WindWise Education

Transforming the Energy of Wind into Powerful Minds

A Curriculum for Grades 6-12

windwise education

www.WindWiseEducation.org

NYSERDA

WindWise Education was developed with funding from the New York State Energy Research & Development Authority.

HOW IS ENERGY CONVERTED TO ELECTRICITY?

LESSON 1

KEY CONCEPT

Students will learn that energy conversion and transfer is an important part of electricity generation.

TIME REQUIRED

2 – 3 class periods

GRADES

6 – 8
9 – 12

SUBJECTS

Physical Science
Mathematics

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BACKGROUND

Energy exists in many forms and can be transformed from one form to another in a process called energy conversion. Energy is "lost" as heat during each energy conversion. Generally, fewer energy conversions mean less energy is "lost" and thus energy efficiency is increased.

OBJECTIVES

At the end of the lesson, students will

- Understand that energy can be converted from one form to another.
- Understand that when energy converts, some energy is "lost" as waste heat.
- Understand that the more conversions and transfers there are in the generation of electricity, the more opportunities there are for energy to be "lost" as waste heat

METHOD

Students will explore the important natural process of energy conversion through a combination of a demonstration and an activity involving cards. They will determine how many energy conversions are involved in making electricity from a variety of fuels and how they compare to each other in terms of efficiency.

MATERIALS

- ❑ 2 lamps, one with an incandescent bulb and the other with a compact fluorescent bulb (of equal brightness, measured in lumens)
- ❑ Calculator
- ❑ 1 card with image of a car *
- ❑ 1 card with image of gasoline *
- ❑ Cards with images of energy sources: coal, oil, natural gas, nuclear, solar, wind, wood, water (each student pair will need 2 energy source cards. Copy and cut the cards you need from the masters provided) *
- ❑ Cards with images of cell phones (2 cards per pair of students) *
- ❑ Blank 3x5 index cards (10 per student)
- ❑ Cards marked with the words “Waste Heat” (10 cards per student. Copy and cut the cards you need from the masters provided).*
- ❑ Marker pens (1 per student)
- ❑ Beans, pennies or other manipulatives
- ❑ Student Worksheets *

*included with this activity

ENERGY LOSSES

Every conversion or transfer results in a "loss" of energy, but the amount loast varies with the specific conversion or transfer.

GETTING READY

- Read about energy conversions and become familiar with the principles and the terms used.
- Have some examples of devices discussed and ready for illustration.
- Copy and cut out enough sets of energy source and cell phone cards for your class. Plan on each pair of students needing two energy source cards and two cell phone cards. Make a few extra in case they are needed.
- To represent waste heat you will need some manipulatives like beans, pennies, etc.
- This lesson has a number of building blocks that will be used in lessons 2, 6, 7 and 8. Allow enough time for this lesson and make sure that students understand the concepts before moving on.

ACTIVITY

Beginning Questions for Students:

- How many of you use at least five things that are powered by electricity each day? What are they?
- Where does energy come from? Can energy be created from nothing?

PART 1: TYPES OF ENERGY

Ask students to name some familiar forms of energy and record their answers on the board. Next, ask students to read the activity reading passage that introduces different forms of energy. Have the class (as a group) try to categorize the list on the board based upon the table of energy types in the reading passage. Talk with the class while categorizing in order to establish a common understanding of types of energy.

PART 2: ENERGY CONVERSION DEMONSTRATION

Step 1

Plug in two lamps, one with an incandescent bulb (IB) and the other with a compact fluorescent lamp (CFL). Make sure the bulbs have the same rating for brightness.

Ask why the bulbs glow and produce light.

Answer: Electricity supplying an IB heats up a thin metal wire, which glows and produces light. In a CFL the electricity heats up mercury gas, which also glows to produce light.

Step 2

Ask some or all of the students to come up and place their hands near (no touching!) each lamp and state what differences they can feel in temperature. Ask why the IB is hotter than the CFL?

Answer: Electricity supplying an IB heats up a thin metal wire, which converts the electricity into two types of radiant energy: visible light (the one we want) and infrared waves (heat, the one we don't want). The infrared waves (heat) are waste heat because we do not want the heat, just the light. Some people have joked that incandescent bulbs are great heaters that accidentally give off some light.

