



## **Clean Energy Curriculum for Colorado Middle and High Schools**

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# *INTRODUCTION AND ACKNOWLEDGEMENTS*

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## Introduction

Colorado State University Extension has always sought to bring University expertise to Colorado communities through our local offices, activities, programs, and partners. With a renewed state focus on clean energy sources as a potential job creator capable of addressing both national security and environmental issues, CSU Extension made a strategic decision to provide relevant and unbiased educational resources to schools. This curriculum represents our efforts to disperse energy information to Colorado's middle and high school youth.

This second edition of the curriculum builds off of the first edition but also incorporates teacher feedback we received based on piloting the lesson plans in the classroom. Teachers still want a curriculum that meets state academic standards for science; includes hands-on, interactive activities; includes locally relevant examples, information, and resources; and contains objective comparisons of the costs and benefits of different energy technologies including solar, wind, energy efficiency, and biofuels. Many teachers also noted the importance of addressing the financial and environmental implications of energy use.

In addition, this edition: adds six lesson plans – two on electricity generation, two new solar lesson plans, and one each on geothermal energy and climate change; adds primer information related to these lesson plans; ties all lesson plans to state math standards, social studies standards, and AP standards for environmental science and physics well as 4-H life skills, projects, and STEM abilities; contains enhanced lesson plans on solar energy and school energy audits; and provides sample sources for materials associated with the lesson plans. Importantly, we've also made powerpoint slides in PDF format available for download for each lesson plan of the curriculum. They are intended to support teachers in presenting background material from the primer and can be found at: [www.ext.colostate.edu/energy/k12.html](http://www.ext.colostate.edu/energy/k12.html)

The curriculum is intended to be practical in that it: makes use of actual sample energy products such as compact fluorescent bulbs, reflective insulation, and mini-solar panels and wind turbines that generate electricity; includes activities designed to analyze a school's energy use and feasibility for renewable energy; and contains relevant articles and local case studies intended to provide a tangible context for learning.

The curriculum is also intended to be flexible in that it: includes a primer that can be used by either teachers or students; addresses multiple science, math, and social studies standards; includes lessons and extensions that can be adapted for different grade levels; contains lessons that can be taught on their own or in conjunction with one another; and contains electronic activity sheets that can be customized easily.

Lesson plans follow an inquiry-based 5-E learning cycle model (outlined in the following section) intended to engage students in learning from start to finish.

In conjunction with summer teacher trainings, online videos, and ongoing support available from Extension agents throughout the state, we believe that our curriculum will be effective in accomplishing CSU Extension's mission of service while meeting the needs of Colorado's teachers. We hope you agree!

## Acknowledgements

Colorado State University Extension received initial funding for the first edition of this curriculum from the Colorado Energy Office and the U.S. Department of Energy. We have received additional financial support for the second edition of this curriculum and associated trainings from Tri-State Generation and Transmission.



Cary Weiner, Clean Energy Specialist for CSU Extension, led the development of this curriculum along with regional STEM specialists Anne Casey, Claire Dixon, Christy Fitzpatrick, and Barb Shaw. Ashlee Adams, former Denver County 4-H Agent, also made significant contributions to the original curriculum.

Parts of the second edition of this curriculum were reviewed by Ann Randall and Stu Reeve.

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## *HOW TO USE THIS CURRICULUM*

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## How to Use This Curriculum

The curriculum is primarily intended for middle and high school science and math teachers and informal energy and 4-H educators, but it can be utilized by social science and other teachers as well. We have designed it to be flexible and practical, and have included suggestions for teachers to make use of the material in a number of different ways.

### Primer

The primer is intended for both students and teachers. It can be used to prepare teachers to introduce and execute lessons with proper background knowledge but can also be used to provide reading selections for students. It is divided into four parts – Energy Basics; Energy Conservation and Efficiency; Renewable Energy; and Energy and Climate Change – that can be utilized independently or in conjunction with one another.

While an overarching picture of energy issues in the U.S. is provided, the primer focuses on Colorado-specific information of special relevance to the lessons included in this curriculum. The National Energy Education Development (NEED) Project “Energy Infobooks” would be excellent, in-depth supplements to this curriculum’s primer ([www.need.org](http://www.need.org)).

### Colorado Academic and 4-H Standards Matrices

The standards matrices provide at-a-glance looks at which lessons meet the following standards:

- Colorado state academic standards (evidence outcomes) for science, math, and social studies (as adopted in December 2009);
- National AP environmental science and physics course topics;
- National College Board performance expectations for science; and
- 4-H life skills, projects, and STEM abilities.

If using this curriculum to meet state standards is your primary objective, choose your lessons based on these matrices. Keep in mind that although some lessons may address standards from multiple grade levels, they may need to be adapted in order to be age appropriate.

### Lesson Plan Logic

The lesson plans are organized according to the logic of the Primer – scientific and energy resource basics are covered in the first three lesson plans. Energy conservation and efficiency is next, followed by renewable energy and climate change lessons.

The idea is that it is important for students – like adult energy consumers – to understand energy basics and the big picture first. Energy conservation and efficiency is next because these topics cover ways in which we use currently energy in our buildings – including schools and homes – that students can readily comprehend and experience first-hand. The renewable energy lessons delve into how selected technologies work and some of the many variables that weigh into a decision to use these technologies. The climate change lesson addresses the complex decision-making and numerous stakeholders involved in transitioning to a clean energy economy in order to reduce greenhouse gas emissions.

It should be noted that the lessons are intended both to be “stand-alone” and to work in conjunction with one another. In other words, an individual lesson can be taught without the need to teach other lessons from the curriculum or lessons can be strung together in order to present a more comprehensive picture of energy.

### **Lesson Plan Suggestions**

Suggested combinations of lesson plans include:

- “Steamin’ Ahead” and “Dynos”
- “Light Bulb or Heat Bulb” before the Lighting portion of “Conduct a School Energy Audit”
- “Conduct a School Energy Audit” before “Are Renewables Right for Me”
- “Colorado Energy Source Webquest” with any of the other lessons
- “The Sun Can Do Watt” before “Solar Car Race”
- “Watt’s Your Angle” before “The Right Site” and “Solar Car Race”
- Any solar and/or wind lessons with “Are Renewables Right for Me”
- “Climate Change Wedge Game” with any of the energy efficiency or renewable energy lessons

It should also be noted that the “Conduct a School Energy Audit” lesson plan contains four different group activities (Heating, Ventilation, and Air Conditioning (HVAC); Lighting; Appliances; and Behavior) that can each comprise a lesson plan in their own right and need not be conducted together. Similarly, “Are Renewables Right for Me” contains both a Solar version and a Wind version that need not be conducted together and that can each serve as independent lesson plans.

Finally, the lessons assume that the material from the Units of Energy chapter of the Primer (1.3) has already been taught to students. Students should be familiar with units of energy before participating in the lessons.

### **Lesson Plan Content**

While much of the lesson plan makeup is straightforward, it is important to have some understanding of certain parts of the lesson plan template.

First, Grade Level is listed according to standards met in any subject area. Check the standards matrices to see if a given lesson plan meets standards for your subject and grade level. In addition, teachers may find that certain lessons can be adapted in order to meet the needs of their students in a certain grade.

Materials are listed and an estimated cost is provided according to what is recommended for each group of students and what is recommended for the class as a whole. Of course, this list may change depending on how many students are in a class and the resources available to a teacher.

In terms of Duration, a class period is assumed to be about 40 minutes. Most lessons give a range of class periods as a Duration (i.e. 1-2 class periods) since it will vary based on how the teacher decides to assign and review the activities and activity sheets. While the activities

themselves are only appropriate for the classroom, activity sheets can often be completed as homework and can either be graded individually or reviewed together as a class and even expanded upon once reviewed. For these reasons, the Duration is often given as a range.

The Primer section of each lesson plan lists only the units of the Primer of most relevance to the lesson, and this material can either be copied and provided to students as reading or used by the teacher as context for the lessons depending on the specific lesson and the inclination of the teacher. It may be helpful to include additional primer material not listed for the lesson in some cases as well.

Related Articles can be used to supplement student learning on the topic area and are often local case studies that bring the lesson into focus here in Colorado. In some cases the related article(s) is singled out as a critical part of conducting the lesson plan.

The next sections – from Engagement to Elaboration – follow the inquiry-based 5-E Learning Cycle but allow teachers to design their own evaluation techniques (this fifth E is not covered here):

- The list of **Engagement** questions are designed to engage students through asking questions with real-world implications that initially don't need to be answered by the teacher.
- The Investigation section allows the students to conduct a hands-on activity and use Activity Sheets (*see below*) in order to “**explore**” answers to those questions experimentally through science.
- The Class Review consists of teachers asking students to share their findings from their activity/experiment with the rest of the class in order to see and understand similarities and differences in results with clarification and “**explanation**” from the readings and/or teacher.
- The Elaboration section requires students to go deeper (“**elaborate**”) into the larger, more generalizable scientific theories behind their explorations in order to learn how the lesson can be applied to other real-world examples.
- The **Evaluation** is left to the teacher.

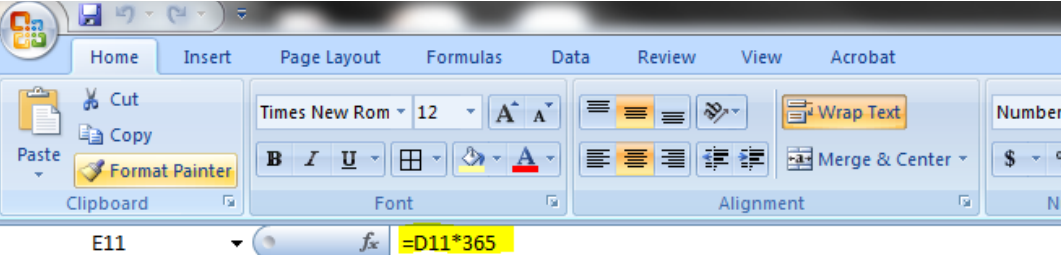
### Activity Sheets

Activity Sheets (using Microsoft Excel) are provided both in blank form for student handouts and electronically ([www.ext.colostate.edu/energy/k12.html](http://www.ext.colostate.edu/energy/k12.html)) with sample data, formulas, and calculations for teacher use. Typically, Activity Sheets require students to enter experimental or research data in a table at the top of the sheet. That raw data is then used as the basis of calculations going from left to right across the Sheet. The raw data and calculations provide the evidence needed to help answer initial Inquiry questions, such as “What are the costs and benefits of renewable energy systems?”.

Once all raw data is collected for a given lesson, calculations can be performed either in class or as homework. The list of Assumptions provided on most Activity Sheets exists in order to help students make correct extrapolations based on their raw data and wherever applicable were verified with external, Colorado expert sources. **That said, Assumptions are provided solely**

**for educational and illustrative purposes and are not intended to be used as the basis of energy decisions.** The Questions at the bottom of the Activity Sheet reinforce the lessons learned from the raw data and calculations and teachers are encouraged to review the list of questions with the students as the Class Review.

The electronic versions of the Activity Sheets with sample data can be used by teachers to see how certain calculations build off each other, the raw data, and/or the Assumptions. Simply click or double-click on a given cell to see the calculation used to get the answer for that cell (see highlights below).



The screenshot shows the Microsoft Excel interface. The formula bar at the top displays the formula  $=D11*365$  for cell E11. Below the formula bar, there are two tables. The first table, titled "Light Bulb or Heat Bulb?", shows temperature data for three types of bulbs (Incandescent, CFL, LED) over a period of 10 minutes. The second table shows cost and energy consumption data for the same three bulb types. Cell E11 in the second table is highlighted, showing the value 53, which is the result of multiplying the kWh per day (0.146) by 365.

Light Bulb or Heat Bulb?							
	Temperature						
Bulb	0 min.	2 min.	4 min.	6 min.	8 min.	10 min.	Delta T
Incandescent	67	82	92	101	103	104	37
CFL	67	70	73	75	76	77	10
LED ( data from teacher)	67	69	71	73	74	75	8

Bulb	Initial cost	Wattage	kWh per day	kWh per year	Cost per year	Hours in lifetime	Number of bulbs needed over 24,000 hours
Incandescent	\$1.00	36.6	0.146	53	\$5.34	1,000	24
CFL	\$2.00	8.5	0.034	12	\$1.24	8,000	3
LED ( data from teacher)	\$18.00	6.7	0.027	10	\$0.98	24,000	1

The highlighted formula shows how 53 kWh per year in cell E11 is a result of multiplying kWh per day (cell D11) times 365.

If so inclined, teachers can ask students to complete the Activity Sheets using Excel, in which case the Sheets will reinforce computer skills.

Excel also enables teachers to easily customize the lesson to meet the needs of their students. For example, certain columns can be “hidden” or deleted if a teacher does not want the students to spend time on a given calculation. In other cases, teachers may choose to keep some pre-entered formulas in the electronic Activity Sheet they provide to students in order to adapt the lesson to a lower grade level. In this example students would still be able to draw conclusions from their raw data without having to perform as many calculations.

### **Glossary**

The Glossary can support both student and teacher understandings of energy-related terms.

### **Appendices**

The appendices are references that apply to multiple lesson plans, and include lists of materials, articles related to the lesson plans, and additional resources to support teachers wishing to take full advantage of this curriculum.

The Additional Resources appendix provides links to CSU Extension video, powerpoint, and other resources designed specifically for this curriculum for use by both formal and informal educators alike.

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# *PRIMER*

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## **Teacher/Student Primer**

### **1.0 Energy Basics**

- 1.1 Forms of Energy
- 1.2 Sources of Energy
- 1.3 Units of Energy
- 1.4 Uses of Energy
- 1.5 Energy Conversion
- 1.6 Electricity Generation

### **2.0 Energy Conservation and Efficiency**

- 2.1 Lighting
- 2.2 Insulation and Heat Transfer
- 2.3 Energy Audits

### **3.0 Renewable Energy**

- 3.1 Solar
- 3.2 Wind
- 3.3 Geothermal
- 3.4 Biofuels

### **4.0 Energy and Climate Change**

- 4.1 Basic Climate Science
- 4.2 Global Overview
- 4.3 Colorado Overview
- 4.4 Solutions



## 1.0 ENERGY BASICS

In order to understand and gain an appreciation for the lesson plans included in this curriculum, students should have a basic understanding of the different forms of energy, sources of energy, units of energy, and uses of energy.

### 1.1 Forms of Energy

Energy forms are either **potential** or **kinetic**. **Potential** energy comes in forms that are stored - including chemical, gravitational, mechanical, and nuclear. **Kinetic** energy forms are doing work — like electrical, heat, light, motion, and sound.

#### **What Is Energy?**

Energy makes change possible. We use it to do things for us. It moves cars along the road and boats over the water. It bakes a cake in the oven and keeps ice frozen in the freezer. It plays our favorite songs on the radio and lights our homes. Energy is needed for our bodies to grow and it allows our minds to think.

Scientists define energy as the ability to do work. Modern civilization is possible because we have learned how to change energy from one form to another and use it to do work for us and to live more comfortably.



#### **Forms of Energy**

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

Potential Energy	Kinetic Energy
Potential energy is stored energy and the energy of position — gravitational energy. There are several forms of potential energy.	Kinetic energy is motion —of waves, electrons, atoms, molecules, substances, and objects.
<b>Chemical Energy</b> is energy stored in the bonds of atoms and molecules. Batteries, biomass, petroleum, natural gas, and coal are examples of stored chemical energy. Chemical energy is converted to thermal energy when we burn wood in a fireplace or burn gasoline in a car's engine.  <b>Mechanical Energy</b> is energy stored in objects by tension. Compressed springs and stretched rubber bands are examples of stored mechanical energy.	<b>Radiant Energy</b> is electromagnetic energy that travels in transverse waves. Radiant energy includes visible light, x-rays, gamma rays and radio waves. Light is one type of radiant energy. Sunshine is radiant energy, which provides the fuel and warmth that make life on Earth possible.  <b>Thermal Energy</b> , or heat, is the vibration and movement of the atoms and molecules within substances. As an object is heated up, its atoms and molecules move and collide faster. Geothermal

<p><b>Nuclear Energy</b> is energy stored in the nucleus of an atom — the energy that holds the nucleus together. Very large amounts of energy can be released when the nuclei are combined or split apart. Nuclear power plants split the nuclei of uranium atoms in a process called <b>fission</b>. The sun combines the nuclei of hydrogen atoms in a process called <b>fusion</b>.</p> <p><b>Gravitational Energy</b> is energy stored in an object's height. The higher and heavier the object, the more gravitational energy is stored. When you ride a bicycle down a steep hill and pick up speed, the gravitational energy is being converted to motion energy. Hydropower is another example of gravitational energy, where the dam "piles" up water from a river into a reservoir.</p>	<p>energy is the thermal energy in the Earth.</p> <p><b>Motion Energy</b> is energy stored in the movement of objects. The faster they move, the more energy is stored. It takes energy to get an object moving, and energy is released when an object slows down. Wind is an example of motion energy. A dramatic example of motion is a car crash, when the car comes to a total stop and releases all its motion energy at once in an uncontrolled instant.</p> <p><b>Sound</b> is the movement of energy through substances in longitudinal (compression/rarefaction) waves. Sound is produced when a force causes an object or substance to vibrate — the energy is transferred through the substance in a wave. Typically, the energy in sound is far less than other forms of energy.</p> <p><b>Electrical Energy</b> is delivered by tiny charged particles called electrons, typically moving through a wire. Lightning is an example of electrical energy in nature, so powerful that it is not confined to a wire.</p>
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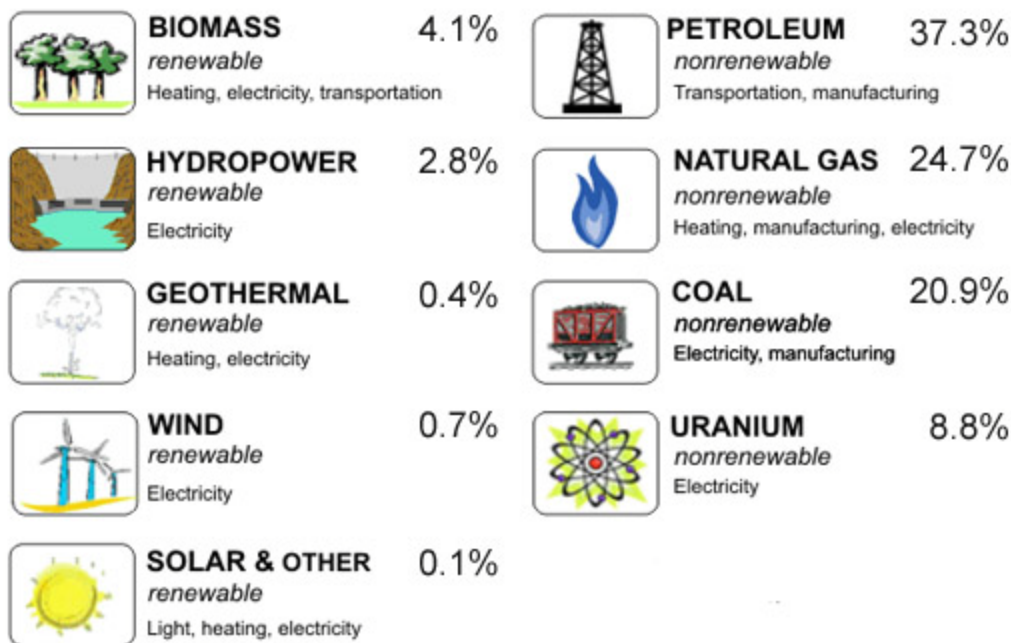
From: U.S. Energy Information Administration - [www.eia.doe.gov/kids/](http://www.eia.doe.gov/kids/)

## **1.2 Sources of Energy**

We use many different energy sources to do work. When we use electricity in our home, the electrical power was probably generated by burning coal or natural gas, by a nuclear reaction, or by a hydroelectric plant at a dam. Therefore, coal, natural gas, nuclear, and hydro are called energy sources. When we fill up a gas tank, the source might be petroleum or ethanol made by growing and processing corn.

Energy sources are divided into two groups — renewable (an energy source that can be easily replenished) and nonrenewable (an energy source that we are using up and cannot recreate). Renewable and nonrenewable energy sources can be used to produce secondary energy sources including electricity and hydrogen.

## U.S. Energy Consumption by Source, 2009



Source: U.S. Energy Information Administration, Annual Energy Review 2009 (August 2010)

In the United States, most of our energy comes from nonrenewable energy sources. Coal, petroleum, natural gas, propane, and uranium are nonrenewable energy sources. They are used to make electricity, to heat our homes, to move our cars, and to manufacture all kinds of products.

These energy sources are called nonrenewable because their supplies are limited. Petroleum, for example, was formed millions of years ago from the remains of ancient sea plants and animals. We can't make more petroleum in a short time.

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

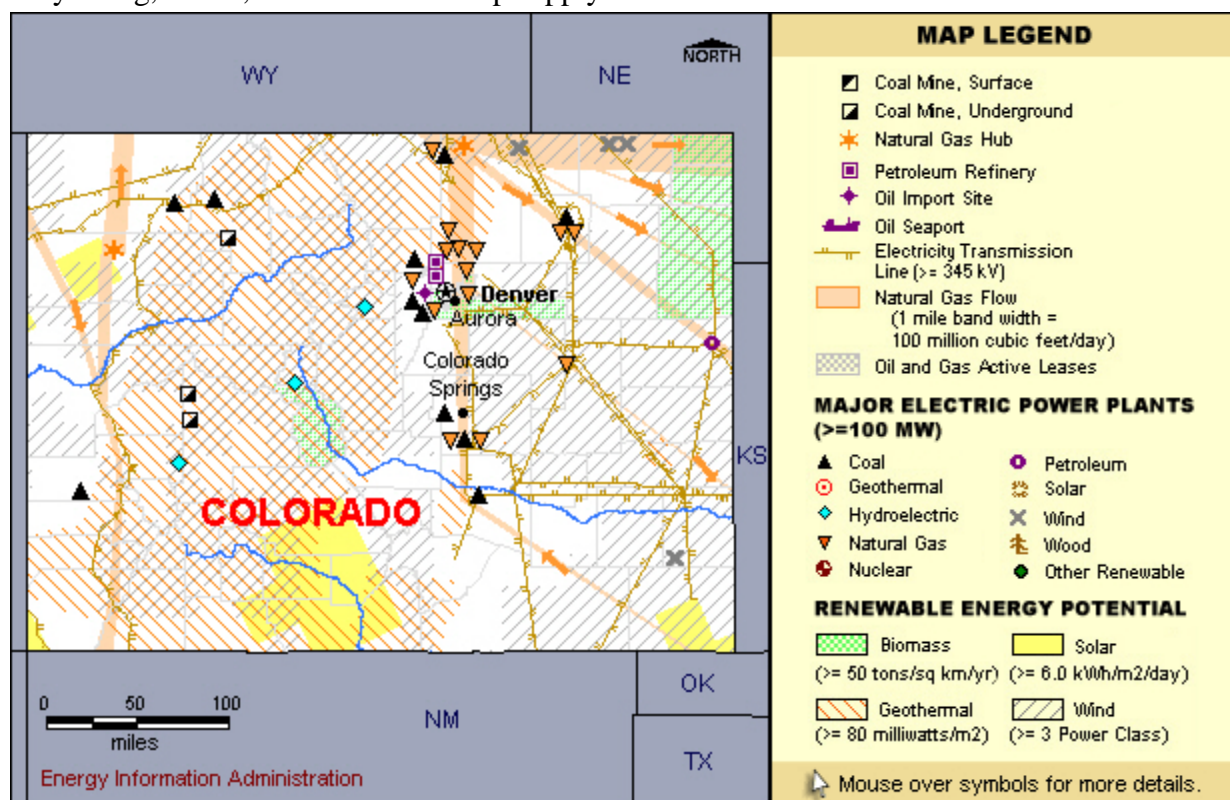
Adapted From: U.S. Energy Information Administration – [www.eia.doe.gov/kids/](http://www.eia.doe.gov/kids/)

### Energy Sources in Colorado

Colorado has substantial conventional fossil fuel and renewable energy resources. The State contains several fossil fuel-rich basins, including the Sand Walsh, Piceance, Paradox, and San Juan basins in the west, and the Denver and Raton basins in the east. Ten of the Nation's 100 largest natural gas fields and three of its 100 largest oil fields are found in Colorado. Substantial deposits of bituminous, subbituminous, and lignite coal are also found in the state.

Colorado's eastern plains and high Rocky Mountain ridges offer wind power potential, and geologic activity in the mountain areas provides potential for geothermal power development. According to the National Renewable Energy Laboratory, Colorado ranks fifth in the U.S. for solar power potential. Major rivers flowing from the Rocky Mountains offer hydroelectric power resources. Corn and other crops like canola grown in the flat eastern part of the State offer potential resources for ethanol and biofuels production. The Colorado economy is not energy intensive. The transportation and industrial sectors are the leading energy-consuming sectors in the state, but the residential and commercial sectors are not far behind.

Colorado oil production typically accounts for around 1 percent of the U.S. total. Most production takes place in the Denver and Piceance basins. Crude oil output serves Colorado's two refineries in Commerce City north of Denver. Several petroleum product pipelines from Wyoming, Texas, and Oklahoma help supply the Colorado market.



Although the Denver metropolitan area was the first area in the nation to require the use of motor gasoline blended with ethanol to reduce carbon monoxide emissions, the state is relatively new to large-scale ethanol production. Colorado produces ethanol mostly from corn at small facilities in the northeastern part of the State. Colorado's smallest ethanol production plant is co-located with the Coors brewery in Golden and uses waste beer to produce ethanol for fuel consumption. Using waste beer to produce ethanol lowers the emissions of volatile organic compounds from the Coors brewery significantly.

Colorado is a top natural gas-producing state. Conventional and unconventional output from several Colorado basins typically accounts for more than 5 percent of U.S. natural gas production. Coalbed methane (unconventional natural gas produced from coal seams) accounts

for about 30% of Colorado's natural gas production, and around 25% of all coalbed methane produced in the United States. Coalbed methane production is active in the San Juan and Raton Basins, and further development is possible in northwest Colorado's Piceance Basin, which holds the second-largest proved reserves in the nation.

### **Natural Gas and Fracking**

About three-fourths of Colorado households use natural gas as their primary energy source for home heating, one of the highest shares in the nation. Natural gas consumption by the electric power sector has been increasing since 2003, with a dramatic increase in 2007 putting the sector second only to the residential as the leading natural gas-consuming sector in Colorado. Much of the increased use of natural gas in Colorado and the U.S. is a result of growing use of a technology called hydraulic fracturing, or "fracking".

Fracking is the process of creating small cracks, or fractures, in underground geological formations to allow oil or natural gas to flow into the wellbore and thereby increase production. In Colorado, the target geologic formation for fracking is often more than 7,000 feet below the ground surface and more than 5,000 feet below any drinking water aquifers. To fracture a formation, special fracturing fluids are injected down the well bore and into the formation. These fluids typically consist of water, sand, and chemical additives. The pressure created by injecting the fluid opens the fractures. Fracture treatment of oil and gas wells in Colorado began in the 1970s and has evolved since then.

Groundwater quality and water use associated with fracking have recently become sources of controversy in the state and nation. Not all chemical additives used in fracking have been disclosed to the public. On the other hand, the Colorado Oil and Gas Conservation Commission requires the industry to take a number of steps to ensure groundwater protection when fracking.

Water is the primary component of most fracking fluids. The amount of water needed to frack a well in Colorado depends on the geologic basin, the formation, and the well. For example, approximately 50,000 to 300,000 gallons may be used to frack a shallow coalbed methane well in the Raton Basin, while up to 5 million gallons may be used to frack a horizontal well in the DJ Basin. For perspective, one million gallons is the amount of water consumed by:

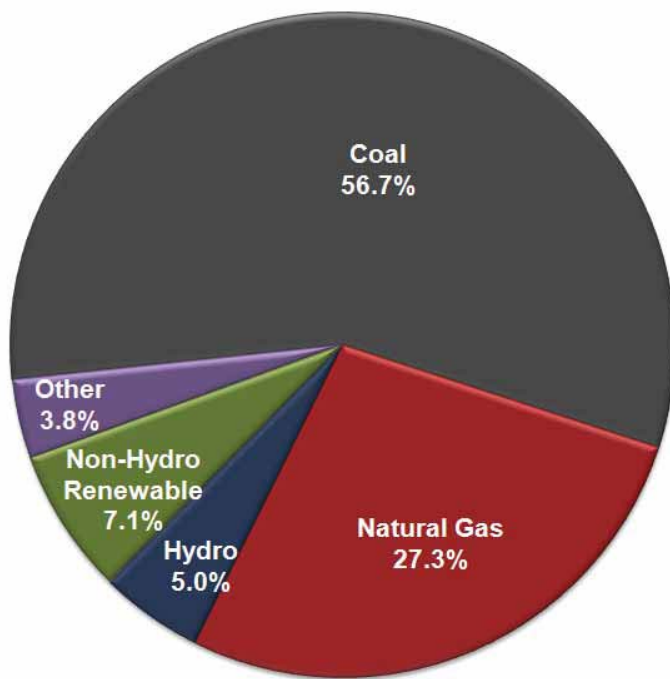
- A 1,000 megawatt coal-fired power plant in 2.5 hours
- A golf course in 5 days
- 1.5 acres of corn in a season

According to the U.S. EPA, twenty five percent to 75% of the fracking fluid (99.5% water) can not be recycled or reused after fracking. Fracking – like all energy development – is a complex subject that cannot easily be unraveled in this brief summary.

Source: U.S. Energy Information Administration – [www.eia.gov](http://www.eia.gov) and Colorado Oil and Gas Conservation Commission and U.S. EPA Draft Plan to Study the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources



## Electric Power in Colorado



Colorado Electric Power Mix, 2009

In 2009, 57% of Colorado's power was generated at coal-fired power plants. Non-hydro renewable resources represented 7% of the generation mix in 2009. Recent legislation is steering the state toward a more diverse mix of generation resources that will increasingly tap into the state's abundant natural gas and renewable energy sources – primarily wind, solar, and to a lesser extent, biomass, small hydropower, and geothermal. A majority of the electricity sold to customers in Colorado comes from power plants located in the state. Power is also transported to Colorado from power plants located in Wyoming and Nebraska.

Hydroelectric power also constitutes a portion of Colorado's energy mix (5%). The majority of the hydroelectric power supplied to Colorado is from federally owned dams. Colorado utilities do not generate any power from nuclear sources, though a small amount of nuclear power is imported into the state.

From: 2010 Colorado Utilities Report – [www.colorado.gov/energy](http://www.colorado.gov/energy)

## 1.3 Units of Energy

Physical units reflect measures of distances, areas, volumes, heights, weights, mass, force, and energy. Different types of energy are measured by different physical units:

- Barrels or gallons for petroleum
- Cubic feet for natural gas
- Tons for coal
- Kilowatt-hours for electricity

### Electrical Units

A kilowatt-hour is one thousand (1,000) watt-hours, which means that one watt of energy is consumed over 1,000 hours, that five watts of energy is consumed over 200 hours, or equivalent.

A watt is a measure of electrical power equal to volts times amps:  $\text{Watt} = \text{Volts} \times \text{Amps}$

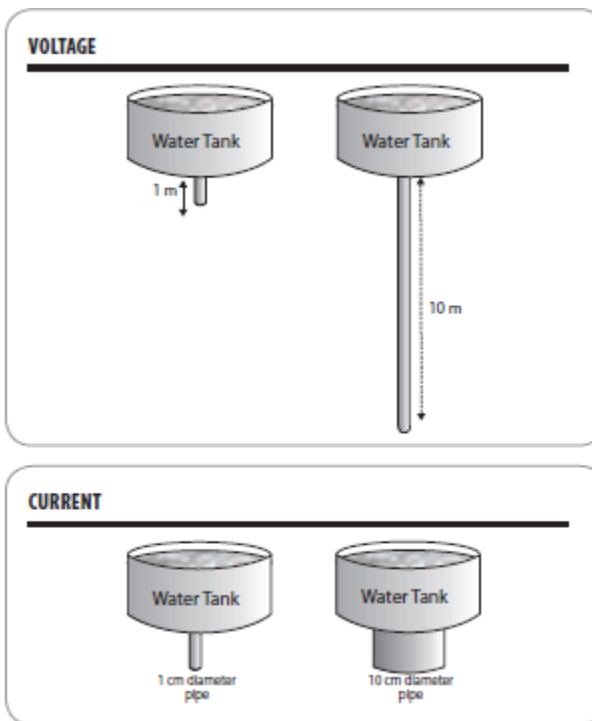
Voltage (V) is a measure of the pressure applied to electrons to make them move. Using a water analogy, if a tank of water were suspended one meter above the ground with a one-centimeter pipe coming out of the bottom, the water pressure would be similar to the force of a shower. If the same water tank were suspended 10 meters above the ground, the force of the water would be much greater, possibly enough to hurt you. Just as the 10-meter tank applies greater pressure



than the 1-meter tank, a 10-volt power supply (such as a battery) would apply greater pressure than a 1-volt power supply.

AA batteries are 1.5-volt; they apply a small amount of voltage for lighting small flashlight bulbs. A car usually has a 12-volt battery—it applies more voltage to push current through circuits to operate the radio or defroster. The standard voltage of wall outlets is 120 volts—a dangerous voltage. An electric clothes dryer is usually wired at 240 volts—a very dangerous voltage.

Going back to the water analogy, the water current is the number of molecules of water flowing past a fixed point; electrical current is the number of electrons flowing past a fixed point.



Electrical current (I) is defined as electrons flowing between two points having a difference in voltage. Current is measured in amperes or amps (A). One ampere is  $6.25 \times 10^{18}$  electrons per second passing through a circuit.

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

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

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

From: National Energy Education Development (NEED) Project Secondary Electricity Infobook

### Other Units

To compare different fuels, we need to convert the measurements to the same units:

Some popular units for comparing energy include British Thermal Units (Btu), barrels of oil equivalent, metric tons of oil equivalent, and metric tons of coal equivalent.

In the United States, the Btu, a measure of heat energy, is the most commonly used unit for comparing fuels. Because energy used in different countries comes from different places, the Btu content of fuels varies slightly from country to country.

The Btu content of each fuel provided below and used in the energy calculator reflects the average energy content for fuels consumed in the United States.

ENERGY UNIT	BTU CONTENT
1 barrel (42 gallons) of crude oil	5,800,000 Btu
1 gallon of gasoline	124,238 Btu (based on U.S. consumption, 2008)
1 gallon of diesel fuel	138,690 Btu
1 gallon of heating oil	138,690 Btu
1 barrel of residual fuel oil	6,287,000 Btu
1 cubic foot of natural gas	1,027 Btu (based on U.S. consumption, 2008)
1 therm of natural gas	102,700 Btu (based on U.S. consumption, 2008)
1 gallon of propane	91,033 Btu
1 short ton of coal	19,977,000 Btu (based on U.S. consumption, 2008)
1 kilowatt-hour of electricity	3,412 Btu

Example 1:

You have a natural gas furnace in your home that used 400 therms of natural gas for heating last winter. Your neighbor has electric baseboard heating that used 3,500 kilowatt-hours for heating last winter. To determine which home used more energy for heating, you can convert the natural gas and electricity consumption figures into Btus, as follows:

Natural Gas: 400 therms (your house)	X	102,700 Btu per therm	= 41,080,000 Btu
Electricity: 5,200 kWh (neighbor's house)	X	3,412 Btu per kWh	= 17,742,400 Btu

Answer: Your neighbor used more energy to heat her house!

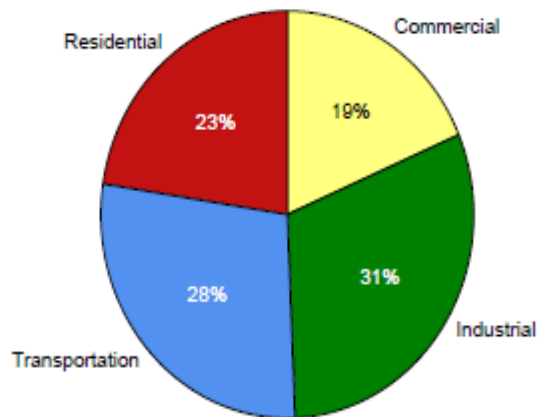
Source: U.S. Energy Information Administration - [www.eia.doe.gov/kids/](http://www.eia.doe.gov/kids/)

## **1.4 Uses of Energy**

The United States is a highly developed and industrialized society. We use a lot of energy in our homes, in businesses, in industry, and for personal travel and transporting goods.

- The industrial sector includes facilities and equipment used for manufacturing, agriculture, mining, and construction.
- The transportation sector comprises vehicles that transport people or goods, such as: cars, trucks, buses, motorcycles, trains, subways, aircraft, boats, barges, and even hot air balloons.
- The residential sector consists of homes and apartments.
- The commercial sector includes buildings such as offices, malls, stores, schools, hospitals, hotels, warehouses, restaurants, places of worship, and more.

End-Use Sector Shares of Total Consumption, 2010

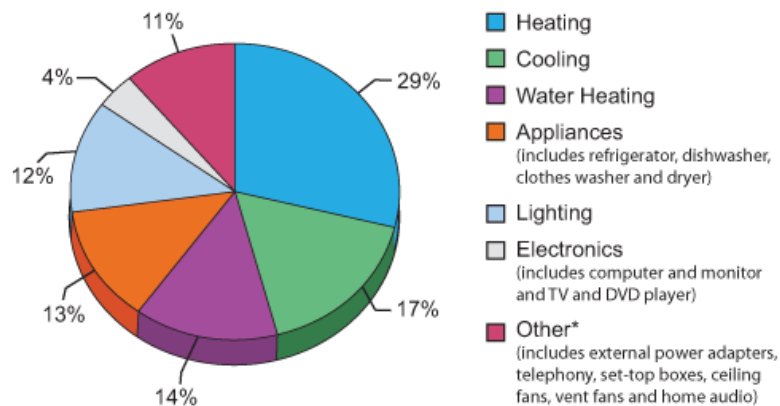


From: U.S. Energy Information Administration – [www.eia.doe.gov](http://www.eia.doe.gov)

## Residential Uses

### Where Does My Money Go?

Annual Energy Bill for a typical Single Family Home is approximately \$2,200.



Within the residential sector, the majority of energy in an average home in the U.S. goes toward space heating. In certain parts of Colorado such as the high mountains, many residents do not have active cooling systems at all. This chart can look very different depending on climate.

The average home in Colorado uses 8,160 kWh of electricity and 691 therms of natural gas per year.

See 2.3 Energy Audits for school energy use information.

From: U.S. Environmental Protection Agency – [www.energystar.gov](http://www.energystar.gov)

## **1.5 Energy Conversion**

When energy changes between potential and kinetic forms of energy it is referred to as **energy conversion**. It is important to note that heat is transferred to the surrounding environment during all energy conversions. Examples include:

- The chemical energy in food that is converted to mechanical energy (moving our muscles) by a process similar to burning called respiration. Energy is needed to break apart the food molecules, and during the process, thermal (heat) energy is generated. Feel your arm; this warmth is the energy that is released by respiration within your cells.
- Let's say you are using the energy you gained from food to operate a pair of scissors. Heat is transferred (lost) during this activity, too. There is friction when the blades of the scissors slide against each other to cut paper. Friction, the resistance to sliding, rubbing, or rolling of one material against another, requires extra work to overcome and results in energy loss through heat. This thermal (heat) energy escapes into the environment.

With each energy conversion, transferred heat leads to a slight increase in the thermal energy in the environment. In other words, this thermal energy is "lost" in to environment (eventually lost in space!) and not useable.

### **The Laws of Thermodynamics**

During the conversion process, all the energy that enters a conversion device is turned into other forms of energy. That is, you end up with an equal quantity of energy before and after the conversion. This is another way of stating the *first law of thermodynamics* that energy can neither be created nor destroyed.

However, not all the energy is converted into the desired form of energy (such as light).

**Although the *quantity* of energy is the same before and after conversion, the *quality* is different.** An incandescent light bulb has a thin wire filament mounted inside it. When the bulb is turned on, an electrical current passes through the filament, heating it up so much that it emits light. The thermal energy that is produced by the light bulb is often called wasted heat, because it is difficult to use this form of energy to do work.

The energy that is wasted when a light bulb shines exemplifies the *second law of thermodynamics* that states that with each energy conversion from one form to another, some of the energy becomes unavailable for further use. Applied to the light bulb, the second law of thermodynamics says that 100 units of electrical energy cannot be converted to 100 units of light energy. Instead, of the 100 units that are used to generate light, 95 are needed to heat the filament.

### **Second Law of Thermodynamics and Energy Efficiency**

In terms of energy, efficiency means how much of a given amount of energy can be converted from one form to another useful form. That is, how much of the energy is used to do what is intended (e.g., produce light) compared to how much is lost or "wasted" (e.g. as heat).

A formula for energy efficiency is the amount of useful energy obtained from a conversion divided by the energy that went into the conversion (efficiency = useful energy output / energy input). For example most incandescent light bulbs are only 5 percent efficient (.05 efficiency = f units of light out / 100 units of electricity in).

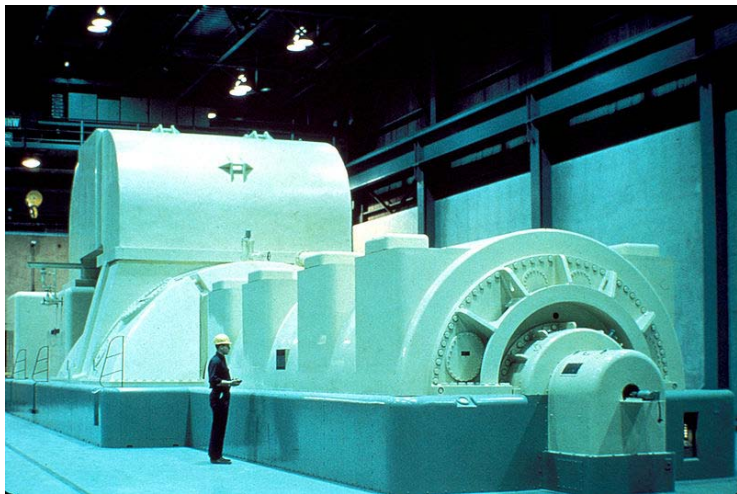
Because of unavoidable compliance with the second law of thermodynamics, no energy conversion device is 100 percent efficient. Even natural systems must comply to this law. Most modern conversion devices -- such as light bulbs and engines -- are inefficient. The amount of usable energy that results from the conversion process (electricity generation, lighting, heating, movement, etc.) is significantly less than the initial amount of energy. In fact, of all the energy that is incorporated into technologies such as power plants, furnaces, and motors, on average only about *16 percent* is converted into practical energy forms or used to create products. Where did the other 84 percent go? Most of this energy is lost as heat to the surrounding atmosphere.

From: Wisconsin K-12 Energy Education Program – [www.uwsp.edu](http://www.uwsp.edu)

## **1.6 Electricity Generation**

A generator is a device that converts mechanical energy into electrical energy. In 1831, Michael Faraday discovered that when a magnet is moved inside a coil of wire, electrical current flows in the wire. This discovery, known as Faraday's Law, proves that there is a relationship between electricity and magnetism.

A typical generator such as the steam turbine below uses powerful magnets and many coils of wire.



Faraday's Law tells us that the magnet must be moved inside the coil of wire to cause electrons to flow. You can also move the coil of wire inside the magnetic field to make electricity. A generator does this by having a rotating shaft with coils or magnets attached. On a steam turbine, for example, pressure from steam spins a giant rotor inside the generator. A number of different fuel sources, such as coal, natural gas, and biomass can be burned to create the heat needed to

produce steam. Very hot water from inside the earth – a geothermal heat source – can also be used to produce steam to run a generator.

By using a generator, we are able to take mechanical energy (rotating turbine) and convert it into electrical energy that we can use in our homes and schools.

Adapted from: Kid Wind – <http://learn.kidwind.org> and U.S. Nuclear Regulatory Commission

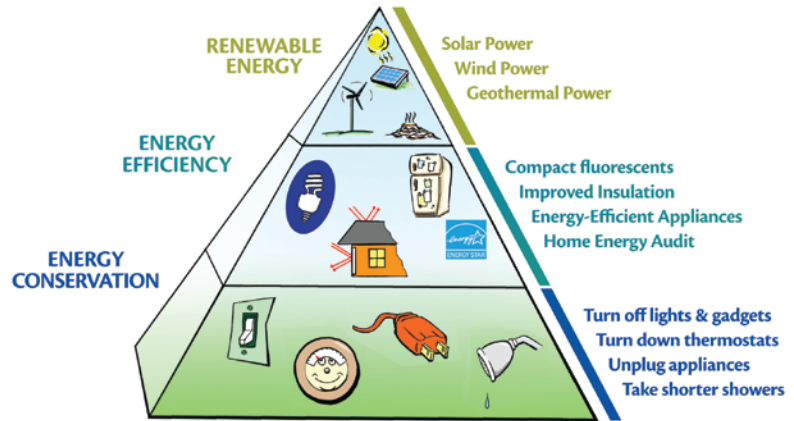


## **2.0 ENERGY CONSERVATION AND EFFICIENCY**

While the terms “energy conservation” and “energy efficiency” are sometimes used interchangeably, each term has a distinct definition. The graphic below is helpful when thinking about the two terms.

Energy conservation means not wasting energy. This is mostly accomplished by changing one’s behavior (i.e. taking shorter showers). Energy efficiency in a scientific sense means how much of a given amount of energy can be converted from one form to another useful form. In practical applications, energy efficiency means producing a desired result using as little energy as possible. This is usually accomplished by using energy efficient technologies that cost money.

### **The Smart Energy Living® Pyramid**



For example, turning off a light conserves energy. Running a compact fluorescent bulb instead of an incandescent bulb is using energy efficiently.

It is important to note that the base of the Smart Energy Living Pyramid is energy conservation. This suggests that one should do all one can to conserve energy by changing behavior before spending money to become more energy efficient. It’s the quickest and least expensive way to save energy and money. Energy efficiency comes next – after reducing our demand for energy in the first place through conservation one should use energy efficiently when it is required. This means that one should make smaller investments that have quick payback periods and increase comfort (i.e. through air sealing and improved insulation). Energy efficiency measures can also reduce the cost of purchasing a renewable energy system since those systems are sized based on how much energy is used.

Taking this concept further, many building scientists endorse a “whole house” or “whole building” approach to energy management. The whole building approach to energy efficiency is a way of thinking about how the passive and active energy systems in a building are interconnected. By becoming more efficient in one aspect of building energy use, consumers can gain opportunities to become more efficient in others. One example of this approach is using enough insulation (passive) to reduce the heating needs – and thereby the size of the furnace (active) – of a home.



## **2.1 Lighting**

Lighting accounts for a significant portion of the electricity used in the United States. In schools, about 30 percent of the total electricity bill is for lighting, and in homes about ten percent. Most of the light in residences is produced by incandescent light bulbs. If we converted to efficient lighting technologies, the electricity consumed for lighting would be reduced by 70 percent. Reducing the electricity used for lighting by just one percent would eliminate the need for an average-sized power plant. Recent developments have resulted in compact fluorescent lights (CFLs) that are four times as efficient as incandescent bulbs and last up to 13 times longer. Over the life of the bulbs, CFLs cost the average consumer less than half the cost of traditional incandescent bulbs for the same amount of light. In addition, CFLs produce very little heat, reducing the need for air conditioning in warm weather. Most schools and commercial buildings use fluorescent lighting. There are different fluorescent systems available. New fluorescent lighting systems are much more efficient than earlier lights and provide more natural light.

In light of these developments, new federal legislation set energy efficiency standards for light bulbs that require them to use less energy to provide light. The Energy Independence and Security Act (EISA) specified a change effective in January 2012 for incandescent 100-watt bulbs, with the maximum watts allowed reduced to 72. In 2013, 75-watt bulbs will be reduced to 53 watts, and in 2014, 60- and 40-watt bulbs will be reduced to a maximum of 43 and 29 watts respectively. These energy-efficient light bulbs will use 30% less electricity than today's average bulb. Rather than banning incandescent bulbs, this legislation may result in a new generation of high-efficiency incandescents to go along with already-efficient CFLs and light-emitting diodes (LEDs). Some incandescent bulbs that do not meet the new energy efficiency standards will still be available for specialty applications such as heat lamps and colored lights.

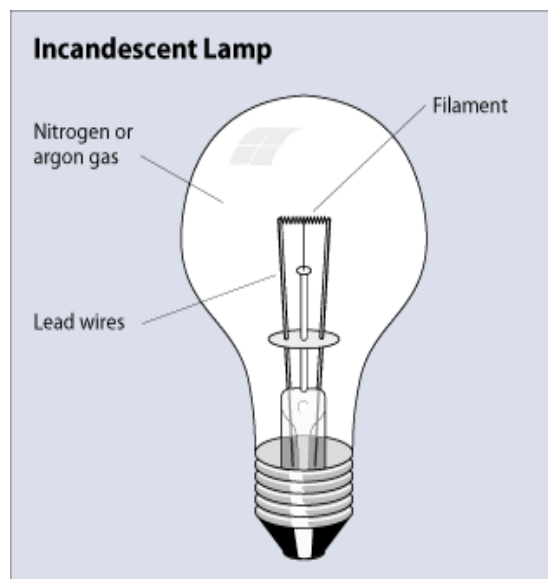
Source: National Energy Education Development Project Learning\_Conserving Teacher Guide and U.S. Department of Energy

### **How do incandescents work?**

Incandescent lighting is the oldest and most common type of lighting used in homes. It has traditionally delivered about 85% of household illumination.

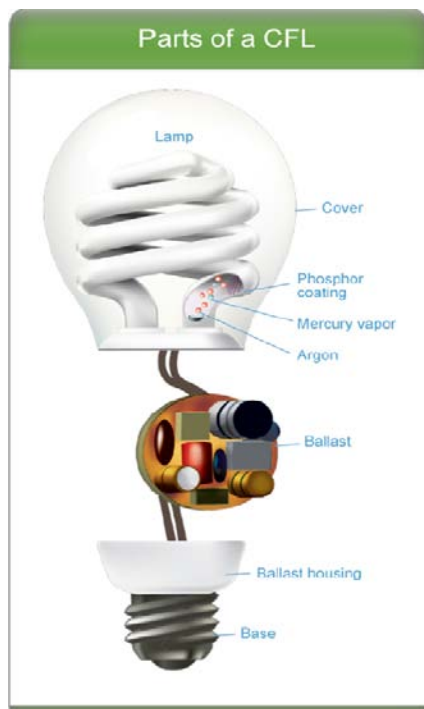
In incandescent lamps, light is emitted when electricity flows through—and heats—a tungsten filament. They light up instantly, providing a warm light and excellent color rendition. You can also dim them. However, incandescent lamps have a low efficacy compared to other lighting options (10–17 lumens per watt) and a short average operating life (750–2500 hours).

From: U.S. Department of Energy - [www.energysavers.gov](http://www.energysavers.gov)





## How do CFLs work?



CFLs produce light differently than incandescent bulbs. In an incandescent, electric current runs through a wire filament and heats the filament until it starts to glow. In a CFL, an electric current is driven through a tube containing argon and a small amount of mercury vapor. This generates invisible ultraviolet light that excites a fluorescent coating (called phosphor) on the inside of the tube, which then emits visible light.

CFLs need a little more energy when they are first turned on, but once the electricity starts moving, use about 75 percent less energy than incandescent bulbs. A CFL's ballast helps "kick start" the CFL and then regulates the current once the electricity starts flowing.

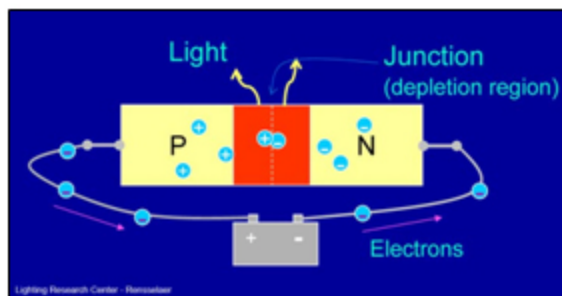
Older CFLs used large and heavy magnetic ballasts that caused a buzzing noise in some bulbs. Most CFLs today — and all ENERGY STAR qualified CFLs — use electronic ballasts, which do not buzz or hum. They are generally stated to last about 10,000 hours.

"Flicker checkers" are one type of device that can be used to indicate which style of fluorescent light is present in commercial buildings (see the Flicker Checker information sheet for more information).

From: U.S. Environmental Protection Agency - [www.energystar.gov](http://www.energystar.gov)

## How do LEDs work?

LEDs differ from traditional light sources in the way they produce light. In an incandescent lamp, a tungsten filament is heated by electric current until it glows or emits light. In a fluorescent lamp, an electric arc excites mercury atoms, which emit ultraviolet (UV) radiation. After striking the phosphor coating on the inside of glass tubes, the UV radiation is converted and emitted as visible light.



An LED, in contrast, is a semiconductor diode. It consists of a chip of semiconducting material treated to create a structure called a p-n (positive-negative) junction. When connected to a power source, current flows from the p-side or anode to the n-side, or cathode, but not in the reverse direction. Charge-carriers (electrons and electron holes) flow into the junction from electrodes. When an electron meets a hole, it falls into a lower energy level, and releases energy in the form of a photon (light).

The specific wavelength or color emitted by the LED depends on the materials used to make the diode. Red LEDs are based on aluminum gallium arsenide (AlGaAs). Blue LEDs are made from indium gallium nitride (InGaN) and green from aluminum gallium phosphide (AlGaP). "White" light is created by combining the light from red, green, and blue (RGB) LEDs or by coating a blue LED with yellow phosphor.

Energy Star qualified LEDs use at least 75 percent less energy and last at least 15 times longer than an incandescent bulb. They are generally stated to last 25,000 hours.

From: U.S. Department of Energy - [www1.eere.energy.gov](http://www1.eere.energy.gov) and U.S. Environmental Protection Agency - [www.energystar.gov](http://www.energystar.gov)

### Comparison of Power Conversion of White Light Sources

All light sources convert electric power into radiant energy and heat in various proportions.

Incandescent lamps emit primarily infrared (IR), with a small amount of visible light.

Fluorescent and metal halide sources convert a higher proportion of the energy into visible light, but also emit IR, ultraviolet (UV), and heat. LEDs generate little or no IR or UV, but convert only 15%-25% of the power into visible light; the remainder is converted to heat that must be conducted from the LED die to the underlying circuit board and heat sinks, housings, or luminaire frame elements. The table below shows the approximate proportions in which each watt of input power is converted to heat and radiant energy (including visible light) for various white light sources.

	<b>Incandescent † (60W)</b>	<b>Fluorescent† (Typical linear CW)</b>	<b>LED*</b>
<b>Visible Light</b>	8%	21%	15- 25%
<b>IR</b>	73%	37%	~0%
<b>UV</b>	0%	0%	0%
<b>Total Radiant Energy</b>	81%	58%	15- 25%
<b>Heat (Conduction + Convection)</b>	19%	42%	75- 85%
<b>Total</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>

† IESNA Handbook ; \* Varies depending on LED efficacy. This range represents best currently available technology in color temperatures from warm to cool.

