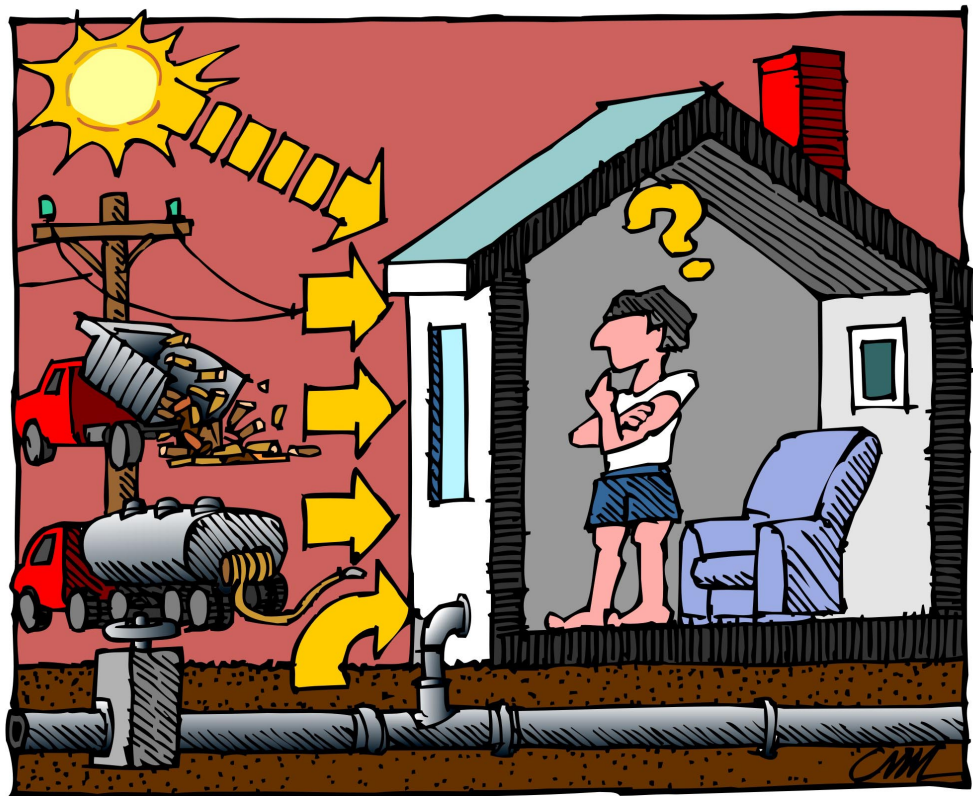
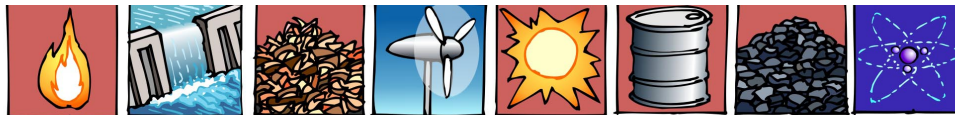


# ENERGY THINKING



NORTHEAST SUSTAINABLE ENERGY ASSOCIATION

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The **Northeast Sustainable Energy Association (NESEA)** is the Northeast's leading organization of professionals and concerned citizens working in sustainable energy and whole systems thinking. NESEA facilitates the widespread adoption and use of sustainable energy by providing support to industry professionals and by educating and motivating consumers to adopt sustainable energy and green building practices.

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# Introduction

Energy—where we get it and how we use it—can be expected to change radically during the lifetimes of our children. The world’s ability to produce oil fast enough to meet rising worldwide demand is being stressed. This situation can only be expected to grow worse over the lifetime of our students, unless we shift away from a dependence on oil. Rising carbon dioxide emissions, mainly from burning fossil fuels (our primary energy resources) are a major cause of global warming. It is increasingly clear this will exact a considerable cost on the world’s environment and population, especially on future generations—unless vast changes are made to our energy systems and ways we use energy.

The choices society will make during this time of change will have profound effects on today’s students and future generations. Our most abundant fossil fuel, coal, is also currently our dirtiest to use, causing significant degradation to land, air, and water resources and posing health risks to coal workers and communities neighboring coal mines and power plants. Do we increase its use to supplant diminishing access to oil? Nuclear power, with its promise of low to no global warming pollution, brings with it other risks and highly radioactive waste products that must be secured safely for tens of thousands of years—longer than the current history of mankind. Do these risks outweigh the risks of global climate change? Whether the use of renewable wind, hydro, solar, and biomass energy resources—arguably the most environmentally benign sources of energy— will be used to the fullest is largely a political decision that can, and will be influenced by future votes, purchases, and ideas of today’s students. The same can be said with regard to energy efficiency levels of cars, appliances, and buildings and how we choose to use energy resources.