In a CFL bulb, the electricity is used to vaporize a mercury gas, which causes it to emit radiant energy (UV Waves). This energy reacts with a coating on the inside of the bulb, transforming the UV waves to visible light waves.

Even though the CFL has more energy conversions, an IB uses 3-5 times more energy than a CFL to create the same amount of light. All that extra energy was wasted—creating heat, a byproduct we do not need.

How well you convert one energy form into another is called conversion efficiency. The more efficient the conversion, the less energy is lost to waste. The Extension Activities in Lesson 1 and Lesson 2 explore these ideas in more detail.

Reiterate the two important points learned from this demonstration:

First, energy is converted from its original form of electricity to a new form light. Energy has this capacity and regularly changes from one form to another to cause "work" to occur, in this case the production of light.

Second, when energy converts from one form to another, there is always some energy lost. Usually the loss is to heat and in many energy conversions, the amount of heat produced is substantial. Have the students consider that a car gets very hot when it runs. This is waste heat from the chemical energy stored in gasoline as it is converted to the kinetic energy of motion of the car.

Feel the temperature difference between the incandescent and fluorescent bulbs.

PART 3: ENERGY TRANSFER & ENERGY CONVERSION CHAINS

Step 1
Make sure students understand the differences between energy transfer and energy conversion.

Use examples from the Reading Passage.

Energy Transfer Example—The energy of the main crankshaft of a car transfers to the tires, which make it move = Mechanical Energy to Mechanical Energy.

Energy Conversion Example—Coal is burned to heat water in a power station = Chemical energy (within the coal) to Thermal Energy (Infrared or Heat).

Step 2: Demonstrate a series of conversions

LEARNING ENERGY CHAINS

Learning to make energy chains is confusing for the first few times. We recommend that you do many practice examples on page 15, so the students build a library.

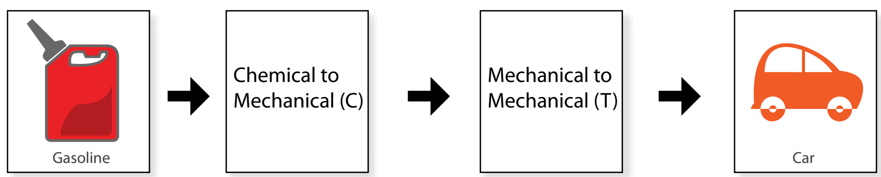
Help students understand that energy goes through a series of conversions before it can power a common item such as a cell phone or MP3 player. They will do this by demonstrating energy transfers and conversions using the gasoline and car cards. Place the gasoline card in the center of the table and the car card on the right. You can also do this on the board as an example.

Gas to Car Moving

To show the conversions involved between gasoline and the car, write the energy conversions needed on blank cards and add them to the chain.

- **Chemical Energy → Mechanical Energy**
  Chemical energy in the gasoline (fuel) is converted to mechanical energy as the piston is moved by combustion/explosion.

- **Mechanical Energy → Mechanical Energy (Energy Transfer)**
  Mechanical energy of the engine crankshaft is transferred to the axles and wheels through a variety of physical connections.

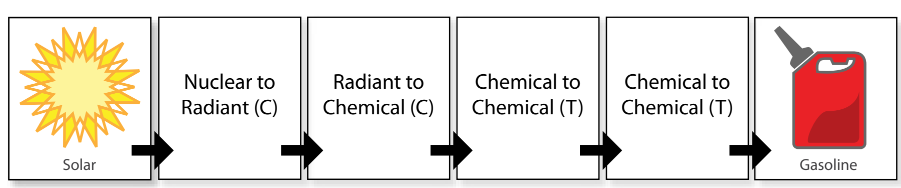


Production of Gasoline

Ask the students where the energy in the oil comes from. Since it is a type of fossil fuel (like coal and natural gas), the starting point is plants and animals buried millions of years ago and changed by heat and pressure.

A possible chain for some fossil fuels may be Sun → Gasoline

- **Nuclear Energy → Radiant Energy**
  Nuclear fusion on the sun being transformed to visible light waves
- **Radiant Energy → Chemical Energy**
  Visible light waves driving photosynthesis, which allows plants to produce sugar energy and grow larger
- **Chemical Energy → Chemical Energy (Energy Transfer)**
  Dead plants being compressed at high pressure and temperature for millions of years and turning into oil
- **Chemical Energy → Chemical Energy (Energy Transfer)**
  Oil being refined into gasoline



In addition to the conversions and transfers, a lot of energy is used to refine oil to gasoline and still more is used to transport the gasoline from refineries to gas stations.