From: U.S. Department of Energy - [www1.eere.energy.gov](http://www1.eere.energy.gov)

## **2.2 Insulation and Heat Transfer**

Heat can be transferred in one (or in a combination) of three ways: conduction, convection, and radiation. Good heat insulators are substances that are poor conductors of heat.

Heat transfer by conduction requires that heat be moved between things that are in contact with each other. For example, a glass rod is not nearly as good at conducting heat than is a similar sized iron rod. If you were to hold on to one end of a glass rod while you held the other end in a flame for a time, you might feel little or no warmth at the end you were holding. On the other hand, if you were to perform a similar experiment with a common metal nail, you wouldn't be able to hold it very long before your end got uncomfortably hot. This little thought experiment is an illustration of heat transfer by conduction. Iron is a better thermal (heat) conductor than glass.

If one were to melt glass, and then spin it into very fine fibers, and then fluff and tangle the fibers together to form a blanket, one would have essentially made a batt of fiberglass insulation such as might be used to insulate the walls of a home. The material works as an insulator because glass fibers are poor conductors of heat AND, when fluffed into a blanket, they trap air (also a rather poor conductor of heat) so that convection currents cannot be easily established within the mass of material. The effect is to greatly slow heat flow by either conduction or convection.

Insulation provides a resistance to heat flow by conduction. Properly insulating decreases heat flow by providing an effective resistance to the flow of heat. Insulation's resistance to heat flow is measured or rated in terms of its thermal resistance or R-value.



The higher the R-value is, the greater the insulating effectiveness. The R-value depends on the type of insulation and includes its material, thickness, and density. When calculating the R-value of a multilayered installation, add the R-values of the individual layers. Installing more insulation in your home increases the R-value and the resistance to heat flow.

The effectiveness of insulation's resistance to heat flow also depends on how and where the insulation is installed. For example, insulation that is compressed will not provide its full rated R-value. The overall R-value of a wall or ceiling will be somewhat different from the R-value of the insulation itself because some heat flows around the insulation through the studs and joists. Therefore, it's important to properly install your insulation to achieve the maximum R-value.

The amount of insulation or R-value you'll need depends on your climate, type of heating and cooling system, and the section of the house you plan to insulate.

What you see:		What it probably is	Depth (inches)	Total R-value
Loose fibers	light-weight yellow, pink, or white	fiberglass	_____	=2.5×depth
	dense gray or near-white, may have black specks	rock wool	_____	=2.8×depth
	small gray flat pieces or fibers (from newsprint)	cellulose	_____	=3.7×depth
Granules	light-weight	vermiculite or perlite	_____	=2.7×depth
Batts	light-weight yellow, pink, or white	fiberglass	_____	=3.2×depth

From: U.S. Department of Energy - [www.newton.dep.anl.gov](http://www.newton.dep.anl.gov) and [www.ornl.gov](http://www.ornl.gov) and [www1.eere.energy.gov](http://www1.eere.energy.gov)

### Heating and Cooling Degree Days

Heating engineers who wanted a way to relate each day's temperatures to the demand for fuel to heat buildings developed the concept of heating degree days.

To calculate the heating degree days for a particular day, find the day's average temperature by adding the day's high and low temperatures and dividing by two. If the number is above 65, there are no heating degree days that day. If the number is less than 65, subtract it from 65 to find the number of heating degree days. For example, if the day's high temperature is 60 and the low is 40, the average temperature is 50 degrees. 65 minus 50 equals 15 heating degree days.

Cooling degree days are also based on the day's average minus 65. They relate the day's temperature to the energy demands of air conditioning. For example, if the day's high is 90 and the day's low is 70, the day's average is 80. 80 minus 65 equals 15 cooling degree days.

From: USA Today – [www.usatoday.com](http://www.usatoday.com)

## 2.3 Energy Audits

Aside from making a lighting system more efficient and adding insulation to a building, there are a number of other ways to conserve energy and become more energy efficient:

- Plugging air leaks by: installing plywood, rigid foam board, door sweeps, and weatherstripping; caulking around windows, doors, and plumbing penetrations; closing fireplace dampers; inserting foam seals in electrical outlets; and other measures can reduce heating and cooling costs.
- Setting a water heater at 120 degrees (or its medium setting) or 140 degrees for a water heater associated with a dishwasher with a booster heater, wrapping an older water heater with an insulating blanket, and using low-flow showerheads can reduce water heating costs.
- Cleaning or replacing a furnace filter every 1-3 months during the heating season can reduce heating costs by 5%.

- Using a thermostat to adjust the temperature of a space when it's not occupied or when occupants are sleeping can save about 1 percent of heating and cooling costs per degree adjusted.
- Reducing or eliminating “phantom loads” (the energy used by some appliances even after they're turned off) by turning off power strips, unplugging appliances, and/or using “smart” power strips can reduce electricity use.
- Purchasing efficient appliances can save money on the energy used to operate the appliances over their lifetimes. Although the initial cost of the efficient appliances may be high, lower operating costs can make the investment pay off over the life of the appliance.



An energy assessment, also known as an energy audit, is the first step to assess how much energy your school, home, or building consumes and to evaluate what measures you can take to become more energy efficient. An assessment will show you problems that may, when corrected, save you significant amounts of money over time.

During the assessment, you can pinpoint where your building is losing energy. Energy assessments also determine the efficiency of your building's heating and cooling systems. An assessment may also show you ways to conserve hot water and electricity. Depending on the building and your inclination, you can perform a simple energy assessment yourself, or have a professional energy auditor carry out a more thorough assessment.

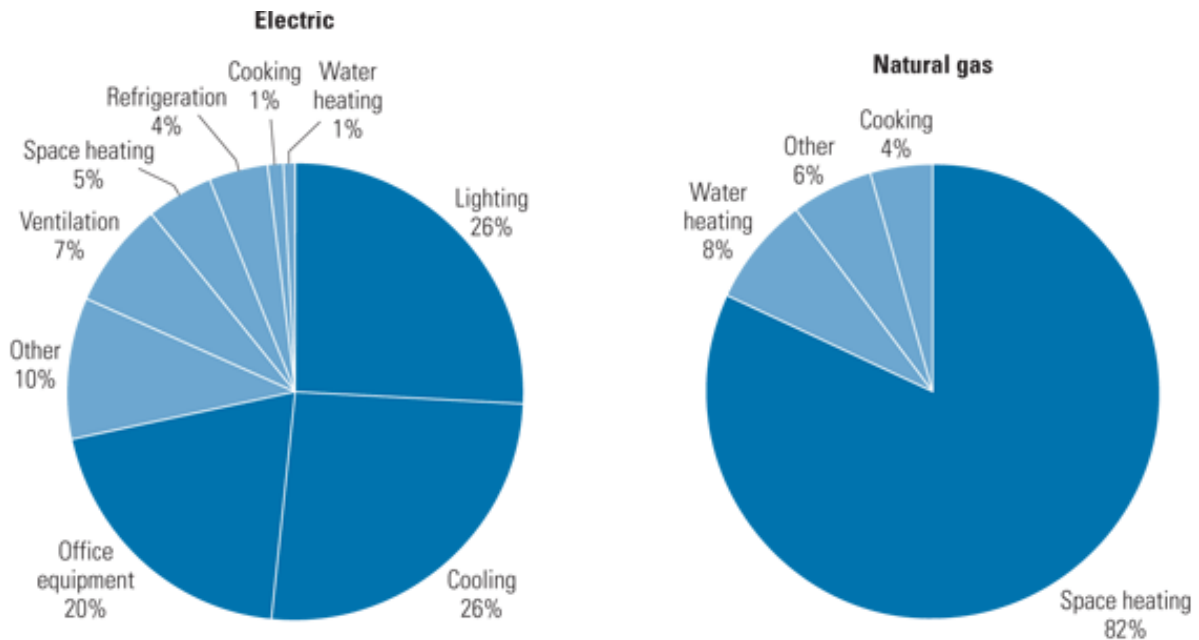
A professional auditor uses a variety of techniques and equipment to determine the energy efficiency of a structure. Thorough assessments often use equipment such as blower doors, which measure the extent of leaks in the building envelope, and infrared cameras, which reveal hard-to-detect areas of air infiltration and missing insulation.

From: U.S. Department of Energy - [www.energysavers.gov](http://www.energysavers.gov)

### **School Energy Use**

Typically, space heating, cooling, and lighting together account for nearly 70 percent of school energy use (see below). Plug loads—such as computers and copiers—constitute one of the top three electricity end uses, after lighting and cooling.

Most of the electricity consumed by educational facilities is used for lighting, cooling, and plug loads such as computers and copiers; most of the natural gas is used for space heating. Each school's energy profile is different, so these charts are not representative of all schools. For example, school buildings in warmer climates will tend to show a larger share of electricity used for space cooling than those in cooler climates.



Courtesy: E source; from Commercial Building Energy Consumption Survey, 1999 data

Energy intensity in schools varies widely and is influenced by both weather conditions and specific operating characteristics such as building size, classroom seating capacity, and the presence of an on-site cafeteria. On-site energy intensity in schools can range from less than 10,000 Btu per square foot (ft<sup>2</sup>) to over 500,000 Btu/ft<sup>2</sup>. Given this large variation and skewed distribution, it can be misleading to assess a school building's performance by comparing its average energy intensity.

From: U.S. Environmental Protection Agency - [www.energystar.gov](http://www.energystar.gov)



### **3.0 RENEWABLE ENERGY**

Renewable energy sources include biomass, geothermal energy, hydropower, solar energy, and wind energy. They are called renewable energy sources because they are naturally replenished. Day after day, the sun shines, the wind blows, and the rivers flow. We use renewable energy sources mainly to make electricity, but also as fuel (biofuels) and to heat and cool (geothermal heat pumps).

#### **Renewable Energy Policy in Colorado**

While renewable energy sources still make up only a small fraction of our total energy generated and our electricity generated, Colorado has stood out as a state that has aggressively deployed clean and renewable energy technologies. In particular, Colorado House Bill 10-1001, signed by Governor Bill Ritter Jr. on March 22, 2010, increased the state's Renewable Energy Standard (RES) to 30% by 2020 for Investor Owned Utilities (IOUs) - Xcel Energy and Black Hills

Corporation. This means that 30% of the electricity generated by those two companies must come from renewable sources by 2020.

Furthermore, the legislation created a requirement that 3% of all electric sales must come from renewable distributed generation (DG) by 2020.

According to the California Energy Commission, “distributed energy resources are small-scale power generation technologies (typically in the range of 3 to 10,000 kW) located close to where electricity is used (e.g., a home or business) to provide an alternative to or an enhancement of the traditional electric power system” ([www.energy.ca.gov](http://www.energy.ca.gov)).



**Distributed energy generation decreases the need for expensive transmission infrastructure and minimizes "lines losses" of electric power from transmitting electricity over large areas.**

As background, Colorado was the first state in the U.S. to adopt a RES by a vote of the people. After four consecutive years of failing in the legislature, the measure was taken to the ballot through a citizen's initiative in 2004. Amendment 37 created a 10% RES standard for IOUs to be achieved by 2015. Amendment 37 also established net metering and interconnection standards for the state's IOUs as well as a “carve out” for solar generation. Under Amendment 37 in addition to the 10% goal, 4% of that renewable energy must be solar generation with half of that being “central” or utility scale solar and the other half from rooftop type of distributed installations.

In 2007, Xcel Energy the state's largest IOU serving ~60% of the electric load, was on track to reach the existing 10% standard by the end of the year - seven years early. Later that year, House Bill 07-1281 was introduced and passed, doubling the renewable energy standard to 20% for

IOUs and, for the first time included the Rural Electric Coops and Municipal Electric Utilities with their own 10% goal by 2020.

In the 2010 legislative session, HB10-1001 increased the standard to 30% for IOUs and modifying the “solar carveout” to a larger 3% DG requirement. This standard is the highest in the Rocky Mountain West and one of the most aggressive in the country.

From: Colorado Governor’s Energy Office - [www.colorado.gov/energy](http://www.colorado.gov/energy)

### **3.1 Solar**

Solar is the Latin word for sun—a powerful source of energy that can be used to heat, cool, and light our homes and businesses. That's because more energy from the sun falls on the earth in one hour than is used by everyone in the world in one year. A variety of technologies convert sunlight to usable energy for buildings. The most commonly used solar technologies for homes and businesses are solar water heating, passive solar design for space heating and cooling, and solar photovoltaics for electricity.

#### **Solar Photovoltaics**

Solar cells, also called photovoltaic (PV) cells, convert sunlight directly into electricity. PV gets its name from the process of converting light (photons) to electricity (voltage), which is called the PV effect. The PV effect was discovered in 1954, when scientists at Bell Telephone discovered that silicon (an element found in sand) created an electric charge when exposed to sunlight. Soon solar cells were being used to power space satellites and smaller items like calculators and watches. Today, thousands of people power their homes and businesses with individual solar PV systems. Utility companies are also using PV technology for large power stations.



Solar panels used to power homes and businesses are typically made from solar cells combined into modules that hold about 40 cells. A typical home will use about 10 to 20 solar panels to power the home. The panels are usually mounted at a fixed angle facing south, or they can be mounted on a tracking device that follows the sun, allowing them to capture the most sunlight. Many solar panels combined together to create one system is called a solar array. For large electric utility or industrial applications, hundreds of solar arrays are interconnected to form a large utility-scale PV system.

Traditional solar cells are made from silicon, are usually flat-plate, and generally are the most efficient. Second-generation solar cells are called thin-film solar cells because they are made from amorphous silicon or nonsilicon materials such as cadmium telluride. Thin film solar cells use layers of semiconductor materials only a



few micrometers thick. Because of their flexibility, thin film solar cells can double as rooftop shingles and tiles, building facades, or the glazing for skylights.

Third-generation solar cells are being made from variety of new materials besides silicon, including solar inks using conventional printing press technologies, solar dyes, and conductive plastics. Some new solar cells use plastic lenses or mirrors to concentrate sunlight onto a very small piece of high efficiency PV material. The PV material is more expensive, but because so little is needed, these systems are becoming cost effective for use by utilities and industry. However, because the lenses must be pointed at the sun, the use of concentrating collectors is limited to the sunniest parts of the country.

From: National Renewable Energy Laboratory - [www.nrel.gov](http://www.nrel.gov)

### How Solar PV Works

Sunlight is composed of photons, or particles of solar energy. These photons contain various amounts of energy corresponding to the different wavelengths of the solar spectrum.

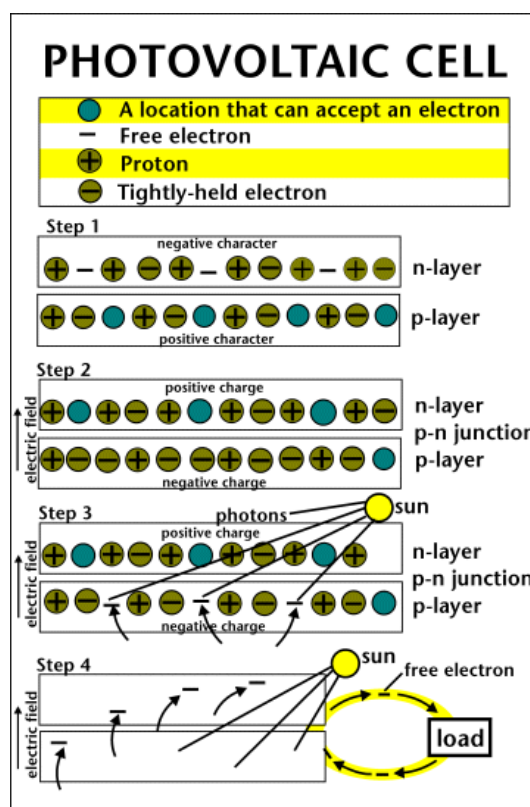
When photons strike a photovoltaic cell, they may be reflected, pass right through, or be absorbed. Only the absorbed photons provide energy to generate electricity. When enough sunlight (energy) is absorbed by the material (a semiconductor), electrons are dislodged from the material's atoms. Special treatment of the material surface during manufacturing makes the front surface of the cell more receptive to free electrons, so the electrons naturally migrate to the surface.

When the electrons leave their position, holes are formed. When many electrons, each carrying a negative charge, travel toward the front surface of the cell, the resulting imbalance of charge between the cell's front and back surfaces creates a voltage potential like the negative and positive terminals of a battery. When the two surfaces are connected through an external load, such as an appliance, electricity flows.

From: National Energy Education Development (NEED) Project - [www.need.org](http://www.need.org)

### Series and Parallel

An electric circuit consists of the various conductors that lead from the negative to the positive terminal of a source of electricity. The various parts of a typical house circuit include a fuse or circuit breaker, wires, switches, wall outlets, and light sockets and bulbs.



A circuit through which electricity is flowing is said to be closed. The circuit can be opened, or broken, by turning off a switch or by removing a fuse, pulling out a plug, or disconnecting the wires. A circuit generally contains a load - a device such as a light bulb or appliance that provides resistance in the circuit. If a current is allowed to flow from one terminal to another with very little resistance, a short circuit exists. Unless such a current is quickly stopped by a fuse or circuit breaker, the wires may heat up enough to start a fire.

There are two basic methods of wiring a circuit such as a circuit needed to connect PV panels to one another—in series and in parallel. In the series circuit the current flows through one device (such as a light bulb) to reach the next. In the parallel circuit the current enters and leaves each device separately. Devices connected in series each carry the same amount of current; devices connected in parallel are each subjected to the same voltage. Many electrical applications use a combination of these two types of circuits.

Adapted from: HowStuffWorks: <http://science.howstuffworks.com>

### **Tilt and Azimuth**

For a fixed PV array, the tilt angle is the angle from horizontal of the inclination of the PV array ( $0^\circ$  = horizontal,  $90^\circ$  = vertical). A tilt angle equal to the location's latitude normally maximizes annual energy production. Increasing the tilt angle favors energy production in the winter when the sun is lower in the sky, and decreasing the tilt angle favors energy production in the summer when the sun is higher.

For roof-mounted PV arrays, the table below gives tilt angles for various roof pitches (in ratio of vertical rise to horizontal run).

**PV Array Tilt Angle by Roof Pitch**

Roof Pitch	Tilt Angle ( $^\circ$ )
4/12	18.4
5/12	22.6
6/12	26.6
7/12	30.3
8/12	33.7
9/12	36.9
10/12	39.8
11/12	42.5
12/12	45.0

For a fixed PV array, the azimuth angle is the angle clockwise from true north that the PV array faces. An azimuth angle of 180° (south-facing) for locations in the northern hemisphere and 0° (north-facing) for locations in the southern hemisphere normally maximizes energy production. For the northern hemisphere, increasing the azimuth angle favors afternoon energy production, and decreasing the azimuth angle favors morning energy production. The opposite is true for the southern hemisphere.

### Azimuth Angles by Heading

Heading	Azimuth Angle (°)
N	0 or 360
NE	45
E	90
SE	135
S	180
SW	225
W	270
NW	315

From: National Renewable Energy Laboratory - [www.nrel.gov](http://www.nrel.gov)

## **3.2 Wind**

We have been harnessing the wind's energy for hundreds of years. From old Holland to farms in the United States, windmills have been used for pumping water or grinding grain. Today, the windmill's modern equivalent—a wind turbine—can use the wind's energy to generate electricity.

Wind turbines, like windmills, are mounted on a tower to capture the most energy. At 100 feet (30 meters) or more aboveground, they can take advantage of the faster and less turbulent wind. Turbines catch the wind's energy with their propeller-like blades. Usually, three blades are mounted on a shaft to form a rotor.

Wind turbines can be used as stand-alone applications, or they can be connected to a utility power grid or even combined with a photovoltaic (solar cell) system. For utility-scale (megawatt-sized) sources of wind energy, a large number of wind turbines are usually built close together to form a wind plant. Several electricity providers



**These wind turbines near Lamar, Colorado, are part of the 162-MW Colorado Green Wind Farm. Each turbine produces 1.5 megawatts of electricity.**

today use wind plants to supply power to their customers.

Stand-alone wind turbines are typically used for water pumping or communications. However, homeowners, farmers, and ranchers in windy areas can also use wind turbines as a way to cut their electric bills.

Small wind systems also have potential as distributed energy resources. Distributed energy resources refer to a variety of small, modular power-generating technologies that can be combined to improve the operation of the electricity delivery system.

## How Wind Turbines Work

Like old fashioned windmills, today's wind machines (also called wind turbines) use blades to collect the wind's kinetic energy. The wind flows over the blades creating lift, like the effect on airplane wings, which causes them to turn. The blades are connected to a drive shaft that turns an electric generator to produce electricity.

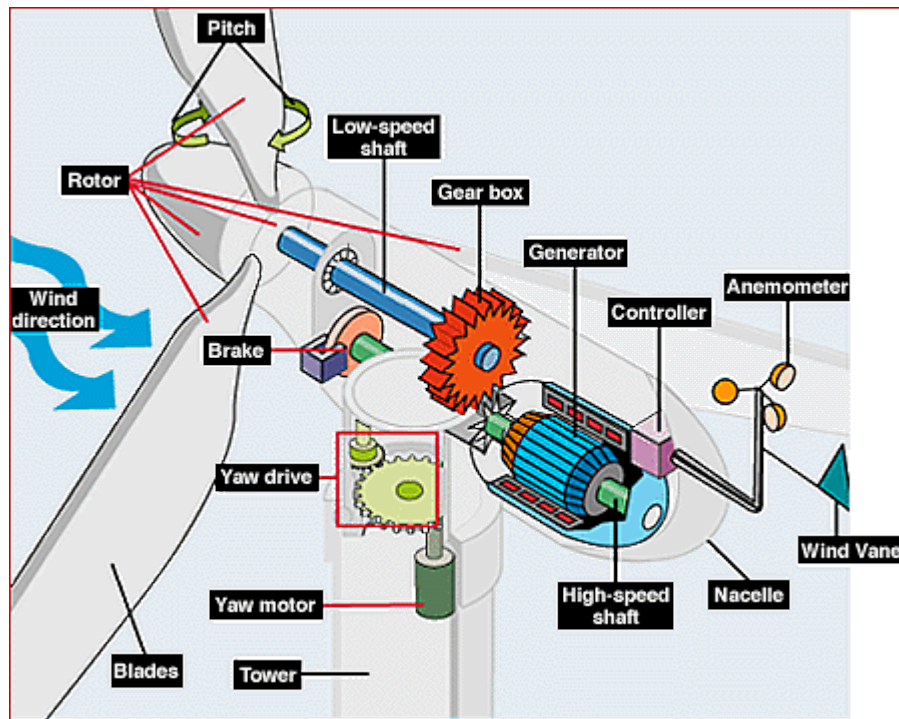


Diagram of Windmill Workings

With the new wind machines, there is still the problem of what to do when the wind isn't blowing. At those times, other types of power plants must be used to make electricity.

From: National Renewable Energy Laboratory - [www.nrel.gov](http://www.nrel.gov)

The power in the wind is determined by the following equation:

$$\text{Power in the Wind} = \frac{1}{2}\rho AV^3$$

Where:

$\rho$  (pronounced “rho”) = density of the air

A = area swept by the blades

V = (velocity) wind speed

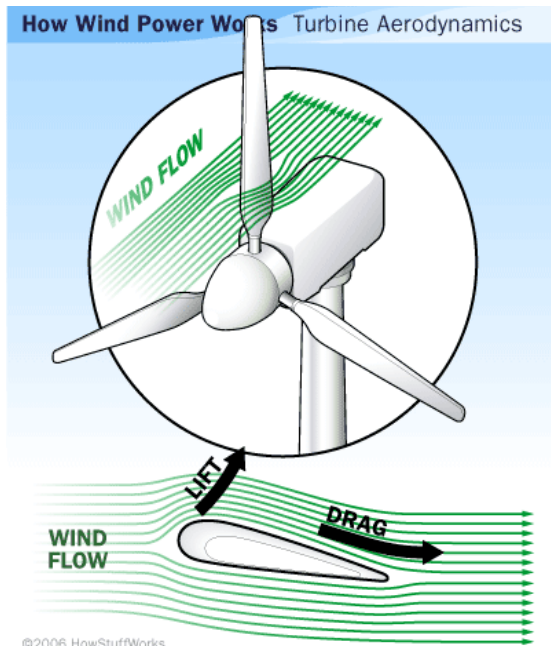
Because power depends on the wind speed cubed, wind speed is the single most important factor in determining the power available to a wind turbine. Air density is a variable that cannot be controlled by technology and decreases with increases in elevation. The swept area of the blades (length of a blade squared times pi) is dependent on how long the turbine blades are.

It is also important to note that increasing the height of a turbine tower will result in increased wind speeds and therefore increased electricity generation and that increasing tower height tends to be cost-effective when feasible:

Tower height	Wind speed (mph)	kWh/year	System cost	Incremental cost from 60'	Incremental savings	Payback period on incremental cost
60'	7.3	2,709	\$48,660	--	---	---
80	9.3	6,136	\$49,841	\$1,176	\$377	3.1
100	10.7	9,338	\$51,346	\$2,681	\$1,027	2.6

From [www.renewwisconsin.org](http://www.renewwisconsin.org)

## Blade Design



©2006 HowStuffWorks

Unlike the old-fashioned Dutch windmill design, which relied mostly on the wind's force to push the blades into motion, modern turbines use more sophisticated aerodynamic principles to capture the wind's energy most effectively. The two primary aerodynamic forces at work in wind-turbine rotors are **lift**, which acts perpendicular to the direction of wind flow; and **drag**, which acts parallel to the direction of wind flow.

Turbine blades are shaped a lot like airplane wings -- they use an airfoil design. In an airfoil, one surface of the blade is somewhat rounded, while the other is relatively flat. Lift is a pretty complex phenomenon and may in fact require a Ph.D. in math or physics to fully grasp. But in one simplified explanation of lift, when wind travels over the rounded, downwind face of the blade, it has to move faster to reach the end of

the blade in time to meet the wind travelling over the flat, upwind face of the blade (facing the direction from which the wind is blowing).

Since faster moving air tends to rise in the atmosphere, the downwind, curved surface ends up with a low-pressure pocket just above it. The low-pressure area sucks the blade in the downwind direction, an effect known as "lift." On the upwind side of the blade, the wind is moving slower and creating an area of higher pressure that pushes on the blade, trying to slow it down. Like in the design of an airplane wing, a high lift-to-drag ratio is essential in designing an efficient turbine blade. Turbine blades are twisted so they can always present an angle that takes advantage of the ideal lift-to-drag force ratio. Different blade designs will result in different lift-to-drag ratios and hence generate more or less electricity under the same wind speed regime. Further, voltage is a factor of how fast the blades spin while current is a factor of how much torque the blades create when spinning.

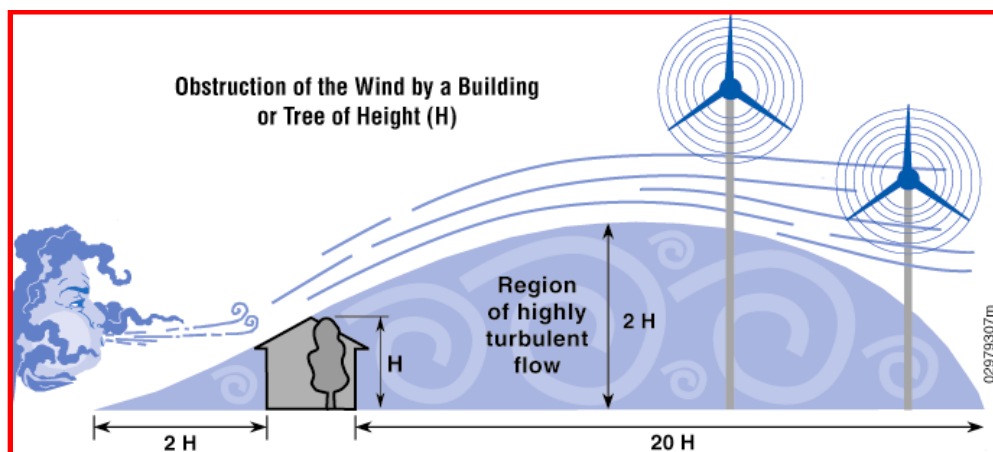
From: How Stuff Works – <http://science.howstuffworks.com>

### Wind Energy in Colorado

A small wind energy system may provide you with an economical source of electricity if you live in an area with fairly steady strong winds and at least one-half acre of open land.

Personal impressions of the windiness of a site are often not reliable – it is better to use an objective measure. The most precise information can be obtained by placing an anemometer (a device that measures wind speed) on your site for at least one year.

A faster method is to look up wind data from the Colorado wind resource map and the anemometer loan program. Winds on your site should be at least class 2 (annual wind speeds averaging 9.8 to 11.5 mph at 50 meters above ground level) to be suitable for wind generation. In general, the following picture illustrates siting guidelines to be followed for a wind turbine with regard to upwind obstructions:



You need to make sure your local zoning codes or covenants allow wind turbines and the fairly tall towers that allow them to catch enough wind to make electricity. You also need to do enough research to learn whether a turbine will pay for itself quickly enough to meet your financial requirements.



Small wind systems designed for individuals, businesses and farm or ranch operators are growing dramatically and evolving rapidly. The industry group, American Wind Energy Association, predicts a thirty-fold increase in the U.S. in the next five years.

While the cost of a wind turbine is steep, the wind energy system will not require further electrical purchases in the future. This allows you to avoid unpredictable future costs of other fuels by paying for wind energy upfront.

### **Considerations for Wind**

- Zoning regulations vary dramatically across states, counties and municipalities. Check with your county planning and zoning office before proceeding. In many urban counties, height restrictions may rule out a wind tower. It is always a good idea to discuss the idea with your neighbors, as they may have input on placement.
- Maintenance varies by system, so ask about requirements when you are considering which kind of turbine to buy and when you are reviewing literature from different manufacturers. Many small wind turbines require regular maintenance that generally consists of periodic inspections and adjustments. Representatives of manufacturers can give you an idea of the expected maintenance schedule and help you arrange maintenance. A rule of thumb is to allocate about 1 percent of the installed cost of the wind system for operation and maintenance expenses over the life of the system.
- When you considering buying a system, ask about its anticipated lifespan. Most reputable small turbines should perform well for many years with only periodic maintenance required. Buy a turbine that has a good track record and a good warranty— at least five years is preferable. A warranty is one indication of the manufacturer's confidence in the product. In general, you can expect 20 years from a properly maintained turbine from a reputable manufacturer.
- Small wind turbines emit no pollution and need no water. They also reduce the amount of pollutants that your utility would emit if you were relying on electricity from burning coal, for example. According to the American Wind Energy Association, over its life, a small residential wind turbine can offset approximately 1.2 tons of air pollutants and 200 tons of greenhouse gas pollutants (carbon dioxide and other gases which cause global warming). Although the impact of wind turbines on wildlife, especially birds, is of concern to many people, research has shown that bird impacts with small, unlighted turbines are quite rare. House windows and outdoor cats have a much greater negative impact. The [National Wind Coordinating Collaborative](#) has a list of wildlife/wind interaction publications for more information.
- Most modern residential turbines are quite quiet – similar to ambient noise levels under average wind conditions.

From: Colorado State University Extension - [www.ext.colostate.edu](http://www.ext.colostate.edu)

### **3.3 Geothermal**

The word “geothermal” comes from the Greek words geo (earth) and therme (heat); thus it refers to heat from the earth. It is the use of the natural temperatures contained in the earth or water to heat and cool buildings. Geothermal energy is broken down into three types: direct-use for heating; direct use for electricity generation; and indirect use by heat pumps (also known as geoechange systems or ground source heat pumps).

#### **Direct Use for Heating**

Most direct-use geothermal relies on elevated temperature ground water to either heat buildings directly or to generate electricity. Direct-use geothermal heating is limited to areas that have naturally occurring hot springs or easy access to elevated temperature ground water in the 100 – 250°F range. This water is good for use in spas, greenhouses, or building heating systems – including heating entire portions of cities!

#### **Direct Use for Electricity**

Historically, direct use for electrical generation required water temperatures above 300°F, although technology has now made it possible to generate electricity with water temperatures lower than 300°F. There are four different methods used to generate electricity from geothermal resources – flash power plants, dry steam plants, binary plants, and flash/binary combined plants.

Flash power plants operate by separating the geothermal waters into steam and hot water. As the waters emerge from the ground, they are under pressure. The water “flashes” as it reaches the surface, producing steam along with the hot water. The hot water, or “brine”, is re-injected back into the geothermal reservoir. The steam is utilized to operate a turbine that generates the electricity.



A geothermal power plant in Iceland used for electricity generation

A dry steam plant utilizes steam to run the turbines to produce the power. The wells are dry wells that only produce steam. No hot water or brine is produced by the well so no re-injection is required. Yellowstone National Park is an area where this technology can be used.

A binary power plant is a newer method of electricity generation and uses geothermal water that is lower than 300oF. These power plants use the hot water to heat another liquid. In a heat exchanger, the water transfers its heat to a liquid such as isobutene, pentafluoropropane, or other organic fluid that boils at a lower temperature. The liquids never come in contact with each other. The vapor formed from the other liquid is then used to power the turbine that generates the electricity.

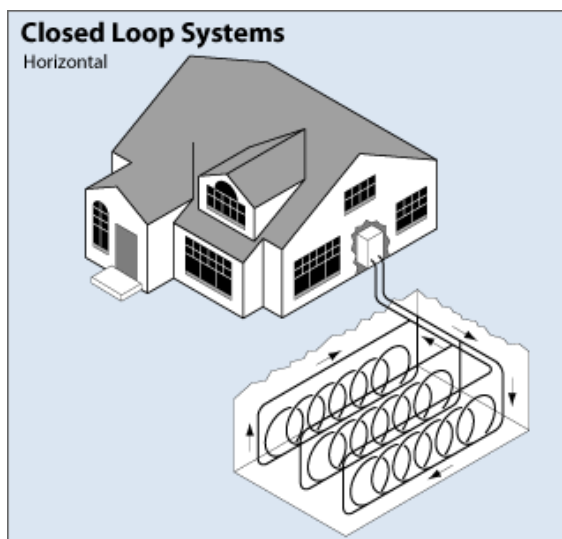


A flash/binary system utilizes both the flash of the water and the steam of the binary system. The initial steam production is used to run turbines. The hot water is then used in a binary system, transferring its heat to the organic fluid. Again, the organic fluid boils at a lower temperature and produces vapors that operate a turbine.

## Geothermal Exchange

Geoexchange systems - or geothermal heat pumps - are the most common form of geothermal energy used in homes and commercial buildings and use the ambient temperature in the earth or water to heat or cool a building. Heat is removed from a substrate during the winter to heat a building and then during the summer the heat is removed from the building and put back into the substrate. The substrate is usually the earth but can also be water. A mix of water and antifreeze is used as the heat transfer fluid.

Closed loop systems include horizontal, vertical, and pond/lake systems. These systems are all self-contained, with the liquid heat transfer fluid never coming in contact with the earth or pond/lake. Closed loop systems receive their name from the piping configuration used to collect and disperse the heat from the substrate.



U.S. Department of Energy

Horizontal systems use a series of pipes laid horizontally in a trench through which the heat transfer fluid is circulated. The pipes can also be looped in a “slinky” configuration to utilize a smaller trench.

Vertical systems are typically used in existing residential areas or for commercial buildings where long horizontal trenches are not an option because of land constraints. A series of vertical holes are drilled about 20 feet apart and 100-400 feet deep. The piping is placed in the holes with a U-bend at the bottom of each hole. The holes are all connected together to form the system.

The pond/lake system is similar to the horizontal system but requires a pond/lake of certain dimensions. Coils of pipes are placed at least eight feet below the surface (to prevent freezing) through which the heat transfer fluid is circulated. This is the least costly method as it does not require drilling.

In each of these systems, the heat transfer fluid passes through the substrate, goes into a building heat exchanger, and the resulting heat or cold is distributed through the building by a forced air or hydronic distribution network.

Geoexchange can save between 25 and 50% in energy consumption when compared to conventional heating and cooling systems. They also have comparable life-cycle costs and low annual operating costs.

### **3.4 Biofuels**

Unlike other renewable energy sources, biomass can be converted directly into liquid fuels, called "biofuels," to help meet transportation fuel needs. The two most common types of biofuels in use today are ethanol and biodiesel.

Ethanol is an alcohol, the same as in beer and wine (although ethanol used as a fuel is modified to make it undrinkable). It is most commonly made by fermenting any biomass high in carbohydrates through a process similar to beer brewing. Today, ethanol is made from starches and sugars, but scientists are developing technology to allow it to be made from cellulose and hemicellulose, the fibrous material that makes up the bulk of most plant matter.



Ethanol can also be produced by a process called gasification. Gasification systems use high temperatures and a low-oxygen environment to convert biomass into synthesis gas, a mixture of hydrogen and carbon monoxide. The synthesis gas, or "syngas," can then be chemically converted into ethanol and other fuels.

Ethanol is mostly used as blending agent with gasoline to increase octane and cut down carbon monoxide and other smog-causing emissions. Some vehicles, called Flexible Fuel Vehicles, are designed to run on E85, an alternative fuel with much higher ethanol content than regular gasoline.

Biodiesel is made by combining alcohol (usually methanol) with vegetable oil, animal fat, or recycled cooking grease. It can be used as an additive (typically 20%) to reduce vehicle emissions or in its pure form as a renewable alternative fuel for diesel engines.

Research into the production of liquid transportation fuels from microscopic algae, or microalgae, is reemerging. These microorganisms use the sun's energy to combine carbon dioxide with water to create biomass more efficiently and rapidly than terrestrial plants. Oil-rich microalgae strains are capable of producing the feedstock for a number of transportation fuels—biodiesel, "green" diesel and gasoline, and jet fuel—while mitigating the effects of carbon dioxide released from sources such as power plants.

From: National Renewable Energy Laboratory - [www.nrel.gov](http://www.nrel.gov)

#### **Biodiesel**

Biodiesel, a diesel fuel substitute that can be made from a variety of oils, fats, and greases, is made by reacting vegetable oil or animal fat with an alcohol (usually methanol or ethanol) and a catalyst (usually sodium hydroxide or potassium hydroxide). This process separates the glycerin

from the oil or fat. The resulting product, biodiesel, is thinner than the original oil or fat and thus works better in a diesel engine.

Biodiesel is of interest to farmers for a number of reasons: it can provide an additional market for vegetable oils and animal fats; it can allow farmers to grow the fuel they need for farm machinery; and it can decrease U.S. dependence on imported oil since fuel feedstocks can be grown domestically.

Biodiesel is a renewable source of energy that can help reduce greenhouse gas emissions and minimize the “carbon footprint” of agriculture. It contributes less to global warming because the carbon in the fuel was removed from the air by the plant feedstock.

In addition, biodiesel produces less air pollution (exhaust emissions) than diesel made from fossil fuels. A 1998 study by the USDA and US DOE found that using pure biodiesel in urban buses “results in substantial reductions in life cycle emissions of total particulate matter, carbon monoxide and sulfur oxides (32%, 35% and 8% reductions, respectively, relative to petroleum diesel’s life cycle).”

Biodiesel is an accepted fuel and fuel additive in the United States and around the world. It is registered as a fuel with the Environmental Protection Agency. The National Biodiesel Board lists over 200 firms that produce biodiesel commercially in the United States and Canada. Hundreds of governments, national parks, school districts and utility companies in the United States use biodiesel blends to run their fleets.

The term “biodiesel” refers to 100 percent pure fuel, designated as B100, that meets the American Society for Testing and Materials (ASTM) requirements for biodiesel fuel in its D6751 standard. The term “biodiesel blend” refers to a blend of pure biodiesel with petro-diesel, typically represented by the letter B followed by a number. The number refers to the volumetric percentage of biodiesel. Biodiesel can be used in standard diesel engines in any percentage — from B1, which is 1-percent biodiesel mixed with 99-percent petro-diesel, to pure biodiesel, known as B100.

### **Feedstocks for Biodiesel**

Commonly used feedstocks for the production of biodiesel include soybean, rapeseed/canola, used (waste) vegetable oils, and tallow (animal fat). Mustard biodiesel is being studied at the University of Idaho and Colorado State University, and Montana State University and CSU are conducting research on camelina for biodiesel production. Safflower, sunflower, and hazelnut produce oil that could be used for biodiesel. Warm climate tree oils such as palm oil and jatropha are used as biodiesel feedstocks in some parts of the world.



Canola is a popular oilseed crop in Europe and Canada and is also grown in Colorado.

Feedstocks for biodiesel are generally chosen based on price and performance. Some are better for cold temperature conditions. All the above feedstocks have alternative uses and markets, so the prices can fluctuate depending on demand.

### **Biodiesel and Straight Vegetable Oil**

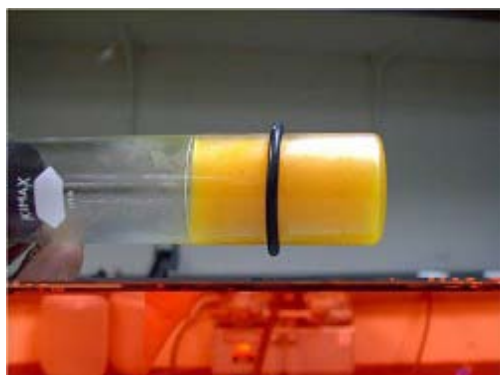
Biodiesel is not the same as straight vegetable oil (SVO) or animal fat. A normal diesel engine will eventually be damaged through the use of straight vegetable oil or straight animal fat fuel. Vegetable oils or animal fats must be converted into biodiesel by reacting the oil or fat with an alcohol and a catalyst. This process is referred to as "transesterification".

From: National Sustainable Agriculture Information Service – [www.attra.org](http://www.attra.org)

Alternatively, diesel engines can be modified for heating so the SVO moves through the fuel lines and burns effectively when it reaches the combustion chamber of the engine. And in yet a more radical approach, the SVO can be combined with regular unleaded gasoline (RUG) in a 3:1 ratio and run in diesel engines as farmers in the Rocky Ford area have done for several years to power farm machines and vehicles with favorable results. Moreover, the “cake” that remains after processing the oilseeds (canola, sunflower, and camelina) is an optimum feed for animal herds, and offers a financial return along with the oil.

From: Colorado State University Extension - <http://blog.thatsnatural.info/bridging-biofuel-transition-simplified-approach-straight-vegetable-oil/>

### **Challenges with Using Biodiesel Fuel**



**Pure biodiesel or fuels with a high percentage of biodiesel will gel at low temperatures.**

Cold temperatures can be a problem for high-percentage blends of biodiesel. B100 made from soybean oil will cloud at temperatures slightly above freezing and can clog fuel filters if the temperature drops below 28°F. Biodiesel blends with diesel fuel are preferred in such conditions.

Because biodiesel is a strong solvent, it will probably loosen debris in pipes and tanks, clogging filters initially. This problem can be remedied by changing filters soon after first use. Sometimes rubber hoses and gaskets on older vehicles don't hold up well with B100. Pre-1991 vehicles should be monitored for hose degradation or seal weepage. If these occur, the hoses and seals should be replaced with viton-based parts.

Engine warranties are not affected by the use of biodiesel, although dealers are frequently confused on this point. Manufacturers' warranty statements only cover the parts and assembly of the engines and never cover problems caused by the fuel, regardless of whether the fuel is petroleum-based diesel or biodiesel. Questions about liability for damages caused by a specific fuel should be addressed to the fuel supplier.

From: National Sustainable Agriculture Information Service – [www.attra.org](http://www.attra.org)

## 4.0 ENERGY AND CLIMATE CHANGE

The hydrocarbons found in fossil fuels provide the energy content to power most of our homes, businesses, industries, and vehicles. When burned, these fossil fuels also release carbon dioxide and other gases which contribute to global climate change. Global climate change is already beginning to impact the earth's natural ecosystems, agriculture, world economies, and our human-built environments.

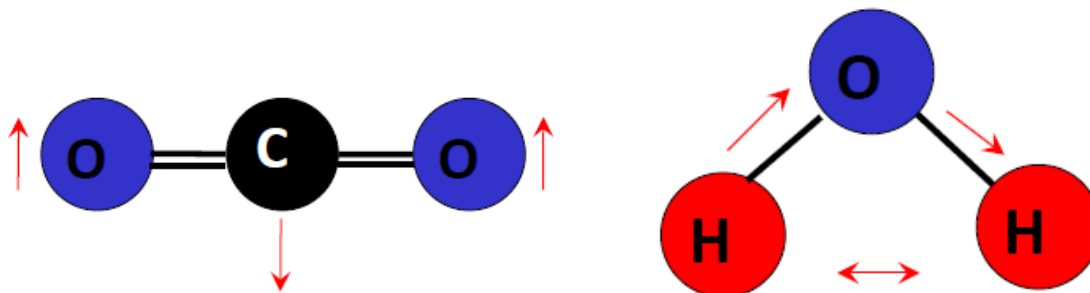
### 4.1 Basic Climate Change Science

The science behind climate change can be complex, but at its most basic chemical level can be widely understood.

Nearly all of the air in our atmosphere is made of nitrogen ( $N_2$ ) and oxygen ( $O_2$ ), in which two atoms of the same element share electrons. Heat radiated up from the surface of the earth can be absorbed by these molecules. But because these are “diatomic” molecules that are limited in the ways they can vibrate and shift, they can't trap heat particularly well.



Carbon dioxide ( $CO_2$ ) and water vapor ( $H_2O$ ) are slightly more complex molecules that have more ways to maneuver and therefore are better at trapping heat as it tries to pass through them.



So, when we add carbon dioxide to our atmosphere, the atmosphere traps more heat and the average temperature of the earth rises. This science is not new – John Tyndall actually measured the absorption capacity of  $CO_2$  back in 1863!

### 4.2 Global Overview

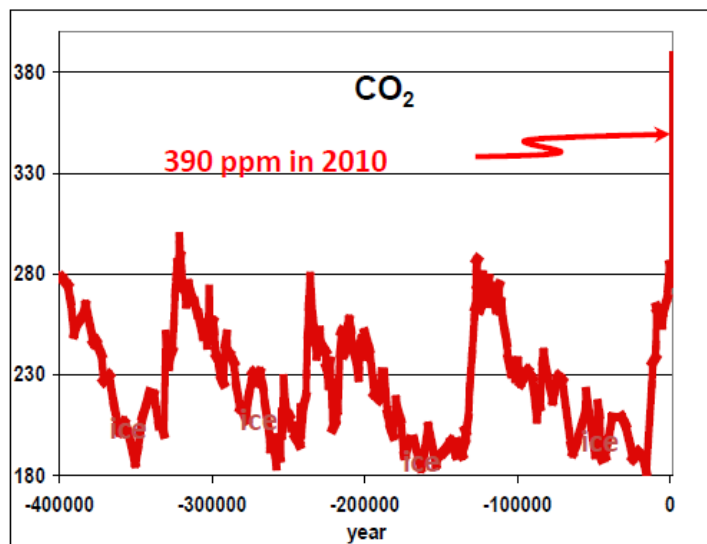
So are global levels of  $CO_2$  rising and is this rise caused by humans? Yes, and yes.

The chart below shows that over the past 420,000 years,  $CO_2$  in the atmosphere has varied between 180 and 280 parts per million, beating in time with the last four glacial cycles. Since the

Industrial Revolution CO<sub>2</sub> has risen very rapidly and as of 2010 was measured at 390 parts per million.

Climate experts believe that with a continued rise in CO<sub>2</sub> levels, the earth can experience average temperature rises between 2 and 5 degrees Celsius (3.6 to 9 degrees Fahrenheit). In the Arctic, the temperature rise is predicted to be 8 to 14 degrees F. In North America, this temperature rise is predicted to be 5 to 11 degrees F.

From: Colorado State University Professor of Atmospheric Science Scott Denning

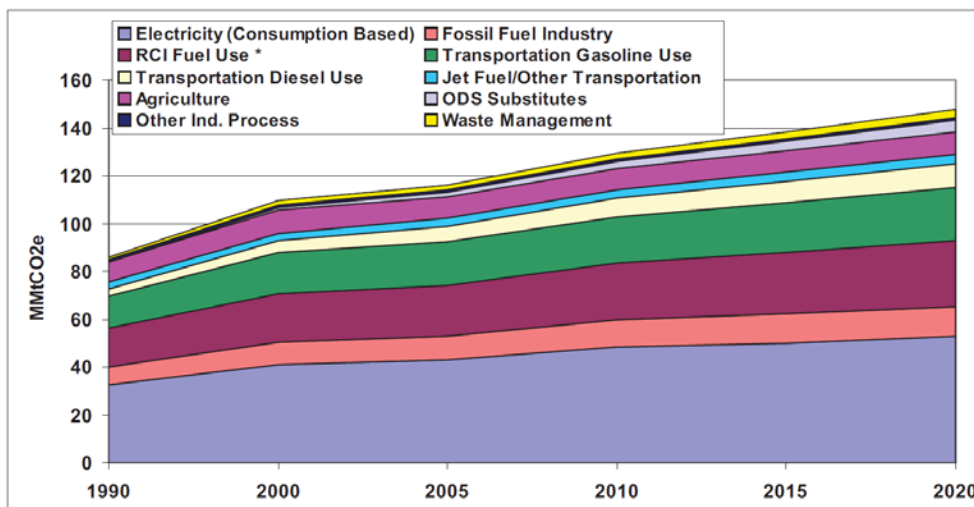


### 4.3 Colorado Overview

In Colorado, temperature rises of 10 degrees F would mean that Denver's average temperatures become like those of Amarillo, Texas. Grand Junction would develop average temperatures like those of Tucson, Arizona. Consequences for Colorado's water resources, crops, ski economy, forests, and more could be significant.

The chart below shows the historical, current, and projected sources of greenhouse gas emissions in Colorado.

Figure ES-2. Colorado Gross GHG Emissions by Sector, 1990-2020: Historical and Projected



\* RCI = direct fuel use in residential, commercial, and industrial sectors; ODS Substitutes = ozone depleting substances substitutes. Other Industrial Processes include process-related GHG emissions from cement and lime manufacturing; semiconductor manufacture; soda ash, limestone, and dolomite use; and electricity transmission and distribution systems.

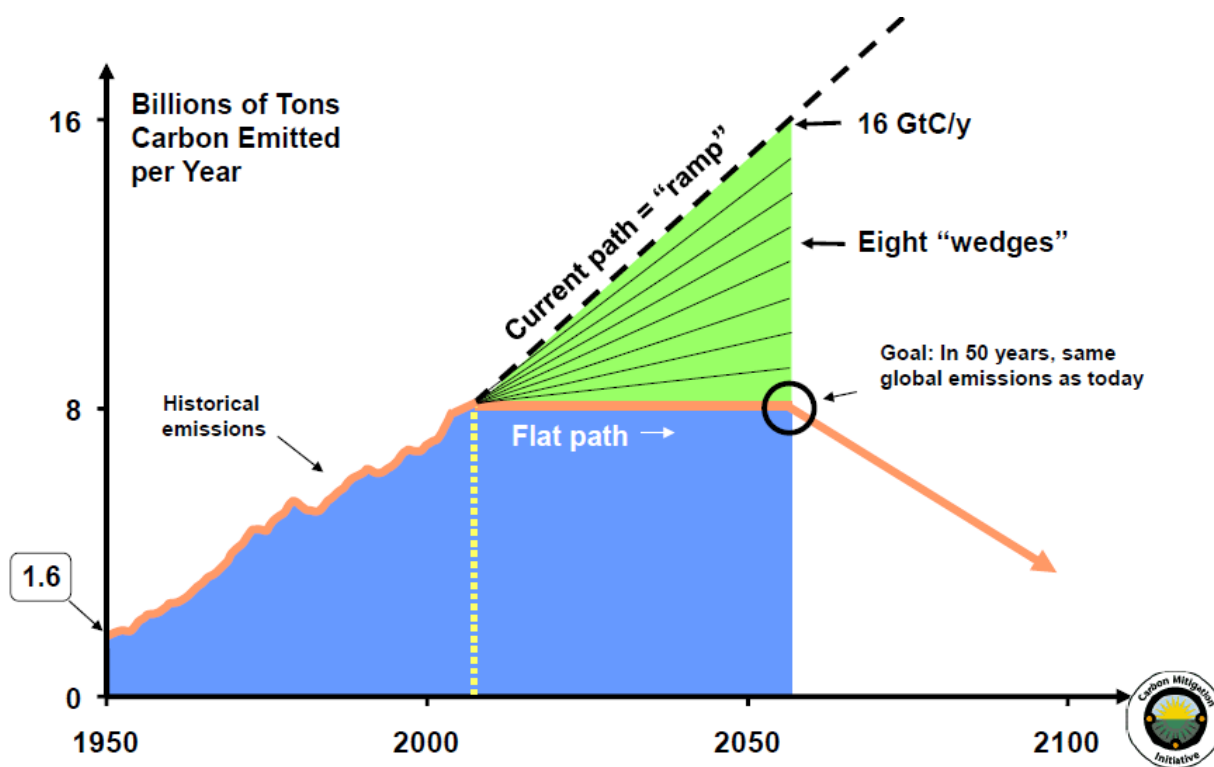
From: Center for Climate Strategies – [www.coloradoclimate.org](http://www.coloradoclimate.org)



Based on Colorado's electricity mix, each kilowatt-hour of electricity generated in the state emits approximately 1.4 lbs. of carbon dioxide into the atmosphere (410 lbs./mBTU). Each therm of natural gas burned for heating emits about 11.7 pounds of CO<sub>2</sub> (117 lbs./mBTU). Electricity generated from coal (about 215 lbs. per mBTU depending on the source) emits about twice as much CO<sub>2</sub> as electricity generated from natural gas, while electricity generated from solar, wind, and geothermal electricity are emissions free.

## 4.4 Solutions

In Colorado and across the globe, CO<sub>2</sub> emissions are expected to continue rising. The Carbon Mitigation Initiative (CMI) at Princeton University has analyzed what it would take to slow our emissions so that the level of emissions in 2055 is no greater than what we emitted in 2005. This wouldn't stop global climate change due to human activity, but it would be a start.



The triangle in green represents the difference between our current path of global carbon emissions and a “flat” path of no increases in emissions over the next 50 years. That triangle is sometimes referred to as the “stabilization triangle”. By 2055, the difference between the current path and the flat path is 8 billion tons of carbon emissions per year.

The stabilization triangle can then be broken down into eight slices, or “wedges”, that each represent 1 billion tons of carbon emissions avoided per year. The CMI went further and identified a number of actions we could take by 2055 that are already commercially viable and that would result in 1 wedge (1 billion tons) of carbon avoided, including:

- Doubling the fuel efficiency of the world's cars
- Substituting 1,400 natural gas electric plants for an equal number of coal-fired plants
- Tripling the world's nuclear capacity
- Installing 1 million two MW (megawatt) wind turbines to replace coal electricity
- Installing 20,000 square kilometers (7,700 square miles) – an area almost the size of New Jersey – worth of solar panels to replace coal electricity
- Eliminating all tropical deforestation
- Using conservation tillage on all cropland in the world

The challenges associated with achieving these reductions in predicted carbon emissions are huge but so are the consequences of “doing nothing”.

