electricity*

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

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

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

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

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

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

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

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

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

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

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

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

Future Demand

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

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

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

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

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

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

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

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

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

The Greenhouse Effect

Earth's Atmosphere

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

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

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

Sunlight and the Atmosphere

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

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

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

The Greenhouse Effect

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

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

THE GREENHOUSE EFFECT

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

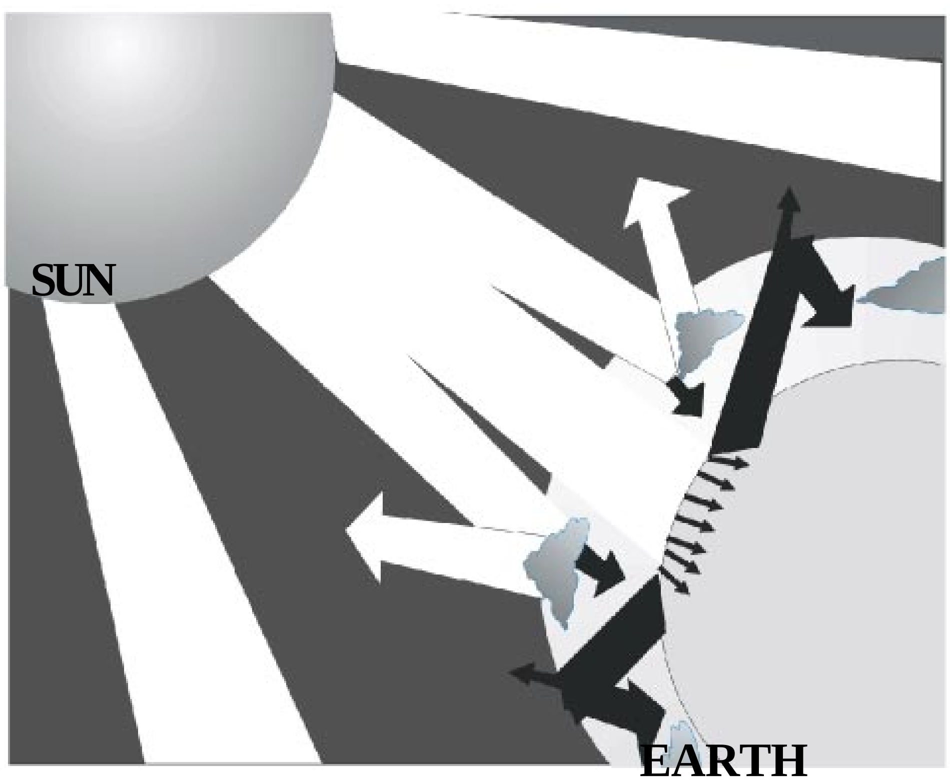
Half of the radiant energy passes through the atmosphere and reaches the earth, where it turns into heat (black arrows).

Some of this heat energy is absorbed by the earth.

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

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

The trapped heat energy flows back toward the earth.



Greenhouse Gases

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

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

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

Global Climate Change

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

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

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

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

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

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

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

Greenhouse gases are more than 97 percent water vapor.