Step 3: Waste Heat
When energy is converted from the sun into the motion of a car via the creation of gasoline, energy is lost at each step as waste heat in the same way as with the light bulb demonstration earlier. You can symbolize this by simply adding the words "Waste Heat" at each point in the chain where a conversion or transfer occurs.

Using the cards: Add waste heat cards above each conversion.

On your illustration on the blackboard, write in "Waste Heat" above each conversion.

Additional Practice
There are many other examples you can do with students on the handout sheets (page 15). Some of these are energy transfers and others are energy conversions. It is a good idea to walk students through a few examples so they understand a conversion versus transfer, as this is an important distinction.

After you have completed some transformations and conversions as a class, select a few from the sheet and write them on the board. The students can then attempt to complete these on their worksheets.

PART 4: POWERING A CELL PHONE

Step 1
Hand out two different energy source cards (coal, oil, natural gas, nuclear, solar, wind, wood or water) to each pair of students and two cards with an image of a cell phone. In addition, provide each pair of students with the following:

- Blank index cards to fill in the energy conversions and transfers
- The list of energy conversions they should use for this activity (on page 15)
- Beans (or other manipulatives) to act as waste heat

Using only their energy source cards, students should determine the chain of energy conversions and transfers needed to provide energy to the cell phones. Students will create chains showing how each energy source is used to create electricity and then how that electricity is used to run the cell phone. Since students are starting with different sources, these chains will be different.

Have students begin by placing the energy source card in the center of their desk and the cell phone card on the right. Students will then write the energy conversions and transfers needed on index cards and place them in line to show each conversion between the energy source and the cell phone.

They can use the list of energy conversions that were discussed previously to choose the appropriate conversions for each step. They may come up with other ideas.

RENEWABLE ENERGY

One common classification system for energy is to label energy either Renewable or Non-Renewable. These terms relate to how energy is used by human society rather than being fundamental to energy itself. Non-renewable energy is generally extracted from natural resources such as fossil fuels (coal, oil and natural gas), while renewable energy is taken from natural processes as they occur (solar energy, wind energy and hydroelectric power). When energy is released from coal to create electricity, the stock of coal is reduced; hence it is non-renewable. However, energy used from the wind to turn a turbine is not consumed in the same way. Wind energy production does not make the future less windy!

Have students add five waste heat manipulatives at each conversion point where heat may be generated.

Make sure students save these as they will use them in the next step.

Step 2: Recording & Discussion
Once students have built a chain, have them transcribe their chains onto their worksheets.

Have students present their chain to the class.

Class discussion

- How easy or hard was this activity? What parts were confusing or challenging?
- Do you think your chains capture all the conversions or transfers? Could there be some you missed?
- Do your energy chains show all the conversions required to create the fuel source?
- Which chains are the longest? Why?
- What do you think is more efficient, a long chain of conversions or a short chain? Why?
- Which forms of energy produce the least amount of waste in order to power the cell phone?
- Are there other factors involved besides the number of conversions that we need to consider as we decide which power sources are used to generate electricity?

PART 5: THERMODYNAMICS AND ENERGY MATH

Step 1: 1st & 2nd Laws of Thermodynamics – Energy Math
The First Law of Thermodynamics says that energy cannot be created or destroyed. You can change it to different forms through conversion or transfer.

The Second Law of Thermodynamics—or the Law of Increased Entropy— says that while *quantity* of energy remains the same (see First Law), the *quality* of energy deteriorates. As we convert or transform one form of energy to another, some of the usable energy is converted into unusable energy, which is “lost” to our use. This is the "waste heat."

For the purpose of this activity, assume that all energy conversions are 50% efficient (in reality, the amount of energy lost in conversions varies widely). In other words, only 50% of the usable energy in the original form is converted to the new form and 50% of the energy is lost as unusable heat.

Step 2
Demonstrate this energy “loss” by doing a simple demonstration.