Adapted From: Carbon Mitigation Initiative, Princeton University - <http://cmi.princeton.edu/>



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# *COLORADO ACADEMIC STANDARDS MATRICES*

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**COLORADO ACADEMIC STANDARD MATRIX - SCIENCE**

Grade	Standard	Grade Level Expectation	GLE Number	Evidence Outcomes	Colorado Energy Source Webquest	Steamin' Ahead	Dynamos	Light Bulb or Heat Bulb?	The Value of R-Value	Conduct a School Energy Audit	The Sun Can do Watt?	Watt's Your Angle?	The Right Site	Solar Car Race	Measuring the Wind	Blade Design Competition	Are Renewables Right for Me?	Earth Energy	Biofuels in Your Backyard	Climate Change Wedge Game
High School	Earth Systems Science	There are costs, benefits, and consequences of exploration, development, and consumption of renewable and nonrenewable resources	ESS_5	a. Develop, communicate, and justify an evidence-based scientific explanation regarding the costs and benefits of exploration, development, and consumption of renewable and nonrenewable resources	X			X	X	X									X	X
				b. Evaluate positive and negative impacts on the geosphere, atmosphere, hydrosphere, and biosphere in regards to resource use	X			X	X	X									X	X
				c. Create a plan to reduce environmental impacts due to resource consumption						X							X			X
				d. Analyze and interpret data about the effect of resource consumption and development on resource reserves to draw conclusions about sustainable use	X															X
High School	Physical Science	Energy exists in many forms such as mechanical, chemical, electrical, radiant, thermal, and nuclear, that can be quantified and experimentally determined	PSCI_5	a. Develop, communicate, and justify an evidence-based scientific explanation regarding the potential and kinetic nature of mechanical energy			X												X	
				b. Use appropriate measurements, equations and graphs to gather, analyze, and interpret data on the quantity of energy in a system or an object			X	X		X		X	X	X			X		X	
				c. Use direct and indirect evidence to develop predictions of the types of energy associated with objects			X	X		X	X	X	X	X			X		X	
				d. Identify different energy forms, and calculate their amounts by measuring their defining characteristics			X	X	X	X	X	X	X	X						

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High School	Physical Science	When energy changes form, it is neither created nor destroyed; however, because some is necessarily lost as heat, the amount of energy available to do work decreases	PSCI_6	a. Use direct and indirect evidence to develop and support claims about the conservation of energy in a variety of systems, including <u>transformations to heat</u>			X	X	X	X	X		X	X				X		
				b. Evaluate the energy conversion efficiency of a variety of energy <u>transformations</u>			X	X		X	X		X	X				X		X
				c. Describe energy transformations both quantitatively and qualitatively			X	X			X			X				X	X	
				d. Differentiate among the characteristics of mechanical and electromagnetic waves that determine their energy			X													
				e. Examine, evaluate, question, and ethically use information from a variety of sources and media to investigate energy conservation and loss																
8	Life Science	Human activities can deliberately or inadvertently alter ecosystems and their resiliency	BIOL_1	a. Develop, communicate, and justify an evidence-based scientific example of how humans can alter ecosystems	X															X
				b. Analyze and interpret data about human impact on local <u>ecosystems</u>	X															X
				c. Recognize and infer bias in print and digital resources while researching an <u>environmental issue</u>	X															
				d. Use technology resources such as online encyclopedias, online databases, and credible websites to locate, organize, analyze, evaluate, and synthesize information about human impact on local ecosystems	X															
				e. Examine, evaluate, question, and ethically use information from a variety of sources and media to investigate an <u>environmental issue</u>	X															

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8	Physical Science	Identify and calculate the direction and magnitude of forces that act on an object, and explain the results in the object's change of motion	PSCI_1	a. Predict and evaluate the movement of an object by examining the forces applied to it										X	x	x				
				b. Use mathematical expressions to describe the movement of an object									X	X	x	x				
				c. Develop and design a scientific investigation to collect and analyze speed and acceleration data to determine the net forces acting on a moving object										X	X	x				
8	Physical Science	There are different forms of energy, and those forms of energy can be changed from one form to another – but total energy is conserved	PSCI_2	a. Gather, analyze, and interpret data to describe the different forms of energy and energy transfer	X	X	X	X			X	X	X	X		X	X	X	X	
				b. Develop a research-based analysis of different forms of energy and energy transfer	X	X	X	X			X	X	X	X		X	X	X	X	
				c. Use research-based models to describe energy transfer mechanisms, and predict amounts of energy transferred		X	X						X	X			X			
6	Earth Systems Science	Earth's natural resources provide the foundation for human society's physical needs. Many natural resources are nonrenewable on human timescales, while others can be renewed or recycled	ESS_3	a. Research and evaluate data and information to learn about the types and availability of various natural resources, and use this knowledge to make evidence-based decisions	X							X	X	X			X		X	X
				b. Identify and evaluate types and availability of renewable and nonrenewable resources	X							X	X	X	X		X	X	X	X
				c. Use direct and indirect evidence to determine the types of resources and their applications used in communities	X								X	X			X	X	X	X
				d. Research and critically evaluate data and information about the advantages and disadvantages of using fossil fuels and alternative energy sources	X												X		X	X



**COLORADO ACADEMIC STANDARD MATRIX - MATH**

Grade	Standard	Grade Level Expectation	GLE Number	Evidence Outcomes	Colorado Energy Source Webquest **	Steamin' Ahead	Dynamos	Light Bulb or Heat Bulb?	The Value of R-Value	Conduct a School Energy Audit	The Sun Can do Watt?	Watt's Your Angle?	The Right Site	Solar Car Race	Measuring the Wind	Blade Design Competition	Are Renewables Right for Me?	Earth Energy	Biofuels in Your Backyard	Climate Change Wedge Game
High School	Data Analysis, Statistics, and Probability	Statistical methods take variability into account, supporting informed decision-making through quantitative studies designed to answer specific questions	DASP_1	a. Formulate appropriate research questions that can be answered with statistical analysis				X	X	X		X	X	X		X	X	X		
				b. Determine appropriate data collection methods to answer a research question				X	X	X		X	X	X		X	X	X		
				c. Explain how data might be analyzed to provide answers to a research question				X	X	X		X	X	X		X	X	X		
High School	Data Analysis, Statistics, and Probability	The design of an experiment or sample survey is of critical importance to analyzing the data	DASP_2	a. Identify the characteristics of a well-designed and well-conducted survey																
				b. Identify the characteristics of a well-designed and well-conducted experiment			X	X	X	X		X	X	X		X	X			
				c. Differentiate between the inferences that can be drawn in experiments versus observational studies				X	X	X		X	X	X		X	X			
High School	Data Analysis, Statistics, and Probability	Visual displays and summary statistics condense the information in data sets into usable knowledge	DASP_3	a. Identify and choose appropriate ways to summarize numerical or categorical data using tables, graphical displays, and numerical summary statistics (describing shape, center and spread) and accounting for outliers when appropriate			X	X	X	X		X	X	X		X	X		X	
				b. Define and explain how sampling distributions (developed through simulation) are used to describe the sample-to-sample variability of sample statistics			X	X	X	X		X	X	X		X	X			
				c. Describe the relationship between two categorical variables using percents				X	X								X			
				d. When the relationship between two numerical variables is reasonably linear, apply* the least-squares criterion for line fitting, use Pearson's correlation coefficient as a measure of strength, and interpret the slope and y-intercept in the context of the problem				X	X	X		X					X			

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High School	Data Analysis, Statistics, and Probability	Randomness is the foundation for using statistics to draw conclusions when testing a claim or estimating plausible values for a population characteristic	DASP_4	a. Define and explain the meaning of significance (both practical and statistical)				X	X	X		X				X	X			
				b. Explain the role of p-values in determining statistical significance				X	X	X		X				X	X			
				c. Determine the margin of error associated with an estimate of a population characteristic				X	X	X		X				X	X			
High School	Number Sense, Properties, and Operations	The complex number system includes real numbers and imaginary numbers	NSPO_1	a. Show that between any two rational numbers there are an infinite number of rational numbers, and that between any two irrational numbers there are also an infinite number of irrational numbers				X	X	X		X				X	X		X	
				b. Express the square root of a negative number using imaginary numbers																
High School	Number Sense, Properties, and Operations	Formulate, represent, and use algorithms with real numbers flexibly, accurately, and efficiently	NSPO_2	a. Use appropriate computation methods that encompass estimation and calculation				X	X	X	X	X	X	X			X	X		
				b. Use technology to perform operations (addition, subtraction, multiplication, and division) on numbers written in scientific notation																
				c. Describe factors affecting take-home pay and calculate the impact (PFL)				X	X	X							X			
				d. Design and use a budget, including income (net take-home pay) and expenses (mortgage, car loans, and living expenses) to demonstrate how living within your means is essential for a secure financial future (PFL)																
High School	Number Sense, Properties, and Operations	Systematic counting techniques are used to describe and solve problems	NSPO_3	a. Use combinatorics (Fundamental Counting Principle, permutations and combinations) to solve problems in real-world contexts						X		X					X		X	



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High School	Patterns, Functions, and Algebraic Structures	Functions model situations where one quantity determines another and can be represented algebraically, graphically, and using tables	PFAS_1	a. a. Determine* when a relation is a function using a table, a graph, or an equation			X	X	X	X		X	X	X			X			X
				b. Demonstrate the relationship between all forms of linear functions using point-slope, slope-intercept, and standard form of a line			X	X	X	X		X	X	X			X			X
				c. Represent* linear, quadratic, absolute value, power, exponential, logarithmic, rational, trigonometric (sine and cosine), and step functions in a table, graph, and equation and convert from one representation to another			X					X					X			
				d. Determine the inverse (expressed graphically or in tabular form) of a function from a graph or table																
				e. Categorize sequences as arithmetic, geometric, or neither and develop formulas for the general terms related to arithmetic and geometric sequences						X		X					X			
High School	Patterns, Functions, and Algebraic Structures	Graphs and tables are used to describe the qualitative behavior of common types of functions	PFAS_2	a. Evaluate* a function at a given point in its domain given an equation (including function notation), a table, and a graph			X	X	X	X		X	X	X			X			
				b. Identify* the domain and range of a function given an equation (including function notation), a table, and a graph			X	X	X	X		X	X	X			X			
				c. Identify* intercepts, zeros (or roots), maxima, minima, and intervals of increase and decrease, and asymptotes of a function given an equation (including function notation), a table, and a graph				X	X	X		X	X	X			X			
				d. Make qualitative statements about the rate of change of a function, based on its graph or table			X	X	X	X		X	X	X		X	X			X

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High School	Patterns, Functions, and Algebraic Structures	Parameters influence the shape of the graphs of functions	PFAS_3	a. Apply* transformations (translation, reflection, dilation) to a parent function, f(x)				X	X	X							X			
				b. Interpret the results of these transformations verbally, graphically, and symbolically				X	X	X							X			
High School	Patterns, Functions, and Algebraic Structures	Expressions, equations, and inequalities can be expressed in multiple, equivalent forms	PFAS_4	a. Perform and justify steps in generating equivalent expressions by identifying properties used including the commutative, associative, inverse, identity, and distributive properties				X	X	X							X			
				b. Apply the properties of positive and negative rational exponents to generate equivalent algebraic expressions including those involving nth roots				X	X								X			
				c. Solve equations for one variable in terms of the others				X	X								X			
High School	Patterns, Functions, and Algebraic Structures	Solutions to equations, inequalities and systems of equations are found using a variety of tools	PFAS_5	a. Find* solutions to quadratic and cubic equations and linear inequalities by using appropriate algebraic methods such as factoring, completing the square, graphing or using the quadratic formula				X	X	X		X					X			
				b. Find* solutions to equations involving power, exponential, rational and radical functions																
				c. Solve* systems of linear equations and inequalities with two variables																
High School	Patterns, Functions, and Algebraic Structures	Quantitative relationships in the real world can be modeled and solved using functions	PFAS_6	a. Represent, solve*, and interpret problems in various contexts using linear, quadratic, and exponential functions				X	X								X			
				b. Represent, solve*, and interpret problems involving direct and inverse variations and a combination of direct and inverse variation																
				c. Analyze* the impact of interest rates on a personal financial plan (PFL)																
				d. Evaluate* the costs and benefits of credit (PFL)																
				e. Analyze various lending sources, services, and financial institutions (PFL)																

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High School	Shape, Dimension, and Geometric Relationships	Attributes of two- and three-dimensional objects are measureable and can be quantified	SDGR_1	a. Calculate (or estimate when appropriate) the perimeter and area of a two-dimensional irregular shape												X	X			
				b. Justify, interpret, and apply the use of formulas for the surface area, and volume of cones, pyramids, and spheres including real-world situations												X	X	X		
				c. Solve for unknown quantities in relationships involving perimeter, area, surface area, and volume												X	X			
				d. Apply the effect of dimensional change, utilizing appropriate units and scales in problem-solving situations involving perimeter, area, and volume								X					X			
High School	Shape, Dimension, and Geometric Relationships	Objects in the plane and their parts, attributes, and measurements can be analyzed deductively	SDGR_2	a. Classify polygons according to their similarities and differences																
				b. Solve for unknown attributes of geometric shapes based on their congruence, similarity, or symmetry												X	X			
				c. Know and apply properties of angles including corresponding, exterior, interior, vertical, complementary, and supplementary angles to solve problems. Justify the results using two-column proofs, paragraph proofs, flow charts, or illustrations								X	X	X		X	X			
				d. Develop conjectures and solve problems about geometric figures including definitions and properties (congruence, similarity, and symmetry). Justify these conjectures using two-column proofs, paragraph proofs, flow charts, or illustrations												X	X			

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High School	Shape, Dimension, and Geometric Relationships	Objects in the plane can be transformed, and those transformations can be described and analyzed mathematically	SDGR_3	a. Make conjectures involving two-dimensional objects represented with Cartesian coordinates. Justify these conjectures using two-column proofs, paragraph proofs, flow charts, and/or illustrations								X					X			
				b. Represent transformations (reflection, translation, rotation, and dilation) using Cartesian coordinates								X					X			
				c. Develop arguments to establish what remains invariant and what changes after a transformation (reflection, translation, rotation, and dilations). Justify these conjectures using two-column proofs, paragraph proofs, flow charts, and/or illustrations								X					X			
				d. Using construction tools, including technology, make conjectures about relationships among properties of shapes in the plane including those formed through transformation. Justify these conjectures using two-column proofs, paragraph proofs, flow charts, and/or illustrations												X	X			
High School	Shape, Dimension, and Geometric Relationships	Right triangles are central to geometry and its applications	SDGR_4	a. Apply right triangle trigonometry (sine, cosine, and tangent) to find indirect measures of lengths and angles								X					X			
				b. Apply the Pythagorean theorem and its converse to solve real-world problems								X					X			
				c. Determine the midpoint of a line segment and the distance between two points in the Cartesian coordinate plane								X					X			

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8	Data Analysis, Statistics, and Probability	Visual displays and summary statistics of two-variable data condense the information in data sets into usable knowledge	DASP_1	a. Given a scatter plot, calculate quadrant count ratio to quantify the magnitude and strength of the association between two variables for numeric data as positive, negative, or no correlation				X	X	X		X	X	X	X		X			
				b. Given a scatter plot suggesting a linear relationship, draw a line of fit to make predictions			X	X	X	X		X	X	X	X		X			
				c. Use time series plots (line graphs) to analyze the trend of a set of data over time		X		X	X			X	X	X			X			X
8	Number Sense, Properties, and Operations	In the real number system, rational and irrational numbers are in one to one correspondence to points on the number line	NSPO_1	a. Compare and order sets of integers and rational numbers that are expressed as fractions, decimals, or percents				X	X	X	X	X					X			
				b. Given a whole number from 0 - 100, determine whether it is a perfect square or find the two consecutive whole numbers between which its square root lies																
				c. Approximate the location of square roots between two whole numbers on a number line																
8	Number Sense, Properties, and Operations	Formulate, represent, and use algorithms with rational numbers flexibly, accurately, and efficiently	NSPO_2	a. Add, subtract, multiply and divide rational numbers including integers positive and negative fractions and decimals				X	X	X	X				X		X	X	X	
				b. Apply computational methods to solve multi-step application problems involving percentages and rational numbers				X	X	X		X					X		X	
				c. Analyze how credit and debt impact personal financial goals (PFL)																

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8	Patterns, Functions, and Algebraic Structures	Linear functions model situations with a constant rate of change and can be represented algebraically, graphically, and using tables	PFAS_1	a. Convert from one representation of a linear function to another, including situations, tables, equations (slope-intercept form), and graphs			X	X	X	X		X	X	X	X		X			
				b. Use representations of linear functions to analyze situations and solve problems			X	X	X	X		X	X	X	X		X			X
				c. Identify the dependent and independent variable in real-world situations			X	X	X	X		X	X	X	X		X	X		X
				d. Identify and interpret the slope(rate of change) and y-intercept in graphs, in tables, and from equations in slope-intercept form				X	X	X		X	X	X	X		X			
				e. Model and graph two linear equations in slope-intercept form on the same coordinate plane and interpret the point of intersection as the solution to the system of equations																
8	Patterns, Functions, and Algebraic Structures	Properties of algebra, equality, and inequality are used to solve linear equations and inequalities	PFAS_2	a. Use the distributive, associative, and commutative properties to simplify algebraic expressions											X		X			
				b. Solve one-variable equations including those involving multiple steps, rational numbers, variables on both sides, and the distributive property				X	X	X		X			X		X			
				c. Solve inequalities in one variable including negative coefficients and graph the solution on a number line																
				d. Represent the distributive property in a variety of ways including numerically, geometrically, and algebraically				X	X	X		X			X		X			
8	Patterns, Functions, and Algebraic Structures	Graphs and tables can be used to distinguish between linear and nonlinear functions	PFAS_3	a. Given a table or graph determine if the function is linear			X	X	X	X		X	X	X	X	X	X			X
				b. Explain the properties of linear functions in tables and graphs			X	X	X	X		X	X	X	X	X	X			X

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8	Shape, Dimension, and Geometric Relationships	Objects in the plane and their parts and attributes can be analyzed	SDGR_1	a. Classify quadrilaterals and apply angle and side properties, including the sum of the interior angles																
				b. Apply properties of complementary, supplementary, and vertical angle relationships		X									X		X			
				c. Apply properties of parallel lines including corresponding angles and alternate interior angles																
8	Shape, Dimension, and Geometric Relationships	Direct and indirect measurements can be used to describe and make comparisons	SDGR_2	a. Use properties of similar triangles to find unknown lengths																
				b. Use the Pythagorean Theorem to find unknown lengths in right triangles																
				c. Use proportional reasoning to estimate distance, weight, and capacity		X														
				d. Use proportional reasoning to convert among measures including dimensional analysis		X									X	X	X			
7	Data Analysis, Statistics, and Probability	Visual displays and summary statistics with one-variable data condense the information in data sets into usable knowledge	DASP_1	a. Distinguish between median as middle number and mean as balance point for an ordered set of data				X	X	X		X			X		X			
				b. Use Mean Absolute Deviation (MAD) to analyze the spread of a set of data				X	X	X		X			X		X			
				c. Construct and interpret dot plots, histograms, stem-and-leaf plots, and circle graphs				X	X	X		X	X	X	X		X			
				d. Construct and interpret a box plot using the five-number summary and identify the interquartile range (IQR) for a set of data				X	X	X		X			X		X			
				e. Compare sets of data using shape (skewed, normal, uniform), with appropriate measures of central tendency (mean, median, mode), and appropriate measures of spread (range, IQR, MAD)								X	X				X			
				f. Given a frequency table, calculate relative frequencies																

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7	Number Sense, Properties, and Operations	In the real number system, rational numbers have a unique location on the number line	NSPO_1	a. Read, write, locate on number line, compare and order integers and positive rational numbers				X	X		X	X	X			X	X		X	
				b. Apply the definition of absolute value with integers, quantifying the distance from zero				X	X			X					X			
				c. Express large and small numbers using scientific notation																
7	Number Sense, Properties, and Operations	Formulate, represent, and use algorithms with integers and positive rational numbers flexibly, accurately, and efficiently	NSPO_2	a. Simplify numeric expressions using the order of operations				X	X	X	X	X			X		X		X	
				b. Add, subtract, multiply, and divide integers				X	X	X	X	X			X		X	X	X	
				c. Use mental math and estimation strategies to solve problems involving percents						X							X		X	
				d. Solve problems involving percent of a number, discounts, taxes, simple interest, percent increase, and percent decrease								X					X		X	
7	Number Sense, Properties, and Operations	Proportional reasoning involves comparisons and multiplicative relationships among ratios	NSPO_3	a. Use ratio relationships to solve for a missing value in a proportion						X					X		X			
				b. Model proportional relationships with bar models, ratio tables, and similar figures				X	X	X		X					X			
				c. Explain the difference between a ratio, rate, and unit rate				X	X	X		X			X		X			
				d. Estimate and compute unit cost of consumables (to include unit conversions if necessary) sold in quantity to make purchase decisions based on cost and practicality (PFL)				x	x	x										
7	Patterns, Functions, and Algebraic Structures	Relationships involving the constant rate of change are modeled and solved using linear functions	PFAS_1	a. Given a linear situation (including direct variation), identify variables and write an equation in slope-intercept form			X	X	X	X		X	X	X	X		X			
				b. Given a linear equation (including direct variation), substitute input values to create a table and graph coordinate points in all four quadrants																



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7	Shape, Dimension, and Geometric Relationships	Objects in space and their parts and attributes can be measured and analyzed	SDGR_1	a. Develop and apply formulas and procedures for the surface area and volume of right cylinders and right prisms																
				b. Develop and apply formulas and procedures for area of regular polygons, circumference and area of circles, and area of composite figures		X										X	X			
				c. Identify and construct two-dimensional nets of prisms and cylinders																
7	Shape, Dimension, and Geometric Relationships	Proportional reasoning is used to make indirect measurements	SDGR_2	a. Describe the relationship between the circumference and diameter of a circle								X			X		X			
				b. Read and interpret scales on maps																
				c. Use proportions to convert from one set of units to another within customary and metric systems using standard units of measure for length, weight, capacity and time											X		X			
6	Data Analysis, Statistics, and Probability	Questions can be answered by collecting and analyzing data and data displays	DASP_1	a. Formulate questions for populations larger than the classroom																
				b. Recognize that a sample may not represent a population accurately															X	
				c. Recognize bias in surveys	X		X	X	X	X		X			X	X	X			
				d. Utilize appropriate techniques to design a random sample																
				e. Recognize the use of deceptive scales on a graph that make differences look much larger than they are, or the use of pictographs with areas that are proportioned incorrectly																
6	Data Analysis, Statistics, and Probability	Mathematical models are used to determine probability	DASP_2	a. Determine probabilities through experiments or simulations																
				b. Express the probability of an event using fractions, decimals, and percents																
				c. Make a table, tree diagram or an organized list to determine possible outcomes of two or more compound events				X	X	X		X					X			X
				d. Predict outcomes of events using experimental and theoretical probabilities						X		X			X		X			

Grade	Standard	Grade Level Expectation	GLE Number	Evidence Outcomes	Colorado Energy Source Webquest **	Steamin' Ahead	Dynamos	Light Bulb or Heat Bulb?	The Value of R-Value	Conduct a School Energy Audit	The Sun Can do Watt?	Watt's Your Angle?	The Right Site	Solar Car Race	Measuring the Wind	Blade Design Competition	Are Renewables Right for Me?	Earth Energy	Biofuels in Your Backyard	Climate Change Wedge Game
6	Number Sense, Properties, and Operations	In the real number system, positive rational numbers are represented in multiple equivalent forms	NSPO_1	a. Read, write, compare, convert and order positive rational numbers in a variety of forms including proper and improper fractions, mixed numbers, decimals, and percents				X	X	X	X	X			X		X		X	
				b. Express whole numbers as products of prime factors with exponents and use prime factorization to find the greatest common factor and least common multiple of two numbers																
				c. Express the quotient and remainder of a whole number division problem (a/b or a ÷ b) using fractions, terminating decimals, or repeating decimals						X	X				X		X			
				d. Locate positive fractions and decimals on a number line																
6	Number Sense, Properties, and Operations	Formulate, represent, and use algorithms with positive rational numbers flexibly, accurately, and efficiently	NSPO_2	a. Model and compute the addition, subtraction, multiplication and division of positive fractions, decimals, and combinations of fractions and decimals				X	X	X	X				X		X		X	
				b. Solve multi-step word problems involving fractions, decimals and whole numbers						X					X		X		X	
				c. Estimate sums, differences, products and quotients of rational numbers using common fractions, common decimals, and whole numbers						X			X	X	X		X		X	
				d. Compare and round positive numbers from thousandths through millions																
6	Number Sense, Properties, and Operations	Quantities can be expressed and compared using ratios and rates	NSPO_3	a. Apply the multiplicative identity to create equivalent fractions and to reduce fractions to simplest form											X		X			
				b. Express the comparison of two whole number quantities using differences, part-to-part ratios, and part-to-whole ratios in real contexts, including investing and saving (PFL)				X	X	X							X			
				c. Compute unit rates in real-world situations involving mixtures, concentrations, and distance-time relationships		X		X	X	X			X	X			X			

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6	Patterns, Functions, and Algebraic Structures	Patterns can be described using words, tables, and graphs	PFAS_1	a. Extend the pattern and describe the rule for arithmetic and geometric sequences				X	X	X		X			X		X			
				b. Model linear situations using tables and graphs, and convert between these two representations			X	X	X	X		X	X	X	X		X			
				c. Given a linear equation, substitute non-negative input values to create a table and graph coordinate points in the first quadrant				X	X	X		X			X		X			
6	Patterns, Functions, and Algebraic Structures	Variables are used to represent unknown quantities	PFAS_2	a. Describe patterns by using words and variables with mathematical symbols				X	X	X		X			X	X	X			
				b. Evaluate expressions by substituting whole number values for variables																
6	Shape, Dimension, and Geometric Relationships	Polygons can be described, classified, and analyzed by their attributes	SDGR_1	a. Develop and apply formulas and procedures for finding area of triangles, parallelograms, and trapezoids		X														
				b. Describe properties of polygons up to ten sides using accurate vocabulary and notation																
				c. Classify triangles and apply angle and side properties, including the sum of the interior angles											X		X			
				d. Use accurate geometric notation to describe angles, lines, and segments								X			X	X	X			
6	Shape, Dimension, and Geometric Relationships	Standard units provide common language for communicating measurements	SDGR_2	a. Connect metric prefixes to place value																
				b. Measure to the nearest sixteenth of an inch																
				c. Select and use appropriate units to accurately measure length, weight, capacity and time in problem-solving situations		X						X	X				X			
				d. Use a protractor to measure angles to the nearest degree								X	X	X	X		X			
*Using all tools including graphing technology **Mathematics standards cannot be determined before topic is researched. The open ended nature of this lesson could cover any of the above standards.																				



**COLORADO ACADEMIC STANDARD MATRIX - SOCIAL STUDIES**

Grade	Standard	Grade Level Expectation	GLE Number	Evidence Outcomes	Colorado Energy Source Webquest	Steamin' Ahead	Dynamos	Light Bulb or Heat Bulb?	The Value of R-Value	Conduct a School Energy Audit	The Sun Can do Watt?	Watt's Your Angle?	The Right Site	Solar Car Race	Measuring the Wind	Blade Design Competition	Are Renewables Right for Me?	Earth Energy	Biofuels in Your Backyard	Climate Change Wedge Game
High School	Civics	Research, formulate positions, and engage in appropriate civic participation to address local, state, and national issues or policies	CIVI_1	a. Engage ethically in civic activities including discussing current issues, advocating for their rights and the rights of others, practicing their responsibilities, influencing governmental actions, and other community service learning opportunities	X					X							X			
				b. Evaluate how individuals and groups can effectively use the structure and functions of various levels of government to shape policy																
				c. Describe the roles and influence of individuals, groups, and the press as checks on governmental practices																
				d. Identify which level of government is appropriate for various policies and demonstrate an ability to appropriately engage with that level of government																
				e. Critique various media sources for accuracy and perspective	X															

Grade	Standard	Grade Level Expectation	GLE Number	Evidence Outcomes	Colorado Energy Source Webquest	Steamin' Ahead	Dynamos	Light Bulb or Heat Bulb?	The Value of R-Value	Conduct a School Energy Audit	The Sun Can do Watt?	Watt's Your Angle?	The Right Site	Solar Car Race	Measuring the Wind	Blade Design Competition	Are Renewables Right for Me?	Earth Energy	Biofuels in Your Backyard	Climate Change Wedge Game
High School	Civics	Purposes of and limitations on the foundations, structures and functions of government	CIVIL_2	a. Describe the origins, purposes and limitations of government and include the contribution of key philosophers and documents																
				b. Identify the structure, function, and roles of members of government and their relationship to democratic values																
				c. Analyze and explain the importance of the principles of democracy and the inherent competition among values. Values to include but not be limited to freedom and security, individual rights and common good, and rights and responsibilities																X
				d. Analyze the role of the founding documents and the evolution of their interpretation through governmental action and court cases. Documents to include but not limited to the United States Constitution and the Bill of Rights																
				e. Use media literacy skills to locate multiple valid sources of information regarding the foundations, structures, and functions of government																
				f. Analyze how court decisions, legislative debates, and various and diverse groups have helped to preserve, develop, and interpret the rights and ideals of the American system of government																
				g. Evaluate the effectiveness of our justice system in protecting life, liberty, and property																

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High School	Economics		ECON_1	a. Analyze the relationships between economic goals and the allocation of scarce resources	X												X			X
				b. Explain how economic choices by individuals, businesses, governments, and societies incur opportunity costs	X												X			X
				c. Understand that effective decision-making requires comparing the additional (marginal) costs of alternatives with the additional (marginal) benefits	X			X	X	X	X	X	X	X		X	X	X	X	X
				d. Identify influential entrepreneurs and describe how they have utilized resources to produce goods and services																
High School	Economics	Economic policies affect markets	ECON_2	a. Analyze how government activities influence the economy. Topics to include but not limited to: taxation, monetary policy, and the Federal Reserve	X												X			
				b. Recognize the interaction between foreign and domestic economic policies. Topics to include but not limited to: embargoes, tariffs, and subsidies																
				c. Identify government activities that affect the local, state, or national economy	X												X			
				d. Give examples of the role of government in a market economic system																
				e. Analyze how positive and negative incentives influence the economic choices made by individuals, households, businesses, governments, and societies	X			X	X	X							X		X	
				f. Compare and contrast monetary and fiscal policies of the United States government that are used to stabilize the economy																

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High School	Economics	Design, analyze, and apply a financial plan based on short- and longterm financial goals (PFL)	ECON_4	a. Develop a financial plan including a budget based on short- and longterm goals				X	X	X							X			
				b. Analyze financial information for accuracy, relevance, and steps for identity protection																
				c. Describe factors affecting take-home pay																
				d. Identify sources of personal income and likely deductions and expenditures as a basis for a financial plan																
				e. Describe legal and ethical responsibilities regarding tax liabilities																
High School	Economics	Analyze strategic spending, saving, and investment options to achieve the objectives of diversification, liquidity, income, and growth (PFL)	ECON_5	a. Compare and contrast the variety of investments available for a diversified portfolio																
				b. Evaluate factors to consider when managing savings and investment accounts				X	X	X							X			
				c. Explain how economic cycles affect personal financial decisions																
				d. Describe the appropriate types of investments to achieve the objectives of liquidity, income and growth																
High School	Geography	Use different types of maps and geographic tools to analyze features on Earth to investigate and solve geographic questions	GEOG_1	a. Gather data, make inferences and draw conclusions from maps and other visual representations	X							X	X	X			X			X
				b. Create and interpret various graphs, tables, charts, and thematic maps	X							X	X	X			X			X
				c. Analyze and present information using a variety of geographic tools and geographic findings in graphs, tables, charts, and thematic maps	X												X			
				Locate physical and human features and evaluate their implications for society													X			



Grade	Standard	Grade Level Expectation	GLE Number	Evidence Outcomes	Colorado Energy Source Webquest	Steamin' Ahead	Dynamos	Light Bulb or Heat Bulb?	The Value of R-Value	Conduct a School Energy Audit	The Sun Can do Watt?	Watt's Your Angle?	The Right Site	Solar Car Race	Measuring the Wind	Blade Design Competition	Are Renewables Right for Me?	Earth Energy	Biofuels in Your Backyard	Climate Change Wedge Game
High School	Geography	Explain and interpret geographic variables that influence the interactions of people, places, and environments	GEOG_2	a. Apply geography skills to help investigate issues and justify possible resolutions involving people, places, and environments. Topics to include but not limited to how people prepare for and respond to natural hazards									X				X			X
				b. Identify, evaluate, and communicate strategies to respond to constraints placed on human systems by the physical environment													X			
				c. Explain how altering the environment has brought prosperity to some places and created environmental dilemmas for others																X
				d. Research and interpret multiple viewpoints on issues that shaped the current policies and programs for resource use	X															X
				e. Explain how information and changing perceptions and values of places and environment influence personal actions	X			X	X	X						X	X		X	X
				f. Define sustainability and explain how an individual's actions may influence sustainability	X			X	X	X						X	X		X	X
High School	Geography	The inter connected nature of the world, its people, and places	GEOG_3	a. Explain how the uneven distribution of resources in the world can lead to conflict, competition, or cooperation among nations, regions, and cultural groups	X												X			
				b. Explain that the world's population is increasingly connected to and dependent upon other people for both human and natural resources	X															X
				c. Explain how migration of people and movement of goods and ideas can enrich cultures, but also create tensions	X															
				d. Analyze how cooperation and conflict influence the division and control of Earth	X															
				e. Analyze patterns of distribution and arrangements of settlements and the processes of the diffusion of human activities																
				f. Make predictions and draw conclusions about the global impact of cultural diffusion																

Grade	Standard	Grade Level Expectation	GLE Number	Evidence Outcomes	Colorado Energy Source Webquest	Steamin' Ahead	Dynamos	Light Bulb or Heat Bulb?	The Value of R-Value	Conduct a School Energy Audit	The Sun Can do Watt?	Watt's Your Angle?	The Right Site	Solar Car Race	Measuring the Wind	Blade Design Competition	Are Renewables Right for Me?	Earth Energy	Biofuels in Your Backyard	Climate Change Wedge Game
8	Geography	Use geographic tools to analyze patterns in human and physical systems	GEOG_1	a. Interpret maps and other geographic tools as a primary source to analyze a historic issue		X														
				b. Describe the nature and spatial distribution of cultural patterns																
				c. Recognize the patterns and networks of economic interdependence																
				d. Explain the establishment of human settlements in relationship to physical attributes and important regional connections	X	X														
				e. Calculate and analyze population trends																
7	Economics	The distribution of resources influences economic production and individual choice (Economics and PFL)	ECON_2	a. Give examples that illustrate connections between resources and manufacturing																
				b. Identify patterns of trade between places based on distribution of resources																
				c. Compare and contrast the relative value and different uses of several types of resources	X												X			X
				d. Use supply and demand analysis to explain how prices allocate scarce goods in a market economy																
				e. Define resources from an economic and personal finance perspective																
				f. Explain the role of taxes in economic production and distribution of resources (PFL)																
				g. Define the various types of taxes students will pay as adults (PFL)																
				h. Demonstrate the impact of taxes on individual income and spending (PFL)																

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7	Geography	Use geographic tools to gather data and make geographic inferences and predictions	GEOG_1	a. Interpret maps and other geographic tools to find patterns in human and physical systems	X	X							X				X			
				b. Describe the characteristics and distribution of physical systems, cultural patterns and economic interdependence to make predictions. Topics to include but not limited to environmental issues and cultural diffusion	X	X							X							X
				c. Collect and analyze data to make geographic inferences and predictions regarding the Eastern Hemisphere																
				d. Ask and answer questions after examining geographic sources	X	X							X							
7	Geography	Regions have different issues and perspectives	GEOG_2	a. Classify data to construct thematic maps and make inferences									X							
				b. Analyze and interpret data using geographic tools and create maps	X												X			
				c. Construct maps using fundamental principles to identify key information and analyze regional issues and perspectives in the Eastern Hemisphere																
				d. Explain how the physical environment of a place influences its economy, culture, and trade patterns													X			
6	Geography	Use geographic tools to solve problems	GEOG_1	a. Use longitude, latitude, and scale on maps and globes to solve problems																
				b. Collect and analyze data to interpret regions in the Western Hemisphere	X															
				c. Ask multiple types of questions after examining geographic sources	X								X							
				d. Interpret and communicate geographic data to justify potential solutions to problems	X								X				X			
				e. Distinguish different types of maps and use them in analyzing an issue	X															
6	Geography	Human and physical systems vary and interact	GEOG_2	a. Classify and analyze the types of connections between places	X								X				X			
				b. Identify physical features and explain their effects on people in the Western Hemisphere	X												X			
				c. Give examples of how people have adapted to their physical environment	X															



# NATIONAL ADVANCED PLACEMENT COURSE TOPICS MET - SCIENCE

AP Test	Grade	Topic	Sub-topic	Colorado Energy Source Webquest	Steamin' Ahead	Dynamos	Light Bulb or Heat Bulb?	The Value of R-Value	Conduct a School Energy Audit	The Sun Can do Watt?	Watt's Your Angle?	The Right Site	Solar Car Race	Measuring the Wind	Blade Design Competition	Are Renewables Right for Me?	Earth Energy	Biofuels in Your Backyard	Climate Change Wedge Game
Environmental Science	High School	I. Earth Systems and Resources	A. Earth Science Concepts (Solar Intensity and Latitude)							X	X	X	X						
		V. Energy Resources and Consumption	A. Energy Concepts (Energy forms; power; units; conversions; Law of Thermodynamics)	X	X		X	X	X	X	X	X	X	X	X	X	X	X	
			B. Energy Consumption 2. Present global energy use 3. Future Energy Needs	X					X							X			X
			F. Energy Conservation	X			X	X	X										X
			G. Renewable Energy (Solar energy, solar electricity, biomass, wind energy, geothermal, environmental advantages and disadvantages)	X						X	X	X	X	X	X	X	X	X	X
Physics B	High School	I. Newtonian Physics Work, Energy, Power	C. 3. Conservation of Energy a) (2) Describe and identify situations in which mechanical energy is converted to other forms of energy.		X	X								X	X	X			
		II. Fluid Mechanics and Thermal Physics	2. Laws of Thermodynamics b) (3) Compute the actual efficiency of a heat engine		X	X													
		III. Electricity and Magnetism B. Conductor, capacitors, dielectrics	1. Electrostatics with Conductors c) (1) Describe the process of charging by induction																
		III. Electricity and Magnetism B. Electric Circuits	1. Current, Resistance, Power b) (1) Relate current and voltage for a resistor							X	X		X		X				
			2. Steady-state direct current circuits with batteries and resistors only a) (1) Identify on a circuit diagram whether resistors are in series or parallel.										X						
			2. Steady-state direct current circuits with batteries and resistors only c) (1) Determine a single unknown current, voltage or resistance							X	X	X	X		X				
			2. Steady-state direct current circuits with batteries and resistors only d) (2) Identify or show correct methods of connecting meters into circuits in order to measure voltage or current							X	X	X	X	X	X				
		Laboratory and Experimental Situations	2. Observe and measure real phenomena		X	X	X	X	X	X	X	X	X	X	X	X	X		
			3. Analyze data	X	X	X					X	X	X	X		X	X	X	
			5. Communicate results	X	X	X			X			X	X			X	X		X



# NATIONAL COLLEGE BOARD STANDARD MATRIX - SCIENCE

College Board Standards for College Success	Grade	Objective	Performance Expectations	Colorado Energy Source Webquest	Steamin' Ahead	Dynamos	Light Bulb or Heat Bulb?	The Value of R-Value	Conduct a School Energy Audit	The Sun Can do Watt?	Watt's Your Angle?	The Right Site	Solar Car Race	Measuring the Wind	Blade Design Competition	Are Renewables Right for Me?	Earth Energy	Biofuels in Your Backyard	Climate Change Wedge Game
Science Practices	High School and Middle School	SP2.1 Data Collection - Students select and use appropriate measurement methods and techniques for gathering data, and systematically record and organize observations and measurements.	No Performance Expectation		X	X	X	X	X	X	X	X	X	X	X	X	X	X	
		SP2.2 Evaluating Data for Evidence - Students determine which data from a specific investigation can be used as evidence to address a scientific question or to support a prediction or an explanation, and distinguish credible data from noncredible data in terms of quality.	No Performance Expectation	X	X		X	X		X	X			X	X	X			
		SP4.1 Constructing Explanations - Students construct explanations that are based on observation and measurements of the world, on empirical evidence and on reasoning grounded in the theories, principles and concepts of the discipline.	No Performance Expectation		X	X	X	X		X	X	X	X	X	X		X	X	
	Middle School	ES1.2 Energy Transfer	ESM-PE.1.2.1a - Identify internal and external sources of energy (i.e., solar radiation and geothermal energy) on Earth that drive the movement of air, water and Earth's materials.							X	X	X	X				X		
	High School		ESH-PE.1.2.2 - Explain local wind patterns (e.g., land/sea breezes, mountain/valley breezes) in terms of convection, identifying pressure differences, direction of wind, and areas of uneven heating.											X	X				
	Middle School	ES 2.1 Atmosphere as a System	ESM-PE.2.1.2c - Explain, based on the mechanisms involved in the "greenhouse effect", how the atmosphere is warmed.																X

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Earth Science	High School	ES 2.4 Climate	ESH-PE.2.4.3 - Give examples of how human activity (e.g. heat islands, deforestation, burning of fossil fuels) has induced climate changes. Include descriptions of cause-and-effect interactions.																X
	Middle School	ES2.5 Planetary Evolution	ESM-PE.2.5.3 - Predict how changes in rotation might change the length of day and the amount of insolation.							X	X	X	X						
	High School		ESH-PE.2.5.2 - Describe how the angle of solar incidence impacts the following: length of daylight, atmospheric filtration and distribution of sunlight in any location.							X	X	X	X						
	High School	ES5.1 Humans and Natural Resources	ESH-PE.5.1.3 - Identify a local natural resource (e.g., metallic, nonmetallic, water, fossil fuel), and make claims about its benefits to society and about the environmental impacts related to its development.	X					X							X		X	X
Physical Science	Middle School	PS.1.5 Magnetic and Electric Charge Interactions	PS-PE.1.5.6 Predict qualitatively what happens to the electric force on an object (decreases, stays the same or increases) when the amount of charge changes.			X				X	X		X						
		PS.4.1 Mechanical Energy Transfer (Work) and Energy Changes	PS-PE.4.1.3a - Given a real-world situation involving an interaction between two objects defined as a system, Observe changes in each object during the interaction.											X	X		X		
			PS-PE.4.1.4 - Explain, predict and represent how changing the size of the force or the distance over which the force acts changes the amount of mechanical energy transferred during the interaction.											X	X				



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		PS.4.5 Thermal Energy	PS-PE.4.5.2 Give real-world examples of situations of thermal energy transfer (heat) by conduction, convection and radiation.				X	X									X		
Chemistry	High School	C.3.2 Energy Transfers and Transformations	C-PE.3.2.1c Gather and record data about the change in temperature as thermal energy is added to or removed from a system.				X	X									X		
Physics	High School	P.1.3 Contact Interactions and Forces	P-PE.1.3.6 Give examples of everyday phenomena and/or technological devices that involve contact interactions, and identify interacting objects (such as an energy source [motor]—moving blades of a helicopter interacting with the surrounding air).											X	X		X		
		P.1.5 Electrical Interactions and Forces	P-PE.1.5.3 Investigate and explain the differences between charging electrical conductors and insulators by contact and charging by induction.			X													
		P.3.2 Electric Current Interactions and Energy	P-PE.3.2.3 Investigate the relationship between current and potential difference (measured in volts and sometimes referred to as voltage) for different circuit devices (e.g., light bulb, commercial resistor).							X	X		X						
		P.4.3 Electromagnetic Interactions and Fields	P-PE.4.3.2 Identify, in different problems, whether or not there would be an electromagnetic interaction between a given wire in a circuit and a nearby magnet.			X													
			P-PE.4.3.5 Investigate, and make a claim about, the variables that affect the magnitude of the induced electric current created by a changing magnetic field. Justification is based on the evidence and Faraday's law of induction.			X													



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## *4-H MATRICES*

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H Representation	H Sub-Division	4-H Life Skill	Colorado Energy Source Webquest	Steamin' Ahead	Dynamos	Light Bulb or Heat Bulb?	The Value of R-Value	Conduct a School Energy Audit	The Sun Can do Watt?	Watt's Your Angle?	The Right Site	Solar Car Race	Measuring the Wind	Blade Design Competition	Are Renewables Right for Me?	Earth Energy	Biofuels in Your Backyard	Climate Change Wedge Game
Head	Managing	Resiliency											X	X				
		Keeping Records	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
		Wise Use of Resources	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		Planning/Organizing		X	X	X	X	X	X	X	X	X				X		X
		Goal Setting	X					X				X		X		X		X
	Thinking	Service Learning						X										
		Critical Thinking	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		Problem Solving	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		Decision Making		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		Learning to Learn	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Heart	Caring	Nurturing Relationships																
		Sharing																
		Empathy																
		Concern for Others						X							X		X	
	Relating	Accepting Differences																X
		Conflict Resolution																
		Social Skills																
		Cooperation						X			X	X				X		X
		Communication	X					X			X	X			X	X	X	X
Hands	Giving	Community Service/ Volunteering						X							X		X	
		Leadership						X							X		X	
		Responsible Citizenship				X	X	X	X	X	X		X	X	X		X	X
		Contributions to Group Effort						X				X			X	X	X	X
	Working	Marketable Skills	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
		Teamwork						X				X				X	X	X
		Self-Motivation						X										
Health	Being	Self-Esteem																
		Self-Responsibility				X	X	X							X		X	
		Character																
		Managing Feelings																
		Self-Discipline	X					X										
	Living	Healthy Lifestyle Choices																
		Stress Management																
		Disease Prevention																
		Personal Safety		X	X	X	X									X		



4-H Project	Colorado Energy Source Webquest	Steamin' Ahead	Dynamos	Light Bulb or Heat Bulb?	The Value of R-Value	Conduct a School Energy Audit	The Sun Can do Watt?	Watt's Your Angle?	The Right Site	Solar Car Race	Measuring the Wind	Blade Design Competition	Are Renewables Right for Me?	Earth Energy	Biofuels in Your Backyard	Climate Change Wedge Game
Artistic Clothing																
Beef																
Bicycle					X											
Cake Decorating																
Ceramics																
Child Development																
Clothing Construction																
Computers	X		X			X					X	X	X		X	
Consumer Savvy					X	X										
Dairy																
Dog																
Electricity	X	X	X	X		X	X	X	X	X	X	X	X			X
Entomology																
Financial Champions	X			X	X	X	X	X	X		X	X	X		X	
Foods and Nutrition																
Forestry															X	
Fowl (Poultry/Turkey)															X	
Gardening																
Geospatial							X	X	X	X	X	X	X	X		
Global Citizenship																X
Goat																
Heritage Arts																
Home Environment																
Horse																
Horseless Horse																
Leadership																
Leathercraft																
Model Rocketry																
Outdoor Adventure																
Photography																

4-H Project	Colorado Energy Source Webquest	Steamin' Ahead	Dynamos	Light Bulb or Heat Bulb?	The Value of R-Value	Conduct a School Energy Audit	The Sun Can do Watt?	Watt's Your Angle?	The Right Site	Solar Car Race	Measuring the Wind	Blade Design Competition	Are Renewables Right for Me?	Earth Energy	Biofuels in Your Backyard	Climate Change Wedge Game
Rabbit																
Range Management															X	
Robotics			X													
Scrapbooking																
Sheep																
Shooting Sports																
Small Engines		X	X		X	X	X	X	X	X	X	X				
Sportfishing																
Swine																
The Power of the Wind											X	X				
Veterinary Science																
Visual Arts																
Weeds																
Wildlife																
Woodworking					X			X					X			



4-H STEM Ability	Colorado Energy Source Webquest	Steamin' Ahead	Dynamos	Light Bulb or Heat Bulb?	The Value of R-Value	Conduct a School Energy Audit	The Sun Can do Watt?	Watt's Your Angle?	The Right Site	Solar Car Race	Measuring the Wind	Blade Design Competition	Are Renewables Right for Me?	Earth Energy	Biofuels in Your Backyard	Climate Change Wedge Game
Build/Construct		X	X	X	X		X	X	X	X	X	X		X	X	
Categorize/Order/Classify		X	X	X	X	X		X	X			X	X		X	X
Collaborate						X				X				X		X
Collect Data	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Communicate/Demonstrate	X					X		X	X	X		X		X	X	X
Compare/Contrast	X	X	X	X	X	X	X	X	X	X			X	X	X	
Design Solutions						X	X	X	X	X		X		X		
Develop Solutions						X	X	X	X	X			X	X		X
Draw/Design		X	X			X				X		X		X		
Evaluate	X			X	X	X				X			X	X	X	X
Hypothesize	X			X	X	X	X	X	X	X	X	X	X	X	X	
Invent/Implement Solutions	X	X				X				X		X	X	X	X	
Infer	X			X	X	X	X	X	X	X	X	X	X		X	
Intrepret/Analyze/Apply	X					X				X		X			X	X
Measure		X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Model/Graph/Use Numbers				X	X	X	X	X	X	X	X	X	X	X	X	
Observe	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Optimize					X	X				X		X		X	X	
Organize/Order/Classify				X	X	X		X	X			X			X	X
Plan Investigations	X	X				X							X			
Predict	X		X	X	X	X	X	X	X		X	X	X		X	
Problem Solve	X			X	X	X				X		X	X	X	X	X
Question	X	X		X	X	X	X	X	X	X		X	X	X	X	X
Redesign		X	X			X				X		X		X		
Research a Problem	X					X							X			
State a Problem	X					X						X				
Summarize	X			X	X	X	X	X	X		X	X	X	X	X	X
Test		X	X	X	X	X	X	X	X		X	X	X	X	X	
Troubleshoot		X	X		X	X				X		X		X		
Use Tools		X	X	X	X	X	X	X	X	X	X	X	X	X	X	



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# *LESSON PLANS*

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## **List of Lesson Plans**

### Energy Basics

1. Colorado Energy Source Webquest
2. Steamin' Ahead
3. Dynamos

### Energy Conservation and Efficiency

4. Light Bulb or Heat Bulb?
5. The Value of R-Value
6. Conduct a School Energy Audit

### Renewable Energy

7. The Sun Can do "Watt"?
8. "Watt's" Your Angle?
9. The Right Site
10. Solar Car Race
11. Measuring the Wind
12. Blade Design Competition
13. Are Renewables Right for Me?
14. Earth Energy
15. Biofuels in Your Backyard

### Energy and Climate Change

16. Climate Change Wedge Game



## **Lesson 1: Colorado Energy Source Webquest**

### **Adopted/Revised From**

NEED, Idaho National Laboratory

### **Grade Level**

6-12

### **Objectives**

- Recognize, appraise and debate bias in literature
- Examine the relevant literature on the internet to gather information about a specific energy source
- Construct a powerpoint (or other) presentation describing the findings from the literature search
- Discuss and debate the similarities and differences between renewable and non-renewable energy resources
- Evaluate resource development potential of renewable energy in Colorado

### **Overview**

Students research different energy sources using the internet and prepare a powerpoint or other presentation to give to the class.

### **Materials**

- Computers with internet access
- Powerpoint and projector optional

### **Estimated Cost of Materials**

None

### **Computer Required?**

Yes

### **Duration**

1-2 full class periods for research and 1 class period for presentations

### **Primer References**

1.2 Sources of Energy

1.4 Uses of Energy

### **Related Articles**

- “[Dark Side of Solar Cells Brightens](#)” – Scientific American
- “[Cost Works Against Alternative and Renewable Energy Sources in Time of Recession](#)” – New York Times
- “[A Plan to Power 100 Percent of the Planet with Renewables](#)” – Scientific American
- “[Colorado Boosts its RPS to 30% by 2020](#)” – Renewable Energy World

## Engagement

These questions should result in a list of energy sources named by the students, to include the ten sources of energy listed below:

Coal  
Natural gas  
Nuclear  
Hydropower  
Wind  
Solar  
Geothermal  
Biomass  
Biofuels  
Oil

1. How do we use energy in our daily lives? In the classroom?
2. How do we generate the electricity used in this classroom or at home?
3. Are those renewable or non-renewable resources? Are there alternatives?
4. How do we heat this classroom or our homes?
5. Are those renewable or non-renewable resources? Are there alternatives?
6. What energy source do we use to fuel our vehicles?
7. Is this a renewable or non-renewable resource? Are there alternatives?
8. What other types of resources do we use in Colorado and throughout the world to generate energy?

## Investigation

Now we're going to learn how to conduct an unbiased literature search in order to understand the advantages and disadvantages of different energy sources:

1. Divide the students into small groups of 2-3.
2. Have each group choose one of the ten listed energy sources to research via the internet and the related articles.
3. Read the students each of the following paragraphs and ask them to detect bias in each one:
  - a. A new solar photovoltaic array was constructed in Colorado yesterday. The panels were an expensive local solution to global warming, which itself has not been proven. It remains to be seen how much electricity is actually generated by the panels and whether the neighbors object to the "new look" of their community.
  - b. A new solar photovoltaic array was constructed in Colorado yesterday. The panels were tastefully installed to match the surrounding environment and will reduce energy costs for participating customers. "This technology benefits everyone – the customers, the environment, the economy, and the community", said Joe Schmidt, a local solar installer.



4. Explain to the students that their research should be unbiased and that they should cite a minimum of four unbiased websites in their presentations.
5. Hand out the lesson's List of Suggested Websites to all students to use in their research.
6. Each group should prepare a 5-10 minute powerpoint presentation to present to the class that includes the following (charts and graphs encouraged); citations should be placed on each slide as applicable:
  - a. Energy source name.
  - b. Is it renewable or non-renewable?
  - c. If non-renewable, how many years of world/U.S. reserves are left?
  - d. Is it used for electricity generation, heating, and/or transportation fuel?
  - e. What percent of Colorado's electricity or heating does the source supply?  
What percent of the U.S.'s transportation fuel does the source supply?
  - f. How is the source converted into usable energy?
  - g. Can the energy source produce energy upon demand?
  - h. Is the energy from the source commonly used where it is generated?
  - i. Use resource maps or other data to comment on the abundance of the source in Colorado and in your region of Colorado.
  - j. How does the cost of using the energy source compare to alternatives?
  - k. What are the environmental costs and benefits of the energy source, including impacts on wildlife habitat, ecosystems, and the atmosphere?
  - l. Do you believe the source is overutilized, underutilized, or utilized at the right level in Colorado? Why?