Through activities in this unit, students will implement an easy-to-use structure—the *Energy Thinker’s Diagram*—to analyze and evaluate energy use in their lives and propose changes that could reduce unwanted consequences of energy use that students consider important. Reduced risks of global warming, energy price fluctuations, or lessened impacts of energy use on the environment or human health are just a few examples.

To accomplish these tasks, students research energy resources and issues through media articles, *Energy Information Cards* (provided), the Internet, and personal experience. Students identify current energy resources used and energy resources available in Pennsylvania for transportation, electricity, heat, and hot water. Students evaluate whether an energy resource is renewable or not and what impact its use might have on the environment, human health, and society.

Along the way, students examine the scientific concepts of energy sources, forms, transformations, efficiency, and heat transfer (conduction, convection, and radiation). Students experiment with electric generators powered by wind, water, and light; they also conduct tests heating model buildings with different types of insulation (thermal and radiant barriers) and sealing leaks.

By applying system concepts of goals, inputs, processes, outputs, and feedback, students propose energy improvements at home and compose an action plan at school that could, if implemented, reduce the unwanted side effects of the school’s current energy use.

For instructors, this unit includes information on energy use in Pennsylvania and the scientific concepts and technological devices covered in the unit. It also includes construction guides for instructors to develop classroom experiments and energy demonstrations. Assessment rubrics and expected student responses to worksheet and classroom activities are supplied in each chapter.

## Unit Organization

The unit is organized into teacher background information, student energy cards, and five activity chapters. Chapter 1 sets the foundation and should be run prior to activities in the following chapters. Chapters 2 through 4 address energy for transportation, electricity, and home heat and hot water, respectively. Chapter 5 provides a culminating student activity.

### Student Energy Cards

Included are thirty-five cards that, collectively, depict the processing, distribution, and use of energy for transportation, electricity, home heat, and hot water.

Each card is identified graphically as representing an energy goal, an energy resource, or an energy process and contains an informative graphic and written text on a specific energy topic.

Chapters 2 through 4 use the cards for specific activities and cards supply an information source for activities in Chapter 5. Cards can also be used for many suggested extension activities.

### Chapter 1: Energy Around Us

Students explore energy use in the classroom and are introduced to *Energy Thinking* and the *Energy Thinker's Diagram*—a systems approach to analyzing energy use that students will use in all subsequent chapters.

### Chapter 2: Energy to Go Chapter 3: Abracadabra, Electricity! Chapter 4: Warm and Cozy

Each of these chapters builds on the previous and each addresses different energy concepts. For instance, an understanding of energy use for transportation developed through activities in Chapter 2 helps students analyze impacts of transporting fuel to electrical power plants in Chapter 3. Students apply their understanding of electric power developed through activities in Chapter 3 to analyzing energy resources used for home heat and hot water in Chapter 4.

If there is a need to shorten the time spent on this unit, the teacher should select one or two of these three chapters to skip. The remaining chapter(s) will need minor modifications to insert information not covered due to skipping a previous chapter.

### Chapter 5: Energy Display and Action Plan

Students apply what they have learned when they create displays of energy use at their school that identify:

- goals of energy use
- energy resources used by the school
- transportation and processing of energy for use by the school
- wanted and unwanted results of energy use
- action plan to reduce unwanted results



## Chapter Organization

Chapters 3 and 4 both require an extra level of preparation the first year that chapter activities are run. In both cases, the instructor will need to construct classroom experiment and demonstration materials, such as mini-wind turbines or experimental model houses constructed from juice boxes.

Information on materials to purchase and construction instructions are included in the handout section at the back of each chapter.

Each chapter includes:

- an introduction
- overview
- objectives
- statement on standards met
- background reading for instructors on the chapter topic
- preparation instructions for the instructor
- running the activity
- assessment guidance
- activity construction information (needed in Chapters 3 and 4 for first year implantation)
- student handouts

## A Note on Units

For the convenience of the instructor, this unit uses English units to describe items that must be bought from stores that most likely still use English units—fabric stores that sell cloth by the yard and juice boxes that come in gallon and ounce sizes are two examples.

This unit uses English units in situations where students need to think about a quantity that is generally measured in the United States using English units—miles per gallon or inches of insulation are two examples—or where the common measuring tool sold in the U. S. uses English units, such as bi-therm thermometers\* that show degrees in Fahrenheit.

In all other cases, following standard scientific practice, this unit uses metric units.