Start with the Car Example

Sun to Car Moving

- 100 Beans 1. Nuclear Energy ➔ Radiant Energy
  Nuclear fusion in the sun creating solar energy

  100 x 0.50 = 50 (50% = 0.50)

- 50 Beans 2. Radiant Energy ➔ Chemical Energy
  Photosynthesis allowing plants to make sugar and grow

- 25 Beans 3. Chemical Energy ➔ Chemical Energy (Energy Transfer)
  Plants being compressed for millions of years and turning into oil

- 12 Beans 4. Chemical Energy ➔ Chemical Energy (Energy Transfer)
  Oil being refined into gasoline (Rounded down to create an even number)

- 6 Beans 5. Chemical Energy ➔ Mechanical Energy
  Gas combustion moving piston

- 3 Beans 6. Mechanical Energy ➔ Mechanical Energy (Energy Transfer)
  Piston moving crankshaft and axle and tires

Using this example, only 3% of the energy (3 beans of 100) coming from the sun is what is left to make the car move.

Step 2

Using the chains that they just completed in Part 4, have students calculate the amount of energy that is used to perform useful work in the cell phone. Start with 100 beans at the original energy source as in the car example. This could provide an estimate of the efficiency of the series of energy conversions that have to occur to make the cell phone work.

EXTENSIONS

Extension Activity 1: Conversion Efficiency

The efficiency of energy conversions can vary widely depending on the conversion. For example, electric heaters and hair dryers are around 100% efficient because they are designed so that the waste heat is the desired result of the conversion.

It is important to keep in mind that it is not always the number of conversions or transfers that can lead to energy being wasted or lost, it is also the efficiency of the conversion or transfer.

Looking at the efficiency chart (page 20), notice that some conversions that are very short (for example, Sun to Electricity) are also very inefficient. How would this compare to a long series of conversions from Coal (or other fossil fuel) to Electricity. Which one chain is most efficient? Try this for other energy sources: Wind to Electricity, Natural Gas to Electricity.

Extension Activity 2: Bulb Temperatures
Take two thermometers and use a clamp stand to hold it three inches away from each type of light bulb, being careful to make it as close to the same distance from each bulb as possible. Measure the difference in temperature between the two, as accurately as you can.

This difference will be proportional to the difference between the energy output of each bulb and represents the difference in efficiency between the two. Make sure you also measure the ambient temperature in the room while you are conducting the experiment.

See if this function is roughly correct.

$$\frac{\text{Temp IB} - \text{Ambient Temperature}}{\text{Temp CFL} - \text{Ambient Temperature}} = \frac{\text{Watts IB}}{\text{Watts CFL}}$$

Extension Activity 3: Campus Applicances
Assign students to research various appliances on campus to assess how efficient they are at converting energy. They can assess lighting, heating, cooling, and computer systems and perform an analysis of transportation, including school district vehicles and commuting vehicles.

VOCABULARY

Energy – The capacity for doing work; usable power (as heat or electricity); the resources for producing such power.

Energy Conversion or Transformation – The conversion of energy from one form to another. For example, when coal (chemical energy) is burned, it produces heat (thermal energy) that is then captured and used to turn a generator (mechanical energy), which transforms the energy into electricity (electrical energy).

Non-Renewable Energy – An energy source which is present in a limited quantity. At some point this energy resource will become scarce.

Renewable Energy – An energy source that is naturally replenished. Examples include biomass, wind, geothermal, hydro, and solar energy. See sidebar.

Thermodynamics – The study of the conversion of energy into work and heat and its relationship to variables such as temperature, volume and pressure.

Waste Heat – As energy is converted from one form to another, some energy is converted to heat and “lost” from the resulting form.

Work – In physics, mechanical work is the amount of energy transferred by a force acting through a distance. For example, the amount of an electric current travelling down a wire to a light bulb lighting the bulb is work.

NY STATE STANDARDS

Intermediate Level Science–Standard 1: Analysis, Inquiry, and Design

Students will use mathematical analysis, scientific inquiry, and engineering design, as appropriate, to pose questions, seek answers, and develop solutions.

Scientific Inquiry
Key Idea 1:

The central purpose of scientific inquiry is to develop explanations of natural phenomena in a continuing, creative process.

Major Understandings:

S1.3: Represent, present, and defend their proposed explanations of everyday observations so that they can be understood and assessed by others.

Intermediate Level Science–Standard 4: The Physical Setting

Students will understand and apply scientific concepts, principles, and theories pertaining to the physical setting and living environment and recognize the historical development of ideas in science.

Key Idea 4:

Energy exists in many forms, and when these forms change, energy is conserved.