### **Class Review**

Now we're going to compare the advantages and disadvantages of different energy sources and come up with a vision for Colorado's energy future.

1. Each group makes their presentation.

### **Elaboration**

Students should at least read "[Colorado Boosts its RPS to 30% by 2020](#)" and as time allows the article "[A Plan to Power 100 Percent of the Planet with Renewables](#)".

1. Is a 30% Renewable Portfolio Standard too high, too low, or just right?
2. Project the "Colorado Electric Power Mix, 2009" (after this lesson plan) onto a screen or hand copies out to your students, and facilitate the class into agreeing on a vision for Colorado's energy source mix by 2020 and 2050.

### **Instructor Notes**

- Should some of the links for the Suggested Websites become broken over time, ask students to reference the Source (i.e. U.S. Energy Information Administration) to find needed information.

**Extensions and Variations**

- Reports do not have to be done in Powerpoint – they can also be done as oral reports, with posters, etc.
- Debate the advantages and disadvantages of the energy sources, or selected energy sources.

**References/For More Information**

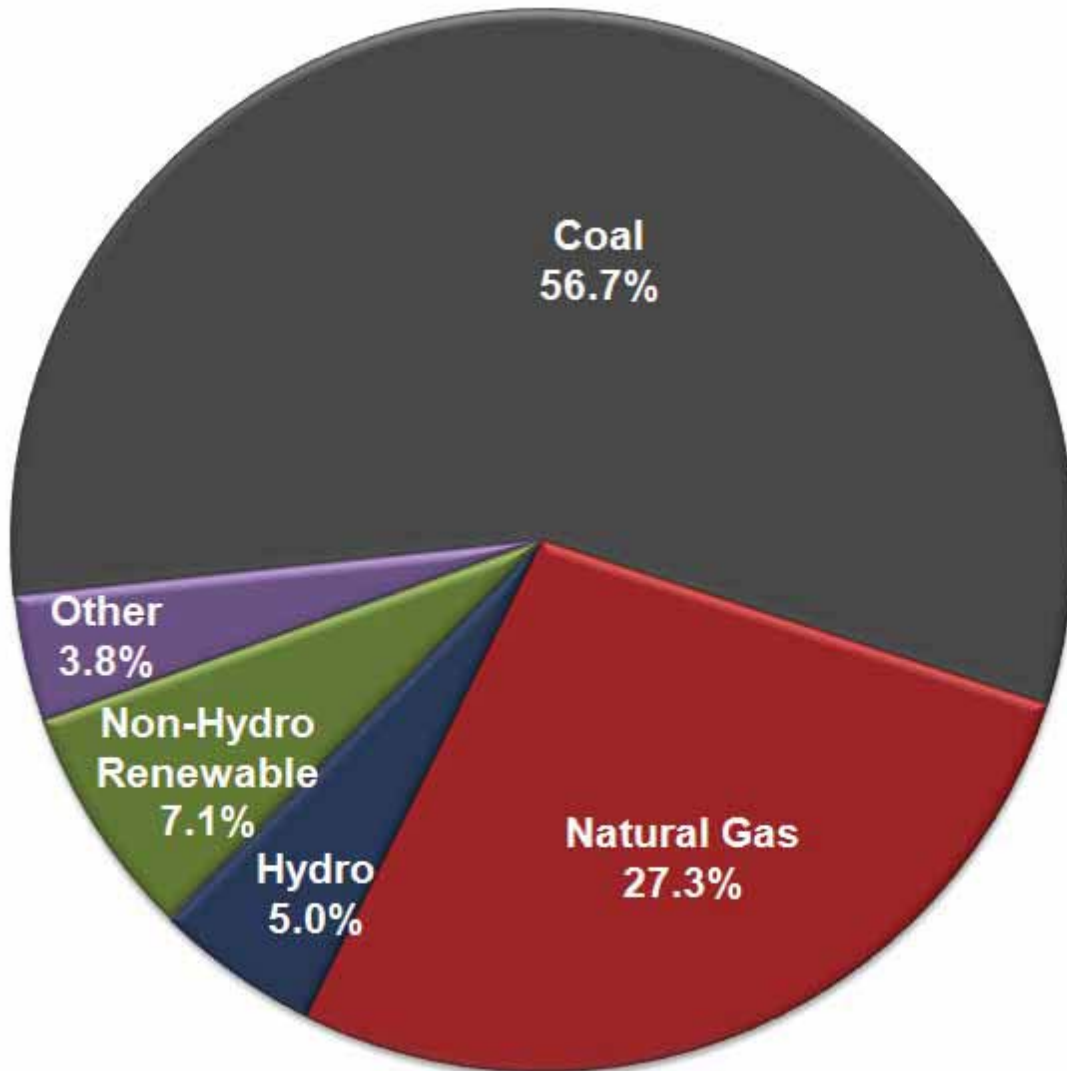
2010 Colorado Utilities Report:

<http://www.colorado.gov/energy> under “Energy Information”

## Colorado Energy Source Webquest: List of Suggested Websites

Source	Website	Topic	Description
U.S. Energy Information Administration	<a href="http://www.eia.doe.gov/kids/">http://www.eia.doe.gov/kids/</a>	All	Comprehensive overviews of each energy source
U.S. Energy Information Administration	<a href="http://www.eia.gov/cfapps/state/state_energy_profiles.cfm?sid=CO">http://www.eia.gov/cfapps/state/state_energy_profiles.cfm?sid=CO</a>	All	Colorado energy production, consumption, cost data
U.S. Department of Energy	<a href="http://apps1.eere.energy.gov/sates/state_specific_information.cfm/state=CO">http://apps1.eere.energy.gov/sates/state_specific_information.cfm/state=CO</a>	All	Colorado-specific energy information under “Energy Summary” and “Energy Statistics”
Pace University	<a href="http://www.powerscorecard.org/technologies.cfm">http://www.powerscorecard.org/technologies.cfm</a>	All	Environmental analyses for different energy technologies
California Energy Commission	<a href="http://energyquest.ca.gov/story/index.html">http://energyquest.ca.gov/story/index.html</a>	All	Student-friendly overviews of each energy source
Electric Power Research Institute	<a href="http://mydocs.epri.com/docs/CorporateDocuments/SectorPages/GEN/ReferenceCard.pdf">http://mydocs.epri.com/docs/CorporateDocuments/SectorPages/GEN/ReferenceCard.pdf</a>	Electricity generation	Comparison of financial, environmental, and practical considerations for different technologies
Colorado Governor's Energy Office	<a href="http://rechargecolorado.com/images/uploads/pdfs/2010_Colorado_Utility_Report_7-26-10.pdf">http://rechargecolorado.com/images/uploads/pdfs/2010_Colorado_Utility_Report_7-26-10.pdf</a>	Electricity generation and natural gas	Most recent and accurate breakdown of Colorado electricity sources and utility electricity generation and cost data
U.S. Department of Energy	<a href="http://www1.eere.energy.gov/geothermal/maps.html">http://www1.eere.energy.gov/geothermal/maps.html</a>	Geothermal	Geothermal resource map
U.S. Energy Information Administration	<a href="http://www.eia.doe.gov/oiaf/ieo/index.html">http://www.eia.doe.gov/oiaf/ieo/index.html</a>	Non-renewables	Energy reserve data for non-renewable resources
U.S. Department of Energy	<a href="http://www.energysavers.gov/renewable_energy/">http://www.energysavers.gov/renewable_energy/</a>	Renewable energy	Overviews of renewable energy sources
National Renewable Energy Laboratory	<a href="http://www.nrel.gov/gis/">http://www.nrel.gov/gis/</a>	Renewable energy	Resource maps for Colorado and the U.S.
Wind Powering America	<a href="http://www.windpoweringamerica.gov/images/windmaps/co_50m_800.jpg">http://www.windpoweringamerica.gov/images/windmaps/co_50m_800.jpg</a>	Wind	Wind resource map for Colorado

## Colorado Electric Power Mix, 2009



From: 2010 Colorado Utilities Report – [www.rechargecolorado.com](http://www.rechargecolorado.com)

## Lesson 2: Steamin' Ahead

### Adopted/Revised From

“A Model Geothermal Steam Engine,” Edison Science Education Series 1992 and Geothermal Power: <http://www.energyeducation.tx.gov/pdf/51ainv.pdf>

### Grade Level

6-8

### Objectives

- Construct a steam turbine
- After building the first turbine, determine criteria for a “good” design, collect and analyze data on those criteria
- Modify design for maximum efficiency

### Overview

Students construct a steam-powered turbine, experiment with the materials for the turbine blades and hub and angle of the blades to produce a smooth, easy spin. As a class, students determine what characteristics are common in the good design, rate each turbine on those characteristics, and discuss how electricity is generated by using a steam powered generator.

### Materials

Per participant

- 1 newspaper (complete section) for each coffee can
- 1 coffee can with plastic lid (1lb either metal or plastic)
- 1 pair scissors
- 1 protractor
- 1 plastic spoon
- 1 Styrofoam cup
- 1 pencil and paper

Group materials

- 2-4 rolls duct tape
- Water (access to a faucet is ideal)
- 10-15 lbs dry ice (**See safety instructions below before purchasing dry ice**)
- 1 cooler (thickly lined with newspaper – at least 28 quart size)
- **Gloves and tongs (for the teacher to handle dry ice)**
- Hammer to break dry ice into chunks
- Scale (optional)

Turbine hub suggested materials (others materials can also be suitable)

- Jumbo push pins
- Large paperclips
- Golf tees

Turbine blade suggested materials (others materials can also be suitable)

- Aluminum foil – heavy duty
- Gallon plastic milk jug (emptied and clean)
- Styrofoam cups (offer this material in the 2<sup>nd</sup> round, during the redesign)

### **Estimated Cost of Materials**

\$8/student or group

### **Computer Required**

No

### **Duration**

3–4 class periods

### **Primer References**

1.1 Forms of Energy

1.6 Electricity Generation

### **Related Articles**

N/A

### **Engagement**

1. What is the difference between a generator and a turbine?
2. The blades of a wind turbine are pushed by the wind. What other forms of power can we utilize to spin turbines?
3. Some areas of Colorado have hot springs. How can this form of power be used to spin a turbine?
4. Renewable energy comes from sources of power that are not finite (like oil). How many can you name? Do they all work the same?

### **Investigation**

We are going to build a steam powered turbine that can use the energy contained in various fuel sources to generate electricity. Each student will build their own turbine prototype, with the goal of building the most efficient design. You will have several different kinds of materials to use for the blade design and the hub of the turbine. We will determine what characteristics are common among the most efficient designs, and use those criteria to collect data on each turbine.

1. Distribute the “per participant” materials.
2. Have a central location for the shared “group” materials, and go through the different materials available for the turbine hub and the turbine blades.
3. Discuss how each material is different (for example, the weight of the aluminum foil, Styrofoam, and milk jug plastic compared to the overall strength of each material). How will each material impact the overall blade design?
4. Discuss variables in this experiment. When students begin their modifications on their design, they will have more success when they test only one variable at a time. Please see Instructor Notes on ideas for developing criteria for analyzing each design.

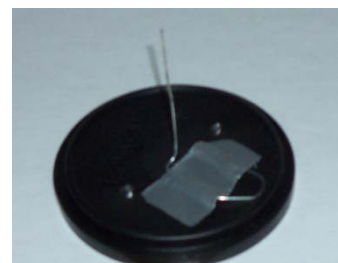
Base of steam turbine:

1. Put the lid on the coffee can. With scissors, carefully punch a hole in the coffee can lid located 1-2" from the rim. On the opposite side of the lid from your first hole, punch another hole located 1-2" from the rim.
2. Use all the newspaper to wrap the sides and bottom of the coffee can. Be sure that you leave enough of a lip on the can to secure the coffee can lid. Secure the newspaper ice.



Hub of steam turbine (*i.e.* push pin or golf tee):

1. You have several kinds of hubs to select based on your best guess of which will allow the blades of the steam turbine to spin the best. Pick which hub you want to use.
2. Attach your hub to the center of the lid of the coffee can (point up) with duct tape.
3. When you have the option to modify your design, you can try different hubs.



Blades of steam turbine (*i.e.* aluminum foil or plastic milk jug):

1. The basic blade design on this steam turbine is made from a single circle of your chosen material, and then cut into 8 wedges (like cutting a pie into 8 pieces).
2. If you select the milk jug, use a side that is the flattest.
3. Remove the lid from the coffee can, and use the pencil or a permanent marker to trace the coffee can lid on the blade material you selected (plastic milk jug, foil, Styrofoam...). Cut out the circle.
4. The hub point will be the pivot point for the blades at the very center of your blade circle. Use a piece of duct tape in the center of the blade material that the point of the hub will touch. This will help to hold the point in the center of the blades circle as well as protect the blade circle from being torn by the point. Which will work better - a square or round piece of duct tape? Make a dot with your pencil directly in the center of your duct tape, which is directly in the center of your blade circle.
5. On the blade circle, you will be making 8 blades by cutting from the edge of the circle to the duct tape center. Do NOT cut all the way through your circle to separate each blade, but leave the center whole (the blades are one large piece). Hint: Use a protractor, and make each blade section  $\frac{1}{8}$  of the circle. Why?
6. You may later want to try a design in which the blades to attach to something that then attaches to the hub.



Evaluating your steam turbine:

1. Before adding the dry ice, students should try to determine the efficiency of the design by finding ways of measuring. For example, is the overall design the most symmetrical? The area and angle of each wing on the milk jug circle can be used. The least difference among the 8 wings could mean the most symmetrical design. Is it the number of times the milk jug circle turns? Ask the class what other criteria could be measured to determine the efficiency of the turbine, then hand out the activity sheets.



**2. See Instructor Notes (below) for more detail on the evaluation of the turbines.**

Testing your steam turbine:

1. As a class, discuss how to handle dry ice safely.
2. Fill the coffee can about  $\frac{3}{4}$  full with water.
3. Your teacher will give you a spoon and a piece of dry ice in a Styrofoam cup. Carefully add the dry ice to the water. (**See safety instructions below for handling dry ice.**)
4. Secure the coffee can lid on the coffee can. Place the blades' duct tape center mark on the coffee hub point.
5. The blades work better if they are set at an angle. Begin testing what angle will get your steam turbine to spin. Record each time you make an adjustment and the results you obtain from that adjustment in the activity sheet.
6. Remember to share your results with your classmates. By sharing, you will find ideas for improving your design.
7. When you get your blades to spin, what adjustments do you need/want to make to improve the design? Describe your adjustments and your results. Remember to only change one variable at a time.
8. If your dry ice stops sublimating, it is probably encased in water ice or it has completely sublimated. Pour out your water in the sink and refill your coffee can. If you don't get any steam after adding new water, your teacher will give you additional dry ice to continue your experiments.

**Class Review**

- Evaluate each person's design to determine what are the common factors in an efficient design, and the common factors for a less efficient design.
- Have the class compare and contrast number of turns over a given time period, differences in wing areas, and differences in blade angles.
- As a class, graph the relationships between: a) differences in wing areas and number of turns over the predetermined time frame; and b) differences in blade angles and number of turns over a predetermined time frame.
- What are the common features of the most efficient designs?

**Elaboration**

- Have students read the Primer References.
- Steam generators use heat to boil water and produce steam. In this exercise, we are using dry ice for safety reasons. Dry ice is cold. Is it a suitable substitute?
- What are some of the pros and cons of using different types of energy to power turbines?

**Instructor Notes**

- Discuss dry ice safety instructions with the students before dispensing the dry ice.
  - \*\*\*\*\*WARNING! \*\*\*\*\*
  - Handle with extreme CAUTION!
  - Dry Ice is very cold  $-78.5^{\circ}\text{C}$  ( $-109^{\circ}\text{F}$ ).
  - Do NOT handle with bare hands.
  - Use dry gloves when handling (in this lesson, students do not touch the dry ice, but transport it by a Styrofoam cup and plastic spoon).



- Do NOT ingest dry ice.
- Do NOT seal in glass or other tightly closed containers.
- Do NOT enter poorly ventilated areas where used or stored.
- Do NOT leave children or pets in a vehicle with dry ice.
- Carbon dioxide gas is not poisonous or toxic, but it will NOT support life.
- If transported in a vehicle, leave at least one window open, or otherwise provide for ample fresh air ventilation.
- This lesson can be done with partners or in small groups.
- Instead of using heat for producing steam, this lesson uses sublimating dry ice in water. Although dry ice can damage skin, it takes longer than using hot steam and the risk of scalding injuries.
- The photographs in this lesson (and the video online) are from a working steam turbine using the following materials:
  - large paperclip for turbine hub
  - aluminum foil for turbine blades
- Guiding students to determine criteria to evaluate turbine design: Symmetry and balance are both important pieces to developing a design that efficiently turns under steam power. Ultimately it would be the number of turns per minute, but how do the students best obtain that result? Suitable criteria, therefore, are the number of turns per minute, the materials used, the blade area, the symmetry of each blade, the mass of the blades, placement of the holes in the coffee can lid, number of blades, and the angle of the blade. The only tricky variable is the symmetry of each blade. Not only does blade area factor into symmetry, but how uniform each blade is to the other also factors in to symmetry. You can use indices to evaluate this component.

### Extension and Variations

- Design a steam turbine and generator. How would you build it? Sketch out your blue prints, labeling the materials you would use, and detail how it would work.
- In depth analysis: To analyze the symmetry of each blade, have your students select the length at the midpoint of the longer side (L), the width at the midpoint of the shorter side (W), and the surface area (SA). To easily compare results, develop a formula:  $(L/W)/SA$ . Example:  $L=8.4\text{cm}$ ,  $W=4.0\text{cm}$ ,  $SA=14.8\text{cm}^2$  or  $(8.2/4.0)/14.8=0.1385$ . Each blade would be measured, and the blades then compared by index numbers obtained. Additionally, students can compare different blade designs from all the turbines, regardless of the shape this way.
- Analyzing student selected criteria: Students first need to graph the symmetry index for each blade and find the slope. The most symmetrical blades will be a straight horizontal line ( $m=0$ ). To evaluate and compare all the turbines, students need to identify the most important component (number of turns per minute). To evaluate the effectiveness of each design, the students need to produce a series of graphs, using the number of turns per minute as the X axis, and then angle, then surface area, and slope of the blade indices graphed. Each datum can then be identified by type of material used (*i.e.* red for milk jug plastic, blue for aluminum, and green for Styrofoam).
- Using the map located at <http://www.nrel.gov/gis/geothermal.html>, determine if you live in an area that can utilize geothermal energy. After reading the Primer on Geothermal

Energy (3.3) and one or more of the articles linked to below, have a class discussion on how geothermal energy might be used to power a steam turbine:

- “<http://coloradoenergynews.com/2011/03/bureau-of-land-management-colorado-partner-on-geothermal-development/>” – Colorado Energy News, March 15, 2011
- “[http://www.chieftain.com/news/region/geothermal-electricity-a-possibility/article\\_02db3304-74a2-11e1-a338-0019bb2963f4.html](http://www.chieftain.com/news/region/geothermal-electricity-a-possibility/article_02db3304-74a2-11e1-a338-0019bb2963f4.html)” – The Pueblo Chieftain, March 23, 2012
- “[http://www.pagosadailypost.com/news/19789/Significant\\_Steps\\_Towards\\_Geothermal\\_Greenhouse\\_Project/](http://www.pagosadailypost.com/news/19789/Significant_Steps_Towards_Geothermal_Greenhouse_Project/)” – Pagosa Daily Post, January 19, 2012
- “[http://www.cres-energy.org/techbasics/geothermal\\_div1.html](http://www.cres-energy.org/techbasics/geothermal_div1.html)” – An overview of geothermal energy with specifics about Colorado geothermal resources brought to you by CRES, the Colorado Renewable Energy Society

### **References/For More Information**

U.S. Department of Energy

<http://www.eere.energy.gov/topics/geothermal.html>

Geothermal Power (magazine)

<http://www.energyeducation.tx.gov/pdf/51ainv.pdf>

**Steamin' Ahead**

Description of Turbine Design	Number of Blades	Mass of Blades (oz.)	Angle of Turbine Blades (in degrees relative to coffee can)	Area of Largest Wing (cm <sup>2</sup> )	Area of Smallest Wing (cm <sup>2</sup> )	Difference (cm <sup>2</sup> )	Number of Turns Over Given Time (per teacher)

**Questions**

1. What factors resulted in the turbine working as hoped for?
2. What would improve the efficiency of the turbine design?
3. What would need to be introduced into the turbine in order to generate electricity?
4. How would efficiency be measured for a turbine capable of generating electricity?



## Lesson 3: Dynamos

### Adopted/Revised From

[http://amasci.com/coilgen/generator\\_1.html](http://amasci.com/coilgen/generator_1.html)

[www.teachingengineering.org](http://www.teachingengineering.org)

### Grade Level

6-12

### Objectives

- Construct two dynamo electric generators
- Troubleshoot and reconstruct for the most efficient design
- Compare similarities and differences between the two
- Explain how electricity is generated by identifying the common component in both

### Overview

Students observe magnetic properties of electricity flowing through a wire, construct 2 different generators, troubleshoot until they both are functioning, and compare/contrast the similarities and differences to determine how electricity is generated.

### Materials

#### Opening Activity

- Tape
- One Magnetic compass per group
- One 6" wire
- One AA battery per group

#### Generator #1

- Four ½"x1"x2" rectangular ceramic magnets per group (i.e. Radio Shack #64-1877)
- One roll of enamel-coated magnet wire, 200 feet 30 gauge (i.e. Radio Shack part # 278-1345)
- One 12V DC piezo buzzer, 3.0-28V DC, 5mA (i.e. Radio Shack 273-0060)
- One heavy duty corrugated cardboard strip 3.5" x 10" (from recycled box) per group
- One 3-4" nail per group
- One small cork per group
- Template of corrugated cardboard (see template design below)
- One craft knife (i.e. American Science & Surplus #93796)
- One multimeter per group (i.e. Kid Wind #H0022)
- Sandpaper – fine grit, ½ sheet per group
- One ruler per group
- One rubber band per group
- Adhesive tape

### Generator #2

- Six to twelve strong ½ inch diameter circular magnets (magnet strength rating = 10; i.e. Craft Power Magnets, Hobby Lobby sku# 179762)
- One roll of enamel-coated magnet wire, 200 feet 30 gauge (i.e. Radio Shack part # 278-1345)
- One 12V DC piezo buzzer, 3.0-28V DC, 5mA (i.e. Radio Shack part # 273-0060)
- One clear plastic tube at least slightly larger than ½ inch in diameter, at least 5” long (like a pen casing or a small plastic test tube or a cylinder from a container of beads)
- One multimeter per group
- One rubber band per group
- Sandpaper – fine grit, ½ sheet per group

### Elaboration Activity (optional)

- One AA battery per group
- 50 feet of 30 gauge magnet wire per group
- One large iron nail per group
- Sandpaper
- Adhesive tape
- Twelve paperclips per group

### Estimated Cost of Materials

\$50

### Computer Required

No

### Duration

2 class periods

### Primer References

- 1.1 Forms of Energy
- 1.2 Sources of Energy
- 1.3 Units of Energy
- 1.6 Electricity Generation

### Related Articles

- The Institute for Energy Research: Colorado Energy Facts (2010)  
<http://www.instituteforenergyresearch.org/state-regs/pdf/Colorado.pdf>

### Engagement

1. What is electricity?
2. How can we control electricity?
3. Why is that important?
4. How can electricity be generated?
5. Why are we using magnets when we generate electricity?

## Investigation

We are going to build two types of electric generators and compare how they are similar and how they are different in order to figure out what is producing electricity. Students will use a AA battery to explore the induction effect between magnetic and electric fields and assess how this current affects the magnetic needle of a compass:

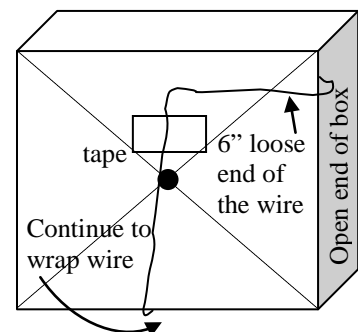
1. Divide the students into four groups.
2. Hand each group 1 AA battery, 6" length of insulated wire, tape, and a compass.
3. One student will tape one end of the wire to the positive pole of the battery.
4. One student will hold the compass level so that the needle is parallel to the floor and everyone in the group can see it.
5. The student with the battery will hold the battery directly under the compass.
6. A third student will take the dangling wire and encircle the compass with it, holding it by its insulation and bringing the exposed wire end just up to the negative pole of the battery.
7. When everyone is watching the compass needle, the student with the wire will briefly touch the negative pole of the battery. The compass needle will jump as it reacts to the changed electric field. Do this several times to be sure of the effect. **Caution: Do not hold the wire against the battery for more than a fraction of a second. The battery and wire will become very hot quickly!**
8. Have all the students read the following passage from [www.teachingengineering.org](http://www.teachingengineering.org):

Electric fields and magnetic fields are closely linked. Magnetic fields affect moving electrons, a principle that underlies iron's, nickel's, and cobalt's easy attraction to magnets. The reverse is also true: moving electrons create magnetic fields. The net movement of electrons in a simple circuit is sufficient to generate a magnetic field. The stronger the electric current, the stronger the magnetic field induced is. If there is no electric current, then there is no magnetic field.

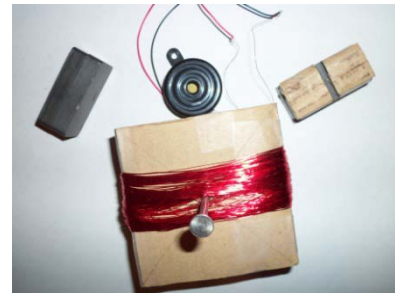
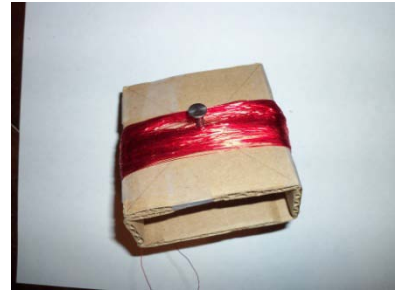
9. Assign half of the groups to Generator 1 and the other half to Generator 2.
10. Supply each group with the materials listed according to which generator they will be building.

### Generator #1:

1. Using the template following this lesson plan, cut the corrugated cardboard outer rectangle (10"x3.5"). This is called the housing.
2. Score the four inner lines with the edge of the scissors.
3. Fold the rectangle at the scored lines, using the ruler as a brace to get straight edges.
4. Panel #5 will fold over Panel #1. Tape to secure.
5. Tape all edges of your open ended box to reinforce corners.
6. Mark your box at the center point, using your ruler to find the midpoint (draw a line diagonally corner to corner in each direction, and the midpoint is at the intersection of the two lines) as indicated by the template's black circle.
7. Use the nail to carefully poke a hole at the midpoint on both sides of the box. Reinforce the underside of the box with your hand while poking the hole so that the cardboard is not bent during this process. Poke a hole directly opposite on the other side of the box. Don't poke your hand!



8. Insert the nail into both holes and push the cork on the nail's sharp end. The cork must not rub on the box as the nail spins.
9. The wire will be wrapped around the housing, and not over the open ends of the box. Each end of the wire will be attached to a buzzer. Place 15cm (6") of wire inside the box to use later to attach your buzzer. Tape the lead wire securely to the outside of the box (see diagram).
10. Lightly wrap the wire around the outside of the cardboard housing about 300 times until you have used all the wire. Wrap the wire on either side of the nail. Do not wrap tightly, because the pressure will crush the box.
11. Leave 15cm (6") of wire to attach the buzzer.
12. Sandpaper 1" of the ends of the wire to remove any enamel insulation.
13. Sandpaper 1" of the buzzer wires to remove any insulation (if needed).
14. Securely twist the wire from the generator to one end of the buzzer wire. Double check that the wire is secure.
15. Securely twist the other wire from the generator to the other buzzer wire. Double check that the wire is secure. You can secure the buzzer to the housing with a rubber band as long as it does not restrict the movement of the nail or magnets.
16. Place the magnets around the nail.
17. Make two small spacers out of cardboard for the magnets the thickness of the nail and the width of the magnet. The length of the spacers will be less than half the length of the magnet. This will stabilize your magnet assembly. Insert between the two magnets on either side of the nail. The nail/magnet assembly needs to spin smoothly. If not, you need to alter the design, keeping the magnets as close to the inside of the box as possible. You can tape the spaces in place.
18. Spin your nail and magnet housing. If you don't hear the buzzer, spin the nail and magnet house in the opposite direction. (Why?) Make sure that the wire from the buzzer is touching the wrapped wire and not the insulated part of the wire.



### Generator #2:

1. Use the 1.5V battery to hear what the piezo buzzer sounds like when it is supplied with 1.5 volts by holding the positive (red) and negative (black) wires to the (+) and (-) ends of the battery. After listening to the buzzer, disconnect the battery.
2. Now to make the electric generator - first the wire is wrapped around the cylinder/tube: Leaving about 5 inches of wire hanging down, tape the wire down to the center of the cylinder. Wrap the red enamel-coated magnet wire carefully and neatly around the center of the clear plastic cylinder. **PLEASE NOTE:** Leave the 5 inch "tail" hanging from the beginning of the wire so that when you are finished wrapping, both the beginning and the



end of the wire are accessible. Both ends are required to connect to an electrical device. This step will take a long time – there are 200 feet of wire to wrap. Be patient and neat. Don't let the wrapping become more than about 1 inch in width.

3. When the other end of the wire is *finally* reached, leave about 5 inches hanging down and tape it in place.
4. Place all of the stack magnets carefully in the cylinder and close it up. This is the electric generator. You may want to tape the cylinder caps down. The momentum of the heavy magnets when the cylinder is shaken can sometimes cause them to burst through the cylinder cap.
5. To produce electricity, all that is needed is motion. Gently rock the cylinder back and forth to allow the magnets to travel through the wire coil. The changing magnetic field creates an electric field within the coil of wire.
6. Connect the buzzer to the ends of the wire. First carefully sand the enamel coating off the wire. Connect one of the copper generator wires to one of the buzzer wires. It does not matter which one. Tape them together to ensure a strong hold. Repeat this process with the other wires.
7. To power the buzzer, rock the cylinder back and forth. Every time the magnets travel through the coil of wire it will emit a small beep. If the buzzer is secured to the cylinder with a rubber band to make it more stable, then energetic shaking will make the buzzer emit an almost continuous noise.
8. To make the column of magnets move even faster, take one of the magnets and secure it tightly using "Tacky" or tape or clay to one end of the cylinder *in the opposite direction (repulsion) from the other magnets*. This magnet will act like a spring to "bounce" the other magnets back through the wire coil.



### **Class Review**

1. Pair one team who built Generator 1 with a team who built Generator 2. You will have two or three sub-groups.
2. Share how each generator was built and how it functions for the other team in the sub-groups.
3. Discuss and record similarities and differences between these two generators.
4. Determine how electricity is generated.
5. Which generator produced more electricity? Attach the multimeter to the wire/buzzer interface, and record the amount of milliamps. Graph the results.
6. Each sub-group shares their findings with the class, including the graph for milliamps. Are there any differences among the generators? Discuss the implications for those differences.

## Elaboration

1. Have students read the Primer References.
2. Make an electromagnet: (adapted from <http://www.historyforkids.org/scienceforkids/physics/electricity/doing/electromagnet.htm>)

Having produced an electric current from a changing magnetic field, now have the students create an electromagnet from an electric current:

  - a. Each group needs an AA battery, 50 feet of 30 gauge magnet wire, a large iron nail, fine sandpaper, some tape and paperclips.
  - b. Wind the wire around the nail, taking care not to wind either end underneath the coil.
  - c. Carefully sand the enamel coating off the ends of the wire.
  - d. Use the tape to attach one end of the wire to one pole of the battery, and attach the other wire to the other pole.
  - e. The electric current flowing around the iron nail will induce a magnetic field which will line up the magnetic dipoles in the iron material. Check to see if the nail is magnetic by holding it over the paperclips.
  - f. Disconnect the battery as soon as the nail starts to feel warm. **Caution: It can get very hot! Do not delay disconnecting the battery as soon as it starts to feel warm.**
  - g. Carefully slide the nail out of the coil of wire. It should hold on to a little of its magnetism. Dropping the nail will shake the dipoles and it will lose its magnetism.

## Instructor Notes

- Use alligator clips to attach the generator wires to the buzzer or multimeter.
- You can use one miniature bulb 1.5V, 25mA per group (i.e. Radio Shack 272-1139) instead of the buzzer, but you will need to darken the room when testing the generators.

## Extension and Variations

- Allow teams to design and build their generator. Have them present to the class with the pros and cons of each design.

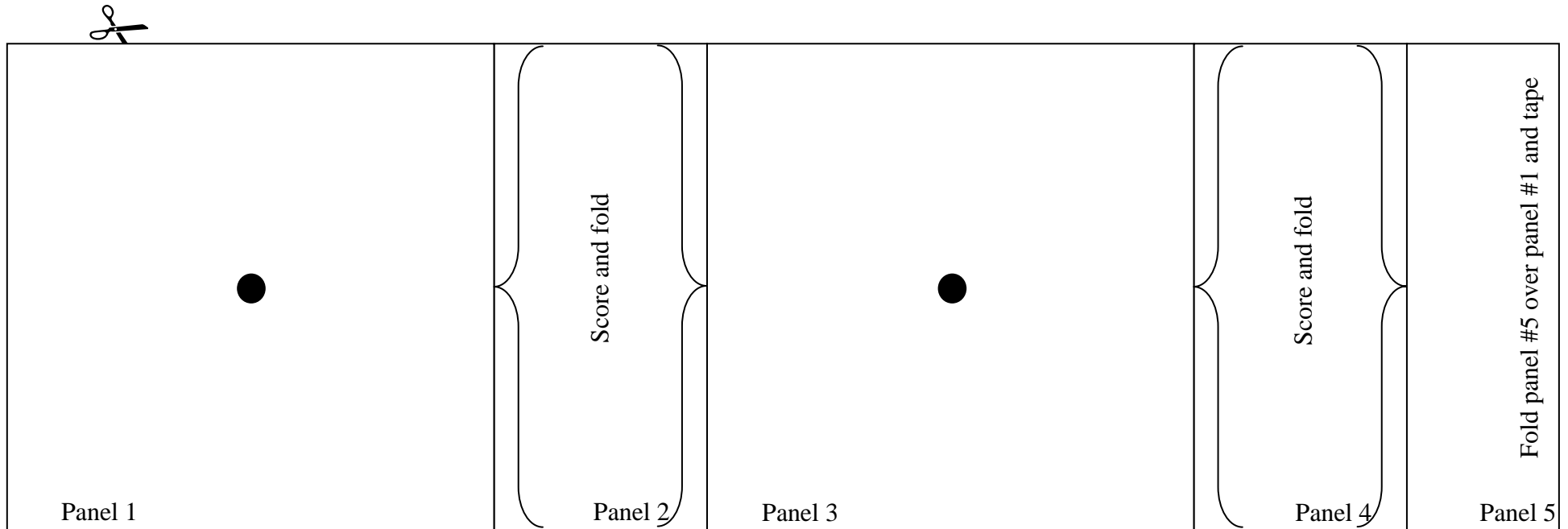
## References/For More Information

US Energy Information Administration:

<http://www.eia.gov/electricity/state/colorado/>

Template for Generator #1 corrugated cardboard rectangular housing for dynamo.

Cut out the large outer rectangle. Score on inner lines where indicated in panels #2 and #4 and fold into a box with open top and bottom. Tape panel #5 to panel #1. Black circles are centered for inserting nail on panel #1 and #3.





## **Dynamos**

### **Qualitative Analysis**

1. Record similarities between Generator 1 and Generator 2:	
1	
2	
3	
4	
5	
2. Record differences between Generator 1 and Generator 2:	
1	
2	
3	
4	
5	

3. Determine what is necessary to generate electricity (shared characteristics not excluded by any differences). Write a paragraph explaining your reasoning.

### Quantitative Analysis

4. Attach the multimeter outside the buzzer. Generate electricity in 3 states: slow, medium, and fast. Record the amps and volts for each and use that data to calculate watts.

Generator 1	<b>Speed</b>	<b>milliAmps</b>	<b>Volts</b>	<b>milliwatts</b>
	Low			
	Medium			
	Fast			

Generator 2	<b>Speed</b>	<b>milliAmps</b>	<b>Volts</b>	<b>milliwatts</b>
	Low			
	Medium			
	Fast			

5. Design a graph to best describe your subgroup results.

6. Collect data from the entire class and graph those results. How is the class graph similar and different from the individual subgroup results?

7. Discuss bias in this experiment. What steps can you do to reduce the bias in this experimental design?

8. Consider the two generators. Identify the best use for each design to harvest energy from: wind, geothermal, wave, and water.

## **Lesson 4: Light Bulb or Heat Bulb?**

### **Adopted/Revised From**

National Energy Education Development Project, Xcel Energy

### **Grade Level**

6-12

### **Objectives**

- Identify the different types of light bulbs
- Compare different light bulbs efficiencies
- Describe the energy costs of each type of bulb
- Discuss carbon emissions of each type of bulb

### **Overview**

Students compare the light output, heat output, electricity use, costs, and carbon emissions of incandescent, compact fluorescent, and LED light bulbs.

### **Materials**

- One incandescent light bulb per group
- One compact fluorescent light bulb per group
- Two lamp sockets with AC plugs per group
- Two thermometers per group and one per entire class
- One Kill-a-watt power monitor or similar per group
- One LED light bulb per class (minimum)
- Access to two outlets (i.e. via a power strip) per group

### **Estimated Cost of Materials**

\$35 per group

### **Computer Required?**

No

### **Duration**

1-2 class periods

### **Primer References**

1.1 Forms of Energy

2.1 Lighting

### **Related Articles**

- [“Mesa County Valley School District 51 Grand Junction, Colorado Case Study”](#) – Southwest Energy Efficiency Project

## Engagement

1. What does it mean to be “energy efficient”?
2. Why is it important?
3. What are some ways we can become more energy efficient at home and at school? (lighting)
4. Name some different types of light bulbs. (Use bulbs as visual aids.)

## Investigation

Now we’re going to see experimentally how efficient different light bulbs are and what this means for costs and carbon emissions:

1. Divide the students into small groups (no more than 5 per group recommended).
2. Supply each group with listed materials – power monitors may need to be shared depending on how many the class has in total.
3. Mention that each bulb emits approximately the same amount of light.
4. Demonstrate the activity using LED bulb in front of entire class:
5. Use a thermometer to read the room temperature aloud to the class.
6. Screw the LED bulb into a lamp socket.
7. Plug a power monitor into an outlet and then plug the lamp socket into the monitor.
8. Find the monitor’s value for Watts and read aloud to class.
9. Place the thermometer 1.5 inches from the end of the bulb so that the bottom reader captures the heat of the bulb and read the temperature aloud to the class.
10. Tell them to repeat these activities with their incandescent and CFL bulbs (and LED is they have them) in order to compare light output, heat output, electricity use, and cost data using the activity sheet for this lesson.
11. Bulbs should be at least 8 inches away from each other
12. The bulbs should be on for 10 minutes in order to complete the activity sheets.

## Class Review

1. Ask the groups to share the results of their experiments by reviewing each of the questions on the activity sheets as a class.
2. Which bulb would you purchase? Why?

## Elaboration

Now we have to figure out why some bulbs are more efficient than others:

1. Have students read the Primer References.
2. How does each bulb produce light from electricity?
3. As a class, list or “map” the energy forms associated with the transfer of energy from its source at a coal-fired power plant to the light we see from each of the bulbs.
4. During which energy transfer does the most significant inefficiency take place?

## Instructor Notes

- The bulbs purchased should provide approximately the same amount of lumens (light output). At the time of this writing, retail 8-watt LED bulbs can provide 429 lumens, which is about equivalent to a 9-watt CFL and a 40-watt incandescent.



- Two groups should be able to share the same power strip.
- Have these instructions on hand should a CFL break (also found in Appendix A):  
<http://www.epa.gov/cfl/cflcleanup.pdf>
- If a CFL burns out, recycle them by finding a location at Earth 911:  
<http://earth911.com/recycling/hazardous/cfl/>
- ***Warning: Bulbs will be VERY HOT to the touch during and after the activity.***

### **Extensions and Variations**

- Conduct the Lighting portion of the Conduct a School Energy Audit lesson.

### **References/For More Information**

U.S. Department of Energy:

[www.energysavers.gov](http://www.energysavers.gov)



### Light Bulb or Heat Bulb?

	Temperature						
Bulb	0 min.	2 min.	4 min.	6 min.	8 min.	10 min.	Delta T
Incandescent							
CFL							
LED ( data from teacher)							

Bulb	Initial cost	Wattage	kWh per day	kWh per year	Cost per year	Hours in lifetime	Number of bulbs needed over 24,000 hours	Cost of bulbs over 24,000 hours	kWh over 24,000 hours	Cost of electricity over 24,000 hours	Total costs over 24,000 hours	CO2 emissions over 24,000 hours (lbs.)
Incandescent	\$0.50					1,000						
CFL	\$1.50					8,000						
LED ( data from teacher)	\$10.00					24,000						

### **Assumptions**

One kilowatt-hour = 1,000 watts running for one hour

Each bulb runs an average of 4 hours/day

Electricity costs 10 cents/kWh

1.4 lbs. of CO2 is emitted per kWh (as of 2011 in Xcel service territory)

## Questions

1. Which bulb emits the least heat? The most?
2. Graph the relationship between the temperature  $\Delta T$  and electricity use in watts.
3. Compared to an incandescent, what is the difference in initial costs for a CFL and an LED?
4. How long would it take to make up for these differences through reduced electricity costs?
5. How much would 1 lb. of CO<sub>2</sub> emissions have to be worth (in dollars) to make an LED "cost-effective"?

## **Lesson 5: The Value of R-Value**

### **Adopted/Revised From**

NEED, Xcel Energy

### **Grade Level**

6-12

### **Objectives**

- Discuss and describe the importance of insulation for home energy efficiency
- Measure the cost savings over a specific amount of time with the addition of insulation
- Estimate the “payback period” for adding insulation

### **Overview**

Students compare the properties, R-values, costs, and potential energy and cost savings associated with insulation.

### **Materials (per group)**

- One ice tray
- Three thermometers
- Three sections of insulation
- Six rubber bands (optional)

### **Estimated Cost of Materials**

\$15 per group

### **Computer Required?**

No

### **Duration**

1-2 class periods

### **Primer References**

2.2 Insulation and Heat Transfer

### **Engagement**

1. What does it mean to be energy efficient?
2. Why is it important?
3. What would it be like to live in a house with no insulation?
4. What are the benefits of insulating a building?

### **Investigation**

Now we’re going to explore if using above average levels of insulation really makes a difference in the comfort, energy costs, and carbon emissions of a home or building:

1. Fill one ice tray per group with water so that the water is frozen in time for the activity.
2. Familiarize yourself with relevant background information in the teacher primer, ask students the inquiry questions, and tease out the answers to those questions.
3. Divide the students into small groups (no more than 5 recommended) and have one student per group retrieve the group's ice tray.
4. As the student is retrieving the ice tray, supply the groups with the other listed materials.
5. Once all group members have all materials, students place or rubber band one section of insulation randomly atop one third of the ice tray – this represents the average amount of insulation in a home.
6. Students should then layer two sections of insulation over another third of the ice tray in the same fashion representing an *above*-average amount of insulation in a home.
7. Students should then place (or rubber band) one thermometer directly atop the ice (the “control” representing no insulation) and each of the two sections of insulation.
8. Students should record relevant data on the activity sheets.

### **Class Review**

1. Ask the groups to share the results of their experiments by reviewing each of the questions on the activity sheets as a class.
2. Which level of insulation would you purchase for your home? Why?

### **Elaboration**

Now we have to figure out what makes a material a good insulator:

1. Have students read the Primer References.
2. What is R-value?
3. Do different materials have different R-values?
4. What is it about the foil insulation that makes it a good insulator? (air pockets)

### **Instructor Notes**

- The thermometer placed directly atop the ice tray is the control and represents a home with no insulation. The thermometer placed atop one layer of insulation represents the average home. Two layers of insulation represent a building with an above-average level of insulation.

### **Extensions and Variations**

- Use various types of insulation and/or insulating materials.
- Have each group arrange the control, one layer, and two layer setup in different orders on their ice trays and report differences in findings.

### **References/For More Information**

U.S. Department of Energy:

[www.newton.dep.anl.gov](http://www.newton.dep.anl.gov)

[www.ornl.gov](http://www.ornl.gov)

[www1.eere.energy.gov](http://www1.eere.energy.gov)

### The Value of R-Value

Tray	Temperature						
	0 min.	2 min.	4 min.	6 min.	8 min.	10 min.	Delta T
Control (no insulation)							
Average (one layer)							
Above average (two layers)							

### Questions

1. Graph the temperature change for all three levels of insulation.

2. Use the following equation to calculate a "payback period" for adding insulation to the attic of a home:

$$\text{Years to Payback} = (C(i) \times R(1) \times R(2) \times E) \div (C(e) \times [R(2) - R(1)] \times HDD \times 24)$$

Description of Variable	Figure to be Used
C(i) = Cost of insulation	\$0.50 per square foot
C(e) = Cost of energy	\$0.000008 per Btu
E = Efficiency of the heating system	80% efficient
R(1) = Initial R-value of attic	R-30
R(2) = Desired R-value of attic	R-49
HDD = Heating degree days/year	Find the "Seasonal Norm" for the town closest to you at: <a href="http://www.coloradoenergy.org/procorner/weather/hddz.htm">http://www.coloradoenergy.org/procorner/weather/hddz.htm</a> or similar website

From: U.S. Department of Energy - [www.energysavers.gov](http://www.energysavers.gov)

3. Calculate the number of inches of insulation needed to add R-19 based on the following table:

What you see:		What it probably is	Depth (inches)	Total R-value
Loose fibers	light-weight yellow, pink, or white	fiberglass	_____	=2.5×depth
	dense gray or near-white, may have black specks	rock wool	_____	=2.8×depth
	small gray flat pieces or fibers (from newsprint)	cellulose	_____	=3.7×depth
Granules	light-weight	vermiculite or perlite	_____	=2.7×depth
Batts	light-weight yellow, pink, or white	fiberglass	_____	=3.2×depth

From: Oak Ridge National Laboratories - [www.ornl.gov](http://www.ornl.gov)

Fiberglass (loose) \_\_\_\_\_

Rock Wool \_\_\_\_\_

Cellulose \_\_\_\_\_

Vermiculite \_\_\_\_\_

Fiberglass (batt) \_\_\_\_\_



## **Lesson 6: Conduct a School Energy Audit**

### **Adopted/Revised From**

National Energy Education Development Project, U.S. Department of Energy

### **Grade Level**

6-12

### **Objectives**

- Identify different ways in which energy is used in the school
- Examine different ways energy use can be reduced in the school
- Create a plan to reduce school energy use

### **Overview**

Students conduct a school energy audit.

### **Materials**

- One or more flicker checkers per class
- One or more light meters per class
- One or more power monitors per class

### **Estimated Cost of Materials**

\$40 per group

### **Computer Required?**

No

### **Duration**

1-3 class periods

### **Primer References**

2.0 Energy Conservation and Efficiency

### **Related Articles**

- [“Students Find Big Savings in School Energy Audit”](#) – Rocky Mountain News
- [“High Schools That Create Conservation Culture Save Big on Energy”](#) – Today at Colorado State
- [“PSD Saves Big with Conservation Culture”](#) – Poudre School District
- [“Mesa County Valley School District 51 Grand Junction, Colorado Case Study”](#) – Southwest Energy Efficiency Project

### **Engagement**

1. What is energy conservation?
2. What is energy efficiency?
3. Why is reducing energy use important?

4. What are some ways we use energy in the classroom? In the school?
5. What are some ways we can reduce our energy use at school? (heating and cooling, lighting, appliances)

### Investigation

Now we're going to examine our school to determine ways we can reduce our energy use:

1. Show all students how to record data in the Heating and Cooling activity sheet:
  - The column labeled "X" refers to the number of items (i.e. windows, thermostats) fitting the given description (i.e. thermostat is adjusted to save energy). The column labeled "of Y" refers to the total number of items (i.e. windows, thermostats) located during the audit.
  - "Percent in need of upgrade" refers to the percent of items not meeting the described description as mentioned above (i.e. 2 out of 3 thermostats aren't adjusted).
  - "% savings potential" is an estimate how much energy might be saved from upgrading each item (as a % of the entire school's energy use) and is a given. When multiplied times the percent of items in need of an upgrade, students can calculate the "total % savings potential".
  - Therms, dollars, and CO<sub>2</sub> are calculated from the total % savings potential and costs per upgrade are used to calculate payback periods.
2. Show all students how to use a ballast flicker checker and a light meter by referencing the instructions after this lesson plan and watching the online videos here: <http://www.ext.colostate.edu/energy/k12.html>
3. Also show them how to record data in the Lighting activity sheet:
  - The column labeled "Number" refers to the number of items (i.e. bulbs, light fixtures) requiring an upgrade (i.e. because the bulb is incandescent or is on when not needed). The flicker checker should be used to find older, inefficient lights with magnetic ballasts. The light meter should be used to determine if light levels exceed those recommended in the light meter instructions after this lesson plan.
4. Show all students how to use a Kill-a-watt meter to measure wattage when equipment is both on and off by referencing the instructions after this lesson plan and watching the online video here: <http://www.ext.colostate.edu/energy/k12.html>
5. Also show them how to record data in the Appliances activity worksheet as described on the worksheet itself.
6. Show all students how to record information in the Behavior activity worksheet as described in the worksheet itself. Note that ratings should be given after conversations with school staff including custodians as well as other groups (HVAC, Lighting, Appliances).
7. Divide students into 4 groups: 1 group for each of the Appliances, Lighting, HVAC, and Behavior activities. Groups may then wish to sub-divide in order to audit the school more efficiently.
8. Hand out all power monitors to the Appliances group and all flicker checkers and light meters to the Lighting group (likely not enough for each student to have a monitor/flicker checker). Also hand out relevant instruction sheets for the materials.
9. Hand out copies of the relevant activity sheets to each student.

10. Students can audit as much of the school as you permit for the time given.
11. After a designated time period, students should gather back in the classroom to complete the activity sheets.
12. Once all groups complete the activity sheets, complete the Summary activity sheet together as a class in order to see the comprehensive results of the school energy audit.
13. Alternatively, the activity sheets could be completed as homework and the Summary activity sheet can be completed the following day.

### **Class Review**

1. Ask the groups to share the results of their experiments by filling in the summary sheet.
2. Which energy efficiency and conservation measures from each group had the shortest payback periods?
3. Answer the questions on the summary sheet together as a class.

### **Elaboration**

Now we have to check our results and against how other schools use energy:

1. Have students read the Primer references and Related Articles listed above.
2. As a class, discuss how the school audit verified and/or differed from how typical schools use energy.
3. Based on the case study and related articles, draw up a plan for the school to reduce its energy use.

### **Instructor Notes**

- Teachers should familiarize themselves with how to use a power monitor, flicker checker, and light meter by using the devices and referencing the information provided in the curriculum before conducting the lesson.
- For all activities, advise students as to whether or not they are to enter any classrooms, the utility room, the school kitchen, etc. to expand the scope of the audit.
- Arranging for this as well as for custodial staff to be available for an interview by the Behavior team before the lesson is begun is advisable.
- Teachers may also want to contact their school district's energy manager (if applicable) for a consultation prior to the audit.
- Estimated savings provided in the activity sheets is provided for educational purposes only and may not accurately reflect savings associated with listed measures at a given school.

### **Extensions and Variations**

- Any one of the four activities (HVAC, Lighting, Appliances, Behavior) can be conducted as an independent lesson plan for the entire class.
- Students can conduct the walk-through audit (or portions of it) at different times throughout the day in order to find more energy inefficiencies.
- Present class findings to school administrators and/or the school board.
- Use the results to prod school administration to consider a professional audit.
- Hold a fundraiser to raise money to implement selected energy efficiency measures.
- Implement all no-cost energy conservation measures.

- Have students conduct home energy audits.

**References/For More Information**

Colorado Governor's Energy Office K12 Program:

<http://www.colorado.gov/cs/Satellite/GovEnergyOffice/CBON/1251599962874>

Colorado Association of District Energy Managers' Energy Fast Facts and Checklist:

<http://www.casdem.org/resources/checklist.pdf>

## Conduct a School Energy Audit: Heating, Ventilation, and Air Conditioning (HVAC)

HVAC items in blue indicate that an exchange of information with the Behavior group is needed.

Annual school therms/ccfs\*:

HVAC Item	X	of Y	Percent in Need of Upgrade	% Savings Potential	Total % Savings Potential **	Potential annual therms reduced ***	Potential annual dollar savings	Potential annual CO2 reduction (lbs.)	Cost per upgrade	Total cost of upgrades	Payback period (years)
Thermostat located in temperature-neutral location (i.e. not near heating/cooling source)				2.0%					\$60		
Thermostat is adjusted to save energy during unoccupied hours				5.0%					\$80		
Supply and return air vents for forced air not blocked				1.0%					\$0		
No daylight visible around edges of closed doors, windows (to avoid drafts)				0.5%					\$1		
Window coverings to block sun where needed				0.5%					\$150		
Domestic hot water temperature set at 110 °F				0.5%					\$0		
Boiler installed on or after the year 2000				15.0%					Extremely variable		
Exterior doors and windows closed				1.0%					\$0		
Effective weather stripping on exterior doors to prevent drafts				1.0%					\$15		
Deciduous plants to shade southern & western sides of building				2.0%					\$200		
					<b>Total</b>						

### Assumptions

Natural gas prices are \$0.60/therm

One BTU (British Thermal Unit) = 100,000 therms = 100,000 ccfs

One therm = 11.7 lbs. CO2

\* Use your actual or sample natural gas school bill to determine this number (if annual bills aren't available multiply a monthly sample times twelve to get total therms/year)

\*\*Multiply "Percent in Need of Upgrade" times "% Savings Potential"

\*\*\*Multiply "Total % Savings Potential" times "Annual School Therms"

## Questions

1. Which energy conservation and efficiency measures had the shortest payback periods? The longest?
2. How much money could be saved over the course of the year if all energy conservation and efficiency measures were implemented?
3. How much would it cost to implement all energy efficiency and conservation measures?
4. What is the total percent reduction possible in natural gas use?
5. What is the total percent energy reduction possible in BTUs?

## Conduct a School Energy Audit: Lighting

Lighting measures in blue indicate that an exchange of information with the Behavior group is needed.