- \* Cooking or meat thermometers, which are almost always in degrees Fahrenheit, are the most common and easy to find bi-therm thermometer.

## Unit Objectives

By the end of this unit students will be able to:

- ❖ analyze energy, its uses, and its effects on our environment and ecology *from a systems perspective* and recommend actions that can have a positive result on humans, the environment, and society
- ❖ apply knowledge of scientific concepts and technological innovations having to do with energy to this task

In order to succeed at these tasks, students will develop an ability to investigate energy through an understanding of:

- system concepts of goals, inputs, processes, outputs, and feedback
- environmental concepts of renewable vs. non renewable energy
- scientific concepts of energy sources, energy forms, energy transformations, energy efficiency, and heat transfer (conduction, convection, and radiation)
- technological innovations having to do with energy, which include generation of electricity through generators and photovoltaics, heat insulation, transportation of energy, and energy efficient technologies

To help you keep track of students' progress, each chapter includes an *Energy Thinking Assessment Sheet*. The content covered by each assessment sheet is cumulative, as students will have opportunities to improve on skills and knowledge that are introduced in each chapter throughout the unit.

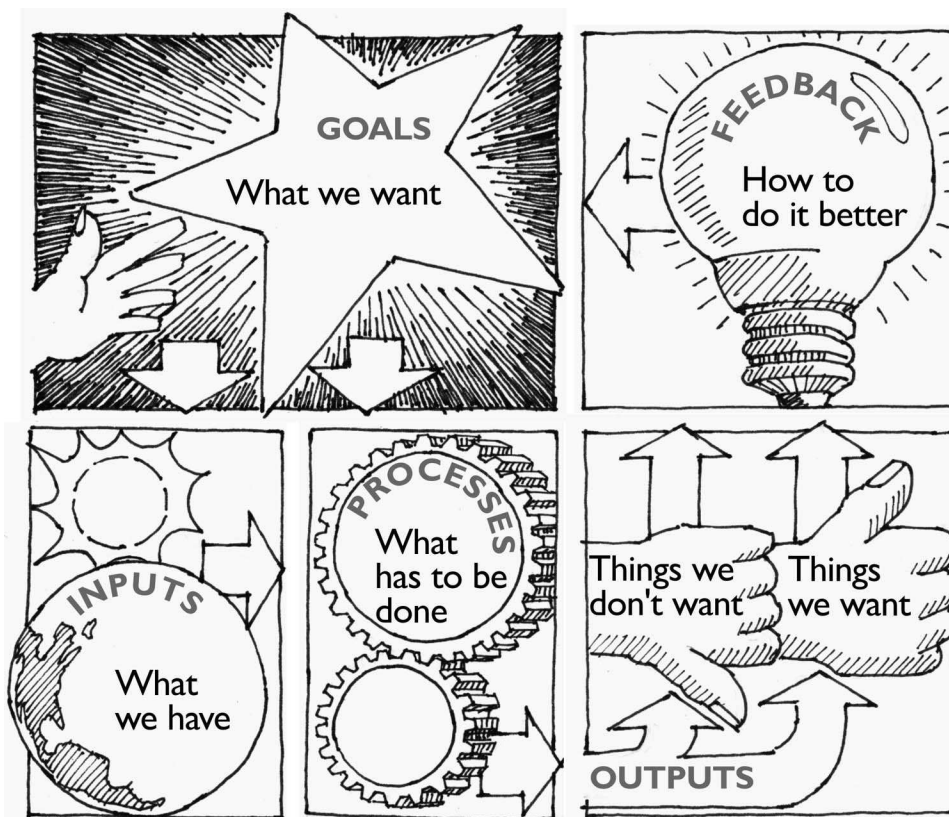
## Teacher Background Reading

We use energy and energy systems to provide us with much of what we need in life. Warm houses in the winter, a variety of foods year-round, lighting and the work of appliances at the flip of a switch are a few examples. Our lives would not be as comfortable, our food as plentiful, or our ability to get around as convenient without the energy systems that support our lifestyles. Yet every energy system also has negative consequences such as air and water pollution, visual impacts, or destruction of animal habitats.

The activities in this chapter will introduce students to (a) a system of thinking about the pros and cons of energy use on society and the environment, and (b) the science and technology of converting natural resources into useful energy and using energy efficiently.

### Energy, Society, and Environment

In this unit, students will use systems thinking to analyze where energy comes from, how it is processed into useful energy and transported, consequences of using energy, and how to reduce negative consequences of energy use. They will do this by viewing energy use as a system that is made up of Goals (what they want), Inputs (what resources are used), Processes (what has to be done), Outputs (positive and negative consequences of energy use), and Feedback (ideas for how the system can be improved).