Major Understandings:

4.1: Describe the sources and identify the transformations of energy observed in everyday life.

4.1a: The Sun is a major source of energy for Earth. Other sources of energy include nuclear and geothermal energy.

4.1b: Fossil fuels contain stored solar energy and are considered nonrenewable resources. They are a major source of energy in the United States. Solar energy, wind, moving water, and biomass are some examples of renewable energy resources.

4.1c: Most activities in everyday life involve one form of energy being transformed into another. For example, the chemical energy in gasoline is transformed into mechanical energy in an automobile engine. Energy, in the form of heat, is almost always one of the products of energy transformations.

4.1d: Different forms of energy include heat, light, electrical, mechanical, sound, nuclear, and chemical. Energy is transformed in many ways.

4.1e: Energy can be considered to be either kinetic energy, which is the energy of motion, or potential energy, which depends on relative position.

4.5: Describe situations that support the principle of conservation of energy.

4.5a: Energy cannot be created or destroyed, but only changed from one form into another.

4.5b: Energy can change from one form to another, although in the process some energy is always converted to heat. Some systems transform energy with less loss of heat than others.


Waste Heat


Waste Heat


Waste Heat


Waste Heat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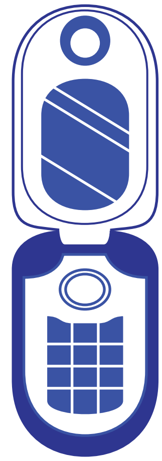
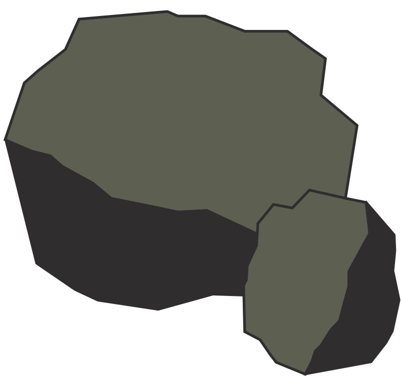
Waste Heat