Lighting Measure	Number	Wattage saved with measure	Hours/month (each)**	Potential monthly kWh reduced	Months in operation/year	Potential annual kWh reduced	Potential annual dollar savings	Potential annual CO2 reduced (lbs.)	Cost per measure	Total cost of measure	Payback period (years)
Replace lamps and magnetic ballast with efficient lamps and electronic ballast (per flicker checker)		74							\$50		
Replace incandescent bulb with compact fluorescent bulb		76							\$2		
Turn hall and other light fixtures off when not needed		117 if magnetic ballasts; 43 if electronic ballasts							\$0		
Remove a lamp from a light fixture because more light is provided than needed (per light meter)		29 if magnetic ballasts; 11 if electronic ballasts							\$0		
Remove lights from drink and vending machines		117							\$0		
Turn athletic field lights off in daylight hours		400*							\$0		
Replace older-looking (compact fluorescent) Exit sign with LED Exit sign		11							\$100		
					<b>Total</b>						

\*Per lamp

\*\*Enter an average number of hours the various types of lights are on per month or a default of 200

### Assumptions

The electric rate can be either \$0.08/kWh or your actual rate, if known

One BTU (British Thermal Unit) = 3,413 kWh

One kWh = 1.4 lbs. CO2

## Questions

1. Which lighting conservation and efficiency measures had the shortest payback periods? The longest?
2. How much money could be saved over the course of the year if all lighting upgrades were implemented?
3. How much would it cost to implement all lighting upgrades?
4. What is the total percent reduction possible in electricity use?
5. What is the total percent energy reduction possible in BTUs?



### Conduct a School Energy Audit: Appliances

Appliances in blue indicate that an exchange of information with the Behavior group is needed.

	CURRENT*						POTENTIAL****								
120 V LOAD**	Watts - on	Watts - off	Hours on/ day	kWh/ month - on	kWh/ month - off	kWh/ year***	Watts - on	Watts - off	Hours on/day	kWh/ month - on	kWh/ month - off	kWh/year	Potential annual kWh reduced	Potential annual dollar savings	Potential annual CO2 reduced (lbs.)
projector															
computer															
computer monitor															
personal space heaters															
personal or group mini- refrigerators															
<b>Total</b>															

\*To enter "Current" data, use a power monitor to measure appliance wattage when the appliance is "on" and "off" and enter results in appropriate columns. Estimate "hours-on/day" and calculate results for other columns.

\*\*Most power monitors only work with 120 volt appliances so check voltage carefully before attempting to measure appliance electricity use.

\*\*\*Multiply "kWh/month - on" times 9 and "kWh/month - off" times 12 and add the results

\*\*\*\*See below to enter "Potential" data:

For "Watts-on", use a power monitor to measure wattage by using certain appliances (i.e. fans) at lower settings and enter that number; otherwise enter the "Current" on wattage.

For "Watts-off", enter "0" if the appliance can be unplugged, plugged into a "smart strip", or plugged into a power strip that can be turned off; otherwise enter the "Current" off wattage.

For "hours-on", enter your best estimate of the lowest number of hours this appliance can be run to save energy per day; otherwise enter the "Current" hours on/day.

**Assumptions**

If measuring a refrigerator, do so during the "on" part of its cycle and during the "off" part of its cycle. Use a default of 5 hours per day for its "Hours on/ day"

The electric rate can be either \$0.08/kWh or your actual rate, if known

One kWh = 1.4 lbs. CO<sub>2</sub>

A new, high efficiency refrigerator uses only 60% of the energy your current refrigerator uses

A "smart" power strip that eliminates "phantom loads" costs \$40

Three appliances could be plugged into one "smart strip"

One BTU (British Thermal Unit) = 3,413 kWh

**Questions**

1. What appliance-related energy conservation and efficiency measures can the school take?
2. What would be the total cost of using smart strips and how long would it take to get your money back (years)?
3. What is the total percent reduction possible in electricity use?
4. What is the total percent energy reduction possible in BTUs?
5. How much money could the school save every year by installing a new, high efficiency refrigerator? If possible, look online to find the cost of a high efficiency fridge the same size as the one currently installed and calculate the payback period in years.

### **Conduct a School Energy Audit: Behavior**

Interview custodial staff and school employees as appropriate to fill out the following behavior-related energy checklist. A score of 1 indicates "strongly agree" while a score of 5 indicates "strongly disagree".

	Score (1-5)	If 3 or above, provide reason	Current responsible party	Comments
HVAC				
Exterior doors and windows closed when running heating or cooling system				
Thermostats adjusted during unoccupied hours (manually or automatically - including use of a building automation system)				
LIGHTING				
Non-essential hallway and common area lights off or dimmed when not needed and/or when daylighting is adequate				
Non-essential gymnasium lights off or dimmed when not needed				
Athletic field lights off when not needed				
Classroom lights off when not needed				
Administrative office lights off when not needed				
APPLIANCES				
Limited or no use of personal space heaters				
Limited or no use of personal or group mini-refrigerators				
Computers turned off when not in use				
Computer monitors turned off when not in use				
Projectors turned off when not in use				
OTHER				

## Questions

1. Exchange information with the HVAC, Lighting, and Appliances groups. How many kWh or therms can be reduced by making each behavior change?
2. How many BTUs can be reduced from behavior changes?
3. How much money could be saved per year through behavior changes?
4. How many lbs. of CO<sub>2</sub> can be reduced through behavior changes?
5. Which actions would be the simplest to take and which would be the most difficult? Why?

### **Conduct a School Energy Audit: Class Summary**

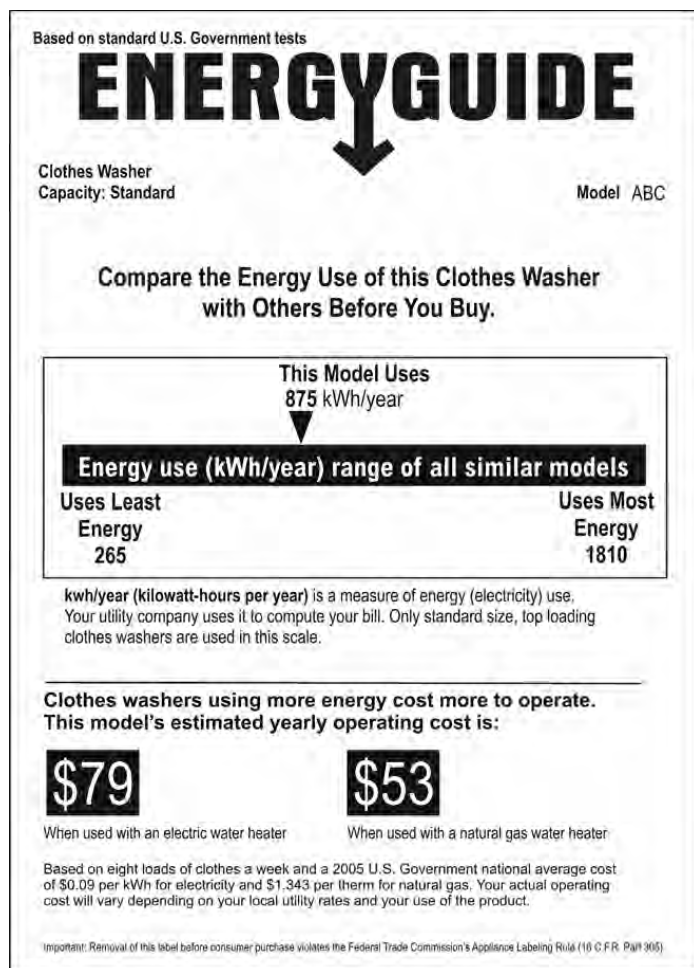
<b>Category</b>	Total potential annual therms reduced	Total potential annual kWh reduced	Total potential annual dollar savings	Total potential annual CO2 reduction (lbs.)	Total cost of all upgrades	Payback period (years)
HVAC						
Lighting						
Appliances						
All combined						
Behavior only						

#### **Questions**

1. Which category of energy upgrades has the lowest cost?
2. Which category of energy measures has the greatest potential savings?
3. Which category of energy measures has the quickest payback period?
4. What is the average cost to reduce one ton of CO2/year?



## Reading Energy Guide Labels



The Federal government requires that appliance manufacturers provide information about the energy efficiency of their products to consumers so that they can compare the life cycle cost of the appliances, as well as the purchase price. The life cycle cost of an appliance is the purchase price plus the operating cost over the projected life of the appliance.

The law requires that manufacturers place EnergyGuide labels on all new refrigerators, freezers, water heaters, dishwashers, clothes washers, room air conditioners, central air conditioners, heat pumps, furnaces, and boilers. The EnergyGuide labels list the manufacturer, the model, the capacity, the features, the amount of energy the appliance will use a year on average, its comparison with similar models, and the estimated yearly energy cost. For refrigerators, freezers, water heaters, dishwashers, and clothes washers, the labels compare energy consumption in kWh/year or therms/year.

For room air conditioners, central air conditioners, heat pumps, furnaces, and boilers, the rating is not in terms of energy consumption, but in energy efficiency ratings, as follows:

**EER: Energy.Efficiency.Rating** (room air conditioners)

**SEER: Seasonal.Energy.Efficiency.Rating** (central air conditioners)

**HSPF: Heating.Season.Performance.Factor** (with SEER heat pumps)

**AFUE: Annual.Fuel.Utilization.Efficiency** (furnaces and boilers)

From: National Energy Education Development (NEED) Project – [www.need.org](http://www.need.org)

For the purpose of the Conduct a School Energy Audit lesson, students can score an appliance based on its age if the Energy Guide label is not available.





## Using a Flicker Checker

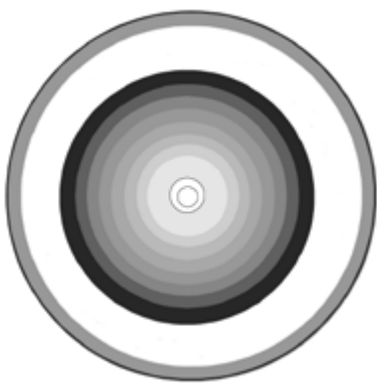
A fluorescent bulb produces light by passing an electric current through a gas using a ballast. The ballast is an electromagnet that can produce a large voltage between the two parts. It is this voltage that gives the electrons of the gas molecules the energy inside the tube. A magnetic ballast has an iron ring wrapped with hundreds of turns of wire. The current from the electrical outlet runs through the wire in the ballast. The wire also is a resistor to some degree, so there is some heat produced. There is also a little heat given off by the gas.

A fluorescent bulb with a magnetic ballast converts about 40 percent of the electricity into light and 60 percent into heat. An electronic ballast has a microchip, like that found in a computer, instead of the coils of wire. This ballast is about 30 percent more efficient in turning electrical energy into light than a magnetic ballast. Some heat is produced in the gas, but not in the ballast itself.

The reason that the Flicker Checker can tell the difference between the magnetic and electronic ballasts is because of the way the current is delivered to the gas. In any outlet in the United States that is powered by an electric company, the electricity is sent as alternating current—it turns on and off 60 times each second. Because the light with the magnetic ballast has wires attached to the outlet, it also turns on and off 60 times per second. The microchip in the electronic ballast can change that frequency. Light bulbs with electronic ballasts are made to turn on and off between 10,000 and 20,000 times each second.

## Using the Flicker Checker

Spin the black and white Flicker Checker on a flat surface located beneath your overhead fluorescent light and away from direct, natural light. Any tabletop should do! If you see smooth, grey rings on the Flicker Checker, the fluorescent fixture contains an electronic ballast. If you see a checkered pattern with hints of color that move from ring to ring, the fixture contains a magnetic ballast. Other indicators of magnetic ballasts; a flickering effect, a buzzing sound and poor quality light. This suggests you have lighting that wastes energy.



**Example of a flicker checker showing smooth grey rings typical of electronic ballasts**



**Flicker checking showing the checkered pattern typical of magnetic ballasts**

From: National Energy Education Development (NEED) Project – [www.need.org](http://www.need.org)



## Using a Light Meter

A light meter is a device used to measure the amount of light in a space, whether natural or artificial. Because using artificial light takes energy, when we provide more light to a space than is needed, we waste energy. We can use light meters to measure how much light we have in a space at a given time and then we can compare our measurements to recommended levels to see if we are wasting energy.

Light can be measured in units such as footcandles, lumens, and lux. One footcandle is the amount of light one candle provides as measured one foot away from the source. In subtle contrast, one lumen is the entire amount of light present in a one foot sphere around a candle. One lux equals one lumen per square meter. One footcandle equals 10.76 lux.

Below are some commonly accepted light levels for different parts of a school. (Note that these levels are lower than recommendations made by the Illuminating Engineering Society of North America.):

AREA	FOOTCANDLES	LUX
Hallways	15 fc	161.4
Classrooms	35-40 fc	376.6 – 430.4
Offices	40-50 fc	430.4 – 538.0

To use your light meter:

1. Remove the cover over the measuring device (if applicable).
2. Turn the meter to the “on” position.
3. Place the meter where light is desired for a given space. For example, light measurements in places like classrooms and offices are usually taken on desks and work stations since that is where the light is needed.
4. Be sure to not hover over the measuring device when trying to taking a measurement as this can artificially lower light level readings.
5. The meter will then display the light level in a unit such as lux.
6. Adjust the “range” switch as necessary (unlikely for school settings) so that no leading zeroes appear in the display.



The light at this workstation is measured where reading commonly takes place.



This meter displays the light level in lux on the digital screen.

The meter reading can then be compared to the suggested levels above to see if a space has more or less light than needed. If more light is being provided than suggested levels above, consider “delamping”, or removing lamps from the space until the suggested light level is reached.



## Using a Power Monitor

Power monitors have various functions that allow you to check different aspects of electricity usage. For testing energy use, the most important ones are Watts (W) and kilowatt hours (kWh). The Watts function measures the instantaneous draw (how much electricity a device is using), whereas the kWh gives the measure of electricity usage over time. For example, a 1,000 watt electric heater running for one hour will use one kWh of electricity.

For the purpose of the Conduct a School Energy Audit lesson, the Watts function can be accessed on a Kill-a-Watt EZ power monitor by:

1. plugging the monitor into an electrical outlet
2. plugging an appliance into the monitor
3. hitting the “Up” button four times until the “Watt” function is displayed.

This can be done both when the appliance is turned on and when it is off (to measure “phantom loads”).

Many power monitors also allow for electricity use to be converted into cost. While a default value (i.e. \$0.10 per kWh) may be pre-entered on a power monitor, monitor users should enter the rate they are charged by their local utility to get the most accurate cost estimates from the monitor.

Functions of less relevance for energy efficiency include Volts (your reading should be close to 120.0, the standard voltage in US electrical outlets), Amps (the measure of the flow rate of electric current), and HZ/PF (60 hertz cycles per second is the standard for alternating current in US electrical outlets).

### Special cases

Some appliances such as fans, space heaters, and hair dryers have multiple settings. You can see the savings potential for using these devices at lower settings by either recording the watts at different settings in different rows, or by recording it in the “potential” column.



Other appliances may have large fluctuations in their draws when actively on. For example, a hair dryer ranged from 240 to 1,000 watts when on high. In this case, take the average of the high and low (620 watts) and enter that into the “on” column.

Still other appliances have such a low draw that they may not immediately register. These may include LED nightlights and carbon monoxide detectors. The electricity usage of these is so small that it may not be worth capturing even over a longer period. It's most important to get accurate readings for the appliances that use the most electricity such as refrigerators or large screen televisions.

Some appliances such as computers and printers use significantly different amounts of energy when “on” depending on whether they are actively “on” or passively “on”. Computers are actively “on” when being used or not in sleep mode. Printers are actively on when printing, not standing by.

It is best to capture the cycling of these active and passive stages over a representative period of time as is done with refrigerators and water heaters. A less accurate means of calculating wattage when “on” would be to record the most common wattage (active or passive) or take the average of the active and passive wattages if they are not too far apart.

### **Maximizing your “potential”**

Use the “potential” columns to compare the cost of using an appliance at different wattage settings. The lower wattage would be entered into the “potential” column (Watts-on) if you currently use the appliance at a higher wattage.

Next, see what you would save by cutting your phantom loads. For each appliance that has a wattage draw even when turned off, enter a “0” in the potential “Watts-off” column. To actually achieve these cost savings, plug each of these devices into a switchable outlet strip and switch it off when you’re not using the device or consider the use of a “smart strip” that automatically cuts phantom loads when the device isn’t in use.



**This stereo uses 15 watts when "off" under a certain display setting.**

The “potential” columns can also allow you to compare the cost of running your current appliance with that of a new, more efficient version. To do this, look for the Energy Guide labels or other estimates of electricity use of the new appliance. Divide the annual estimated kWh of the new appliance by 12.

## **Lesson 7: The Sun Can do “Watt”?**

### **Adapted/ Revised From**

New Mexico Solar Energy Association, Idaho National Laboratory, Wisconsin K-12 Energy Education Program

### **Grade Level**

6-12

### **Objectives**

- Measure the energy produced by a small PV panel with a multimeter
- Construct a motor with a propeller attached and run it using solar energy
- Measure the energy from the solar panel and utilized by the motor driving a propeller
- Discuss the findings with their classmates

### **Overview**

Through a simple hands on demonstration student will be able to describe how sunlight becomes energy to power things.

### **Materials (per group)**

- Small PV panel
- Small motor
- Small propeller made from cardstock, balsa wood or any other material
- Multimeter

### **Estimated Cost of Materials**

\$20 per group

### **Computer Required?**

No

### **Duration**

1 class period

### **Primer References**

1.1 Forms of Energy  
1.5 Energy Conversion  
3.1 Solar

### **Related Articles**

N/A

### **Engagement**

1. Why is energy important?
2. How do we know if the sun gives off energy or not?
3. How can we take sunlight and turn it into something useful?
4. What would be the benefits of using solar energy?
5. What might be the drawbacks?

### **Investigation**

1. Divide students into small groups with the materials listed.
2. Students should construct a small propeller, pinwheel, or similar and attach it to the drive shaft of the motor.
3. Mount the motor to something stable by taping it to a piece of wood or cardboard.
4. Place the PV solar panel in direct sunlight with no shade, connect it to a multimeter and record how many volts are registered.
5. Detach the multimeter from the solar panel and connect it to the motor, connecting red wire to red wire and black wire to black or blue wire. (Often the wire from a motor is blue not black, but it is still the negative lead.)
6. Place the solar PV panel in direct sunlight with no shade. While the propeller is rotating, touch the multimeter test probes to the corresponding terminal on the motor itself, again red to red, black to black or blue wires. Record the voltage reading.

### **Class Review**

1. Have the class share their findings and discuss what their findings might mean.

### **Elaboration**

1. Have students read the Primer References and discuss the following questions.
2. Is the PV Solar Panel by itself potential or kinetic energy?
3. If energy is neither created nor destroyed as it changes form, how do you explain why the voltage reading on the motor is different from the voltage reading with just the PV solar panel by itself?
4. Using the formula ( $\text{efficiency} = \text{useful energy output} / \text{energy input}$ ) and using your data collection, determine how energy efficient the solar power activity performed is.

### **Instructor Notes**

- The motor terminals are located on the motor where the wires have been soldered to the motor.

### **Extensions and Variations**

- Build a small model solar powered house and work to decrease the amount to energy lost. For lesson plan go to, <http://www.talkingscience.org/2011/03/building-a-solar-house/>

### **References/For More Information**

Wisconsin K-12 Energy Education Program- Energy Rules!

<http://www.uwsp.edu/cnr/wcee/keep/Mod1/Rules/EnConversion.htm>



## **The Sun Can Do Watt?**

Voltage of Solar PV Panel	Voltage of Motor attached to PV Panel

### **Questions**

1. Using the formula below, what is the energy efficiency of the conversion from the solar PV cell to the motor:

Useful Energy Output (of motor)/ Energy Input (of solar PV cell) = Energy Efficiency

2. List the energy forms associated with the transfer of energy from its source at the sun to the motor run by the PV panel.

3. What are some ways the motors could be powered by more volts?



## Lesson 8: “Watt’s” Your Angle?

### Adopted/ Revised From

Kid Wind, Idaho National Laboratory, ScienceBuddies.org

### Grade Level

6-12

### Objectives

- Define and apply concepts of tilt and azimuth
- Isolate the tilt and orientation variables from one another
- Measure the energy produced by a small solar PV panel with a multimeter
- Find the optimum tilt and azimuth to maximize voltage production
- Use a sun chart to explain experimental findings
- Draw conclusions and justify them to classmates

### Overview

Students compare the voltage output of a small PV solar panel at different angles and orientations to learn how solar panel location and installation are determined.

### Materials (per group)

- One small (0.5V – 1 V) solar PV panel
- Multimeter
- Sun Path Chart from <http://solardat.uoregon.edu/SunChartProgram.html> for your location
- Thermometer
- Protractor
- Magnetic compass

### Estimated Cost of Materials

\$20 per group

### Computer Required?

Only to download Sun Path Charts

### Duration

1-2 class periods

### Primer References

1.1 Forms of Energy  
1.5 Energy Conversion  
3.1 Solar

### Related Articles

- [Invert Your Thinking: Squeezing more power out of your solar panels](#), Scientific American Blog, August 2009

## Engagement

1. What factors are important when placing a photovoltaic cell for maximum power production?
2. Why are solar panels installed at an angle?
3. Would solar panels be useful year round in Colorado as a primary source of energy? Why or why not?
4. What would be the impact if solar panels could move with the sun?
5. What might be the relationship between temperature and energy?

## Investigation

DO NOT LOOK DIRECTLY INTO THE SUN!

### DAY 1

1. Divide students into small groups with the materials listed.
2. Explain to students that their challenge will be to use the materials provided to generate the greatest possible voltage (you can also determine wattage if your multimeter is capable of picking up amperage). Have them find definitions for tilt and azimuth and discuss to be sure everyone understands the concepts.
3. Go outdoors and have students choose their site for their measurements.
4. Place the PV solar panel in direct sunlight with no shade, connect it to a multimeter and record how many volts are registered. Move the panel around in different combinations of tilt and azimuth and notice the results.
5. Next have students set up a systematic way to measure the effect of changes in tilt and azimuth. Remind them that changing one variable at a time is good scientific practice. *Be sure to record the date and time just before you start the measurements.* If the measurements take more than a few minutes apart, you may want to record a time with each measurement as the sun moves quite quickly some times of the year:
6. First explore the effect of changes in tilt as the azimuth is held constant at an angle that seemed to be effective in the first trials. Use the protractor to make changes in 10 degree increments.
7. Next use your compass to assess the effect of changes in azimuth while holding the tilt constant at the angle found to be most effective. Record findings on the activity sheet.
8. Give each group a sun path chart. To practice interpreting the chart, ask each group to figure out the answer to these questions:
  - a. On what date or dates is the solar elevation closest to  $45^\circ$  at 12:00 pm?
  - b. Where is the solar elevation on June 21 at 9 am?
  - c. What is the solar azimuth (angle east/west) on March 21 at 5 pm?
  - d. Would your shadow be longer on July 21 at 12:00 pm or October 21 at 12:00 pm?
9. Have the students look at the Sun Path chart to determine where the sun was when they were taking their readings on their solar panel. Make sure to discuss the concept of solar noon (see Glossary), especially if the activity is done during daylight savings time. Record the solar elevation on their data sheets. Have them compare this information to the data they collected. What do they notice?

As you get involved with solar energy, you will be very interested in the sun's movements and position because these have such an impact on your system's efficiency. You may already know that the sun is in different positions in the sky in different parts of the year. For example, on the sun path charts you saw that the sun is not nearly as high above the horizon in December 21, the winter solstice, as it is in June 21, the summer solstice. Wonder why?

At the two equinoxes, March 21 and September 21, the sun rises due east and sets due west. At solar noon on the equinoxes, the altitude of the sun is 90 minus the local latitude. For example, if you live in Denver with a latitude of 40 degrees, the altitude of the sun at noon on the equinoxes will be  $90 - 40 = 50$  deg. (This is why you use your latitude as the default tilt angle on stationary panels.) Day length on the equinox everywhere on earth is 12 hours. On the winter solstice, the shortest day of the year, the sun rises well to the south of east, and sets well to the south of west. The altitude of the sun at solar noon will be 23.5 degrees less than it was on the equinox -- or,  $50 - 23.5 = 26.5$  degrees in our Denver example. This will be the lowest that the noon sun will be in the sky all year. On the summer solstice, the longest day of the year in the northern hemisphere, the sun rises well to the north of east, and sets well to the north of west. The altitude of the sun at solar noon will be 23.5 degrees more than it was on the equinox -- or,  $50 + 23.5 = 73.5$  degrees in our Denver example. This will be the highest that the noon sun will be in the sky all year.

The 23.5 degrees referred to above is the tilt of the earth axis of rotation relative to the plane of the earth's orbit. The summer solstice in the northern hemisphere occurs when the North Pole is tilted toward the sun, and the winter solstice when the North Pole is tilted away from the sun. Adapted from <http://builditsolar.com/>

## DAY 2 (optional)

1. Repeat the experiment without varying the method on a different day with a significantly different temperature; this does not have to be the next day.
2. Graph the results for both days and discuss.

## Class Review

1. Ask class to share some of their results of their experiments and what they might mean for solar PV installations.
2. Have students re-discuss Engagement questions as a group using the graphs to respond to those questions.

## Elaboration

Now that we have seen the amount of energy generated by a solar panel in Colorado:

1. Have students read the Primer References and look at the Solar Resource Map from Appendix B using a projector, handouts, or the [website](#).
2. Based on what they have read, the data they have collected, and the solar maps, have students determine if where they live is an ideal location to use solar as a form of energy.
3. Have students discuss how the energy from the sun is transferred to energy in the panel.
4. How does a PV cell work?
5. Is the solar PV panel by itself potential or kinetic energy?
6. If your panels are going to be stationary, what is the best choice of tilt angle and azimuth?
7. If you can move the panels, what changes would you make in the winter? What changes would you make in the summer?
8. The materials in solar cells are very expensive. Scientists and technicians have figured out how to use other materials to concentrate sunlight onto small areas. How do you think they do this?

9. Would solar panels be useful year round in Colorado as a primary source of energy? Why or why not?

### Instructor Notes

- This activity needs to be done on a sunny day.
- Please caution students to not look directly into the sun.
- Doing this activity in early morning or later afternoon will enable students to see the greatest changes of solar energy production from different tilts. (Doing the experiment while the sun is at its highest point will *not* produce significant difference in the data while changing the PV angle or the solar azimuth.)
- Some multimeters won't be able to detect meaningful amps from the panels. If your multimeters can detect amperage, have the students record amps in the activity sheets in order to calculate power (watts).
- During the azimuth variable testing, instruct students to recheck their solar elevation (angle) every time they take a new azimuth measurement to avoid error.
- The panels will need to have the small alligator clips attached to their wires in order to connect them to the multimeters. See the video [here](#). The panels and multimeter can also be connected using separate 2-end alligator clips.
- During the azimuth variable testing, instruct students to recheck their solar elevation (angle) every time they take a new azimuth measurement to avoid error.
- It may be helpful to have students read the box about sun angles and the solstices and equinoxes before they work with the Sun Path chart. Have them locate the solstices and equinoxes on the chart.

### Extensions and Variations

- Have students see if they can increase the energy produced by their panels by connecting two or more together. Experiment with connecting panels in series and parallel. Which would they predict would produce more voltage? If you have a multimeter that can measure 2 amps of current or more, you can also see which arrangement produces more current. By doing the math, Power (in watts) = voltage X current ( $W=VI$ ), students can determine which arrangement produces more power. For some background on the relevance of this concept, read this Related Article in Scientific American <http://blogs.scientificamerican.com/solar-at-home/2009/08/26/invert-your-thinking-squeezing-more-power-out-of-your-solar-panels/>
- Build a small model solar powered house and work to maximize the sunlight available and to decrease energy lost. For a lesson plan go to: <http://www.talkingscience.org/2011/03/building-a-solar-house/>
- Experiment with voltage output by bringing in various light bulbs or a low voltage buzzer to see if the solar panels can light them up. Use a box to provide shade for the bulb to be able to determine if there is faint glow or none at all.

**References/ For More Information**

The Solar Sprint PV Panel: Basic Electricity Review – just what it says and a great reference!

<http://chuck-wright.com/SolarSprintPV/SolarSprintPV.html>

Teach Engineering Lesson: Solar Angles and Tracking Systems

Contributed by: Integrated Teaching and Learning Program, College of Engineering and Applied Science, University of Colorado at Boulder

[http://www.teachengineering.org/view\\_lesson.php?url=collection/cub\\_/lessons/cub\\_pveff/cub\\_pveff\\_lesson01.xml#assoc](http://www.teachengineering.org/view_lesson.php?url=collection/cub_/lessons/cub_pveff/cub_pveff_lesson01.xml#assoc)

U.S. Department of Energy Sunshot Initiative

Good site for career information as well as a discussion on the concentration of sunlight

<http://www1.eere.energy.gov/solar/sunshot/index.html>

U.S. Energy Information Administration-Energy Kids- Renewable Solar

[http://www.eia.doe.gov/kids/energy.cfm?page=solar\\_home-basics](http://www.eia.doe.gov/kids/energy.cfm?page=solar_home-basics)

NREL: Dynamic Maps, GIS Data & Analysis Tools

<http://www.nrel.gov/gis/solar.html>





## Watt's Your Angle?

Location:

Latitude:

Longitude:

### **Day 1**

Date:

Time of Day:

Time of Solar Noon:

Temperature:

Constant Solar Azimuth:

	<b>PV Panel Angle</b>	<b>Voltage</b>	<b>milliAmps (if detectable)</b>	<b>milliWatts (if possible)</b>
First Reading				
Second Reading				
Third Reading				
Fourth Reading				
Fifth Reading				
Sixth Reading				
Seventh Reading*				

Constant Tilt:

<b>Solar Azimuth</b>	<b>Voltage</b>	<b>milliAmps (if detectable)</b>	<b>milliWatts (if possible)</b>

\* Note- Depending on the time of year it is you may have fewer than seven readings.

**Day 2 (Optional)**

Date:

Time of Day:

Time of Solar Noon:

Temperature:

Constant Solar Azimuth:

	<b>PV Panel Angle</b>	<b>Voltage</b>	<b>milliAmps (if detectable)</b>	<b>milliWatts (if possible)</b>
First Reading				
Second Reading				
Third Reading				
Fourth Reading				
Fifth Reading				
Sixth Reading				
Seventh Reading*				

Constant Tilt:

<b>Solar Azimuth</b>	<b>Voltage</b>	<b>milliAmps (if detectable)</b>	<b>milliWatts (if possible)</b>

## Questions

1. Graph the relationship between panel angle and voltage at the constant solar azimuth:
2. Graph the relationship between solar azimuth and voltage at the constant tilt:
3. What combination of tilt and azimuth gives the optimum performance?
4. How does the optimum tilt compare to your latitude? Why is it different or the same?
5. If done on two separate days, how are the results similar and different? Was temperature a factor in the difference?



## **Lesson 9: The Right Site**

**Adopted/ Revised From**  
Build It Solar, Teach Engineering

**Grade Level**  
6-12

### **Objectives**

- Apply knowledge of elevation, azimuth and sun charts
- Determine the suitability of a site for solar energy production

### **Overview**

Students will use simple tools to estimate how much sunlight will fall on a solar collector at a given site over a period of time. They will use this information to decide if a site is an appropriate location for solar energy production.

### **Materials**

- Small (0.5 V – 1 V) solar panels
- Multimeters
- Sun Path chart – available for your location online at:  
<http://solardat.uoregon.edu/SunChartProgram.html>  
(Print charts using the Average Solar Radiation data and do both June to December and December to June.)
- Solar Elevation and Azimuth Gauge – 2 per group available at  
<http://builditsolar.com/SiteSurvey/ElevAzGage.pdf>
- Compasses for finding true south

For each set of gauges:

- 2 pieces of cardboard
- Glue
- 2 small nails or paperclips
- Small weight
- String
- Thin straight piece of material for pointer: pencil, chopstick, small dowel, or a sturdy straw. The pointer will need a hole made at one end.

**Estimated Cost of Materials**  
\$5

**Computer Required**  
Only to download sun path charts and gauge templates

**Duration**  
1-2 class periods

## Primer References

### 3.1 Solar

## Related Articles

N/A

## Engagement

- We know it is very sunny in Colorado. Does that mean that we can efficiently generate solar electricity anywhere in the state?
- If we wanted to put solar collectors (panels) on our school grounds or in our town somewhere, how would we decide the best place to put them?
- What kinds of things do we have to know about the sun to make the best use of its energy?
- What obstacles could interfere with the sun's light reaching a solar collector?

## Investigation

1. Have students look at the overhead map labeled Solar Photovoltaic Resources in the United States in Appendix B to see how much sunlight falls on Colorado. The map can also be found at [http://www.nrel.gov/gis/images/map\\_pv\\_national\\_lo-res.jpg](http://www.nrel.gov/gis/images/map_pv_national_lo-res.jpg). Does the class feel that Colorado is an appropriate place for solar energy production?
2. In “Watt’s Your Angle”, students may have learned that knowing the appropriate tilt and azimuth is important to the efficiency of solar panels. Challenge students to come up with other things that must be considered when placing solar panels. Either brainstorm a list, or if time, give each group of students a multimeter and solar panel. Have them go outdoors and measure the voltage produced in different areas around the school yard. What conditions decrease the voltage produced?
3. Have each group build an azimuth gauge and an elevation gauge:

To make the Elevation gauge:

- a. Paste one copy of the gauge template on a piece of cardboard.
- b. Trim the cardboard along the Sight Line (you will sight along this edge for elevation measurements).
- c. Put a small nail or a paperclip with one end bent up through the center of the Reference Circle where all the lines meet.
- d. Tie one end of a light string to the nail or paperclip and the other end to a small weight like a nut or bolt.

To make the Azimuth angle gauge:

- a. Paste the other template on another piece of cardboard.
- b. Find a thin, straight piece of wood, like a pencil, chopstick or even a sturdy straw and make a small hole near one end. The pointer should be long enough to extend beyond the edge of the gauge. You will site along this pointer to measure azimuth angles.
- c. Attach the pointer to the center of the reference circle using a small nail or bent paperclip.

To see photos of the tools, go to [http://buildditsolar.com/SiteSurvey/site\\_survey.htm](http://buildditsolar.com/SiteSurvey/site_survey.htm)

4. Outside, have each group set up a fairly level workspace where they think they would like to put their collector. In actuality this may be on the roof, but for now, have them work on the ground.
5. Tape the Azimuth angle gauge to a flat surface so that 180° faces true south.
6. Have each group find the azimuth angle and elevation angle of each of the high points along the horizon as seen from their location, starting from the northeast (about 55°) and working around to the northwest (about 305°).
7. To find out the azimuth angle of each object, line up the pointer on the Azimuth gauge with the object and read the angle where the point crosses the number scale.
8. To find the elevation angle, place the gauge right at eye level and look along the sight line. Without moving the gauge, read the number that is crossed by the string.
9. Record both values for each object that is a high point as you move along the horizon.
10. Plot the data for each obstacle on the sun path chart. Connect the dots and fill out the activity sheet.

### **Class Review**

1. Have each group report on their findings.
2. Overall, are any of the locations suitable for placing solar collectors?
3. If there are obstacles, how can those be overcome?

### **Elaboration**

1. Where are the best places in Colorado for solar energy production?
2. What factors are important to consider when looking for a location for solar collectors?
3. What kinds of things do we have to know about the sun to make the best use of its energy?
4. What obstacles interfere with the amount of sunlight reaching a solar collector? What are some ways to mitigate each? Do some research on the effects of trees on solar collectors.
5. What other strategies could you use to improve the amount of sun the collectors receive?

### **Instructor Notes:**

- The sun path charts cover June to December or December to June. Give one of each to each group or to make the activity a bit shorter, have two groups work at each location, one charting the data for Dec to June and the other doing June to December.
- When you make the sun path chart for this activity, use the Average Solar Radiation button.
- Students should learn strategies for finding true south before they start this activity. Learn to find true south at <http://www.buildditsolar.com/SiteSurvey/FindingSouth.htm>
- A small thin piece of wood like a chopstick or a very thin piece of balsa wood, or even a sturdy straw makes a good pointer for the Azimuth gauge. You can make a hole through these materials easily with a nail or paperclip.
- One good way to fasten the string and pointer so they lay flat during use is to unbend one part of a paperclip and stick it up through the string or straw. Then fold it back down snugly.

- Cereal boxes are an inexpensive source of cardboard; however it is sometimes a bit floppy so gluing a double layer together may be helpful.
- When using the azimuth gauge, tape it to the flat surface once it is facing true south so that it does not move when the pointer is moved.

#### **Extensions and Variations:**

- Another tool from Popular Science for assessing obstacles can be found at <http://ncsc.ncsu.edu/wp-content/uploads/SitingActive.pdf>
- For a computer based method of seeing how obstacles impact available sunlight, students can go to Google sketchup, draw their building, add obstacles and use tools to show shadows on any day of the year. Go to <http://www.builditsolar.com/References/SketchUp/SketchUpEx.htm> for more information.

#### **References/For More Information:**

Build It Solar - <http://builditsolar.com/> - look especially at “Getting Started” and “Projects”

North Carolina Solar Center - <http://ncsc.ncsu.edu/wp-content/uploads/SitingActive.pdf>  
(Siting of Active Solar Collectors and Photovoltaic Modules)



## **The Right Site**

Date:

Time:

Location:

Latitude:

Longitude:

<b>Obstacle</b>	<b>Elevation</b>	<b>Azimuth</b>	<b>Hours (solar time) when sunlight hits</b>

## Questions

1. Plot the elevation and azimuth for each obstacle on the sun path chart.
2. For excellent solar energy output, about 6 hours of uninterrupted sunlight between 9 am and 3 pm solar time are needed year-round. Does your site receive this amount of sunlight?
3. What blockages occur during the 6 hour window? What time of the year do they occur? How long do they last?
4. Based on your answers to the questions above and the data you collected, rate your site "excellent", "good", "fair", or "poor" for solar electricity generation and justify your rating.

## **Lesson 10: Solar Car Race**

### **Adopted/Revised From**

NREL Model Car Competition ([http://www.nrel.gov/education/jss\\_hfc.html](http://www.nrel.gov/education/jss_hfc.html))

### **Grade Level**

6-12

### **Objectives**

- Analyze the relationship between voltage, amperage, and load
- Measure the voltage output of multiple solar panels wired in series and in parallel
- Experiment to find the wiring configuration that delivers the most power to the motor
- Apply concepts of tilt and azimuth to create a solar car that optimizes its use of the sun's rays

### **Overview**

Students will experiment with solar panels and motors to produce a car that can run on solar power. They will explore different wiring schemes and different panel angles.

### **Materials (per group)**

- One copy of Benham's disk (see below)
- One cereal box and corrugated cardboard
- One 1.5 volt motor
- One 0.5 V and one 1.0 V solar panels, wire, and alligator clips
- Multimeter
- Protractor
- New pencil and a pencil sharpener
- Glue, tape, scissors, compass, and a hole puncher

### **Estimated Cost of Materials**

\$30 per group

### **Computer Required?**

No

### **Duration**

2 class periods (one to build, one for race)

### **Primer References**

1.1 Forms of Energy  
1.3 Units of Energy  
3.1 Solar

### **Related Articles**

N/A

## Engagement

- How do you use solar panels to achieve maximum power output?
- How is *load* like resistance?

## Investigation

### Part One:

1. Divide students into small groups with the materials listed.
2. Have students read the Exploratorium's "Benham's Disk" description (below). They will learn that the black and white disk will create different colors when it is spun.
3. Have students cut out the disk and glue it to a piece of cardboard. Poke a small hole in the center of the disk and glue it carefully to the axle of the motor. The students will use both panels to power the motor and look for colors on the spinning disk. They will note how the colors change with greater speed.
4. Go outdoors to a sunny spot. (**Safety Note: Do Not Look Directly At The Sun!**) Wire one solar panel to the motor by attaching the wires from the panel to the terminals of the motor. Observe how fast the disk spins. Pivot the panel to different angles with respect to the sun's rays. How is the speed of the motor affected?

### Electric Circuits

An electric circuit consists of the various conductors that lead from the negative to the positive terminal of a source of electricity. The various parts of a typical house circuit include a fuse or circuit breaker, wires, switches, wall outlets, and light sockets and bulbs.

A circuit through which electricity is flowing is said to be closed. The circuit can be opened, or broken, by turning off a switch or by removing a fuse, pulling out a plug, or disconnecting the wires. A circuit generally contains a load - a device such as a lightbulb or appliance that provides resistance in the circuit. If a current is allowed to flow from one terminal to another with very little resistance, a short circuit exists. Unless such a current is quickly stopped by a fuse or circuit breaker, the wires may heat up enough to start a fire.

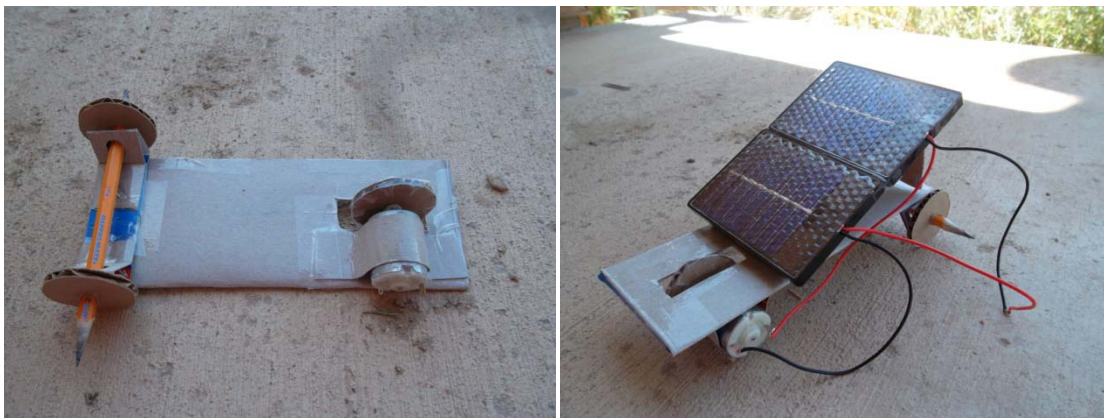
There are two basic methods of wiring a circuit—in series and in parallel. In the series circuit the current flows through one device (such as a lightbulb) to reach the next. In the parallel circuit the current enters and leaves each device separately. Devices connected in series each carry the same amount of current; devices connected in parallel are each subjected to the same voltage. Many electrical applications use a combination of these two types of circuits.

Excerpted from HowStuffWorks, <http://science.howstuffworks.com/electricity-info5.htm>.

5. **Parallel Circuits:** Students should read the box above about electrical circuits. Now have the students add another panel in parallel with the first panel by attaching both of the positive leads from the panels (red) to one of the motor terminals and both of the negative leads (black) from the panels to the other motor terminal. How is the speed affected?
6. **Series Circuits:** Have the students try wiring the panels in series. Disconnect all the wires. Using two panels, connect the positive lead of one panel to the positive terminal of the motor. Connect the negative lead of that panel to the positive lead of a second panel and attach the negative lead to the other motor terminal. How is the speed affected? Ask the students if they think they should wire the panels in parallel or in series to produce the fastest speed.

### Part Two:

1. The students should understand that wiring the panels in series will produce the greatest voltage and the fastest rotational spin. Now they are ready to build their car, using the photos below and template provided after this lesson plan or by creating their own designs.



2. Students should mount their panels on their cars using what they know about tilt and azimuth from the “Watt’s Your Angle” lesson plan. They can experiment with one 0.5V panel and one 1.0V panel to see how the load of the car affects the performance of the motor. Set the time and date of the race so students will have the information they need to create their solar panel mount for the race.
3. Create a race track that runs due north with start and finish lines. Make sure the race track is relatively smooth and located in a sunny spot. At the agreed upon time, start the race. Assign a record keeper to time the cars. Record car characteristics and results in the activity sheet for this lesson.

### Class Review

1. Discuss the results of the race. What characteristics did the winning vehicle have? What was the most crucial factor that led to its being successful?
2. Likewise consider the slowest car. What were the characteristics that led to its lack of success?
3. Use all class results to graph the relationship between voltage and velocity (also graph milliamps and milliwatts with velocity if applicable).
4. What was your car able to do when you had just the 0.5 V panel attached to the motor? The 1.0V panel? Both panels? Discuss what you observed in terms of the concept of load. (Note: see shaded box above.)
5. How can you reduce the load of your car in order to maximize speed?
6. How can you increase the solar radiation to your panel(s) to maximize the speed?

### Elaboration

1. Ask students how they can modify their cars to make them faster. Consider load, aerodynamics, number of panels, friction and weight.
2. Now that they have experienced this activity, ask the students how load is like resistance.
3. If milliamps were detectable, how important was this factor compared to voltage? Why?
4. What are the limitations of solar vehicles?

### **Instructor Notes**

- Some multimeters will not be able to detect milliamps generated from such small panels. If your multimeters can detect milliamps, have your students record this data in their activity sheets to calculate milliwatts (power).
- A finish line should be set a reasonable distance from the start for the race. This is likely going to be 5-10 feet from the start.

### **Extensions and Variations**

1. Build more sophisticated cars using gears, rubber wheels, bigger panels, etc.
2. Consider how to use solar power with other types of transportation.
3. Research solar transportation and create a display.
4. Check out M.I.T.'s Solar Electric Vehicle Team's website: <http://solar-cars.scripts.mit.edu/>.

### **References/For More Information**

Three great resources from the National Renewable Energy Laboratory for investigating different aspects of your solar car –

<http://www.nrel.gov/docs/gen/fy01/30826.pdf>  
<http://www.nrel.gov/docs/gen/fy01/30828.pdf>  
<http://www.nrel.gov/docs/gen/fy01/30830.pdf>

Here is the Exploratorium's Snack Site where you can read about Benham's Disk -  
[http://www.exploratorium.edu/snacks/benhams\\_disk/index.html](http://www.exploratorium.edu/snacks/benhams_disk/index.html)

Learn about the nature of light by building your own spectroscope -  
<http://solar-center.stanford.edu/activities/cots.html>

## Solar Car Race

Race Date:

Race Time:

Description of Solar Car	Mass of Car (oz.)	Number of Panels	Series or Parallel (if applicable)?	Tilt of Panels (degrees)	Voltage of Panels	milliAmps of Panels (if detectable)	milliWatts of Panels (if possible)	Distance to Finish Line (ft.)	Time to Finish Line (sec.)	Velocity (feet/sec.)

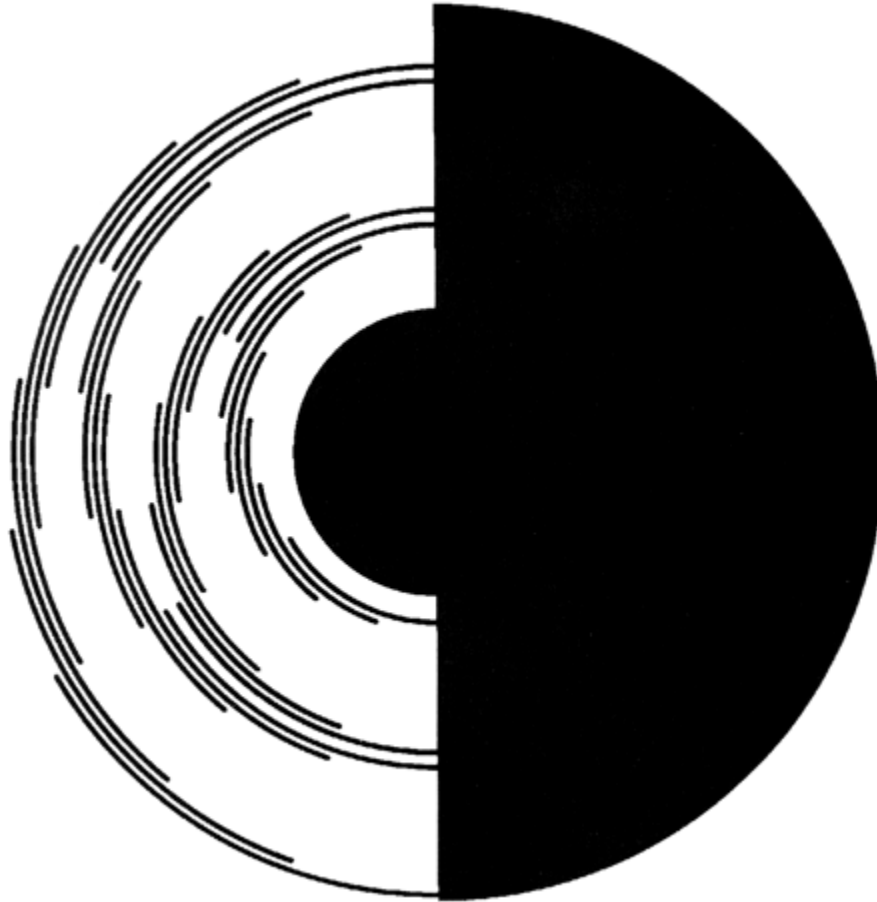
### Questions

1. What would you do to improve your car's design to make it run faster and/or straighter next time?
2. If you were running this race over the course of a few hours, would you set all your panel angles the same? Why or why not?
3. What would be the effects of adding an additional motor to your solar car?





## **Benham's Disk**



Different people see different intensities of colors on this spinning disk. Just why people see color here is not fully understood, but the illusion involves color vision cells in your eyes called cones.

There are three types of cones. One is most sensitive to red light, one to green light, and one to blue light. Each type of cone has a different latency time, the time it takes to respond to a color, and a different persistence of response time, the time it keeps responding after the stimulus has been removed. Blue cones, for example, are the slowest to respond (have the longest latency time), and keep responding the longest (have the longest persistence time).

When you gaze at one place on the spinning disk, you are looking at alternating flashes of black and white. When a white flash goes by, all three types of cones respond. But your eyes and brain see the color white only when all three types of cones are responding equally. The fact that some types of cones respond more quickly than others -- and that some types of cones keep responding longer than others -- leads to an imbalance that partly explains why you see colors.

The colors vary across the disk because at different radial positions on the disk the black arcs have different lengths, so that the flashing rate they produce on the retina is also different.

The explanation of the colors produced by Benham's disk is more complicated than the simple explanation outlined above. For example, the short black arcs that are on all Benham's disks must also be thin, or no colors will appear.

[http://www.exploratorium.edu/snacks/benhams\\_disk/index.html](http://www.exploratorium.edu/snacks/benhams_disk/index.html)

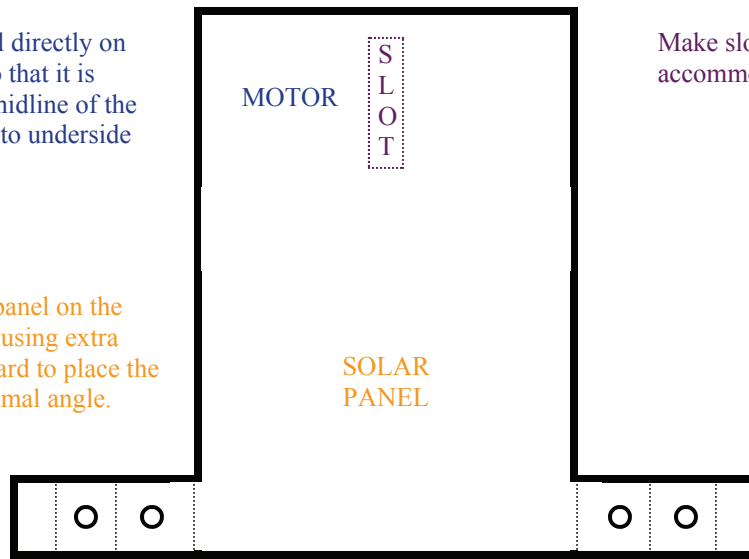


## Solar Car Race: Suggested Template for Solar Car

Use cereal box cardboard for the body of the car and the solar panel stand, and corrugated cardboard for the wheels. Use dimensions that accommodate the solar panels and the motor.

Place front wheel directly on the motor axle so that it is centered on the midline of the car. Tape motor to underside of cardboard.

Place the solar panel on the back of the car, using extra strips of cardboard to place the panel at the optimal angle.

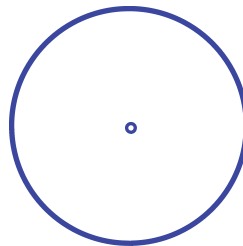


Make slot big enough to accommodate the wheel

Side view of bearing: Fold side tabs under into triangles as shown to support back axle. Punch holes at circles. (You may need to punch holes several times to make them big enough.)



Make three wheels out of corrugated cardboard: Using a protractor, draw a circle with a radius slightly larger than the radius of the motor housing. Attach one wheel to the axle of the motor using a strong glue (like Gorilla Glue), taking care not to get any in the motor housing. Using a pencil that has been sharpened at both ends for an axle, attach the other two wheels in the rear bearing.





## **Lesson 11: Measuring the Wind (Making an Anemometer)**

### **Adopted/ Revised From**

N/A

### **Grade Level**

6- 8

### **Objectives**

- Construct an anemometer to measure wind speed
- Examine the wind resource at your school

### **Overview**

Students build a simple anemometer and translate rotations-per-minute into miles per hour, then use wind speed to make conclusions about electricity generation.

### **Materials (per group)**

- Pencil with full eraser
- Push pin
- 5 small paper drinking cups, ~ 3 oz.
- 2 straws
- Scissors
- Tape
- Permanent marker
- Hole punch
- Stopwatch

### **Estimated Cost of Materials**

\$35 per group

### **Computer Required?**

No

### **Duration**

1 class period

### **Primer References**

3.2 Wind

### **Engagement**

1. How can you measure wind?
2. What are the different ways to measure wind?
3. Why would you want to measure wind?

## Investigation

Now we're going to measure the wind speed outside our classroom to draw conclusions about the relationship between wind speed and electricity generation:

1. Divide the class into small groups and hand out listed materials.
2. Using a hole puncher, punch one hole in 4 small drinking cups, about  $\frac{1}{2}$  inch (1.5 cm) below the rim. (Note, you may choose to trim the rim off the drinking cups if you wish to lighten the weight of the cups).
3. Draw a large **X** on the bottom of one of the 4 small drinking cups and, if possible, color the cup to make it clearly different from the other cups.
4. Take the fifth drinking cup and punch two holes in it, directly opposite from each other, about  $\frac{1}{2}$  inch below the rim. Then punch two more holes in the cup, each  $\frac{1}{4}$  inch below the rim that are equally-spaced between the first two holes to form a cross pattern.
5. Make a hole in the center of the bottom of the cup with four holes in it using the push pin and scissors. This is where the pencil will fit through.
6. Slide a straw through the hole in one of the cups that has only one hole in it. Bend the end of the straw that is inside the cup about  $\frac{1}{2}$  inch and tape it to the inside of the cup.
7. Place the other end of the straw through two of the holes in the fifth cup and then through the hole in one of the other cups. Tape the end of the straw to the inside of the cup. Make sure that the openings of the two cups face in the same direction perpendicular to the middle cup.
8. Repeat steps 4 and 5 with the remaining two cups. Make sure that the opening of each cup faces the bottom of the cup in front of it.
9. Insert the pencil with the eraser facing up through the bottom of the fifth cup. Push the pin through the two straws and into the eraser on the pencil making sure that the cups move freely.
10. You now have a working anemometer! You can use it to measure wind speed. Each time the marked cup spins around that is a full revolution.
11. Have each group assign a timekeeper, 1 or more counters to measure revolutions per minute (rpms), and a holder of the anemometer.
12. Students should take the anemometer outside to fill in the Activity Sheet for up to 10 trials for this lesson.
13. Groups can experiment by measuring wind speeds at different locations outside school (i.e. the north side of the building, the south side of the building, in an open field, etc.)