**Goals:** The primary goal of any energy system is to provide for a human need, such as a house at a comfortable temperature, warm water, well-lit rooms, or moving people and things. Less obvious, but just as important goals are that the energy system be safe and low cost. Other goals may be that our energy systems be as pollution-free as possible, not contribute to global warming, and be independent of foreign-controlled resources, such as Middle East oil.

**Inputs:** The most basic input to an energy system is some natural resource that provides energy. Petroleum, coal, sunlight, wind, natural gas, moving water, wood, and radioactive materials are all examples. Other inputs include materials and energy needed to build such infrastructure as power plants, transmission lines, roads, furnaces, cars, or light bulbs; in short, everything needed to manufacture and maintain the energy system. For simplicity, however, this unit will restrict discussions of inputs solely to natural energy resources.

**Processes:** Converting a natural energy resource into a usable form of energy and transporting it to where it is needed are the most basic processes of an energy system. Converting crude oil into gasoline and gasoline into motion are two processes used in America’s most popular transportation system – getting around in the family car. Transporting crude oil to a refinery and gasoline to a gas station are also processes needed to make this system work.

**Outputs:** All energy systems provide people with something they want or we wouldn’t build them. But they also cause many things to happen that people don’t want. A warm house in the winter, warm water, and well-lit rooms are examples of wanted outputs. Pollution, depletion of resources, impacts on human health, and environmental degradation are examples of unwanted outputs.

**Feedback:** Feedback is thinking, “What would improve this energy system?” This type of question can lead to changing the energy system in ways that retain what you like and reduce what you don’t like about the system. Nearly all ideas on how to change an energy system affect the Input and Processes categories and fit into the following three groups.

- *Change the Energy Resource* (change of Input)
- *Use more Efficient Technologies* (change of Process)
- *Change Human Behavior* (change of Process)

For instance, you may ask, “How can we light our classroom without causing so much air pollution?” Responses may include (a) buy electricity produced by a clean, renewable energy resource, (b) upgrade the room lights to more efficient fixtures or (3) turn lights off when no one is in the room or when sunlight is available. Each of these would fit into one or more of the above groups.

## **Science and Technology of Energy**

In this unit students will learn to identify and explain forms of energy, sources of energy, energy conversions, energy efficiency, and how heat energy moves. It is necessary for students to grasp these concepts in order to best understand and analyze energy use.

### ***Energy***

Energy is the ability to do work or produce change. Another way of saying this is whenever a change has occurred energy was used to produce that change. Some examples include when something is heated or cooled, when something is moved, whenever light or sound are produced, when something grows or when something changes shape.

### ***Energy Forms***

Energy comes in many forms and can be converted from one form to another. Forms of energy include chemical, electrical, mechanical (motion), nuclear, radiant (light), and thermal (heat). Energy is often classified as kinetic (in motion) or potential (stored) energy.

## **Kinetic Energy**

**Electrical Energy** is the movement of electric charges. Electricity, which is the movement of electrons through a wire or other conductor, is an example of electrical energy. Lightning is another example.

**Mechanical Energy** is the movement of objects or matter. Throwing a ball, lifting a weight, pulling a wagon, and pedaling a bike are all examples of mechanical energy. Wind and moving water are also examples of mechanical energy. Sound, which is the movement of atoms and molecules in a wave, is another example of mechanical energy.

**Radiant or Light Energy** travels in electromagnetic waves. It includes visible light, which our eyes can see, but also includes, gamma rays, X-rays, ultraviolet radiation, infrared (heat) radiation, microwaves, and radio waves. Sunlight is an example of radiant energy.

**Thermal (heat) Energy** is the vibration and movement of atoms and molecules within a substance. The hotter a material is, the faster the atoms and molecules that make up that material are moving.

## **Potential Energy**

**Chemical Energy** is energy stored in the bonds that hold molecules together. Food, batteries, fossil fuels, and biomass (plants) are examples of items that have stored chemical energy.

**Stored Mechanical Energy** or **Elastic Energy** is energy stored in objects that are either compressed or stretched. Stretched rubber bands or compressed springs are examples of stored mechanical energy.

**Nuclear Energy** is the energy that holds the nucleus of an atom together. This energy is released when nuclei are combined, which is called fusion, or split apart, which is called fission. Nuclear power plants split atoms (fission) to release energy. The sun releases energy when it combines hydrogen atoms to form a helium atom (fusion).

**Potential Energy** or **Gravitational Energy** is the energy of position. An object has potential energy when it is in a position to be acted upon by gravity. Water stored behind a dam is an example of potential energy. A book teetering on a bookshelf is another example.