## Class Review

1. Ask the class to share the results of their wind speed experiments in order to see how variable different sites were and different groups' results were at the same site.

## Elaboration

Now that we have seen how to measure wind speed:

1. Have students read the Primer References for this lesson.
2. Were any sites suitable for electricity generation (Class 2 or above)?
3. Project the overhead of the Wind resource map from Appendix B or from this [website](#) (or provide handouts). Do class results match what is found on the map? Why or why not?

**Instructor Notes**

- Students can watch for full minutes to determine rpms or for shorter periods and just multiply accordingly.
- You may want to assign 5-10 different locations for the groups to measure their wind speeds.

**Extensions and Variations**

- You can calibrate the anemometer for mph a variety of ways. If you use raw calculations in the classroom, remember to note forces such as drag and friction. What components on the anemometer cause drag and friction? How can you improve the design?

**References/For More Information**

Wind Meters and Wind Measurement

<http://www.anemometertypes.com/>

American Wind Association Wind Resource Map:

[http://www.windpoweringamerica.gov/maps\\_template.asp?stateab=co](http://www.windpoweringamerica.gov/maps_template.asp?stateab=co)





### Measuring the Wind

	Location	Height (from ground)	Time Interval (seconds)	Number of Revolutions	rpm	Wind speed in mph
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

#### **Assumptions**

100 rpm = 10 mph

## Questions

1. How can we calibrate our anemometer so we can measure wind speed?

2. Use the table below to identify what class of wind you measured when the wind blew at its top speed:

Class	MPH*
1	0-12.5
2	12.5-14.3
3	14.3-15.7
4	15.7-16.8
5	16.8-17.9
6	17.9-19.7
7	>19.7

\*Listed wind speeds are typically at 50m

3. What location did the wind blow at its top speed? Why?

## **Lesson 12: Blade Design Competition**

### **Adopted/Revised From**

KidWind Project - Kid Wind MINI Turbine

### **Grade Level**

6-12

### **Objectives**

- Construct a mini wind turbine
- Test the turbine for electricity generating capability
- Compare different turbines with different blade designs
- Identify the factors that help turbines generate electricity

### **Overview**

Students build a mini wind turbine, test the power output in various formats, and then build their own blade designs.

### **Materials (per group)**

- KidWind Mini Blade Design Kit
- Tape
- Scissors
- Cardboard (optional)
- Art Supplies (optional)
- Fan (recommended)

### **Estimated Cost of Materials**

\$150 per group

### **Computer Required?**

No

### **Duration**

1-3 class periods

### **Primer References**

3.2 Wind

### **Engagement**

1. What are some different sources of energy?
2. What are wind turbines used for?
3. What are the different parts of a wind turbine?
4. Describe some different types of wind turbines and blade designs.

## Investigation

Now we're going to investigate how wind energy works by building our own turbines:

1. Divide the groups up depending upon the amount of MINI turbines you have available.
2. Students can take turns building and testing the turbines, however everyone can design their own blades in a final activity.

**Build the KidWind MINI Turbine** base following the KidWind directions (summarized here):

1. Separate the round yellow base from the metal rod (turbine tower).
2. Run the red and black wires from the turbine tail/nacelle through the metal rod and wooden base, thereafter connecting the nacelle to the top of the rod.
3. Inserting the round yellow base up from the hole in the bottom of the wooden base, connect the yellow base to the metal rod inside the hole of the wooden base.
4. Gently push the red blades onto the nacelle. The hole on the back side of the blades will fit by friction onto the nacelle.
5. If you need to remove the blades, you can use a screwdriver to pry the blade set off the nacelle, if needed. Use caution not to break a blade.

**Test the KidWind MINI Turbine** (use a fan (recommended) or go outside for wind):

6. Test #1
  - a. Power Output Board – test the KidWind MINI Turbine by connecting the black wires from the turbine to the black wires to the power output board using the black wire clips.
  - b. Connect the red wires of the turbine to the red wires of the power output board using the red wire clips.
  - c. Run the fan or place outside in the wind and turn the switch to music, flash, and/or torch.
7. Test #2
  - a. Multimeter - to use the multimeter, connect the red test lead to the VOhmMA jack and the black lead to the COM jack.
  - b. Connect the red wires to the red test lead and the black wires to the black test lead.
  - c. Turn on the fan to the low setting and record DC voltage by turning the multimeter dial left to the 500, 200, or 20 setting (20 should work fine since low voltage is expected).
  - d. Then record the amperage (in milliamps) by turning the dial right (past the OFF position) to the 200m setting (or other, but this should work fine for most applications).

## Build and Test Your Own Blades

8. Students can build their own blades using the wooden dowels and corrugated plastic board provided in the KidWind kits and/or other classroom supplies as well as tape and scissors.
9. Once blades are constructed and attached to the turbine, have students fill out the Activity Sheet for this lesson using the multimeter.

**Class Review**

1. Ask the class to share the results of their blade design and wind speed experiments in order to identify the blade design capable of generating the most electricity.
2. Have students discuss the Activity Sheet questions as a class.

**Elaboration**

Now that we have seen how wind turbines work:

1. Have students read the Primer References for this lesson.
2. As a class, list or “map” the energy forms associated with the transfer of energy from its source in the wind to the light we see from the LED light bulb on the turbine.

**Instructor Notes**

- Students in groups can compare different blade designs at the same wind speed or can compare the same blade design at different wind speeds.
- After groups complete their activities the whole class can discuss how different blade designs compare at different wind speeds.
- Turbines should be tested at the same distance away from a fan (i.e. 2 ft.) in order to accurately compare blade designs.
- The blades may need to be manually spun (lightly) in front of the fan before the blades are able to spin from the fan-generated wind alone.

**Extensions and Variations**

- Join three turbines together to form a Wind Farm and measure voltage and amperage.
- Use anemometers from the “Capturing the Wind” lesson to measure the wind speed outside and experiment with different blade designs outside.
- Enter your winning students in a national Blade Design competition – learn more here: <http://learn.kidwind.org/challenge/national/overview>

**References/For More Information**

KidWind Project: [www.kidwind.org](http://www.kidwind.org)



### **Blade Design Competition**

<b>Blade Design</b>	<b>Description*</b>	<b># Blades</b>	<b>Blade Angle (relative to ground)</b>	<b>Blade Length</b>	<b>Weight (if possible)</b>	<b>Fan Setting/ Wind Speed (if known)</b>	<b>Voltage (DC)</b>	<b>Milliamps</b>	<b>Milliwatts</b>
1									
2									
3									
4									
5									

\*Compare the same blade design at different wind speeds or different blade designs at the same wind speed.

## Questions

1. Graph the relationship between wattage and fan setting/wind speed:
2. Which blade design was best? Why?
3. What were the characteristics of the blade designs with the highest currents? Voltages? Why?
4. Which blade design would be the most economical to mass produce? Why?



## **Lesson 13: Are Renewables Right for Me?**

### **Adopted/Revised From**

N/A

### **Grade Level**

6-12

### **Objectives**

- Determine the technical feasibility of wind and/or solar energy at your school
- Calculate the costs and savings associated with solar or wind at your school
- Use online tools to assist in this exercise
- Identify the factors that are considered when deciding if solar and/or wind energy is right for a school

### **Overview**

Students assess the technical and economic feasibility of using wind and/or solar energy to generate electricity at their school using site-specific information from the internet.

### **Materials**

- Computer with internet access
- Tape measure (optional)
- Compass (optional)

### **Estimated Cost of Materials**

None

### **Computer Required?**

Yes

### **Duration**

1-2 class periods

### **Primer References**

1.1 Forms of Energy  
3.1 Solar  
3.2 Wind

### **Related Articles**

- [“Wind Turbines Whip Up Excitement, School Pride”](#) – National Renewable Energy Laboratory

### **Engagement**

1. What energy source(s) currently provide electricity to the school?
2. What are some alternatives? (Use PV panels and/or model wind turbines as visual aids.)
3. What are the advantages and disadvantages of using wind and/or solar energy?

4. Make a hypothesis: which is the better resource for the school (wind or solar)? Why? (Although it may seem windy or sunny all the time, personal observations aren't sufficient to determine whether or not a site would be good for a solar panel or wind turbine.)

### **Investigation**

Now we're going to conduct an assessment of our school and use research data to determine if solar and/or wind is a cost-effective option for our school:

1. Divide the students into groups that want to assess the feasibility of solar and groups that want to assess the feasibility of wind.
2. Based on their group's selection/assignment, students should use the appropriate activity sheet to complete the exercise.

For Solar:

1. Have students in the solar group go out and visually (or with a compass and tape measure) estimate tilt, azimuth, and usable square footage of the school's roof (all major sections) and enter the data into the activity sheet.
2. If the top of the roof cannot be seen, estimate that 65% of the roof square footage is available for solar PV (not interfered with by heating units, vents, etc.).
3. Students should then follow the instructions on the activity sheet to use the National Renewable Energy Lab's online PV Watts tool and deductive skills to analyze that data for electricity generation.
4. If the solar team determines that the school roof is capable of generating more electricity than the school consumes in a year, have the team determine the maximum system size for a solar PV array using information gathered on the activity sheet.

For Wind:

1. Following the activity sheet, students find their CSU Anemometer Loan Program site number (online), enter relevant data, and determine the direction the prevailing winds come from by using the site's wind rose.
2. Then have students in the wind group go out and identify a location on school property as far away from upwind obstructions as possible.
3. Once there, students visually (or with a tape measure) estimate the height and distance away of the most prominent upwind obstruction. (This may or may not be the school building.)
4. Students should then enter this data on the activity sheet and continue their exercise using this sheet.

### **Class Review**

1. Ask the groups to share the results of their experiments by reviewing each of the questions on the activity sheets as a class.
2. Is a solar PV system technically feasible at the school? A wind system?
3. Based on payback periods calculated by the groups, which is the most cost-effective option for your school – wind or solar? Why?

## Elaboration

Now we have to look deeper into how solar and wind energy systems transform solar or wind energy into electricity:

1. Have students read the Primer References.
2. How does each technology generate electricity?
3. As a class, list or “map” the energy forms associated with the transfer of energy from its source at the sun and/or wind to the light we see from a light bulb.
4. During which energy transfer does the most significant inefficiency take place?

## Instructor Notes

### Solar

- If the class has not already conducted the “Watt’s Your Angle” lesson, be sure to transmit that the ideal tilt of a solar panel equals the latitude of a location and the ideal azimuth for anything in the northern hemisphere is true south (180 degrees).
- If an open space owned by the school is a better candidate for solar than the school’s roof (i.e. because it needs to be replaced), ask the students to calculate the usable area, tilt, and azimuth of the open space instead.

### Wind

- It may be worthwhile to investigate whether or not there is enough space at the school to even potentially put up a viable wind turbine before engaging students in this activity.
- The recommended hub height is  $2H$  + the radius of the rotor where  $H$  = the highest point of the most prominent upwind object.
- If a turbine location meets the distance requirement (at least  $20H$  away from obstruction), the ALP site-given hub height can be used.
- Students need to adjust the cost of their turbine and the net energy output of their turbine above \$7.50/watt if the turbine hub height must be increased above the ALP site-given hub height as indicated in the activity sheet “Assumptions”.

## Extensions and Variations

- Have students conduct the Watt’s Your Angle and/or Blade Design Competition lessons either before or after this lesson.
- Use Colorado State University Extension’s Solar PV Feasibility Calculator to more accurately assess the economic feasibility of a school solar array (<http://www.ext.colostate.edu/energy/solar.html>).
- Conduct the school energy audit lesson plan to see what percent of the school’s energy use would be offset using the same solar array/wind turbine after implementing energy efficiency measures. Would system costs for renewable energy decrease?
- Students can present their findings using graphs and or powerpoint to the class and/or school administrators.

## References/For More Information

National Renewable Energy Lab’s PV Watts (Version 1):

<http://rredc.nrel.gov/solar/calculators/PVWATTS/version1/>

Colorado State University Anemometer Loan Program:

<http://www.engr.colostate.edu/ALP/>



## Are Renewables Right for Me - Solar?

Roof section	Tilt	Azimuth	Roof square feet	Number of panels	Maximum watts	Maximum kW (DC)	Annual kWh (AC)*	Value of the electricity	Installed cost before incentives	Rebates and incentives	Total installed cost	Simple payback period (years)	CO2 emissions reduced (tons)
					Total								

### **Assumptions**

Each panel has a 230 watt capacity

Each panel is 15 square feet

As a default, estimate that 65% of a school roof's area is usable for solar PV (not interfered with by air conditioning units, vents, etc.)

For a tilted roof, assume that panels can fill the entire usable area at the tilt and azimuth of the roof itself.

For a flat roof, assume that each panel has a footprint of 30 square feet of roof space that accounts for the panel mount and winter shading at the ideal tilt and azimuth.

For the value of electricity, use the data from an actual school electricity bill or use a default of \$0.08/kWh

It costs \$5.50 per installed watt of solar PV

A tax credit worth 30% of the installed cost is available as an incentive

Each kWh produced will save 1.4 lbs. of CO2 from being emitted

\*Use the National Renewable Energy Lab's online "PV Watts" tool to determine annual kWh:

- Go to <http://redc.nrel.gov/solar/calculators/PVWATTS/version1/> and click on Colorado in the U.S. map.
- Locate the nearest data site to your school and click on it.
- Enter the size, tilt, and azimuth for a section of your school's roof, then click "Calculate" to get AC energy (kWh).
- Repeat for all sections of your school's roof and enter the data in the worksheet.

## Questions

1. Using either the sample school electricity bill (times twelve) or actual school electricity bills over a one-year period, determine what percentage of the school's electricity use can be generated by solar PV.
2. If more than 100%, determine the maximum size system your school would need and calculate the cost and simple payback period on that system.
3. If a solar PV system has a 25-year lifespan, would your school's system be economically feasible?
4. If electricity rates increased to an average of \$0.15 over the 25-year life of the array, would your system be economically feasible?
5. How does tilt affect electrical generation? What is the ideal tilt of a solar PV system at your school?
6. How does azimuth affect electrical generation? What is the ideal azimuth of a solar PV system at your school?

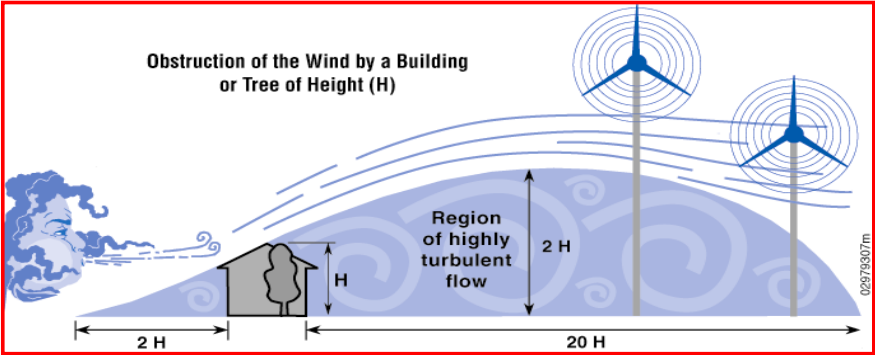
**Are Renewables Right for Me - Wind?**

Identify the best site for a wind turbine at your school:

Annual school kWh used*	ALP site number**	Turbine generating closest kWh under school use	Rotor diameter of turbine (convert to feet)	Hub Height (convert to feet)	Prevailing winds come from (direction)	Identify possible location for turbine	Highest point of most prominent upwind object in feet (H)	Distance away from possible turbine location in feet	20H	Meets horizontal distance requirement?	If no, minimum recommended height of rotor bottom	Minimum recommended hub height

**Assumptions**

A wind turbine should be at least 2H in height if within 20H of the nearest object per below:



Calculate the payback period for a turbine near your school:

	Annual school kWh used*	ALP site number**	Turbine generating closest kWh under school use	Rotor diameter of turbine (convert to feet)	Rotor power (kW)	Average annual net energy output of turbine (kWh)	Annual value of the electricity	Installed cost before incentives	Installed cost after incentives	Simple payback period (years)

**Assumptions**

1 meter = 3.28 feet

For the value of electricity, use the data from an actual school electricity bill or use a default of \$0.08/kWh

It costs \$7.50 per installed watt of wind

A tax credit worth 30% of the installed cost is available as an incentive

Each kWh produced will save 1.4 lbs. of CO2 from being emitted

\*From sample monthly bill times 12 or from actual school billing data

\*\*Use the Colorado State University Anemometer Loan Program website as follows:

- Go to <http://www.engr.colostate.edu/ALP/> and click on "ALP Sites and Data" on the left navigation bar.
- Locate the nearest data site to your school and click on it.



## Questions

1. Based on the height of objects (i.e. trees and building) near your school, is a wind system practical?

2. Using data from your ALP site, graph the relationship between tower hub height and wind speed.

3. Based on the following formula, which factor is the most important in determining the power of wind: air density, the swept area of the blades, or the wind speed?

$$\text{Power in the Wind} = \frac{1}{2}\rho AV^3$$

$\rho$  = air density

A = swept area of the blades

V = wind speed

4. Using either the sample school electricity bill (times twelve) or actual school electricity bills over a one-year period, determine what percentage of the school's electricity use can be generated by the selected wind turbine.

5. If a wind energy system has a 25-year lifespan, would a system near your school be economically feasible? What other factors would affect the economic feasibility of the wind system?



## **Lesson 14: Earth Energy**

### **Adopted/Revised From**

N/A

### **Grade Level**

6-12

### **Objectives**

- Predict the factors that produce the greatest geothermal temperature change
- Design a geoexchange system to implement their predictions
- Collect temperature data
- List common factors that contribute to the greatest geothermal temperature change
- Determine the effectiveness of geoexchange system for both heating and cooling

### **Overview**

Students design a simple geoexchange system in order to both extract heat from and disperse heat into sand.

### **Materials (per group)**

- Two (2) three to six-foot length of ½” poly drip irrigation tubing (the two lengths of tubing for a given group should be the same, but each group can have different sets of lengths)
- Two (2) ½” end caps/plugs for poly drip irrigation tubing
- Two jars, bowls, measuring cups, or similar (4-6 cup capacity each)
- One thermometer
- One trowel (optional)
- One Sterilite tub, 5 gallon bucket, or similar
- Enough sand to fill the tub or bucket 2/3<sup>rd</sup>s full

### **Estimated Cost of Materials**

\$15 per group

### **Computer Required?**

No

### **Duration**

1 class period

### **Primer References**

1.1 Forms of Energy

3.3 Geothermal Energy

### **Related Articles**

- [“Ikea’s cool new digs in Colorado to feature geothermal system”](#) – Denver Post, September 17, 2010

### **Engagement**

1. What do the terms “geo” and “thermal” refer to?
2. How do we usually provide heating and cooling to a home or school?
3. Why would we want to use the earth’s energy to heat and cool our homes or schools instead?

### **Investigation**

Now we’re going to see experimentally how a geothermal system – also called geoexchange or ground-source heat pump - works:

1. Divide the students into small groups (no more than 5 per group recommended) and provide them with the materials listed.
2. Students should fill the tub 2/3 full of sand. The sand represents the ground.
3. Design a geoexchange system to maximize heat exchange between the earth and the tubing, and sketch to record the design.
4. Using the trowel, dig the trench for the tubing if necessary to follow the design.
5. Plug both lengths of the 1/2” drip tubing at 1 end with the end caps.
6. Fill a jar (or similar) with hot water or cold water, and measure the water temperature. Some groups can use hot water and others can use cold, or groups can each conduct the experiment once with hot and once with cold.
7. Temperature should be recorded in the activity sheet.
8. Quickly (to avoid temperature fluctuations from measured temperatures as much as possible) pour the water into the tubing lengths and plug the other ends. One length is to be buried and the other is to be a “control” just laid out in the classroom.
9. Quickly arrange one of their tubing lengths in a 5 gallon bucket or similar to be filled with sand. Arrangements might be circular, loops, linear, etc. Students should arrange their tubing with maximizing heat transfer between the tubing and the sand in mind.
10. Leave no tubing exposed.
11. Once the tubing is completely buried, students should start the 10 minute wait period.
12. Measure and record the temperature of both the sand and the room (air).
13. After exactly 10 minutes, pull tubing out of the sand, remove the end cap from one end of the tubing, pour the water back into the jar, and measure the temperatures of the water. Students should simultaneously pour water out of the control tubing into the other jar and measure the temperature of its water.
14. They can continue to fill out their activity sheets and draw conclusions

### **Class Review**

1. Ask the groups to share the results of their experiments by reviewing each of the questions on the activity sheets as a class.

### **Elaboration**

Now we have to figure out how this concept can be applied to heating and cooling a building:

1. Have students read or otherwise explain the information from the Forms of Energy and Geothermal Energy chapters of the Primer.
2. How do ground source heat pumps work?

3. Is geoexchange a practical option for your school? Why or why not? Where might the loop field be located?

### **Instructor Notes**

1. Different groups may have different results based on the layout of their tubing in the buckets, the lengths of their tubing, starting temperatures, etc.
2. The groups using cold water should use cold enough water so that there is a significant difference between the water temperature and the sand temperature. Ice may need to be added to the cold water.
3. Greater temperature differences may be experienced by groups who start with hot water simply because the initial difference in temperature between the hot water and the sand is likely greater than the initial difference in temperature between the cold water and the sand.
4. If tubs/buckets used by groups are different, this should be noted when comparing temperature fluctuations.

### **Extensions and Variations**

- You may want to start students with all the same lengths of tubing and then have them repeat their experiment with different lengths of tubing, different layouts, and using different buckets (i.e. shallow vs. deep), changing just one variable at a time to compare the effects of different variables on temperature fluctuations.
- If sand is available and accessible at your school's playground, students can replicate this experiment outside using longer runs of tubing. They can experiment with horizontal loops and vertical loops if a decent garden shovel is provided.

### **References/For More Information**

U.S. Department of Energy:

[http://www.energysavers.gov/your\\_home/space\\_heating\\_cooling/index.cfm/mytopic=12640](http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12640)

Colorado Geothermal Working Group:

<http://coloradogeothermal.groupsite.com/main/summary>



**Earth Energy**

Experiment Number	Length of Tubing (ft.)	Type of Container	Temperature of Water - Start (F)	How is Buried Tubing Arranged (i.e. loop, linear, etc.)?	Temperature of Sand (F)	Temperature of Air (F)	Buried Tubing: Temperature of Water - End (F)	Control Tubing: Temperature of Water - End (F)	Temperature Change of Buried Water (F)	Temperature Change of Control Water (F)	Percent Temperature Change of Buried Water	Percent Temperature Change of Control Water

**Questions**

1. Which experiment (one of yours or a classmates) resulted in the greatest water temperature change?
2. What factor - length of tubing, type of container, starting temperature of the water, temperature of the sand/air, the absorption capacity of sand/air, or layout of the tubing - do you believe had the greatest impact on temperature change? Why?
3. Where did thermal energy move from and to in your experiments?
4. Could geoechange be used for both heating and cooling a building? Why or why not?





## **Lesson 15: Biofuels in Your Backyard**

### **Adopted/Revised From**

N/A

### **Grade Level**

6-12

### **Objectives**

- Construct a manual oil expeller
- Employ fire safety procedures
- Operate the manual oil expeller
- Measure mass of seeds and total oil produced
- Calculate oil percentage per gram of seeds
- Discuss, compare and contrast advantages and disadvantages of using vegetable oil from crops grown in Colorado as biofuel

### **Overview**

Students press oil from Colorado oilseeds using a manual expeller and calculate the oil and feed content of the seed.

### **Materials (per group)**

- One PITEBA manual seed press – this should be bolted to a 2' x 4' and then secured to a table top with clamps or otherwise secured per PITEBA instructions (CSU Extension kits for this lesson plan come with a pre-bolted press and all other materials)
- One clear 12 ounce plastic soft drink bottle
- 1 oz. of edible oil (vegetable oil)
- Lamp oil
- Two 4" C-clamps
- One large container (i.e. 4-8 cups capacity)
- One scale
- Enough oilseed to at least fill a 12 oz. soft drink bottle
- One pair of large pliers
- Paper towels
- Scale

### **Estimated Cost of Materials**

\$120 per group

### **Computer Required?**

No

### **Duration**

1-2 class periods

## Primer References

- 1.1 Forms of Energy
- 3.4 Biofuels

## Related Articles

- [“Bridging the Biofuel Transition”](#) – Colorado State University Extension
- [“Case Study 2 – Costilla County Biodiesel Project”](#) – Western Organization of Resource Councils

## Engagement

1. Students should first read the CSU Extension blog entry entitled [“Bridging the Biofuel Transition”](#).
2. What do we use for most of our transportation fuel? (petroleum)
3. Is petroleum renewable or non-renewable?
4. Do we get most of our petroleum from here in the U.S.?
5. Are there alternatives to using petroleum as fuel?

## Investigation

Now we’re going to conduct an experiment to find out the challenges and opportunities behind producing our own straight vegetable oil from seeds that can be grown locally:

1. Divide the students into groups according to the number of presses you have.
2. Supply each group with listed materials. Each group should then:
3. Mount the press securely by tightly clamping the pre-bolted wood (with press) to a table using the two C-clamps so that the crank can still be rotated.
4. Weigh the seeds to be used and the large container according to the activity sheet.
5. Set up the oil press according to the instructions in the kit (highlights in blue below):
6. [Unscrew the adjustment bolt and cap from the press cage.](#)
7. [Remove the expeller screw and grease the washer with edible oil.](#)
8. [Replace the washer, expeller screw, and cap.](#)
9. [Depending on the type of seed \(see chart below\), replace or do not replace the adjustment cap.](#)
10. [Prepare a funnel by cutting a plastic soft drink bottle approximately 15 cm from the outlet. The bottom of the bottle should be kept for later use.](#)
11. [Weigh the bottom of the bottle according to the activity sheet.](#)
12. [Fill the glass container with lamp oil. Thread the wick through the wick holder and place the wick holder into place atop the glass container.](#)
13. [Place the glass container on the foot of the expeller under the chimney. Tighten the container with an elastic band over the two projections. Always check the quality of the elastic band before use!](#)
14. [Place the bottom of the cut soft drink bottle below the oil slit.](#)
15. [Light the wick – note: all common fire safety precautions must be taken including tying hair back, not wearing loose clothing, wearing safety goggles, etc.](#)
16. [Fill the funnel with seed.](#)
17. [Wait 10 minutes to heat the press cage.](#)

18. Right before beginning oil expulsion, place the large container below the cap/adjustment bolt to catch the press cake.
19. Start turning the crank clockwise. The press cake will appear through the 2 holes in the cap. In the beginning some seeds may appear – gently stop the seed from appearing by use of your fingers. The oil will appear through the oil slit in the press cage.
20. If using the adjustment bolt, tighten the bolt gradually after the press cake appears to obtain a good flow of oil.
21. Check regularly the flow of the seed through the funnel. If necessary, use a small wooden stick to break any bridge formation in the funnel. Coarse or broken or angular seeds may lead to bridge formation.
22. If necessary, clean the oil slit with a small knife to avoid blockage.
23. After an allotted time (i.e. 5-10 minutes), instruct the groups to stop expelling and to extinguish their burners.
24. Part of the group should then follow instructions in the kit to clean up the expeller (highlights in blue below), while the other part of the group should weigh the oil and press cake according to the activity sheet:
25. Using the large pliers, remove the cap from the press cage **as soon as possible** considering the temperature of the cap.
26. Clean the cap, adjustment bolt, and press cage thoroughly – **let the cap soak in soapy water if necessary to ensure that all hardened press cake is removed. This may need to be done multiple times over a period of days to ensure that all the press cake is removed, depending on the moisture content of the seeds used.**
27. Once the glass container and wick holder are cool enough, carefully pour the remaining lamp oil back in its original container and put the press back together just as it was found.
28. Refer to the instructions provided in the kit for troubleshooting tips.
29. The oil and press cake can be disposed of or utilized.

Seed Chart:

Seed	Use of Adjustment Bolt
Sunflower	None
Canola	Expel with bolt – at first keep 2 press cake outlets open then tighten until strings of press cake appear
Safflower	None

### Class Review

1. Ask the groups to share the results of their experiments by reviewing each of the questions on the activity sheet as a class.
2. Have the students read the Related Article.
3. From the reading and based on the experiment, what are the potential implications of Rudolph Diesel's early research and engines work for our society today?
4. Graph the relationship between number of acres needed and percent of oil by weight in a seed for all types of seeds utilized by the class.
5. List or debate the advantages and disadvantages of using vegetable oil in place of petroleum fuel.

## **Elaboration**

Now we have to figure out what energy forms are behind the production of biofuels:

1. Have students read the Primer References.
2. As a class, list or “map” the energy forms associated with the transfer of energy from its source in the oilseed crops to a vehicle moving as a result of utilizing biofuels.
3. At what point in the energy forms map is the potential energy in the oil transformed into kinetic energy?

## **Instructor Notes**

- Always follow the instructions found in the kit (also accessible here: <http://www.piteba.com/eng/users%20manual.htm>).
- Be sure that all presses are bolted and mounted securely before expelling.
- Group members can take turns cranking (expelling) to maximize participation – sometimes the crank may be difficult to start and depending on the seed used may require considerable force throughout oil expulsion.
- The wick should be long enough to burn for 20 minutes but short enough to not form too much soot on the press cage – 1/2 inch or so should be sufficient.
- Follow all expelling instructions for specific seeds.
- Use of local seed such as canola (rapeseed) and sunflower is highly encouraged.
- The cap at the end of the press cage must be taken off and cleaned **ASAP** after use, otherwise the press cake hardens and is time-consuming to get off completely.
- If the seed is particularly dry (e.g. the oil is difficult to expel and the press cake is hard in the press cap after use), soak seeds in water for 2 days at a ratio of 0.25 cup for every 2 lbs. of seed.

## **Extensions and Variations**

- Compare the oil content of different types of seeds.
- Use the oil to make biodiesel.

## **References/For More Information**

PITEBA (Press Manufacturer):

<http://www.piteba.com>

## **Biofuels in Your Backyard**

Type of seed	Mass of seeds and container (oz.)	Mass of container minus seeds used	Mass of seeds used	Mass of bottle bottom	Mass of expelled oil and bottle bottom	Mass of expelled oil	Mass of press cake container	Mass of press cake and container	Mass of press cake	Percent oil (of seeds) by mass	Percent press cake (of seeds) by mass

Type of seed	Gallons of diesel per average light truck per year	Total cost of this diesel	Gallons of SVO* needed per year in SVO-RUG blend for this light truck	Gallons of RUG needed per year in SVO-RUG blend	Total cost of this RUG	Total cost of SVO in order to equal total cost of diesel when added to total cost of RUG	Cost per gallon of this SVO (maximum "break-even" cost)	Pounds of seed to produce 1 gal. of SVO	Pounds of seed needed to produce this SVO	Acres of land needed to produce this amount of seed	Pounds of press cake from this amount of seed	Dollar value of this press cake
	655											
	655											
	655											
	655											
	655											

\*SVO = straight vegetable oil

### **Assumptions**

One gallon of vegetable oil = 8 lbs.

16 oz. = 1 lb.

SVO can be mixed with regular unleaded gasoline (RUG) at a 3:1 ratio in diesel engines

RUG costs \$3/gallon

Diesel (petroleum-based) costs \$3.30/gallon

One acre of land can produce approximately 1,500 lbs. of oilseed

Press cake is valued at approximately \$350/ton as livestock feed

### Questions

1. Did the mass of the press cake plus the mass of the oil equal the mass of the seeds used? Why or why not?
2. What percent by mass was the oil content of the seed?
3. What is the maximum "break-even" cost of producing the SVO (per gallon)?
4. How many acres of land would be needed to run a light diesel truck for one year with a 3:1 SVO:RUG blend?

## **Lesson 16: Climate Change Wedge Game**

### **Adopted/Revised From**

Princeton University's Carbon Mitigation Initiative

### **Grade Level**

6-12

### **Objectives**

- Evaluate the growth of carbon emissions over time at the global scale
- Compare current rate of emissions with past rates of emissions
- Identify actions that can help to curb the rate of carbon emissions
- Analyze costs and benefits associated with different emissions reductions actions
- Select a set of actions intended to reduce carbon emissions at the global scale
- Debate and defend the selected actions based on research

### **Overview**

Students analyze different actions that would stabilize global carbon emissions at 2005 levels by 2055 and select the actions they think would be best.

### **Materials (per group)**

- Wedge game worksheets (after this lesson plan)

### **Estimated Cost of Materials**

None

### **Computer Required?**

No

### **Duration**

1-2 class periods

### **Primer References**

4.0 Energy and Climate Change

### **Related Articles**

- "[A Plan to Keep Carbon in Check](#)" – Scientific American, September 2006
- "[Can We Bury Global Warming](#)" – Scientific American, July 2005

### **Engagement**

1. What do you know about global climate change?
2. Do you think climate change is a serious problem?
3. Do you think we can take actions to mitigate climate change?
4. What are some actions we can take to mitigate climate change?
5. What are the difficulties associated with taking action on climate change?

## Investigation

Now we're going to examine the relationship between carbon dioxide and global climate change and analyze different options for reducing global carbon emissions:

1. Have students watch the seven minute online video entitled "[Why Greenhouse Gases Make the Planet Warmer](#)" (Colorado State University). For those without internet access, students should read Primer sections 4.1 and 4.2.
2. Project the Stabilization Triangle slide and explain how it works:
  - Carbon emissions are expected to follow the current path ramp.
  - The purpose of the Wedge Game is to identify ways to take the "flat path" instead, in which carbon emissions in 2055 would be the same as carbon emissions in 2005.
  - The difference between the current path and the flat path forms a triangle referred to as the "stabilization triangle".
3. Project the Eight Wedges slide and explain how it works:
  - The difference between the current path and the flat path of the stabilization triangle is 8 billion tons of carbon emitted/year.
  - If we divide the triangle by eight, each "wedge" represents 1 billion tons of carbon emissions avoided.
  - We can achieve one wedge of avoided carbon in a number of different ways.
4. Divide the students into small groups (no more than 5 per group recommended) and provide them with each with copies of the wedge game worksheets found after this lesson plan.
5. The groups of students then read through the 15 different strategies that will each achieve one wedge of carbon avoided.
6. They should debate and decide upon the eight strategies they want to select to make up their stabilization triangle.
7. They can either label, cut, and glue their selected strategies onto the gameboard provided (after this lesson plan), or they can simply list their selected eight strategies on the Wedge Worksheet. (If using the gameboard they should also use the Wedge Worksheet.)
8. Groups should fill out the Wedge Worksheet completely.

## Class Review

1. Groups should present their stabilization triangles to their classmates, explaining total costs, summarizing challenges, and summarizing perceived stakeholder feedback.

## Elaboration

Now let's reach some conclusions about the challenges we face in curbing global climate change:

1. What are the challenges we face in curbing global climate change?
2. What opportunities are most "ripe" for reducing carbon emissions?
3. How might different stakeholders view various strategies?
4. Are some strategies likely to be more widely accepted than others? Why or why not?
5. Industrialized countries and developing countries now each contribute about half the world's emissions, although the poorer countries have about 85% of the world's



population. (The U.S. alone emits one fourth of the world's CO<sub>2</sub>.) If we agree to freeze global emissions at current levels, that means if emissions in one region of the world go up as a result of economic/industrial development, then emissions must be cut elsewhere. Should the richer countries reduce their emissions 50 years from now so that extra carbon emissions can be available to developing countries? If so, by how much?

6. Nuclear energy is already providing one-half wedge of emissions savings – what do you think the future of these plants should be?

### **Instructor Notes**

1. To conduct a shortened version of the game, ask students to read only the summaries of the 15 Ways to Cut Carbon (below) and to list their strategies on the Wedge Worksheet instead of use the gameboard.
2. Ideally, students would select no more than 6 electricity wedges, 5 transportation wedges, and 5 heat/direct fuel use wedges so that emissions aren't "double counted".
3. There is no "right" solution to the game!

### **Extensions**

- Ask judges from environmental, energy industry, and government organizations to judge the student presentations.
- Ask the students to make a powerpoint or poster presentation instead of an oral presentation defending their stabilization triangles.

### **References/For More Information**

Princeton University Carbon Mitigation Initiative:

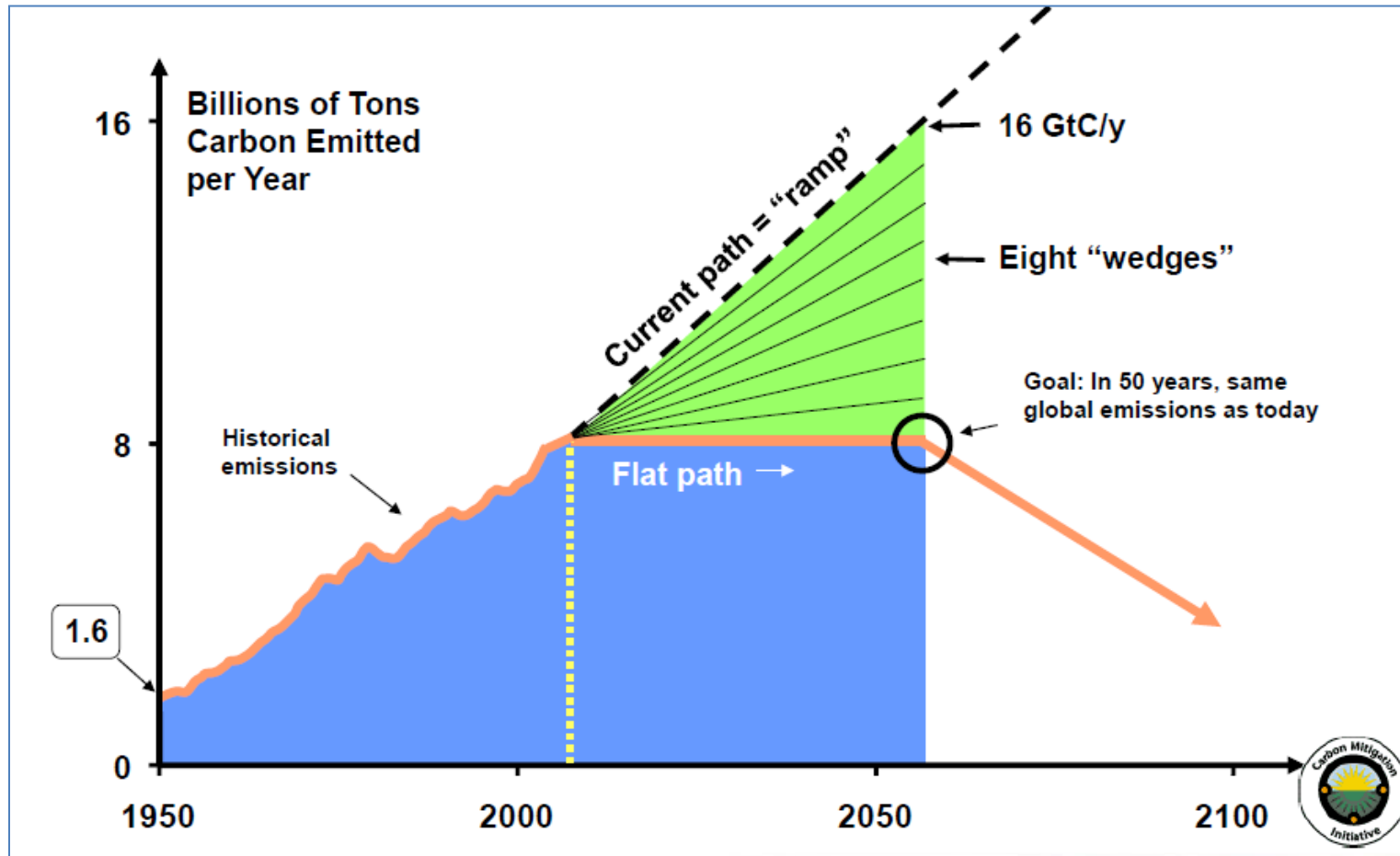
<http://cmi.princeton.edu/>

Changing Climates at Colorado State University:

<http://changingclimates.colostate.edu/>

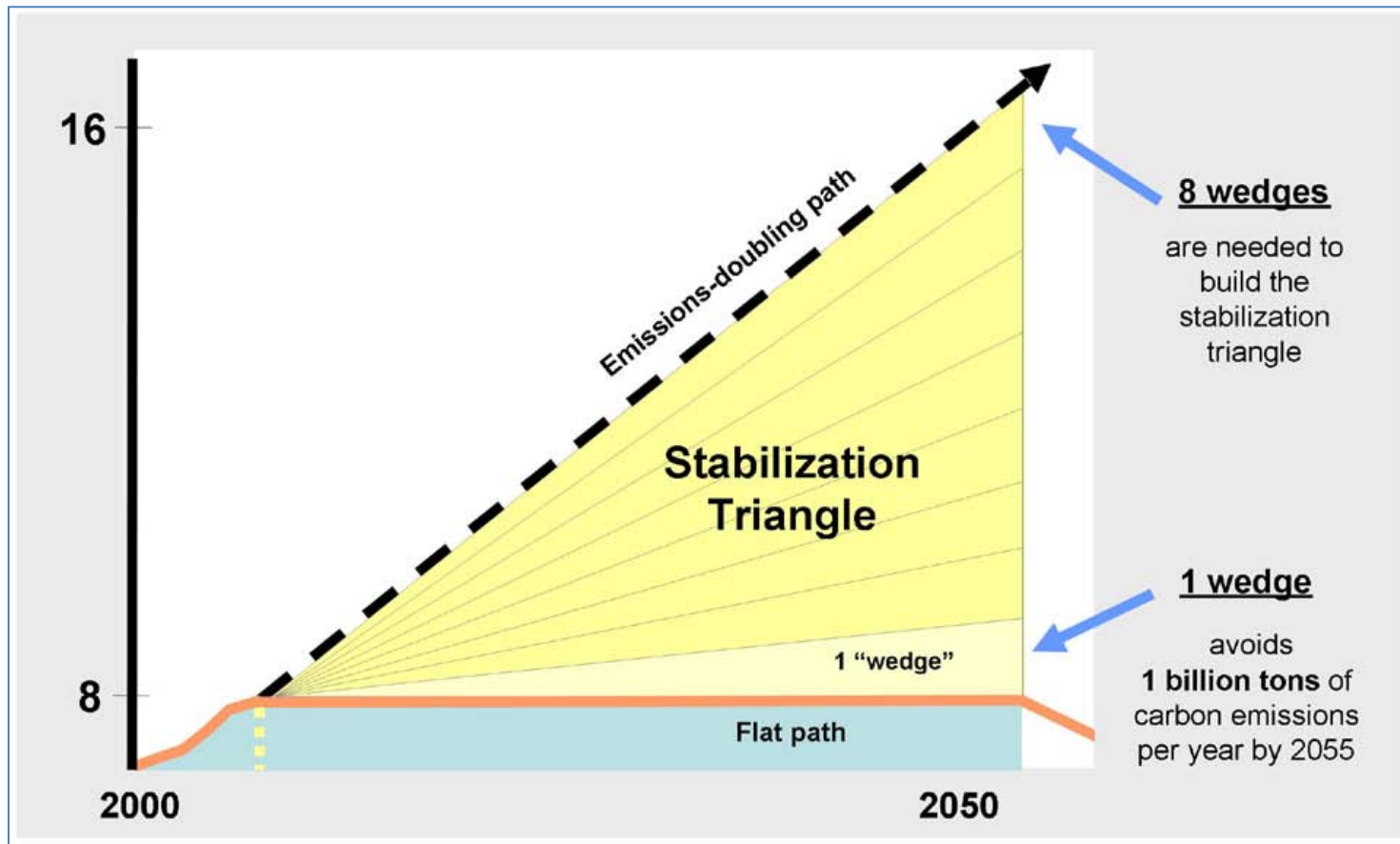


# THE STABILIZATION TRIANGLE





# EIGHT WEDGES





# Increased Efficiency & Conservation



## 1. Transport Efficiency

A typical 30 miles per gallon (30 mpg) car driving 10,000 miles per year emits a ton of carbon into the air annually. Today there are about 600 million cars in the world, and it's predicted that there will be about 2 billion passenger vehicles on the road in 50 years. **A wedge of emissions savings would be achieved if the fuel efficiency of all the cars projected for 2060 were doubled from 30 mpg to 60 mpg.** Efficiency improvements could come from using hybrid and diesel engine technologies, as well as making vehicles out of strong but lighter materials.

Cutting carbon emissions from trucks and planes by making these engines more efficient can also help with this wedge. Aviation is the fastest growing component of transportation.



## 2. Transport Conservation

**A wedge would be achieved if the number of miles traveled by the world's cars were cut in half.** Such a reduction in driving could be achieved if urban planning leads to more use of mass transit and if electronic communication becomes a good substitute for face-to-face meetings.



## 3. Building Efficiency

Today carbon emissions arise about equally from providing electricity, transportation, and heat for industry and buildings. The largest potential savings in the buildings sector are in space heating and cooling, water heating, lighting, and electric appliances.

It's been projected that the buildings sector as a whole has the technological and economic potential to cut emissions in half. **Cutting emissions by 25% in all new and existing residential and commercial buildings would achieve a wedge worth of emissions reduction.** Carbon savings from space and water heating will come from both end-use efficiency strategies, like wall and roof insulation, and renewable energy strategies, like solar water heating and passive solar design.



## 4. Efficiency in Electricity Production

Today's coal-burning power plants produce about one-fourth of the world's carbon emissions, so increases in efficiency at these plants offer an important opportunity to reduce emissions. **Producing the world's current coal-based electricity with doubled efficiency would save a wedge worth of carbon emissions.**

More efficient conversion results at the plant level from better turbines, from using high-temperature fuel cells, and from combining fuel cells and turbines. At the system level, more efficient conversion results from more even distribution of electricity demand, from cogeneration (the co-production of electricity and useful heat), and from polygeneration (the co-production of chemicals and electricity).

Due to large contributions by hydropower and nuclear energy, the electricity sector already gets about 35% of its energy from non-carbon sources. Wedges can only come from the remaining 65%.

Suggested Link:

**IPCC Working Group III Report "Mitigation of Climate Change", Chapters 4, 5 & 6**

[http://www.ipcc.ch/publications\\_and\\_data/publications\\_ipcc\\_fourth\\_assessment\\_report\\_wg3\\_report\\_mitigation\\_of\\_climate\\_change.htm](http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg3_report_mitigation_of_climate_change.htm)

# Carbon Capture & Storage (CCS)



If the CO<sub>2</sub> emissions from fossil fuels can be captured and stored, rather than vented to the atmosphere, then the world could continue to use coal, oil, and natural gas to meet energy demands without harmful climate consequences. The most economical way to pursue this is to capture CO<sub>2</sub> at large electricity or fuels plants, then store it underground. This strategy, called carbon capture and storage, or **CCS**, is already being tested in pilot projects around the world.



## 5. CCS Electricity

Today's coal-burning power plants produce about one fourth of the world's carbon emissions and are large point-sources of CO<sub>2</sub> to the atmosphere. **A wedge would be achieved by applying CCS to 800 large (1 billion watt) baseload coal power plants or 1600 large baseload natural gas power plants in 50 years. As with all CCS strategies, to provide low-carbon energy the captured CO<sub>2</sub> would need to be stored for centuries.**

There are currently 3 pilot storage projects in the world, which each store about 1 million tons of carbon underground per year. Storing a wedge worth of emissions will require 3500 times the capacity of one of these projects.



## 6. CCS Hydrogen

Hydrogen is a desirable fuel for a low-carbon society because when it's burned the only emission product is water vapor. Because fossil fuels are composed mainly of carbon and hydrogen they are potential sources of hydrogen, but to have a climate benefit the excess carbon must be captured and stored.

Pure hydrogen is now produced mainly in two industries: ammonia fertilizer production and petroleum refining. Today these hydrogen production plants generate about 100 million tons of capturable carbon. Now this CO<sub>2</sub> is vented, but only small changes would be needed to implement carbon capture. **The scale of hydrogen production today is only ten times smaller than the scale of a wedge of carbon capture.**

Distributing CCS hydrogen, however, requires building infrastructure to connect large hydrogen-producing plants with smaller-scale users.



## 7. CCS Synfuels

In 50 years a significant fraction of the fuels used in vehicles and buildings may not come from conventional oil, but from coal. When coal is heated and combined with steam and air or oxygen, carbon monoxide and hydrogen are released and can be processed to make a liquid fuel called a "synfuel."

Coal-based synfuels result in nearly twice the carbon emissions of petroleum-derived fuels, since large amounts of excess carbon are released during the conversion of coal into liquid fuel. The world's largest synfuels facility, located in South Africa, is the largest point source of atmospheric CO<sub>2</sub> emissions in the world. **A wedge is an activity that, over 50 years, can capture the CO<sub>2</sub> emissions from 180 such coal-to-synfuels facilities.**

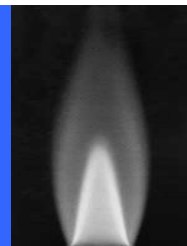
Suggested link:

**IPCC Special Report on Carbon dioxide Capture and Storage, SPM**

[http://www.ipcc.ch/pdf/specialreports/srccs/srccs\\_summaryforpolicymakers.pdf](http://www.ipcc.ch/pdf/specialreports/srccs/srccs_summaryforpolicymakers.pdf)



# Fuel Switching



## 8. Fuel-Switching for Electricity

Because of the lower carbon content of natural gas and higher efficiencies of natural gas plants, producing electricity with natural gas results in only about half the emissions of coal. **A wedge would require 1400 large (1 billion watt) natural gas plants displacing similar coal-electric plants.**

This wedge would require generating approximately four times the Year 2000 global production of electricity from natural gas. In 2060, 1 billion tons of carbon per year would be emitted from natural gas power plants instead of 2 billion tons per year from coal-based power plants.

Materials flows equivalent to one billion tons of carbon per year are huge: a wedge of flowing natural gas is equivalent to 50 large liquefied natural gas (LNG) tankers docking and discharging every day. Current LNG shipments world-wide are about one-tenth as large.

Suggested link:

**U.S. Environmental Protection Agency: Electricity from Natural Gas**

<http://www.epa.gov/RDEE/energy-and-you/affect/natural-gas.html>

# Nuclear Energy



## 9. Nuclear Electricity

Nuclear fission currently provides about 17% of the world's electricity, and produces no CO<sub>2</sub>. **Adding new nuclear electric plants to triple the world's current nuclear capacity would cut emissions by one wedge if coal plants were displaced.**

In the 1960s, when nuclear power's promise as a substitute for coal was most highly regarded, a global installed nuclear capacity of about 2000 billion watts was projected for the year 2000. The world now has about one-sixth of that envisioned capacity. If the remainder were to be built over the next 50 years to displace coal-based electricity, roughly two wedges could be achieved.

In contrast, phasing out the world's current capacity of nuclear power would require adding an additional half wedge of emissions cuts to keep emissions at today's levels.

Nuclear fission power generates plutonium, a fuel for nuclear weapons. These new reactors would add several thousand tons of plutonium to the world's current stock of reactor plutonium (roughly 1000 tons).

**IPCC Working Group III Report "Mitigation of Climate Change", Chapter 4 - Energy Supply**  
<http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter4.pdf>

# Renewable Energy & Biostorage



## 10. Wind Electricity

Wind currently produces less than 1% of total global electricity, but wind electricity is growing at a rate of about 30% per year. **To gain a wedge of emissions savings from wind displacing coal-based electricity, current wind capacity would need to be scaled up by a factor of 10.**

This increase in capacity would require deployment of about 1 million large windmills. Based on current turbine spacing on wind farms, a wedge of wind power would require a combined area roughly the size of Germany. However, land from which wind is harvested can be used for many other purposes, notably for crops or pasture.



## 11. Solar Electricity

Photovoltaic (PV) cells convert sunlight to electricity, providing a source of CO<sub>2</sub>-free and renewable energy. The land demand for solar is less than with other renewables, but **installing a wedge worth of PV would still require arrays with an area of two million hectares, or 20,000 km<sup>2</sup>.** The arrays could be located on either dedicated land or on multiple-use surfaces such as the roofs and walls of buildings. The combined area of the arrays would cover an area the size of the U.S. state of New Jersey, or about 12 times the size of the London metropolitan area.

Since PV currently provides less than a tenth of one percent of global electricity, achieving a wedge of emissions reduction would require increasing the deployment of PV by a factor of 100 in 50 years, or installing PV at about 2.5 times the 2009 rate for 50 years.

A current drawback for PV electricity is its price, which is declining but is still 2-5 times higher than fossil-fuel-based electricity. Also, PV can not be collected at night and, like wind, is an intermittent energy source.



## 12. Wind Hydrogen

Hydrogen is a desirable fuel for a low-carbon society because when it's burned the only emission product is water vapor. To produce hydrogen with wind energy, electricity generated by wind turbines is used in electrolysis, a process that liberates hydrogen from water. **Wind hydrogen displacing vehicle fuel is only about half as efficient at reducing carbon emissions as wind electricity displacing coal electricity, and 2 million (rather than 1 million) windmills would be needed for one wedge of emissions reduction.** That increase would require scaling up current wind capacity by about 20 times, requiring a land area roughly the size of France.

Unlike hydrogen produced from fossil fuels with CCS, wind hydrogen could be produced at small scales where it is needed. Wind hydrogen thus would require less investment in infrastructure for fuel distribution to homes and vehicles.

# Renewables & Biostorage (cont'd)



## 13. Biofuels

Because plants take up carbon dioxide from the atmosphere, combustion of biofuels made from plants like corn and sugar cane simply returns “borrowed” carbon to the atmosphere. Thus burning biofuels for transportation and heating will not raise the atmosphere’s net CO<sub>2</sub> concentration.

The land constraints for biofuels, however, are more severe than for wind and solar electricity. Using current practices, just one wedge worth of carbon-neutral biofuels would require 1/6th of the world’s cropland and an area roughly the size of India. Bioengineering to increase the efficiency of plant photosynthesis and use of crop residues could reduce that land demand, but large-scale production of plant-based biofuels will always be a land-intensive proposition.

Ethanol programs in the U.S. and Brazil currently produce about 20 billion gallons of biofuel per year from corn and sugarcane. **One wedge of biofuels savings would require increasing today’s global ethanol production by about 12 times, and making it sustainable.**



## 14. Forest Storage

Land plants and soils contain large amounts of carbon. Today, there is a net *removal* of carbon from the atmosphere by these “natural sinks,” in spite of deliberate deforestation by people that *adds* between 1 and 2 billion tons of carbon to the atmosphere. Evidently, the carbon in forests is increasing elsewhere on the planet.

Land plant biomass can be increased by both reducing deforestation and planting new forests. **Halting global deforestation in 50 years would provide one wedge of emissions savings.** To achieve a wedge through forest planting alone, new forests would have to be established over an area the size of the contiguous United States.



## 15. Soil Storage

Conversion of natural vegetation to cropland reduces soil carbon content by one-half to one-third. However, soil carbon loss can be reversed by agricultural practices that build up the carbon in soils, such as reducing the period of bare fallow, planting cover crops, and reducing aeration of the soil (such as by no till, ridge till, or chisel plow planting). **A wedge of emissions savings could be achieved by applying carbon management strategies to all of the world’s existing agricultural soils.**

Suggested links:

U.S. DOE, Energy Efficiency & Renewable Energy

<http://www.eere.energy.gov/>

IPCC Working Group III Report "Mitigation of Climate Change", Chapters 8 & 9

[http://www.ipcc.ch/publications\\_and\\_data/publications\\_ipcc\\_fourth\\_assessment\\_report\\_wg3\\_report\\_mitigation\\_of\\_climate\\_change.htm](http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg3_report_mitigation_of_climate_change.htm)



# Stabilization Wedges – 15 Ways to Cut Carbon

 = Electricity Production,  = Heating and Direct Fuel Use,  = Transportation,  = Biostorage

Strategy	Sector	Description	1 wedge could come from...	Cost	Challenges
1. Efficiency – Transport		Increase automobile fuel efficiency (2 billion cars projected in 2050)	... doubling the efficiency of all world's cars from 30 to 60 mpg	\$	Car size & power
2. Conservation - Transport		Reduce miles traveled by passenger and/or freight vehicles	... cutting miles traveled by all passenger vehicles in half	\$	Increased public transport, urban design
3. Efficiency - Buildings	 	Increase insulation, furnace and lighting efficiency	... using best available technology in all new and existing buildings	\$	House size, consumer demand for appliances
4. Efficiency – Electricity		Increase efficiency of power generation	... raising plant efficiency from 40% to 60%	\$	Increased plant costs
5. CCS Electricity		90% of CO <sub>2</sub> from fossil fuel power plants captured, then stored underground (800 large coal plants or 1600 natural gas plants)	... injecting a volume of CO <sub>2</sub> every year equal to the volume of oil extracted	\$\$	Possibility of CO <sub>2</sub> leakage
6. CCS Hydrogen	 	Hydrogen fuel from fossil sources with CCS displaces hydrocarbon fuels	... producing hydrogen at 10 times the current rate	\$\$\$	New infrastructure needed, hydrogen safety issues
7. CCS Synfuels	 	Capture and store CO <sub>2</sub> emitted during synfuels production from coal	... using CCS at 180 large synfuels plants	\$\$	Emissions still only break even with gasoline
8. Fuel Switching – Electricity		Replacing coal-burning electric plants with natural gas plants (1400 1 GW coal plants)	... using an amount of natural gas equal to that used for all purposes today	\$	Natural gas availability
9. Nuclear Electricity		Displace coal-burning electric plants with nuclear plants (Add double current capacity)	... ~3 times the effort France put into expanding nuclear power in the 1980's, sustained for 50 years	\$\$	Weapons proliferation, nuclear waste, local opposition
10. Wind Electricity		Wind displaces coal-based electricity (10 x current capacity)	... using area equal to ~3% of U.S. land area for wind farms	\$\$	Not In My Back Yard (NIMBY)
11. Solar Electricity		Solar PV displaces coal-based electricity (100 x current capacity)	.. using the equivalent of a 100 x 200 km PV array	\$\$\$	PV cell materials
12. Wind Hydrogen	 	Produce hydrogen with wind electricity	... powering half the world's cars predicted for 2050 with hydrogen	\$\$\$	NIMBY, Hydrogen infrastructure, safety
13. Biofuels	 	Biomass fuels from plantations replace petroleum fuels	... scaling up world ethanol production by a factor of 12	\$\$	Biodiversity, competing land use
14. Forest Storage		Carbon stored in new forests	... halting deforestation in 50 years	\$	Biodiversity, competing land use
15. Soil Storage		Farming techniques increase carbon retention or storage in soils	... practicing carbon management on all the world's agricultural soils	\$	Reversed if land is deep-plowed later

For more information, visit our website at <http://cmi.princeton.edu/wedges>.



# Wedge Worksheet

## 1. Record your strategies to reduce total fossil fuel emissions by 8 wedges by 2060.

(1 "wedge" = 1 billion tons carbon per year)

- You may use a strategy more than once
- Use only whole numbers of wedges
- You may use a maximum of
  - 6 electricity wedges (E)
  - 5 transportation wedges(T)
  - 5 heat or direct fuel use wedges (H)

	Strategy	Sector (E,T,H or B)	Cost (\$)	Challenges
1				
2				
3				
4				
5				
6				
7				
8				
<b>TOTALS</b>		E = ____ (6 max) T = ____ (5 max) H = ____ (5 max) B = ____	_____	

## 2. Guess the score each stakeholder group would give your team's triangle on a scale of 1 to 5 (5 = best).

Judge:	Taxpayers/ Consumers	Energy Companies	Environmental Groups	Manufacturers	Industrialized country governments	Developing country governments
Score:						

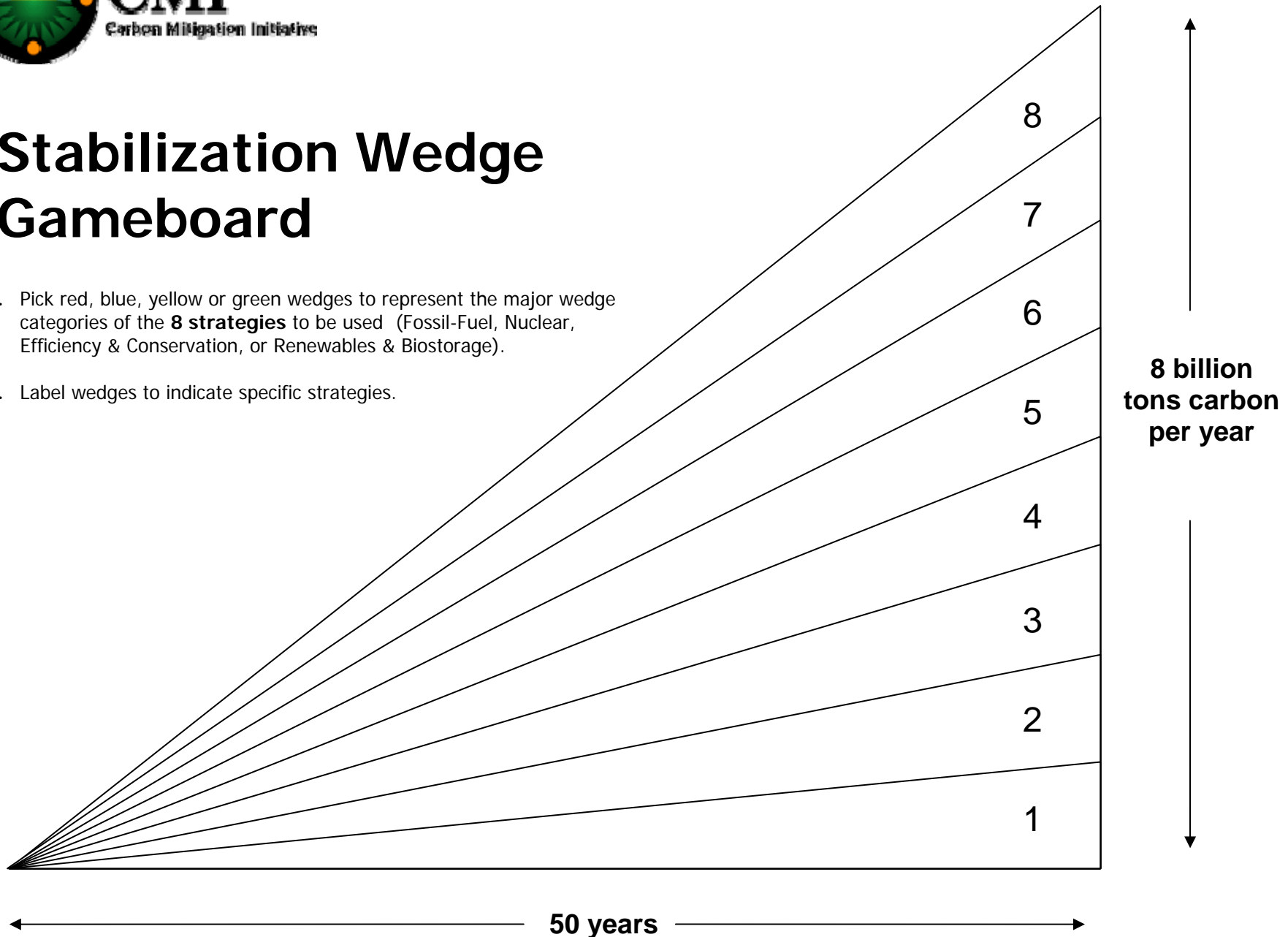






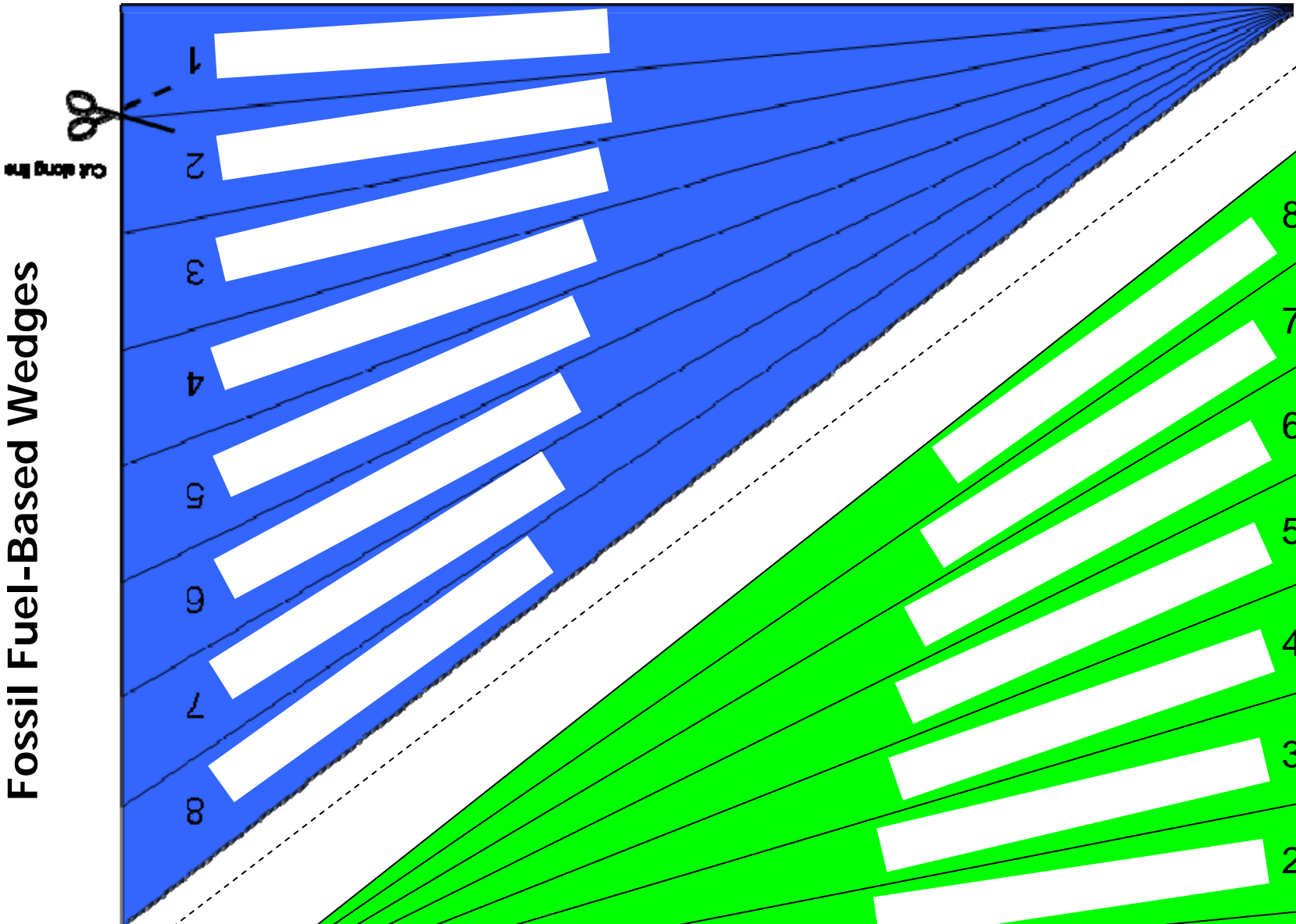
# Stabilization Wedge Gameboard

1. Pick red, blue, yellow or green wedges to represent the major wedge categories of the **8 strategies** to be used (Fossil-Fuel, Nuclear, Efficiency & Conservation, or Renewables & Biostorage).
2. Label wedges to indicate specific strategies.

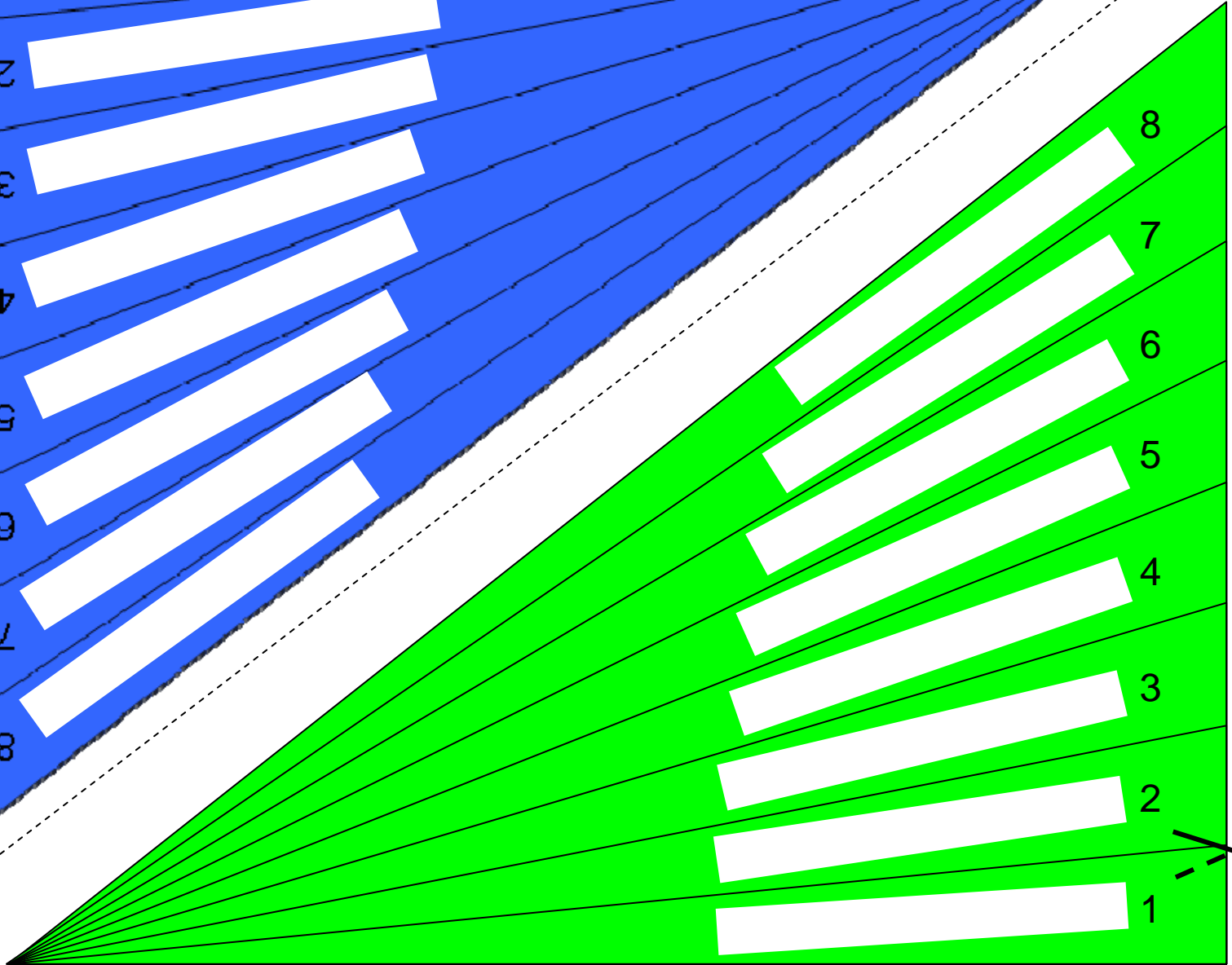




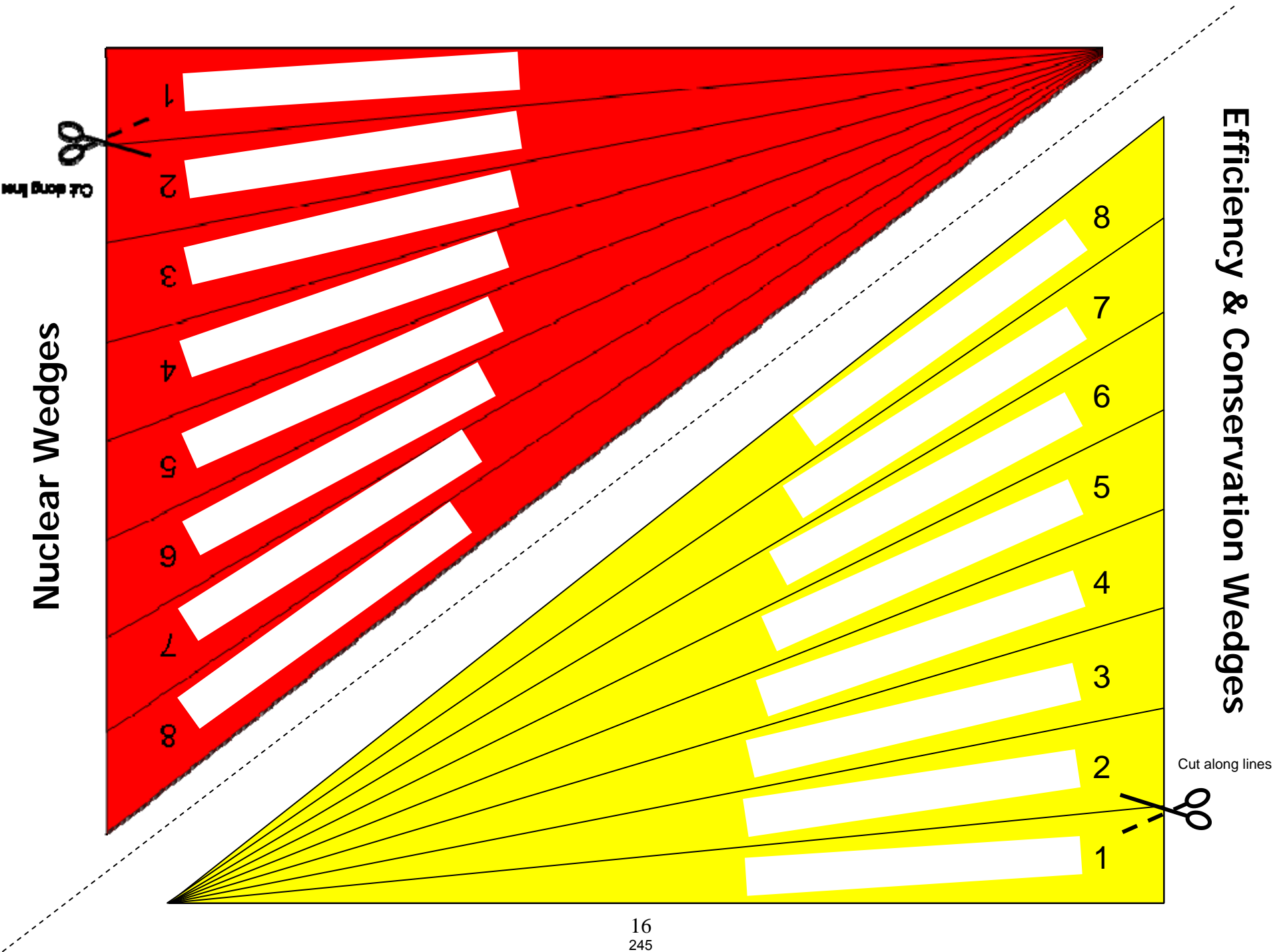
# Fossil Fuel-Based Wedges



# Renewables & Biostorage Wedges







**Nuclear Wedges**

**Efficiency & Conservation Wedges**

Cut along line

Cut along lines



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## *GLOSSARY*

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## Glossary of Energy-Related Terms

### A

#### **Active Power**

The power (in Watts) used by a device to produce useful work. Also called input power.

#### **Air Conditioning**

The control of the quality, quantity, and temperature-humidity of the air in an interior space.

#### **Algae**

Simple plants, usually aquatic, capable of synthesizing their own food by photosynthesis.

#### **Alternating Current**

A type of electrical current, the direction of which is reversed at regular intervals or cycles; in the U.S. the standard is 120 reversals or 60 cycles per second; typically abbreviated as AC.

#### **Alternative Fuels**

A popular term for "non-conventional" transportation fuels derived from natural gas (propane, compressed natural gas, methanol, etc.) or biomass materials (ethanol, methanol).

#### **Ampere**

A unit of measure for an electrical current; the amount of current that flows in a circuit at an electromotive force of one Volt and at a resistance of one Ohm. Abbreviated as amp.

#### **Amp-Hours**

A measure of the flow of current (in amperes) over one hour.

#### **Anaerobic Digester**

A device for optimizing the anaerobic digestion of biomass and/or animal manure, and possibly to recover biogas for energy production. Digester types include batch, complete mix, continuous flow (horizontal or plug-flow, multiple-tank, and vertical tank), and covered lagoon.

#### **Anemometer**

An instrument for measuring the force or velocity of wind; a wind gauge.

#### **Annual Fuel Utilization Efficiency (AFUE)**

The measure of seasonal or annual efficiency of a residential heating furnace or boiler. It takes into account the cyclic on/off operation and associated energy losses of the heating unit as it responds to changes in the load, which in turn is affected by changes in weather and occupant controls.

#### **Annual Solar Savings**

The annual solar savings of a solar building is the energy savings attributable to a solar feature relative to the energy requirements of a non-solar building.

#### **Apparent Power (kVA)**

This is the voltage-ampere requirement of a device designed to convert electric energy to a non-electrical form.

#### **Appliance**

A device for converting one form of energy or fuel into useful energy or work.

#### **Appliance Energy Efficiency Ratings**

The ratings under which specified appliances convert energy sources into useful energy, as determined by procedures established by the U.S. Department of Energy.

#### **Array (Solar)**

Any number of solar photovoltaic modules or solar thermal collectors or reflectors connected together to provide electrical or thermal energy.

#### **Audit (Energy)**

The process of determining energy consumption, by various techniques, of a building or facility.

#### **Auxiliary Energy or System**

Energy required to operate mechanical components of an energy system, or a source of energy or energy supply system to back-up another.

#### **Average Cost**

The total cost of production divided by the total quantity produced.

#### **Average Wind Speed (or Velocity)**

The mean wind speed over a specified period of time.

#### **Avoided Cost**

The incremental cost to an electric power producer to generate or purchase a unit of electricity or capacity or both.

**Azimuth (Solar)**

The angle between true south and the point on the horizon directly below the sun.

**B****Backup Energy System**

A reserve appliance; for example, a stand-by generator for a home or commercial building.

**Ballast**

A device used to control the voltage in a fluorescent lamp.

**Ballast Efficacy Factor**

The measure of the efficiency of fluorescent lamp ballasts. It is the relative light output divided by the power input.

**Ballast Factor**

The ratio of light output of a fluorescent lamp operated on a ballast to the light output of a lamp operated on a standard or reference ballast.

**Barrel (petroleum)**

42 U.S. gallons (306 pounds of oil, or 5.78 million Btu).

**Batt/Blanket**

A flexible roll or strip of insulating material in widths suited to standard spacings of building structural members (studs and joists). They are made from glass or rock wool fibers. Blankets are continuous rolls. Batts are pre-cut to four or eight foot lengths.

**Battery**

An energy storage device composed of one or more electrolyte cells.

**Battery Energy Storage**

Energy storage using electrochemical batteries. The three main applications for battery energy storage systems include spinning reserve at generating stations, load leveling at substations, and peak shaving on the customer side of the meter.

**Bioenergy**

The conversion of the complex carbohydrates in organic material into energy.

**Biogas**

A combustible gas created by anaerobic decomposition of organic material, composed primarily of methane, carbon dioxide, and hydrogen sulfide.

**Biomass**

As defined by the Energy Security Act (PL 96-294) of 1980, "any organic matter which is available on a renewable basis, including agricultural crops and agricultural wastes and residues, wood and wood wastes and residues, animal wastes, municipal wastes, and aquatic plants."

**Biomass Energy**

Energy produced by the conversion of biomass directly to heat or to a liquid or gas that can be converted to energy.

**Biomass Fuel**

Biomass converted directly to energy or converted to liquid or gaseous fuels such as ethanol, methanol, methane, and hydrogen.

**Biomass Gasification**

The conversion of biomass into a gas, by biogasification (see above) or thermal gasification, in which hydrogen is produced from high-temperature gasifying and low-temperature pyrolysis of biomass.

**Blown In Insulation**

An insulation product composed of loose fibers or fiber pellets that are blown into building cavities or attics using special pneumatic equipment.

**Boiler**

A vessel or tank where heat produced from the combustion of fuels such as natural gas, fuel oil, or coal is used to generate hot water or steam for applications ranging from building space heating to electric power production or industrial process heat.

**Boiler Rating**

The heating capacity of a steam boiler; expressed in Btu per hour (Btu/h), or horsepower, or pounds of steam per hour.

**British Thermal Unit (Btu)**

The amount of heat required to raise the temperature of one pound of water one degree Fahrenheit; equal to 252 calories.

**Building Envelope**

The structural elements (walls, roof, floor, foundation) of a building that encloses conditioned space; the building shell.

**Building Orientation**

The relationship of a building to true south, as specified by the direction of its longest axis.

**Bulb**

The transparent or opaque sphere in an electric light that the electric light transmits through.

**C****Calorie**

The amount of heat required to raise the temperature of a unit of water, at or near the temperature of maximum density, one degree Celsius (or Centigrade [C]); expressed as a "small calorie" (the amount of heat required to raise the temperature of 1 gram of water one degree C), or as a "large calorie" or "kilogram calorie" (the amount of heat required to raise one kilogram [1,000 grams] of water one degree C); capitalization of the word calorie indicates a kilogram-calorie.

**Candela**

The luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency  $540 \times 10^{12}$  hertz and that has a radiant intensity in that direction of 1/683 watt per steradian.

**Candle Power**

The illuminating power of a standard candle employed as a unit for determining the illuminating quality of an illuminant.

**Capacity**

The load that a power generation unit or other electrical apparatus or heating unit is rated by the manufacture to be able to meet or supply.

**Capital Costs**

The amount of money needed to purchase equipment, buildings, tools, and other manufactured goods that can be used in production.

**Carbon Dioxide**

A colorless, odorless noncombustible gas with the formula  $\text{CO}_2$  that is present in the atmosphere. It is formed by the combustion of carbon and carbon compounds (such as fossil fuels and biomass), by respiration, which is a slow combustion in animals and plants, and by the gradual oxidation of organic matter in the soil.

**Caulking**

A material used to seal areas of potential air leakage into or out of a building envelope.

**Cell**

A component of an electrochemical battery. A 'primary' cell consists of two dissimilar elements, known as 'electrodes,' immersed in a liquid or paste known as the 'electrolyte.' A direct current of 1-1.5 volts will be produced by this cell. A 'secondary' cell or accumulator is a similar design but is made useful by passing a direct current of correct strength through it in a certain direction. Each of these cells will produce 2 volts; a 12 volt car battery contains six cells.

**Cellulose Insulation**

A type of insulation composed of waste newspaper, cardboard, or other forms of waste paper.

**Central Heating System**

A system where heat is supplied to areas of a building from a single appliance through a network of ducts or pipes.

**Central Power Plant**

A large power plant that generates power for distribution to multiple customers.

**Chemical Energy**

The energy liberated in a chemical reaction, as in the combustion of fuels.

**Circuit**

A device, or system of devices, that allows electrical current to flow through it and allows voltage to occur across positive and negative terminals.

**Climate Change**

A term used to describe short and long-term effects on the Earth's climate as a result of human activities such as fossil fuel combustion and vegetation clearing and burning.

**Cogeneration**

The generation of electricity or shaft power by an energy conversion system and the concurrent use of rejected thermal energy from the conversion system as an auxiliary energy source.

**Collector Tilt**

The angle that a solar collector is positioned from horizontal.

**Combustion**

The process of burning; the oxidation of a material by applying heat, which unites oxygen with a material or fuel.

**Commercial Building**

A building with more than 50 percent of its floor space used for commercial activities, which include stores, offices, schools, churches, libraries, museums, health care facilities, warehouses, and government buildings except those on military bases.

**Commercial Sector**

Consists of businesses that are not engaged in transportation or manufacturing or other types of industrial activities. Standard Industrial Classification (SIC) codes for commercial establishments are 50 through 87, 89, and 91 through 97.

**Compact Fluorescent**

A smaller version of standard fluorescent lamps which can directly replace standard incandescent lights. These lights consist of a gas filled tube, and a magnetic or electronic ballast.

**Conditioned Space**

The interior space of a building that is heated or cooled.

**Conduction**

The transfer of heat through a material by the transfer of kinetic energy from particle to particle; the flow of heat between two materials of different temperatures that are in direct physical contact.

**Conductivity (Thermal)**

This is a positive constant,  $k$ , that is a property of a substance and is used in the calculation of heat transfer rates for materials. It is the amount of heat that flows through a specified area and thickness of a material over a specified period of time when there is a temperature difference of one degree between the surfaces of the material.

**Conductor**

The material through which electricity is transmitted, such as an electrical wire, or transmission or distribution line.

**Conservation**

To reduce or avoid the consumption of a resource or commodity.

**Convection**

The transfer of heat by means of air currents.

**Conventional Fuel**

The fossil fuels: coal, oil, and natural gas.

**Conventional Power**

Power generation from sources such as petroleum, natural gas, or coal. In some cases, large-scale hydropower and nuclear power generation are considered conventional sources.

**Conversion Efficiency**

The amount of energy produced as a percentage of the amount of energy consumed.

**Cooling Degree Day**

A value used to estimate interior air cooling requirements (load) calculated as the number of degrees per day (over a specified period) that the daily average temperature is above 65 degrees Fahrenheit (or some other, specified base temperature). The daily average temperature is the mean of the maximum and minimum temperatures recorded for a specific location for a 24 hour period.

**Cubic Foot (of Natural Gas)**

A unit of volume equal to 1 cubic foot at a pressure base of 14.73 pounds standard per square inch absolute and a temperature base of 60 degrees Fahrenheit.

**Current (Electrical)**

The flow of electrical energy (electricity) in a conductor, measured in amperes.

**Cycle**

In alternating current, the current goes from zero potential or voltage to a maximum in one direction, back to zero, and then to a maximum potential or voltage in the other direction. The number of complete cycles per second determines the current frequency; in the U.S. the standard for alternating current is 60 cycles.

## D

### **Daylighting**

The use of direct, diffuse, or reflected sunlight to provide supplemental lighting for building interiors.

### **Decentralized (Energy) System**

Energy systems supply individual, or small-groups, of energy loads.

### **Declination**

The angular position of the sun at solar noon with respect to the plane of the equator.

### **Degree Day**

A unit for measuring the extent that the outdoor daily average temperature (the mean of the maximum and minimum daily dry-bulb temperatures) falls below (in the case of heating, see Heating Degree Day), or falls above (in the case of cooling, see Cooling Degree Day) an assumed base temperature, normally taken as 65 degrees Fahrenheit, unless otherwise stated. One degree day is counted for each degree below (for heating) or above (in the case of cooling) the base, for each calendar day on which the temperature goes below or above the base.

### **Degree Hour**

The product of 1 hour, and usually the number of degrees Fahrenheit the hourly mean temperature is above a base point (usually 65 degrees Fahrenheit); used in roughly estimating or measuring the cooling load in cases where processes heat, heat from building occupants, and humidity are relatively unimportant compared to the dry-bulb temperature.

### **Demand**

The rate at which electricity is delivered to or by a system, part of a system, or piece of equipment expressed in kilowatts, kilovoltamperes, or other suitable unit, at a given instant or averaged over a specified period of time.

### **Demand Charge**

A charge for the maximum rate at which energy is used during peak hours of a billing period. That part of a power provider service charged for on the basis of the possible demand as distinguished from the energy actually consumed.

### **Demand-Side Management (DSM)**

The process of managing the consumption of energy, generally to optimize available and planned generation resources.

### **Department of Energy (DOE)**

A federal government agency created in 1977, that is entrusted to contribute to the welfare of the United States by providing technical information, and a scientific and educational foundation for technology, policy and institutional leadership to achieve efficiency in energy use, diversity in energy sources, a more productive and competitive economy, improved environmental quality, and a secure national defense.

### **Dimmer**

A light control device that allows light levels to be manually adjusted. A dimmer can save energy by reducing the amount of power delivered to the light while consuming very little themselves.

### **Diode**

An electronic device that allows current to flow in one direction only.

### **Direct Current**

A type of electricity transmission and distribution by which electricity flows in one direction through the conductor; usually relatively low voltage and high current; typically abbreviated as dc.

### **Distributed Generation**

A term used by the power industry to describe localized or on-site power generation.

### **Distribution**

The process of distributing electricity; usually defines that portion of a power provider's power lines between a power provider's power pole and transformer and a customer's point of connection/meter.

### **Domestic Hot Water**

Water heated for residential washing, bathing, etc.

### **Double-Pane or Glazed Window**

A type of window having two layers (panes or glazing) of glass separated by an air space. Each layer of glass and surrounding air space reradiates and traps some of the heat that passes through thereby increasing the windows resistance to heat loss (R-value).

### **Downwind Wind Turbine**

A horizontal axis wind turbine in which the rotor is downwind of the tower.

**Drag**

Resistance caused by friction in the direction opposite to that of movement (i.e., motion) of components such as wind turbine blades.

**E****Efficiency**

Under the First Law of Thermodynamics, efficiency is the ratio of work or energy output to work or energy input, and cannot exceed 100 percent. Efficiency under the Second Law of Thermodynamics is determined by the ratio of the theoretical minimum energy that is required to accomplish a task relative to the energy actually consumed to accomplish the task. Generally, the measured efficiency of a device, as defined by the First Law, will be higher than that defined by the Second Law.

**Efficiency (Appliance) Ratings**

A measure of the efficiency of an appliance's energy efficiency.

**Electrical Energy**

The energy of moving electrons.

**Electrical Charge**

A condition that results from an imbalance between the number of protons and the number of electrons in a substance.

**Electrical System**

All the conductors and electricity using devices that are connected to a source of electromotive force (or generator).

**Electric Circuit**

The path followed by electrons from a generation source, through an electrical system, and returning to the source.

**Electric Energy**

The amount of work accomplished by electrical power, usually measured in kilowatt-hours (kWh). One kWh is 1,000 Watts and is equal to 3,413 Btu.

**Electricity Generation**

The process of producing electricity by transforming other forms or sources of energy into electrical energy; measured in kilowatt-hours.

**Electricity Grid**

A common term referring to an electricity transmission and distribution system.

**Electric Rate**

The unit price and quantity to which it applies as specified in a rate schedule or contract.

**Electric Rate Schedule**

A statement of the electric rate(s), terms, and conditions for electricity sale or supply.

**Electric System**

The physically connected generation, transmission, and distribution facilities and components operated as a unit.

**Electric System Loss(es)**

The total amount of electric energy loss in an electric system between the generation source and points of delivery.

**Electric Power Transmission**

The transmission of electricity through power lines.

**Electric Utility**

A corporation, person, agency, authority or other legal entity that owns and/or operates facilities for the generation, transmission, distribution or sale of electricity primarily for use by the public. Also known as a power provider.

**Electric Vehicles**

A battery-powered electrically driven vehicle.

**Electrolysis**

A chemical change in a substance that results from the passage of an electric current through an electrolyte. The production of commercial hydrogen by separating the elements of water, hydrogen, and oxygen, by charging the water with an electrical current.

**Electromagnetic Energy**

Energy generated from an electromagnetic field produced by an electric current flowing through a superconducting wire kept at a specific low temperature.

**Electron**

An elementary particle of an atom with a negative electrical charge and a mass of 1/1837 of a proton; electrons surround the positively charged nucleus of an atom and determine the chemical properties of an atom.

**Electronic Ballast**

A device that uses electronic components to regulate the voltage of fluorescent lamps.

**Emission(s)**

A substance(s) or pollutant emitted as a result of a process.

**Energy**

The capability of doing work; different forms of energy can be converted to other forms, but the total amount of energy remains the same.

**Energy Audit**

A survey that shows how much energy you use in your house or apartment. It will help you find ways to use less energy.

**Energy Charge**

That part of an electricity bill that is based on the amount of electrical energy consumed or supplied.

**Energy Crops**

Crops grown specifically for their fuel value. These include food crops such as corn and sugarcane, and nonfood crops such as poplar trees and switchgrass. Currently, two energy crops are under development: short-rotation woody crops, which are fast-growing hardwood trees harvested in 5 to 8 years; and herbaceous energy crops, such as perennial grasses, which are harvested annually after taking 2 to 3 years to reach full productivity.

**Energy Efficiency Ratio (EER)**

The measure of the instantaneous energy efficiency of room air conditioners; the cooling capacity in Btu/hr divided by the watts of power consumed at a specific outdoor temperature (usually 95 degrees Fahrenheit).

**Energy Factor (EF)**

The measure of overall efficiency for a variety of appliances. For water heaters, the energy factor is based on three factors: 1) the recovery efficiency, or how efficiently the heat from the energy source is transferred to the water; 2) stand-by losses, or the percentage of heat lost per hour from the stored water compared to the content of the water; and 3) cycling losses. For dishwashers, the energy factor is defined as the number of cycles per kWh of input power. For clothes washers, the energy factor is defined as the cubic foot capacity per kWh of input power per cycle. For clothes dryers, the energy factor is defined as the number of pounds of clothes dried per kWh of power consumed.

**Energy Guide Labels**

The labels placed on appliances to enable consumers to compare appliance energy efficiency and energy consumption under specified test conditions as required by the Federal Trade Commission.

**Energy Intensity**

The relative extent that energy is required for a process.

**Energy Service Company (ESCO)**

A company that specializes in undertaking energy efficiency measures under a contractual arrangement whereby the ESCO shares the value of energy savings with their customer.

**Energy Storage**

The process of storing, or converting energy from one form to another, for later use; storage devices and systems include batteries, conventional and pumped storage hydroelectric, flywheels, compressed gas, and thermal mass.

**Environment**

All the natural and living things around us. The earth, air, weather, plants, and animals all make up our environment.

**Ethanol — Ethyl alcohol (C<sub>2</sub>H<sub>5</sub>OH)**

A colorless liquid that is the product of fermentation used in alcoholic beverages, industrial processes, and as a fuel additive. Also known as grain alcohol.

**Evaporative Cooling**

The physical process by which a liquid or solid is transformed into the gaseous state. For this process a mechanical device uses the outside air's heat to evaporate water that is held by pads inside the cooler. The heat is drawn out of the air through this process and the cooled air is blown into the home by the cooler's fan.

**F****Feedstock**

A raw material that can be converted to one or more products.

**Fiberglass Insulation**

A type of insulation, composed of small diameter pink, yellow, or white glass fibers, formed into blankets or batts, or used in loose-fill and blown-in applications.

**Filament**

A coil of tungsten wire suspended in a vacuum or inert gas-filled bulb. When heated by electricity the tungsten "filament" glows.

**Filter (air)**

A device that removes contaminants, by mechanical filtration, from the fresh air stream before the air enters the living space. Filters can be installed as part of a heating/cooling system through which air flows for the purpose of removing particulates before or after the air enters the mechanical components.

**Flat Plate Solar Thermal/Heating Collectors**

Large, flat boxes with glass covers and dark-colored metal plates inside that absorb and transfer solar energy to a heat transfer fluid. This is the most common type of collector used in solar hot water systems for homes or small businesses.

**Flat Plate Solar Photovoltaic Module**

An arrangement of photovoltaic cells or material mounted on a rigid flat surface with the cells exposed freely to incoming sunlight.

**Flat Roof**

A slightly sloped roof, usually with a tar and gravel cover. Most commercial buildings use this kind of roof.

**Flow Restrictor**

A water and energy conserving device that limits the amount of water that a faucet or shower head can deliver.

**Fluorescent Light**

The conversion of electric power to visible light by using an electric charge to excite gaseous atoms in a glass tube. These atoms emit ultraviolet radiation that is absorbed by a phosphor coating on the walls of the lamp tube. The phosphor coating produces visible light.

**Foam (Insulation)**

A high R-value insulation product usually made from urethane that can be injected into wall cavities, or sprayed onto roofs or floors, where it expands and sets quickly.

**Foam Board**

A plastic foam insulation product, pressed or extruded into board-like forms, used as sheathing and insulation for interior basement or crawl space walls or beneath a basement slab; can also be used for exterior applications inside or outside foundations, crawl spaces, and slab-on-grade foundation walls.

**Foot Candle**

A unit of illuminance; equal to one lumen per square foot.

**Force**

The push or pull that alters the motion of a moving body or moves a stationary body; the unit of force is the dyne or poundal; force is equal to mass time velocity divided by time.

**Forced Air System or Furnace**

A type of heating system in which heated air is blown by a fan through air channels or ducts to rooms.

**Fossil Fuels**

Fuels formed in the ground from the remains of dead plants and animals. It takes millions of years to form fossil fuels. Oil, natural gas, and coal are fossil fuels.

**Frequency**

The number of cycles through which an alternating current passes per second; in the U.S. the standard for electricity generation is 60 cycles per second (60 Hertz).

**Fuel**

Any material that can be burned to make energy.

**Fuel Cell**

An electrochemical device that converts chemical energy directly into electricity.

**Fuel Efficiency**

The ratio of heat produced by a fuel for doing work to the available heat in the fuel.

**Fuel Grade Alcohol**

Usually refers to ethanol to 160 to 200 proof.



**Fuel Oil**

Any liquid petroleum product burned for the generation of heat in a furnace or firebox, or for the generation of power in an engine. Domestic (residential) heating fuels are classed as Nos. 1, 2, 3; Industrial fuels as Nos. 4, 5, and 6.

**Furnace (Residential)**

A combustion heating appliance in which heat is captured from the burning of a fuel for distribution, comprised mainly of a combustion chamber and heat exchanger.

**G****Gasification**

The process in which a solid fuel is converted into a gas; also known as pyrolytic distillation or pyrolysis. Production of a clean fuel gas makes a wide variety of power options available.

**Gasifier**

A device for converting a solid fuel to a gaseous fuel.

**Gasoline**

A refined petroleum product suitable for use as a fuel in internal combustion engines.

**Generator**

A device for converting mechanical energy to electrical energy.

**Geothermal Energy**

Energy produced by the internal heat of the earth; geothermal heat sources include: hydrothermal convective systems; pressurized water reservoirs; hot dry rocks; manual gradients; and magma. Geothermal energy can be used directly for heating or to produce electric power.

**Geothermal Heat Pump**

A type of heat pump that uses the ground, ground water, or ponds as a heat source and heat sink, rather than outside air. Ground or water temperatures are more constant and are warmer in winter and cooler in summer than air temperatures. Geothermal heat pumps operate more efficiently than "conventional" or "air source" heat pumps.

**Gigawatt (GW)**

A unit of power equal to 1 billion Watts; 1 million kilowatts, or 1,000 megawatts.

**Global Warming**

A popular term used to describe the increase in average global temperatures due to the greenhouse effect.

**Greenhouse Effect**

A popular term used to describe the heating effect due to the trapping of long wave (length) radiation by greenhouse gases produced from natural and human sources.

**Greenhouse Gases**

Those gases, such as water vapor, carbon dioxide, tropospheric ozone, methane, and low level ozone that are transparent to solar radiation, but opaque to long wave radiation, and which contribute to the greenhouse effect.

**Grid**

A common term referring to an electricity transmission and distribution system.

**Grid-Connected System**

Independent power systems that are connected to an electricity transmission and distribution system (referred to as the electricity grid) such that the systems can draw on the grid's reserve capacity in times of need, and feed electricity back into the grid during times of excess production.

**H****Head**

A unit of pressure for a fluid, commonly used in water pumping and hydro power to express height a pump must lift water, or the distance water falls. Total head accounts for friction head losses, etc.

**Heat**

A form of thermal energy resulting from combustion, chemical reaction, friction, or movement of electricity. As a thermodynamic condition, heat, at a constant pressure, is equal to internal or intrinsic energy plus pressure times volume.

**Heat Exchanger**

A device used to transfer heat from a fluid (liquid or gas) to another fluid where the two fluids are physically separated.

**Heating Degree Day(s) (HDD)**

The number of degrees per day that the daily average temperature (the mean of the maximum and minimum recorded temperatures) is below a base temperature, usually 65 degrees Fahrenheit, unless otherwise specified; used to determine indoor space heating requirements and heating system sizing. Total HDD is the cumulative total for the year/heating season. The higher the HDD for a location, the colder the daily average temperature(s).

**Heating Fuels**

Any gaseous, liquid, or solid fuel used for indoor space heating.

**Heating, Ventilation, and Air-Conditioning (HVAC) System**

All the components of the appliance used to condition interior air of a building.

**Heat Pump**

An electricity powered device that extracts available heat from one area (the heat source) and transfers it to another (the heat sink) to either heat or cool an interior space or to extract heat energy from a fluid.

**Hertz**

A measure of the number of cycles or wavelengths of electrical energy per second; U.S. electricity supply has a standard frequency of 60 hertz.

**High-Intensity Discharge Lamp**

A lamp that consists of a sealed arc tube inside a glass envelope, or outer jacket. The inner arc tube is filled with elements that emit light when ionized by electric current. A ballast is required to provide the proper starting voltage and to regulate current during operation.

**Horizontal-Axis Wind Turbines**

Turbines in which the axis of the rotor's rotation is parallel to the wind stream and the ground.

**Horsepower (hp)**

A unit of rate of operation. Electrical hp: a measure of time rate of mechanical energy output; usually applied to electric motors as the maximum output; 1 electrical hp is equal to 0.746 kilowatts or 2,545 Btu per hour. Shaft hp: a measure of the actual mechanical energy per unit time delivered to a turning shaft; 1 shaft Hp is equal to 1 electrical Hp or 550 foot pounds per second. Boiler Hp: a measure to the maximum rate to heat output of a steam generator; 1 boiler Hp is equal to 33,480 Btu per hour steam output.

**Hybrid System**

A renewable energy system that includes two different types of technologies that produce the same type of energy; for e.g., a wind turbine and a solar photovoltaic array combined to meet a power demand.

**Hydroelectric Power Plant**

A power plant that produces electricity by the force of water falling through a hydro turbine that spins a generator.

**I****Illuminance**

A measure of the amount of light incident on a surface; measured in foot-candles or Lux.

**Incandescent**

These lights use an electrically heated filament to produce light in a vacuum or inert gas-filled bulb.

**Insolation**

The solar power density incident on a surface of stated area and orientation, usually expressed as Watts per square meter or Btu per square foot per hour.

**Installed Capacity**

The total capacity of electrical generation devices in a power station or system.

**Insulation**

Materials that prevent or slow down the movement of heat.

**Insulator**

A device or material with a high resistance to electricity flow.

**Interconnection**

A connection or link between power systems that enables them to draw on each other's reserve capacity in time of need.

**Intermittent Generators**

Power plants, whose output depends on a factor(s) that cannot be controlled by the power generator because they utilize intermittent resources such as solar energy or the wind.

**Inverter**

A device that converts direct current electricity (from for example a solar photovoltaic module or array) to alternating current for use directly to operate appliances or to supply power to a electricity grid.

**J****Joule**

A metric unit of energy or work; the energy produced by a force of one Newton operating through a distance of one meter; 1 Joule per second equals 1 Watt or 0.737 foot-pounds; 1 Btu equals 1,055 Joules.

**K****Kilowatt (kW)**

A standard unit of electrical power equal to one thousand watts, or to the energy consumption at a rate of 1000 Joules per second.

**Kilowatt-hour**

A unit or measure of electricity supply or consumption of 1,000 Watts over the period of one hour; equivalent to 3,412 Btu.

**Kinetic Energy**

Energy available as a result of motion that varies directly in proportion to an object's mass and the square of its velocity.

**L****Lamp**

A light source composed of a metal base, a glass tube filled with an inert gas or a vapor, and base pins to attach to a fixture.

**Lead Acid Battery**

An electrochemical battery that uses lead and lead oxide for electrodes and sulfuric acid for the electrolyte.

**Life Cycle Cost**

The sum of all the costs both recurring and nonrecurring, related to a product, structure, system, or service during its life span or specified time period.

**Load**

The power required to run a defined circuit or system, such as a refrigerator, building, or an entire electricity distribution system.

**Loose Fill Insulation**

Insulation made from rockwool fibers, fiberglass, cellulose fiber, vermiculite or perlite minerals, and composed of loose fibers or granules can be applied by pouring directly from the bag or with a blower.

**Lumen**

An empirical measure of the quantity of light. It is based upon the spectral sensitivity of the photosensors in the human eye under high (daytime) light levels. Photometrically it is the luminous flux emitted with a solid angle (1 steradian) by a point source having a uniform luminous intensity of 1 candela.

**M****Magnetic Ballast**

A type of florescent light ballast that uses a magnetic core to regulate the voltage of a florescent lamp.

**Marginal Cost**

The cost of producing one additional unit of a product.

**Mean Wind Speed**

The arithmetic wind speed over a specified time period and height above the ground (the majority of U.S. National Weather Service anemometers are at 20 feet (6.1 meters)).

**Mechanical Systems**

Those elements of building used to control the interior climate.

**Megawatt**

One thousand kilowatts, or 1 million watts; standard measure of electric power plant generating capacity.

**Megawatt-hour**

One thousand kilowatt-hours or 1 million watt-hours.

**Methane**

A colorless, odorless, tasteless gas composed of one molecule of Carbon and four of hydrogen, which is highly flammable. It is the main constituent of "natural gas" that is formed naturally by methanogenic, anaerobic bacteria or can be manufactured, and which is used as a fuel and for manufacturing chemicals.

**Metric Ton (Tonne)**

A unit of mass equal to 1,000 kilograms or 2,204.6 pounds.

**Module**

The smallest self-contained, environmentally protected structure housing interconnected photovoltaic cells and providing a single dc electrical output; also called a panel.

**Moisture Content**

The water content of a substance (a solid fuel) as measured under specified conditions being the: Dry Basis, which equals the weight of the wet sample minus the weight of a (bone) dry sample divided by the weight of the dry sample times 100 (to get percent); Wet Basis, which is equal to the weight of the wet sample minus the weight of the dry sample divided by the weight of the wet sample times 100.

**Motor**

A machine supplied with external energy that is converted into force and/or motion.

**Motor Speed**

The number of revolutions that the motor turns in a given time period (i.e. revolutions per minute, rpm).

**N****Nacelle**

The cover for the gear box, drive train, generator, and other components of a wind turbine.

**Name Plate**

A metal tag attached to a machine or appliance that contains information such as brand name, serial number, voltage, power ratings under specified conditions, and other manufacturer supplied data.

**Natural Gas**

A hydrocarbon gas obtained from underground sources, often in association with petroleum and coal deposits. It generally contains a high percentage of methane, varying amounts of ethane, and inert gases; used as a heating fuel.

**Net Generation**

Equal to gross generation less electricity consumption of a power plant.

**Net Metering**

The practice of using a single meter to measure consumption and generation of electricity by a small generation facility (such as a house with a wind or solar photovoltaic system). The net energy produced or consumed is purchased from or sold to the power provider, respectively.

**Nonrenewable Fuels**

Fuels that cannot be easily made or "renewed," such as oil, natural gas, and coal.

**Nuclear Energy**

Energy that comes from splitting atoms of radioactive materials, such as uranium, and which produces radioactive wastes.

**O****Occupancy Sensor**

An optical, ultrasonic, or infrared sensor that turns room lights on when they detect a person's presence and off after the space is vacated.

**Occupied Space**

The space within a building or structure that is normally occupied by people, and that may be conditioned (heated, cooled and/or ventilated).

**Off-Peak**

The period of low energy demand, as opposed to maximum, or peak, demand.

**Ohms**

A measure of the electrical resistance of a material equal to the resistance of a circuit in which the potential difference of 1 volt produces a current of 1 ampere.

**Ohm's Law**

In a given electrical circuit, the amount of current in amperes (i) is equal to the pressure in volts (V) divided by the resistance, in ohms (R).

**Oil (fuel)**

A product of crude oil that is used for space heating, diesel engines, and electrical generation.

**On-Peak Energy**

Energy supplied during periods of relatively high system demands as specified by the supplier.

**On-Site Generation**

Generation of energy at the location where all or most of it will be used.

**Orientation**

The alignment of a building along a given axis to face a specific geographical direction. The alignment of a solar collector, in number of degrees east or west of true south.

**P****Panel (Solar)**

A term generally applied to individual solar collectors, and typically to solar photovoltaic collectors or modules.

**Parabolic Trough**

A solar energy conversion device that uses a trough covered with a highly reflective surface to focus sunlight onto a linear absorber containing a working fluid that can be used for medium temperature space or process heat or to operate a steam turbine for power or electricity generation.

**Parallel**

A configuration of an electrical circuit in which the voltage is the same across the terminals. The positive reference direction for each resistor current is down through the resistor with the same voltage across each resistor.

**Parallel Connection**

A way of joining photovoltaic cells or modules by connecting positive leads together and negative leads together; such a configuration increases the current, but not the voltage.

**Passive Solar (Building) Design**

A building design that uses structural elements of a building to heat and cool a building, without the use of mechanical equipment, which requires careful consideration of the local climate and solar energy resource, building orientation, and landscape features, to name a few. The principal elements include proper building orientation, proper window sizing and placement and design of window overhangs to reduce summer heat gain and ensure winter heat gain, and proper sizing of thermal energy storage mass (for example a Trombe wall or masonry tiles). The heat is distributed primarily by natural convection and radiation, though fans can also be used to circulate room air or ensure proper ventilation.

**Payback Period**

The amount of time required before the savings resulting from your system equal the system cost.

**Peak Demand/Load**

The maximum energy demand or load in a specified time period.

**Peak Power**

Power generated that operates at a very low capacity factor; generally used to meet short-lived and variable high demand periods.

**Peak Shifting**

The process of moving existing loads to off-peak periods.

**Peak Sun Hours**

The equivalent number of hours per day when solar irradiance averages  $1 \text{ kW/m}^2$ . For example, six peak sun hours means that the energy received during total daylight hours equals the energy that would have been received had the irradiance for six hours been  $1 \text{ kW/m}^2$ .