## ***Energy Conversions***

The use of energy is largely the practice of changing energy from a less useful form to a more useful form. A car engine converts chemical energy (gasoline) into mechanical energy, which is used to move the car. Plants convert radiant energy (sunlight) into chemical energy, which they use to grow. Our bodies convert chemical energy (the plants and animals we eat) into mechanical energy. Solar-electric cells convert radiant energy (sunlight) into electricity. Although energy changes form, the total amount of energy never changes. Scientists state this as the Law of Conservation of Energy or the First Law of Thermodynamics: energy can neither be created nor destroyed; it can only be converted from one form to another. Unfortunately, each time energy changes form, not all of it is converted into useful forms of energy. Scientists call this the Second Law of Thermodynamics. A practical way to state this law is to say that energy can never be converted with 100% efficiency. Some energy will always be converted to a less useful form. Often, this less useful form is heat.

## ***Energy Efficiency***

We say something is energy efficient when it converts a relatively large amount of energy into useful energy. The function of a car engine is to convert chemical energy (gasoline) into mechanical energy, but

in doing so it converts a lot of the chemical energy into heat energy. Although we use some of that heat energy to warm the passenger space, most of it is dissipated into the atmosphere. The typical car only converts 10% to 20% of the chemical energy in gasoline into motion. This is not a very efficient use of the chemical energy in the gasoline, but it is the most practical way we have of propelling a car at this time.

A light bulb changes electrical energy into radiant (light) energy but it also changes some of that electrical energy into heat energy. Some types of bulbs are more energy efficient than others. A typical incandescent bulb converts 5% of the electrical energy into light and 95% into heat. Compact fluorescent light bulbs convert 20% of the electrical energy into light and 80% into heat—a fourfold improvement. Because of this, compact fluorescent bulbs don't need to use as much electrical energy to produce the same amount of light, so we call them energy efficient light bulbs. Light emitting diodes, or LEDs, convert even more of the electrical energy into light energy and produce less heat than compact fluorescent bulbs. Therefore, LEDs are more energy efficient than compact fluorescents.

Of course, a light bulb used to light an unused room converts all of the electrical energy into useless energy since an unused room has no need for light. It is like leaving the tap running in the kitchen sink when you are not there. Gas-electric hybrid cars use this strategy to reduce energy use when they are programmed to turn themselves off when the car is at a full stop.

Some hybrid cars make use of another strategy to increase energy efficiency; they don't throw useful energy away, at least, not as much. All cars convert stored energy into the energy of forward motion as they accelerate up to speed. In a regular car, using the brakes converts this useful energy of motion into heat and dissipates it into the atmosphere. Using the brake systems of many hybrid cars converts the energy of forward motion into electricity, which is then stored in batteries for later use.

### ***Heat Transfer***

People throw away a lot of useful energy when they let thermal energy leak rapidly out of buildings. Energy used to heat an indoor living space is wasted if it is allowed to dissipate easily to the outdoor environment. The easier that heat is transferred outside the building, the more energy will be needed to keep the building warm. Very often, this results in buildings using larger furnaces and using more fuel than would otherwise be needed.

Heat is transferred through three means: conduction, convection, and radiation. Understanding these three means of heat transfer enables us to analyze how well a building retains heat. (Or keeps heat from entering the building when it is being cooled.) For more detailed information on conduction, convection, and radiation, see the *Background* section of Chapter 4 (page 4.4).

### ***Energy Sources and Resources***

**Nonrenewable energy** resources cannot be replenished (made again) in a short period of time. Uranium and fossil fuels such as crude oil, natural gas, and coal are all nonrenewable energy resources. Fossil fuels take millions of years to form and there is a limited amount of uranium on earth.

On the other hand, a **renewable energy** resource is one that will never be exhausted. Solar, moving water (hydro-power), wind, geothermal, and biomass (plants or animals) are all examples of energy resources that will always be with us.

All of the above are examples of **natural resources** that humans can extract or use for energy. When we trace where each of these energy resources received its energy, we find the ultimate **sources of energy** for our planet to be the sun, gravity, and nuclear energy.

All of the above but uranium and geothermal derive the energy they hold from the sun. Fossil fuels were made from plants that stored solar energy while growing hundreds of millions of years ago. The energy in wind comes from forces that develop when different air masses are heated by the sun to different temperatures. Water that flows in rivers is lifted to higher elevations by evaporation and wind, which are powered by the sun.

The moving water in waves, which may some day be used to generate electricity, is powered by gravity. The heat in geothermal energy is also generated by gravity as high levels of pressure and friction are created due to the weight of the earth's crust.