**Pellets**

Solid fuels made from primarily wood sawdust that is compacted under high pressure to form small (about the size of rabbit feed) pellets for use in a pellet stove.

**Pellet Stove**

A space heating device that burns pellets; are more efficient, clean burning, and easier to operate relative to conventional cord wood burning appliances.

**Phantom Load**

Any appliance that consumes power even when it is turned off. Examples of phantom loads include appliances with electronic clocks or timers, appliances with remote controls, and appliances with wall cubes (a small box that plugs into an AC outlet to power appliances).

**Phase**

Alternating current is carried by conductors and a ground to residential, commercial, or industrial consumers. The waveform of the phase power appears as a single continuous sine wave at the system frequency whose amplitude is the rated voltage of the power.

**Photon**

A particle of light that acts as an individual unit of energy.

**Photovoltaic (PV; Solar) Array**

A group of solar photovoltaic modules connected together.

**Photovoltaic (Solar) Cell**

Treated semiconductor material that converts solar irradiance to electricity.

**Photovoltaic Device**

A solid-state electrical device that converts light directly into direct current electricity of voltage-current characteristics that are a function of the characteristics of the light source and the materials in and design of the device. Solar photovoltaic devices are made of various semi-conductor materials including silicon, cadmium sulfide, cadmium telluride, and gallium arsenide, and in single crystalline, multi-crystalline, or amorphous forms.

**Photovoltaic (Solar) Module or Panel**

A solar photovoltaic product that generally consists of groups of PV cells electrically connected together to produce a specified power output under standard test conditions, mounted on a substrate, sealed with an encapsulant, and covered with a protective glazing. Maybe further mounted on an aluminum frame. A junction box, on the back or underside of the module is used to allow for connecting the module circuit conductors to external conductors.

**Photovoltaic (Solar) System**

A complete PV power system composed of the module (or array), and balance-of-system (BOS) components including the array supports, electrical conductors/wiring, fuses, safety disconnects, and grounds, charge controllers, inverters, battery storage, etc.

**P/N**

A semiconductor (photovoltaic) device structure in which the junction is formed between a p-type layer and an n-type layer.

**Portfolio Standard**

The requirement that an electric power provider generate or purchase a specified percentage of the power it supplies/sells from renewable energy resources, and thereby guarantee a market for electricity generated from renewable energy resources.

**Potential Energy**

Energy available due to position.

**Power**

Energy that is capable or available for doing work; the time rate at which work is performed, measured in horsepower, Watts, or Btu per hour. Electric power is the product of electric current and electromotive force.

**Power (Output) Curve**

A plot of a wind energy conversion device's power output versus wind speed.

**Power Factor (PF)**

The ratio of actual power being used in a circuit, expressed in watts or kilowatts, to the power that is apparently being drawn from a power source, expressed in volt-amperes or kilovolt-amperes.

**Power Generation Mix**

The proportion of electricity distributed by a power provider that is generated from available sources such as coal, natural gas, petroleum, nuclear, hydropower, wind, or geothermal.

**Power Provider**

A company or other organizational unit that sells and distributes electrical power (e.g., private or public electrical utility), either to other distribution and wholesale businesses or to end-users. Sometimes power providers also generate the power they sell.

**Programmable Thermostat**

A type of thermostat that allows the user to program into the devices' memory a pre-set schedule of times (when certain temperatures occur) to turn on HVAC equipment.

**Propane**

A hydrocarbon gas, C<sub>3</sub>H<sub>8</sub>, occurring in crude oil, natural gas, and refinery cracking gas. It is used as a fuel, a solvent, and a refrigerant. Propane liquefies under pressure and is the major component of liquefied petroleum gas (LPG).

**P-Type Semiconductor**

A semiconductor in which holes carry the current; produced by doping an intrinsic semiconductor with an electron acceptor impurity (e.g., boron in silicon).

**Public Utility or Services Commissions (PUC or PSC)**

These are state government agencies responsible for the regulation of public utilities within a state or region. A state legislature oversees the PUC by reviewing changes to power generator laws, rules and regulations and approving the PUC's budget. The commission usually has five Commissioners appointed by the Governor or legislature. PUCs typically regulate: electric, natural gas, water, sewer, telephone services, trucks, buses, and taxicabs within the commission's operating region. The PUC tries to balance the interests of consumers, environmentalists, utilities, and stockholders. The PUC makes sure a region's citizens are supplied with adequate, safe power provider service at reasonable rates.

**Q****Quad**

One quadrillion Btu. (1,000,000,000,000,000 Btu)

**R****Radiant Barrier**

A thin, reflective foil sheet that exhibits low radiant energy transmission and under certain conditions can block radiant heat transfer; installed in attics to reduce heat flow through a roof assembly into the living space.

**Radiant Energy**

Energy that transmits away from its source in all directions.

**Radiation**

The transfer of heat through matter or space by means of electromagnetic waves.

**Radioactive Waste**

Materials left over from making nuclear energy. Radioactive waste can living organisms if it is not stored safely.

**Rated Life**

The length of time that a product or appliance is expected to meet a certain level of performance under nominal operating conditions; in a luminaire, the period after which the lumen depreciation and lamp failure is at 70% of its initial value.

**Rated Power**

The power output of a device under specific or nominal operating conditions.

**Rate Schedule**

A mechanism used by electric utilities to determine prices for electricity; typically defines rates according to amounts of power demanded/consumed during specific time periods.

**Reflective Insulation**

An aluminum foil fabricated insulator with backings applied to provide a series of closed air spaces with highly reflective surfaces.

**Renewable Energy**

Energy derived from resources that are regenerative or for all practical purposes can not be depleted. Types of renewable energy resources include moving water (hydro, tidal and wave power), thermal gradients in ocean water, biomass, geothermal energy, solar energy, and wind energy. Municipal solid waste (MSW) is also considered to be a renewable energy resource.

**Resistance**

The inherent characteristic of a material to inhibit the transfer of energy. In electrical conductors, electrical resistance results in the generation of heat. Electrical resistance is measured in Ohms. The heat transfer resistance properties of insulation products are quantified as the R-value.

**Resistance Heating**

A type of heating system that provides heat from the resistance of an electrical current flowing through a conductor.

**Retrofit**

The process of modifying a building's structure.

**Rock Wool**

A type of insulation made from virgin basalt, an igneous rock, and spun into loose fill or a batt. It is fire resistant and helps with soundproofing.

**R-Value**

A measure of the capacity of a material to resist heat transfer. The R-Value is the reciprocal of the conductivity of a material (U-Value). The larger the R-Value of a material, the greater its insulating properties.

**S****Seasonal Energy Efficiency Ratio (SEER)**

A measure of seasonal or annual efficiency of a central air conditioner or air conditioning heat pump. It takes into account the variations in temperature that can occur within a season and is the average number of Btu of cooling delivered for every watt-hour of electricity used by the heat pump over a cooling season.

**Seasonal Performance Factor (SPF)**

Ratio of useful energy output of a device to the energy input, averaged over an entire heating season.

**Semiconductor**

Any material that has a limited capacity for conducting an electric current. Certain semiconductors, including silicon, gallium arsenide, copper indium diselenide, and cadmium telluride, are uniquely suited to the photovoltaic conversion process.

**Series**

A configuration of an electrical circuit in which the positive lead is connected to the negative lead of another energy producing, conducting, or consuming device. The voltages of each device are additive, whereas the current is not.

**Series Connection**

A way of joining photovoltaic cells by connecting positive leads to negative leads; such a configuration increases the voltage.

**Setback Thermostat**

A thermostat that can be set to automatically lower temperatures in an unoccupied house and raise them again before the occupant returns.

**Silicon**

A chemical element, of atomic number 14, that is semi-metallic, and an excellent semiconductor material used in solar photovoltaic devices; commonly found in sand.

**Single-Phase**

A generator with a single armature coil, which may have many turns and the alternating current output consists of a succession of cycles.

**Solar Altitude Angle**

The angle between a line from a point on the earth's surface to the center of the solar disc, and a line extending horizontally from the point.

**Solar Air Heater**

A type of solar thermal system where air is heated in a collector and either transferred directly to the interior space or to a storage medium, such as a rock bin.

**Solar Array**

A group of solar collectors or solar modules connected together.

**Solar Azimuth**

The angle between the sun's apparent position in the sky and true south, as measured on a horizontal plane.

**Solar Cell**

A solar photovoltaic device with a specified area.

**Solar Collector**

A device used to collect, absorb, and transfer solar energy to a working fluid. Flat plate collectors are the most common type of collectors used for solar water or pool heating systems. In the case of a photovoltaics system, the solar collector could be crystalline silicon panels or thin-film roof shingles, for example.



**Solar Constant**

The average amount of solar radiation that reaches the earth's upper atmosphere on a surface perpendicular to the sun's rays; equal to 1353 Watts per square meter or 492 Btu per square foot.

**Solar Declination**

The apparent angle of the sun north or south of the earth's equatorial plane. The earth's rotation on its axis causes a daily change in the declination.

**Solar Elevation or Altitude**

The number of degrees that the sun is above the horizon. The elevation is 0° at sunrise and sunset and 90° at solar noon.

**Solar Energy**

Electromagnetic energy transmitted from the sun (solar radiation). The amount that reaches the earth is equal to one billionth of total solar energy generated, or the equivalent of about 420 trillion kilowatt-hours.

**Solar Module (Panel)**

A solar photovoltaic device that produces a specified power output under defined test conditions, usually composed of groups of solar cells connected in series, in parallel, or in series-parallel combinations.

**Solar Noon**

Defined for a given day for a specific longitude, it is the time when the sun crosses the meridian of the observer's location. At solar noon, a shadow cast by a vertical pole will point either directly north or directly south, depending on the observer's latitude and the time of year. It occurs at the exact middle between local sunrise and sunset.

**Solar Radiation**

A general term for the visible and near visible (ultraviolet and near-infrared) electromagnetic radiation that is emitted by the sun. It has a spectral, or wavelength, distribution that corresponds to different energy levels; short wavelength radiation has a higher energy than long-wavelength radiation.

**Solar Space Heater**

A solar energy system designed to provide heat to individual rooms in a building.

**Solar Thermal Electric Systems**

Solar energy conversion technologies that convert solar energy to electricity, by heating a working fluid to power a turbine that drives a generator. Examples of these systems include central receiver systems, parabolic dish, and solar trough.

**Solar Thermal Parabolic Dishes**

A solar thermal technology that uses a modular mirror system that approximates a parabola and incorporates two-axis tracking to focus the sunlight onto receivers located at the focal point of each dish. The mirror system typically is made from a number of mirror facets, either glass or polymer mirror, or can consist of a single stretched membrane using a polymer mirror. The concentrated sunlight may be used directly by a Stirling, Rankine, or Brayton cycle heat engine at the focal point of the receiver or to heat a working fluid that is piped to a central engine. The primary applications include remote electrification, water pumping, and grid-connected generation.

**Solar Thermal Systems**

Solar energy systems that collect or absorb solar energy for useful purposes. Can be used to generate high temperature heat (for electricity production and/or process heat), medium temperature heat (for process and space/water heating and electricity generation), and low temperature heat (for water and space heating and cooling).

**Space Heater**

A movable or fixed heater used to heat individual rooms.

**Stand-Alone Generator**

A power source/generator that operates independently of or is not connected to an electric transmission and distribution network; used to meet a load(s) physically close to the generator.

**Stand-Alone System**

An system that operates independent of or is not connected to an electric transmission and distribution network.

**Stand-By Power**

For the consumer, this is the electricity that is used by your TVs, stereos, and other electronic devices that use remote controls. When you press "off" to turn off your device, minimal power (dormant mode) is still being used to maintain the internal electronics in a ready, quick-response mode. This way, your device can be turned on with your remote control and be immediately ready to operate.

**Steam Boiler**

A type of furnace in which fuel is burned and the heat is used to produce steam.

**Storage Capacity**

The amount of energy an energy storage device or system can store.

**Storage Tank**

The tank of a water heater.

**Storage Water Heater****Storm Windows**

Glass, plastic panels, or plastic sheets that reduce air infiltration and some heat loss when attached to either the interior or exterior of existing windows.

**Supply Side**

Technologies that pertain to the generation of electricity.

**Swamp Cooler**

A popular term used for an evaporative cooling device.

**Swept Area**

In reference to a wind energy conversion device, the area through which the rotor blades spin, as seen when directly facing the center of the rotor blades.

**T****Tankless Water Heater**

A water heater that heats water before it is directly distributed for end use as required; a demand water heater.

**Therm**

A unit of heat containing 100,000 British thermal units (Btu).

**Thermal Efficiency**

A measure of the efficiency of converting a fuel to energy and useful work; useful work and energy output divided by higher heating value of input fuel times 100 (for percent).

**Thermal Energy**

The energy developed through the use of heat energy.

**Thermal Energy Storage**

The storage of heat energy during power provider off-peak times at night, for use during the next day without incurring daytime peak electric rates.

**Thermodynamics**

A study of the transformation of energy from one form to another, and its practical application.

**Thermostat**

A device used to control temperatures; used to control the operation of heating and cooling devices by turning the device on or off when a specified temperature is reached.

**Thin-Film**

A layer of semiconductor material, such as copper indium diselenide or gallium arsenide, a few microns or less in thickness, used to make solar photovoltaic cells.

**Three-phase Current**

Alternating current in which three separate pulses are present, identical in frequency and voltage, but separated 120 degrees in phase.

**Tilt Angle (of a Solar Collector or Module)**

The angle at which a solar collector or module is set to face the sun relative to a horizontal position. The tilt angle can be set or adjusted to maximize seasonal or annual energy collection.

**Time-of-Use (TOU) Rates**

The pricing of electricity based on the estimated cost of electricity during a particular time block. Time-of-use rates are usually divided into three or four time blocks per twenty-four hour period (on-peak, mid-peak, off-peak and sometimes super off-peak) and by seasons of the year (summer and winter). Real-time pricing differs from TOU rates in that it is based on actual (as opposed to forecasted) prices which may fluctuate many times a day and are weather-sensitive, rather than varying with a fixed schedule.

**Tracking Solar Array**

A solar energy array that follows the path of the sun to maximize the solar radiation incident on the PV surface. The two most common orientations are (1) one axis where the array tracks the sun east to west and (2) two-axis tracking where the array points directly at the sun at all times. Tracking arrays use both the direct and diffuse sunlight. Two-axis tracking arrays capture the maximum possible daily energy.

**Transformer**

An electromagnetic device that changes the voltage of alternating current electricity. It consists of an induction coil having a primary and secondary winding and a closed iron core.

**Transmission**

The process of sending or moving electricity from one point to another; usually defines that part of an electric power provider's electric power lines from the power plant buss to the last transformer before the customer's connection.

**Transmission and Distribution Losses**

The losses that result from inherent resistance in electrical conductors and transformation inefficiencies in distribution transformers in a transmission and distribution network.

**Transmission Lines**

Transmit high-voltage electricity from the transformer to the electric distribution system.

**True South**

The direction, at any point on the earth that is geographically in the northern hemisphere facing toward the South Pole of the earth. Essentially a line extending from the point on the horizon to the highest point that the sun reaches on any day (solar noon) in the sky.

**Tube (Fluorescent Light)**

A fluorescent lamp that has a tubular shape.

**Turbine**

A device for converting the flow of a fluid (air, steam, water, or hot gases) into mechanical motion.

**Two-Axis Tracking**

A solar array tracking system capable of rotating independently about two axes (e.g., vertical and horizontal).

**U****Ultraviolet**

Electromagnetic radiation in the wavelength range of 4 to 400 nanometers.

**Utility**

A regulated entity which exhibits the characteristics of a natural monopoly (also referred to as a power provider).

For the purposes of electric industry restructuring, "utility" refers to the regulated, vertically-integrated electric company. "Transmission utility" refers to the regulated owner/operator of the transmission system only.

"Distribution utility" refers to the regulated owner/operator of the distribution system which serves retail customers.

**V****Ventilation**

The process of moving air (changing) into and out of an interior space either by natural or mechanically induced (forced) means.

**Ventilation Air**

That portion of supply air that is drawn from outside, plus any recirculated air that has been treated to maintain a desired air quality.

**Vertical-Axis Wind Turbine (VAWT)**

A type of wind turbine in which the axis of rotation is perpendicular to the wind stream and the ground.

**Visible Radiation**

The visible portion of the electromagnetic spectrum with wavelengths from 0.4 to 0.76 microns

**Volt**

A unit of electrical force equal to that amount of electromotive force that will cause a steady current of one ampere to flow through a resistance of one ohm.

**Voltage**

The amount of electromotive force, measured in volts, that exists between two points.

**Volt-Ampere**

A unit of electrical measurement equal to the product of a volt and an ampere.

**W****Watt**

The rate of energy transfer equivalent to one ampere under an electrical pressure of one volt. One watt equals 1/746 horsepower, or one joule per second. It is the product of Voltage and Current (amperage).

**Watt-hour**

A unit of electricity consumption of one Watt over the period of one hour.

**Wattmeter**

A device for measuring power consumption.

**Wavelength**

The distance between similar points on successive waves.

**Weatherization**

Caulking and weatherstripping to reduce air infiltration and exfiltration into/out of a building.

**Weatherstripping**

A material used to seal gaps around windows and exterior doors.

**Wind Energy**

Energy available from the movement of the wind across a landscape caused by the heating of the atmosphere, earth, and oceans by the sun.

**Windpower Curve**

A graph representing the relationship between the power available from the wind and the wind speed. The power from the wind increases proportionally with the cube of the wind speed.

**Wind Power Plant**

A group of wind turbines interconnected to a common power provider system through a system of transformers, distribution lines, and (usually) one substation. Operation, control, and maintenance functions are often centralized through a network of computerized monitoring systems, supplemented by visual inspection. This is a term commonly used in the United States. In Europe, it is called a generating station.

**Wind Resource Assessment**

The process of characterizing the wind resource, and its energy potential, for a specific site or geographical area.

**Wind Rose**

A diagram that indicates the average percentage of time that the wind blows from different directions, on a monthly or annual basis.

**Wind Speed**

The rate of flow of the wind undisturbed by obstacles.

**Wind Speed Profile**

A profile of how the wind speed changes with height above the surface of the ground or water.

**Wind Turbine**

A term used for a wind energy conversion device that produces electricity; typically having one, two, or three blades.

**Wind Turbine Rated Capacity**

The amount of power a wind turbine can produce at its rated wind speed, e.g., 100 kW at 20 mph. The rated wind speed generally corresponds to the point at which the conversion efficiency is near its maximum. Because of the variability of the wind, the amount of energy a wind turbine actually produces is a function of the capacity factor (e.g., a wind turbine produces 20% to 35% of its rated capacity over a year).

**Wind Velocity**

The wind speed and direction in an undisturbed flow.

**Y****Yaw**

The rotation of a horizontal axis wind turbine around its tower or vertical axis.

**Z****Zoning**

The combining of rooms in a structure according to similar heating and cooling patterns. Zoning requires using more than one thermostat to control heating, cooling, and ventilation equipment.

From: U.S. Department of Energy – [www1.eere.energy.gov](http://www1.eere.energy.gov)

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# *APPENDICES*

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## What to Do if a Compact Fluorescent Light (CFL) Bulb or Fluorescent Tube Light Bulb Breaks in Your Home<sup>1</sup>

Fluorescent light bulbs contain a small amount of mercury sealed within the glass tubing. When a fluorescent bulb breaks in your home, some of this mercury is released as mercury vapor. The broken bulb can continue to release mercury vapor until it is cleaned up and removed from the residence.

To minimize exposure to mercury vapor, EPA recommends that residents follow the cleanup and disposal steps described below. This cleanup guidance represents the minimum actions recommended to clean up a broken CFL, and will be updated as EPA identifies more effective cleanup practices.

### CLEANUP AND DISPOSAL OVERVIEW

The most important steps to reduce exposure to mercury vapor from a broken bulb are:

#### 1. Before cleanup

- a. Have people and pets leave the room.
- b. Air out the room for 5-10 minutes by opening a window or door to the outdoor environment.
- c. Shut off the central forced air heating/air conditioning system, if you have one.
- d. Collect materials needed to clean up broken bulb.

#### 2. During cleanup

- a. Be thorough in collecting broken glass and visible powder.
- b. Place cleanup materials in a sealable container.

#### 3. After cleanup

- a. Promptly place all bulb debris and cleanup materials outdoors in a trash container or protected area until materials can be disposed of properly. Avoid leaving any bulb fragments or cleanup materials indoors.
- b. If practical, continue to air out the room where the bulb was broken and leave the heating/air conditioning system shut off for several hours.

### Before Cleanup

- Have people and pets leave the room, and avoid the breakage area on the way out.
- Open a window or door to the outdoors and leave the room for 5-10 minutes.
- Shut off the central forced-air heating/air conditioning (H&AC) system, if you have one.
- Collect materials you will need to clean up the broken bulb:
  - Stiff paper or cardboard
  - Sticky tape (e.g., duct tape)
  - Damp paper towels or disposable wet wipes (for hard surfaces)
  - Glass jar with a metal lid (such as a canning jar) or a sealable plastic bag(s)

### Cleanup Steps for Hard Surfaces

- Carefully scoop up glass fragments and powder using stiff paper or cardboard and place debris and paper/cardboard in a glass jar with a metal lid. If a glass jar is not available, use a sealable plastic bag. (NOTE: Since a plastic bag will not prevent the mercury vapor from escaping, remove the plastic bag(s) from the home after cleanup.)
- Use sticky tape, such as duct tape, to pick up any remaining small glass fragments and powder. Place the used tape in the glass jar or plastic bag.
- Wipe the area clean with damp paper towels or disposable wet wipes. Place the towels in the glass jar or plastic bag.
- Vacuuming of hard surfaces during cleanup is not recommended unless broken glass remains after all other cleanup steps have been taken. [NOTE: It is possible that vacuuming could spread mercury-containing powder or mercury vapor, although available information on this problem is limited.] If vacuuming is needed to ensure removal of all broken glass, keep the following tips in mind:
  - Keep a window or door to the outdoors open;
  - Vacuum the area where the bulb was broken using the vacuum hose, if available; and
  - Remove the vacuum bag (or empty and wipe the canister) and seal the bag/vacuum debris, and any materials used to clean the vacuum, in a plastic bag.
- Promptly place all bulb debris and cleanup materials, including vacuum cleaner bags, outdoors in a trash container or protected area until materials can be disposed of properly.
  - Check with your local or state government about disposal requirements in your area. Some states and communities require fluorescent bulbs (broken or unbroken) be taken to a local recycling center.
- Wash your hands with soap and water after disposing of the jars or plastic bags containing bulb debris and cleanup materials.
- Continue to air out the room where the bulb was broken and leave the H&AC system shut off, as practical, for several hours.

### Cleanup Steps for Carpeting or Rugs

- Carefully scoop up glass fragments and powder using stiff paper or cardboard and place debris and paper/cardboard in a glass jar with a metal lid. If a glass jar is not available, use a sealable plastic bag. (NOTE: Since a plastic bag will not prevent the mercury vapor from escaping, remove the plastic bag(s) from the home after cleanup.)
- Use sticky tape, such as duct tape, to pick up any remaining small glass fragments and powder. Place the used tape in the glass jar or plastic bag.
- Vacuuming of carpeting or rugs during cleanup is not recommended unless broken glass remains after all other cleanup steps have been taken. [NOTE: It is possible that vacuuming could spread mercury-containing powder or mercury vapor, although available information on this problem is limited.] If vacuuming is needed to ensure removal of all broken glass, keep the following tips in mind:
  - Keep a window or door to the outdoors open;
  - Vacuum the area where the bulb was broken using the vacuum hose, if available, and
  - Remove the vacuum bag (or empty and wipe the canister) and seal the bag/vacuum debris, and any materials used to clean the vacuum, in a plastic bag.
- Promptly place all bulb debris and cleanup materials, including vacuum cleaner bags, outdoors in a trash container or protected area until materials can be disposed of properly.



- Check with your local or state government about disposal requirements in your area. Some states and communities require fluorescent bulbs (broken or unbroken) be taken to a local recycling center.
- Wash your hands with soap and water after disposing of the jars or plastic bags containing bulb debris and cleanup materials.
- Continue to air out the room where the bulb was broken and leave the H&AC system shut off, as practical, for several hours.

### **Future Cleaning of Carpeting or Rugs: Air Out the Room During and After Vacuuming**

- The next several times you vacuum the rug or carpet, shut off the H&AC system if you have one, close the doors to other rooms, and open a window or door to the outside before vacuuming. Change the vacuum bag after each use in this area.
- After vacuuming is completed, keep the H&AC system shut off and the window or door to the outside open, as practical, for several hours.

### **Actions You Can Take to Prevent Broken Compact Fluorescent Light Bulbs**

Fluorescent bulbs are made of glass and can break if dropped or roughly handled. To avoid breaking a bulb, follow these general practices:

- Always switch off and allow a working CFL bulb to cool before handling.
- Always handle CFL bulbs carefully to avoid breakage.
  - If possible, screw/unscrew the CFL by holding the plastic or ceramic base, not the glass tubing.
  - Gently screw in the CFL until snug. Do not over-tighten.
  - Never forcefully twist the glass tubing.
- Consider not using CFLs in lamps that can be easily knocked over, in unprotected light fixtures, or in lamps that are incompatible with the spiral or folded shape of many CFLs.
- Do not use CFL bulbs in locations where they can easily be broken, such as play spaces.
- Use CFL bulbs that have a glass or plastic cover over the spiral or folded glass tube, if available. These types of bulbs look more like incandescent bulbs and may be more durable if dropped.
- Consider using a drop cloth (e.g., plastic sheet or beach towel) when changing a fluorescent light bulb in case a breakage should occur. The drop cloth will help prevent mercury contamination of nearby surfaces and can be bundled with the bulb debris for disposal.

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<sup>1</sup> This document contains information designed to be useful to the general public. This document does not impose legally binding requirements, nor does it confer legal rights, impose legal obligations, or implement any statutory or regulatory provisions. This document does not change or substitute for any statutory or regulatory provisions. This document presents technical information based on EPA's current understanding of the potential hazards posed by breakage of mercury-containing fluorescent lamps (light bulbs) in a typical household setting. Finally, this is a living document and may be revised periodically without public notice. EPA welcomes comments on this document at any time and will consider those comments in any future revisions of this document.





# Sample School Electric Bill

Nov 27, 2009

1

## Customer Bill

ABC Elementary School  
Anytown, USA

Your Electric Company

## Billing and Payment Summary

Account # 000-1234 2 Due Date: Jan 02, 2010 3

Total Amount Due: \$ 7,462.61 4

To avoid a Late Payment Charge of 1.5% please pay by Jan 02, 2010.

Previous Amount Due: \$ 8,152.93

Payments as of Nov 27: \$ 8,152.93

## Meter and Usage

Current Billing Days: 34

## Billable Usage

Schedule 130 10/23 - 11/26 12

Total kWh 12192

Dist Demand 61.0

Demand 57.0 10

Schedule 130 10/23 - 11/26

Total kWh 69888

Dist Demand 272.0

Demand 259.0 10

## Measured Usage 5

Meter: 000-1234 0/23 - 11/26

Current Reading 4147

Previous Reading 4020

Total kWh 12192 6

Current Reading .60

Demand 57.60 11

Multiplier: 96

Meter: 111-4567 0/23 - 11/26

Current Reading 51746

Previous Reading 51382

Total kWh 69888 6

Current Reading 1.35

Demand 259.20 11

Multiplier: 192

## Usage History

## Explanation of Bill Detail

Your Electric Company 1-800-123-4567

Previous Balance 8,152.93

Payment Received 8,152.93

BALANCE FORWARD 0

Non-Residential Service (Schedule 130) 10/23 - 11/26

Distribution Service

Basic Customer Charge 86.52

Distribution Demand 206.29

13 Electricity Supply Service (ESS)

ESS Adjustment Charge 83.93 CR

Electricity Supply kWh 214.94

ESS Demand Charge 558.85 7

Fuel Charge 353.81

Sales and Use Surcharge 2.68 8

14 Non-Residential Service (Schedule 130) 10/23 - 11/26

Distribution Service

Basic Customer Charge 86.52

Distribution Demand 919.87

Electricity Supply Service (ESS)

ESS Adjustment Charge 374.243 CR

Electricity Supply kWh 909.41

ESS Demand Charge 2,539.36 7

Fuel Charge 2,058.15

Sales and Use Surcharge 13.38 8

TOTAL CURRENT CHARGES 7,463.61 9

TOTAL ACCOUNT BALANCE 7,463.61 4

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

Mailed on Nov 28, 2009

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

Bill Date Nov 27, 2009 1

Please Pay by 01/02/2010 3

\$ 7,463.54 4

## Payment Coupon

Amount Enclosed

Account # 000-1234 2

ABC Elementary School  
123 Main Street  
Anytown, USA 98765

Send payment to:

Your Electric Company  
PO BOX 123456  
Anytown, USA 98765

01166005000 0000000009368 6868686 0001234 11272007



# Sample School Natural Gas Bill

## ABC Elementary School Anytown, USA

NOTE: The bill you received on or around Friday, Nov. 2 was calculated using estimated usage instead of the actual meter reading. This invoice reflects your actual meter reading. If your new amount due is more than what was indicated on your previous bill, please remit payment for the difference. If it is less, and you've already paid, the difference will be credited to your account and shown on your next bill. We apologize for the inconvenience.

**1** Account Number 000-12345678 **2** Billing Date Nov 15, 2009 **3** Next Meter Reading Dec 3, 2009 **4** Next Billing Date Dec 4, 2009

Visit our web site at [www.yourgascompany.com](http://www.yourgascompany.com)  
If you have any questions call 1-800-000-0000

### Credits & Charges Since Your Last Bill

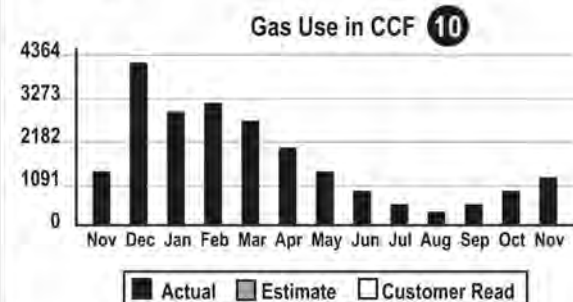
Payments Received - Thank You \$1,302.60 CR **5**  
Outstanding Balance \$0.00

### Current Charges

General Service **6** 282.14  
Delivery **7** 1,377.91  
Gas Supply  
Total Current Charges **8** \$1,660.05  
Total Account Balance \$1,660.05

### Monthly Usage Comparison

Heating Degree Days For 2007 **9** 160 2008 51 NORMAL 138  
This Billing Period



### Billing Period and Meter Readings

Date	Read Type	Reading
October 30, 2007	Actual	70320 <b>11</b>
October 01, 2007	Actual	68985

CCF used in 29 days: 1335 **12**  
Meter Number 123456 **13**

For Gas Leaks, call 1-800-123-4567

Please pay by Dec 10, 2009. To Avoid A Late Charge of 1.5% Per Month

EnergyShare has helped Virginians pay heating bills of all kinds. You can help by adding \$1, \$2, \$5, \$10, \$15, or \$20 to your gas bill payment. **14**

Please make checks payable to Your Gas Company and return this portion with your payment. Thanks!



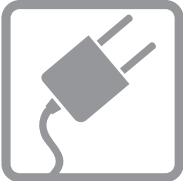
**YOUR GAS COMPANY**  
PO Box 123456 Anytown, USA 98765

PREVIOUS BALANCE	\$0.00
Total Current Charges	\$1,660.05
Total Account Balance	\$1,660.05
Account # 000-12345678	Amount Enclosed <b>16</b>

ABC Elementary School  
123 Main Street  
Anytown, USA 98765

Your Gas Company  
PO BOX 123456  
Anytown, USA 98765

01166005000000000000009368686868600012345678



# Sample Bill Explanation Key

## Sample School Electric Bill Explanation

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1. Bill Mailing Date
2. Customer Account Number
3. Payment Due Date
4. Total Amount Due
5. Meter Readings By Date in Kilowatt-hours (Note that there are two meters on this bill)
6. Actual Kilowatt-hours Consumed
7. Cost of the Electricity Consumed
8. Sales and Use Surcharge
9. Total Current Charges
10. Demand. This is a measurement of the rate at which electricity is used. The monthly demand is based on the 15 minutes during a billing period with the "highest average" kW use. Demand charges are designed to collect some of the generation and transmission-related costs necessary to serve a particular group or class of customers.
11. Actual Demand for the meter
12. Schedule 130. A rate class that determines how much is paid per kWh of usage and kW demand.
13. Electricity Supply Service. Customers are billed for the electricity supply and the delivery of the electricity. The supply charge reflects the cost of generating the electricity at the power plant.
14. Distribution Service. The delivery charge reflects the cost of delivering the electricity from the power plant to the customer.

## Sample School Natural Gas Bill Explanation

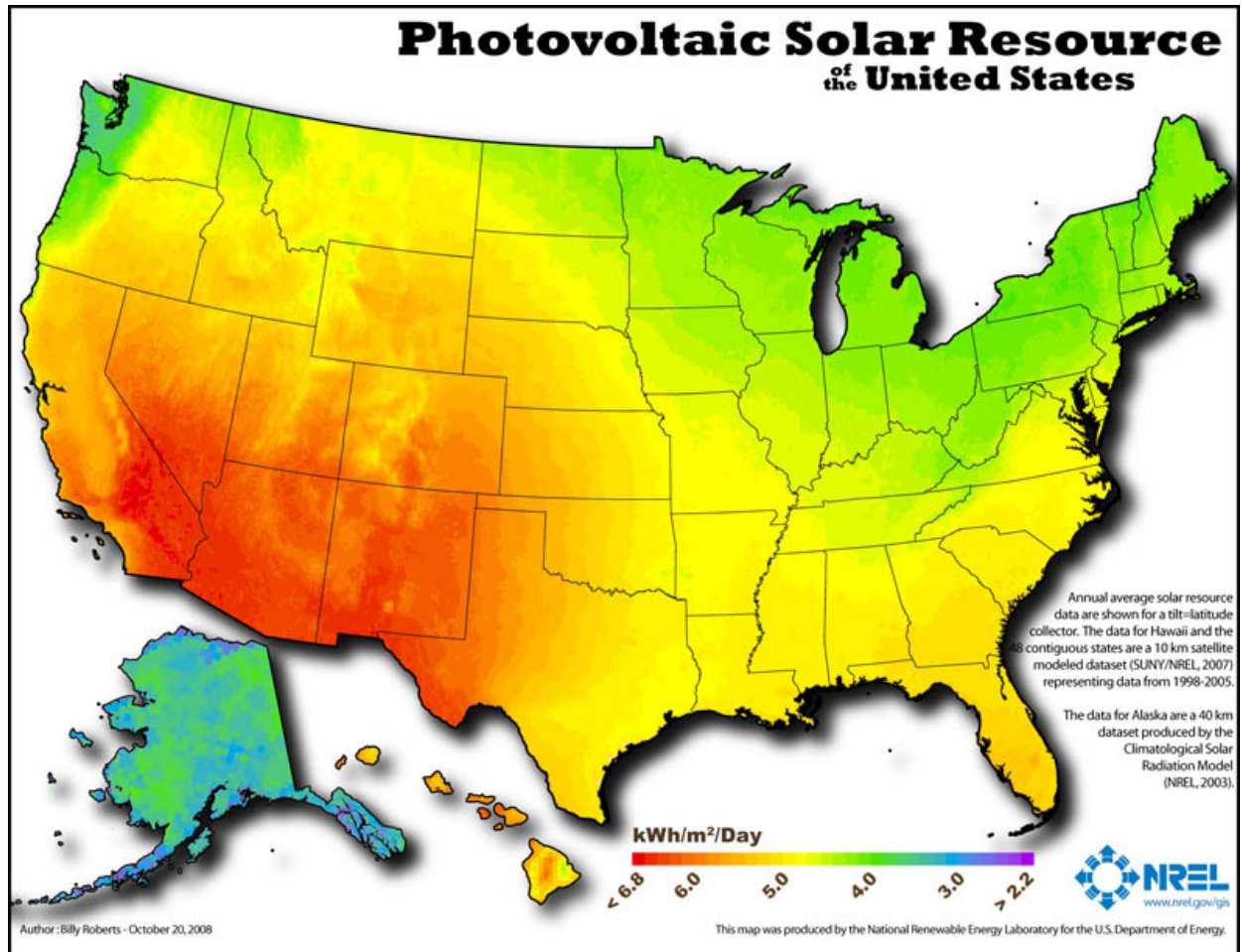
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1. Customer Account Number
2. Date of the Bill
3. Date of Next Meter Reading
4. Date of the Next Bill
5. Last Payment Received
6. Charge for Delivering the Natural Gas to the School
7. Charge for the Natural Gas
8. Total Amount Due
9. Comparison of Heating Degree Days. Degree day is a quantitative index that reflects demand for energy to heat or cool buildings. This index is derived from daily temperature observations at nearly 200 major weather stations in the contiguous United States. The heating year during which heating degree days are accumulated extends from July 1st to June 30th. A mean daily temperature (average of the daily maximum and minimum temperatures) of 65°F is the base for both heating and cooling degree day computations. Heating degree days are summations of negative differences between the mean daily temperature and the 65°F base.
10. Graph of Actual Gas Used by Month for the Last Year
11. The Actual Meter Readings for the Month
12. The Volume of Gas Used in CCF
13. The Meter Number
14. EnergyShare Fund. Most utilities are associated with a fuel fund for needy customers; paying customers can contribute any amount to the fund and note it here.
15. Due Date of Payment
16. Amount Enclosed by Customer

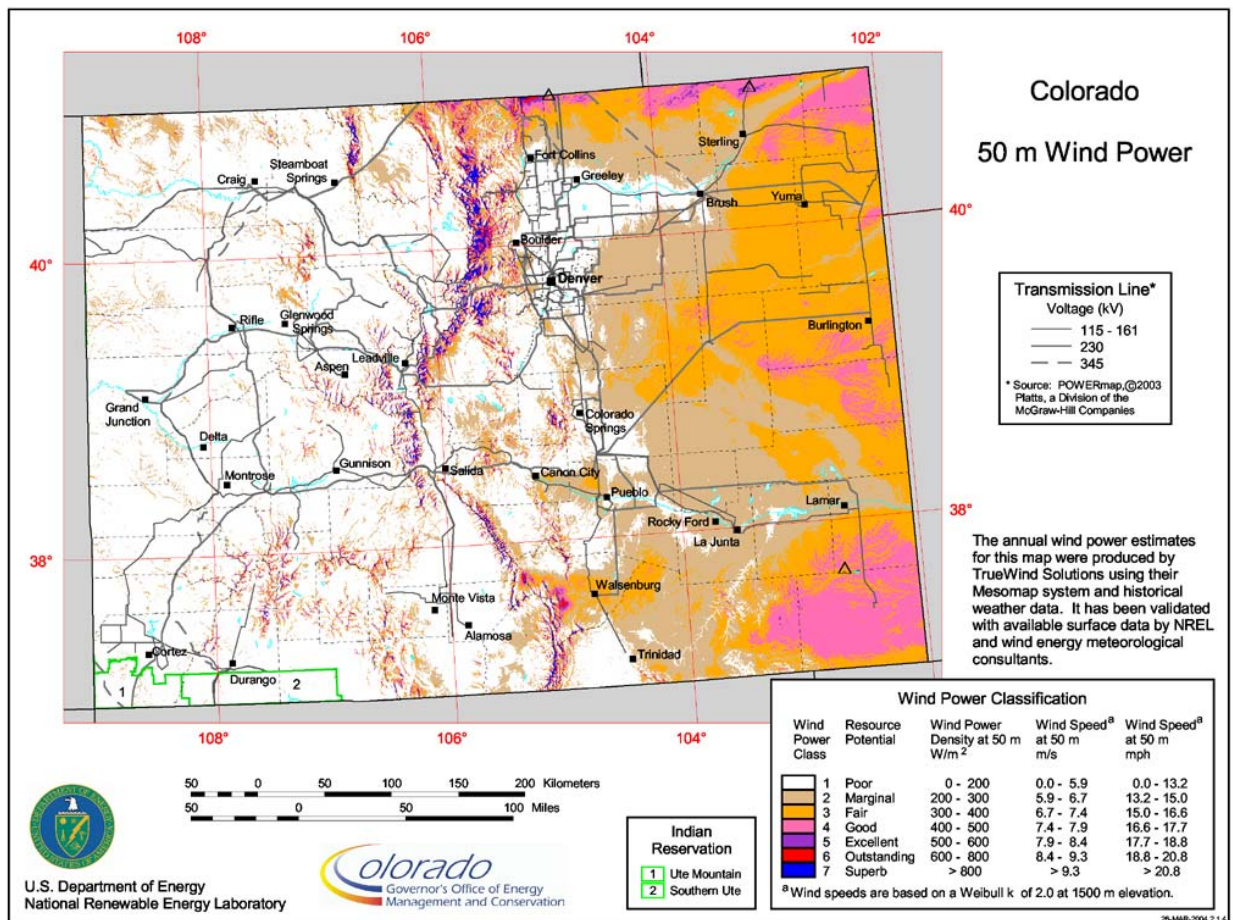




## APPENDIX C: ENERGY RESOURCE MAPS

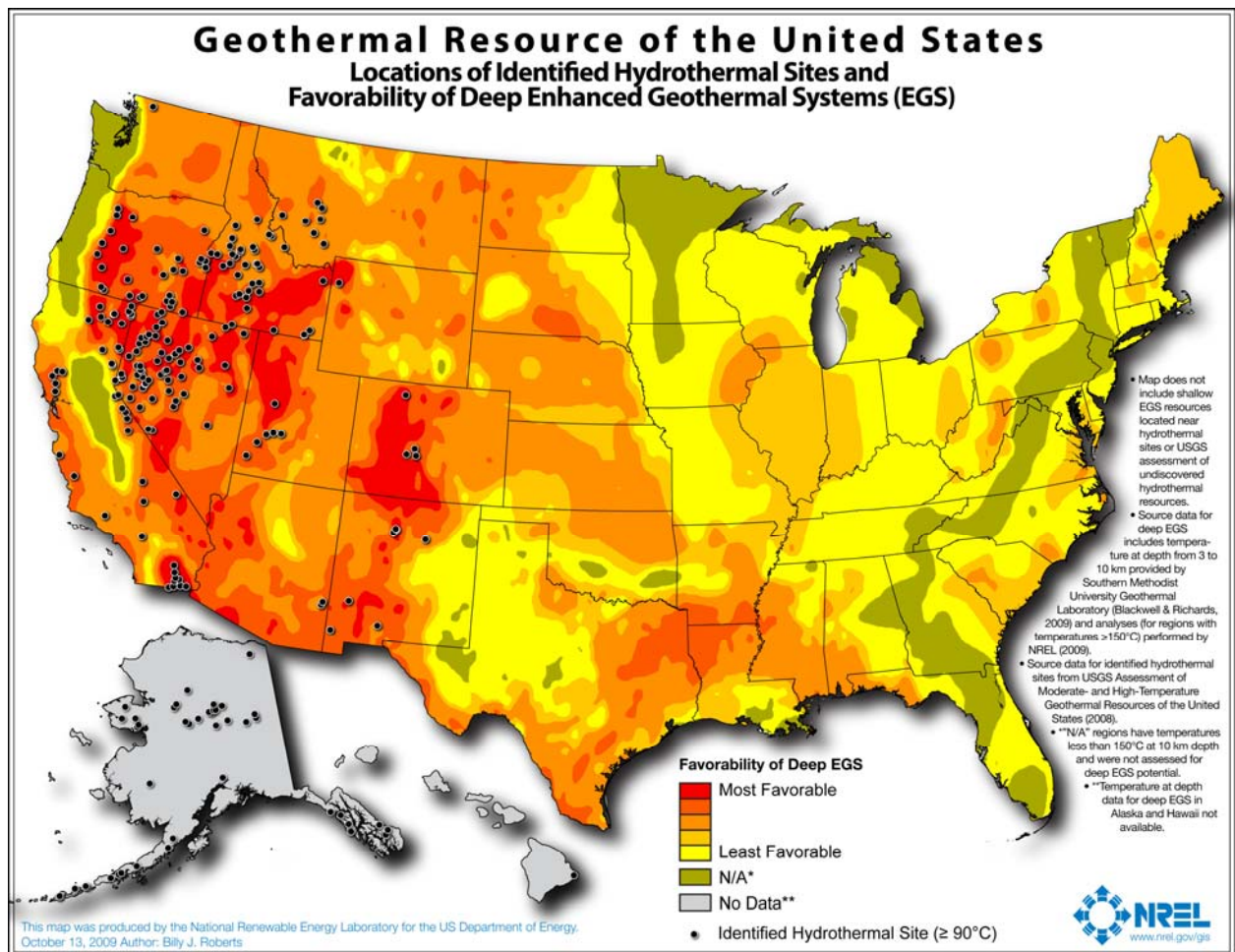


From: [www.nrel.gov](http://www.nrel.gov)



From: [www.nrel.gov](http://www.nrel.gov)





From: [www.nrel.gov](http://www.nrel.gov)



## Appendix D: List of Materials

The following list is solely intended to give teachers ideas of the types of items used in the lesson plans. Colorado State University Extension does not endorse any particular brands, and the list is not exhaustive. **Disposables are not included in this list.**

Lesson Plan(s)	Item	Possible Source
-	Clever catch ball - alternative energy	Amazon, others
All solar	0.5 or 1V solar panels	<a href="http://shop.pitsco.com/store/detail.aspx?Keywords=solar%20panels&amp;by=20&amp;ID=2141&amp;c=0&amp;t=0&amp;l=0">http://shop.pitsco.com/store/detail.aspx?Keywords=solar%20panels&amp;by=20&amp;ID=2141&amp;c=0&amp;t=0&amp;l=0</a>
All solar	Alligator clip	<a href="http://www.radioshack.com/product/index.jsp?productId=2062233&amp;numProdsPerPage=60">http://www.radioshack.com/product/index.jsp?productId=2062233&amp;numProdsPerPage=60</a>
All solar, Steamin' Ahead	Protractor	<a href="http://www.american-classroom-supply.com/acm11200.html">http://www.american-classroom-supply.com/acm11200.html</a>
Biofuels in Your Backyard	Seed press	<a href="http://www.piteba.com/eng/index_eng.htm">http://www.piteba.com/eng/index_eng.htm</a>
Biofuels in Your Backyard	Lamp oil	Hobby store
Biofuels in Your Backyard, Steamin' Ahead	Scale	<a href="http://www.american-classroom-supply.com/ler2345.html">http://www.american-classroom-supply.com/ler2345.html</a>
Blade Design Competition	KidWind mini blade design wind farm	<a href="http://www.kidwind.org/xcart/product.php?productid=421">http://www.kidwind.org/xcart/product.php?productid=421</a>
Conduct a School Energy Audit	Power monitor	Hardware store
Conduct a School Energy Audit	Flicker checker	Hibberts: 1-800-205-4888
Dynamos	1/2"x1"x2" rectangular ceramic magnet	<a href="http://www.radioshack.com/product/index.jsp?productId=2102689">http://www.radioshack.com/product/index.jsp?productId=2102689</a>
Dynamos	30 gauge enamel coated magnet wire	<a href="http://www.radioshack.com/product/index.jsp?productId=2036277">http://www.radioshack.com/product/index.jsp?productId=2036277</a>

Dynamos	12V DC piezo buzzer	<a href="http://www.radioshack.com/product/index.jsp?productId=2062398">http://www.radioshack.com/product/index.jsp?productId=2062398</a>
Dynamos	craft knife	Hobby store
Dynamos	1/2" diameter circular magnet	<a href="http://shop.hobbylobby.com/store/item.aspx?ItemId=194794&amp;F_FilterIds=54504">http://shop.hobbylobby.com/store/item.aspx?ItemId=194794&amp;F_FilterIds=54504</a>
Dynamos, Watts Your Angle, Are Renewables Right for Me	Compass	Various
Earth Energy	Plastic bin	Various
Earth Energy	1/2 inch black poly tubing	Hardware, irrigation supply store
Earth Energy	1/2 end caps	Hardware, irrigation supply store
Light Bulb or Heat Bulb	Compact fluorescent light bulb	Hardware store
Light Bulb or Heat Bulb	Incandescent light bulb	Hardware store
Light Bulb or Heat Bulb	LED bulb	Hardware store
Light Bulb or Heat Bulb	Bulb socket with plug	<a href="http://www.surplussales.com/electrical/LampSockets/LampSockets-3.html">http://www.surplussales.com/electrical/LampSockets/LampSockets-3.html</a>
Light Bulb or Heat Bulb	Power strip	Hardware store
The Sun Can do Watt, Solar Car Race	Motor	<a href="http://shop.pitsco.com/store/detail.aspx?KeyWords=motors&amp;by=20&amp;ID=2997&amp;c=0&amp;t=0&amp;l=0&amp;bhcp=1">http://shop.pitsco.com/store/detail.aspx?KeyWords=motors&amp;by=20&amp;ID=2997&amp;c=0&amp;t=0&amp;l=0&amp;bhcp=1</a>
The Value of R-Value	Ice cube tray	Various
The Value of R-Value	Reflective insulation	Hardware store
Various	Multimeter	<a href="http://www.kidwind.org/xcart/product.php?productid=21">http://www.kidwind.org/xcart/product.php?productid=21</a>
Various	Thermometer	<a href="http://www.american-classroom-supply.com/ler2415.html">http://www.american-classroom-supply.com/ler2415.html</a>
Various	Wire stripper	<a href="http://www.radioshack.com/product/index.jsp?productId=3932542&amp;prodFindSrc=cart">http://www.radioshack.com/product/index.jsp?productId=3932542&amp;prodFindSrc=cart</a>

## Appendix E: List of Related Articles

LESSON	ARTICLE AND LINK
Colorado Energy Source Webquest	<ul style="list-style-type: none"> <li>• <a href="#">“Dark Side of Solar Cells Brightens”</a> – Scientific American</li> <li>• <a href="#">“Cost Works Against Alternative and Renewable Energy Sources in Time of Recession”</a> – New York Times</li> <li>• <a href="#">“A Plan to Power 100 Percent of the Planet with Renewables”</a> – Scientific American</li> <li>• <a href="#">“Colorado Boosts its RPS to 30% by 2020”</a> – Renewable Energy World</li> </ul>
Dynamos	<ul style="list-style-type: none"> <li>• <a href="#">“Colorado Energy Facts”</a> - The Institute for Energy Research</li> </ul>
Light Bulb or Heat Bulb?	<ul style="list-style-type: none"> <li>• <a href="#">“Mesa County Valley School District 51 Grand Junction, Colorado Case Study”</a> – Southwest Energy Efficiency Project</li> </ul>
Conduct a School Energy Audit	<ul style="list-style-type: none"> <li>• <a href="#">“Students Find Big Savings in School Energy Audit”</a> – Energy Audit, Inc.</li> <li>• <a href="#">“High Schools That Create Conservation Culture Save Big on Energy”</a> – Today at Colorado State</li> <li>• <a href="#">“PSD Saves Big with Conservation Culture”</a> – Poudre School District</li> <li>• <a href="#">“Mesa County Valley School District 51 Grand Junction, Colorado Case Study”</a> – Southwest Energy Efficiency Project</li> </ul>
Watt’s Your Angle?	<ul style="list-style-type: none"> <li>• <a href="#">Invert Your Thinking: Squeezing more power out of your solar panels</a> - Scientific American Blog</li> </ul>
Are Renewables Right for Me?	<ul style="list-style-type: none"> <li>• <a href="#">“Wind Turbines Whip Up Excitement, School Pride”</a> – National Renewable Energy Laboratory</li> </ul>
Earth Energy	<ul style="list-style-type: none"> <li>• <a href="#">“Ikea’s Cool New Digs in Colorado to Feature Geothermal System”</a> – Denver Post</li> </ul>
Biofuels in Your Backyard	<ul style="list-style-type: none"> <li>• <a href="#">“Bridging the Biofuel Transition”</a> – Colorado State University Extension</li> <li>• <a href="#">“Case Study 2 – Costilla County Biodiesel Project”</a> – Western Organization of Resource Councils</li> </ul>
Climate Change Wedge Game	<ul style="list-style-type: none"> <li>• <a href="#">“A Plan to Keep Carbon in Check”</a> – Scientific American</li> <li>• <a href="#">“Can We Bury Global Warming”</a> – Scientific American</li> </ul>



## **Appendix F: Additional Resources**

### **Videos**

Videos were put together to support teachers in delivering most lesson plans from this curriculum. To access these videos, visit: [www.ext.colostate.edu/energy/k12.html](http://www.ext.colostate.edu/energy/k12.html)

### **Presentation Supports**

Powerpoint slides in PDF format are available for download for each lesson plan of the curriculum. They are intended to support teachers in presenting background material from the primer and can be found at: [www.ext.colostate.edu/energy/k12.html](http://www.ext.colostate.edu/energy/k12.html)

### **Extension Resources**

Extension staff in various counties throughout Colorado have been trained on this curriculum and are available to train teachers, support trained teachers, loan materials kits for most lesson plans, and make school visits. More information can be found at: <http://www.ext.colostate.edu/energy/k12.html>

### **Kit Materials**

In addition to kits being available through loan via county and regional Extension offices, teachers interested in purchasing materials to carry out the lesson plans can use “Appendix D: List of Kit Materials” as a reference.

### **Content**

The following websites were used extensively during the content development of this curriculum and are outstanding resources for more in-depth energy information:

2010 Colorado Utilities Report – [www.colorado.gov/energy](http://www.colorado.gov/energy)

Build It Solar – [www.builditsolar.com](http://www.builditsolar.com)

Colorado State University Extension - [www.ext.colostate.edu](http://www.ext.colostate.edu)

National Energy Education Development (NEED) Project - [www.need.org](http://www.need.org)

National Renewable Energy Laboratory - [www.nrel.gov](http://www.nrel.gov)

National Sustainable Agriculture Information Service – [www.attra.org](http://www.attra.org)

U.S. Department of Energy - [www.energysavers.gov](http://www.energysavers.gov) and [www1.eere.energy.gov](http://www1.eere.energy.gov)

U.S. Energy Information Administration – [www.eia.gov](http://www.eia.gov) and [www.eia.doe.gov/kids/](http://www.eia.doe.gov/kids/)

U.S. Environmental Protection Agency – [www.energystar.gov](http://www.energystar.gov) and [www.energystar.gov/kids](http://www.energystar.gov/kids)

### **Energy in Schools**

For schools interested in becoming more efficient, the Governor’s Energy Office offers programs that may be able to assist financially and/or technically: [www.colorado.gov/energy](http://www.colorado.gov/energy)  
Schools on Colorado’s Eastern Plains and other windy locations may want to apply for a wind turbine installation through the Wind for Schools Program. Do a web search for more information on this program.

**For more information on Colorado State University’s energy programming, please visit:**  
**[www.ext.colostate.edu/energy](http://www.ext.colostate.edu/energy)**