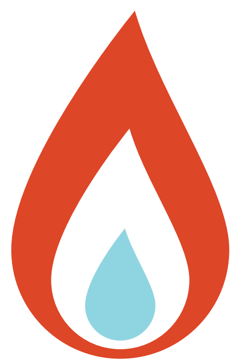
Car



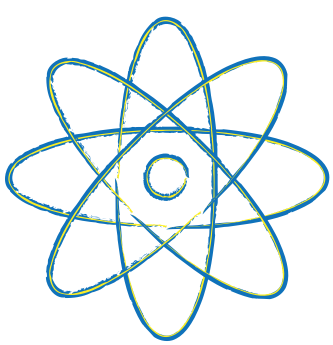
Cell Phone



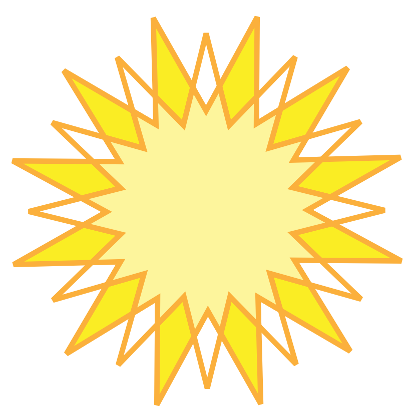
Coal



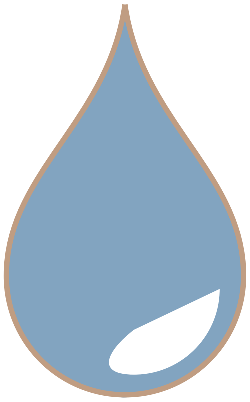
Natural Gas



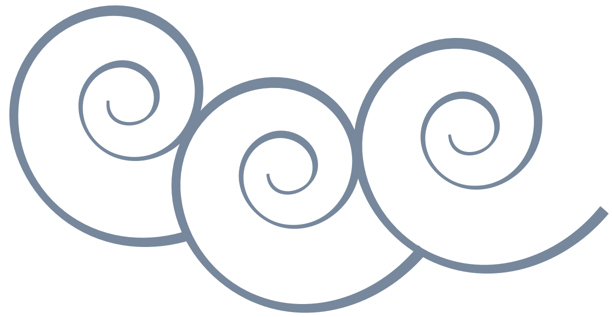
Nuclear



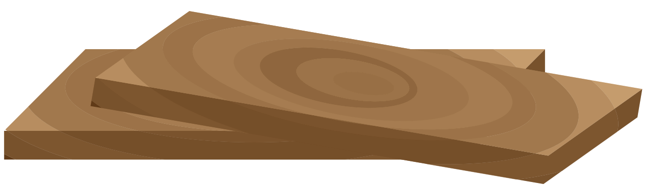
Solar



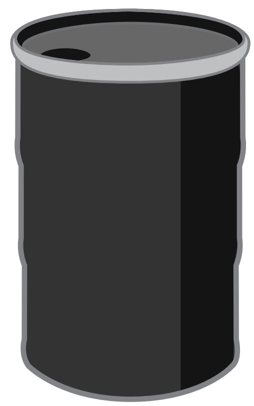
Water



Wind



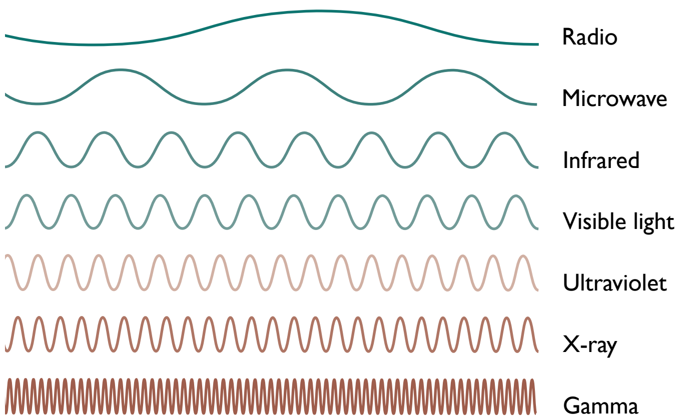
Wood



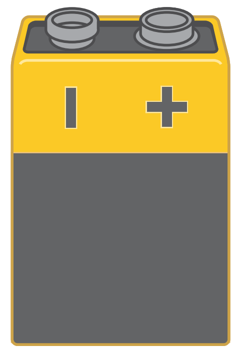
Oil

Gasoline

Electricity



Electromagnetic Waves



Stored

EXAMPLE ENERGY TRANSFERS AND CONVERSIONS

As students do these on the worksheets, they will be part of an energy chain library that students can use to complete their cell phone energy diagrams.

Fuel in a power plant creating moving steam
Chemical Energy (coal) ➔ Radiant Energy (infrared waves) ➔ Thermal Energy (water heating making steam) ➔ Mechanical Energy (steam moving)

Moving steam creating electricity
Mechanical Energy (steam moving) ➔ Mechanical Energy (generator shaft spinning) ➔ Electricity Energy (magnets and wires—induction)

That electrical part sounds magical—see Lesson 7 for more on how a generator actually works!

Sun heating the ground then heating the air, making wind
Nuclear Energy (fusion) ➔ Radiant Energy (infrared waves) ➔ Thermal (ground getting warm) ➔ Radiant Energy (ground releasing infrared waves to air) ➔ Thermal Energy (air heating) ➔ Mechanical Energy (air rising and moving around the planet)

Sun to being warm
Nuclear Energy (fusion) ➔ Radiant Energy (infrared waves) ➔ Thermal Energy (skin warming)

Sun to you walking down the street
Nuclear Energy (fusion) ➔ Radiant Energy (visible light waves) ➔ Chemical Energy (photosynthesis in plants) ➔ Chemical Energy (transform plant food to energy) ➔ Mechanical Energy (muscles moving and you walking)

Sun to electricity (photovoltaic)
Nuclear Energy (fusion) ➔ Radiant Energy (visible and UV waves) ➔ Electrical Energy (via solar panel magic)

Is there another way to get electricity from the sun? Sure!

Sun to electricity (biomass)
Nuclear Energy (fusion) ➔ Radiant Energy (visible light waves) ➔ Chemical Energy (photosynthesis in plants) ➔ Chemical Energy (plant matter being burned) ➔ Radiant Energy (water heating making steam) ➔ Mechanical Energy (steam moving) ➔ Mechanical Energy (generator spinning) ➔ Electrical Energy

Sun to plants growing
Nuclear Energy (fusion) ➔ Radiant Energy (visible light waves) ➔ Chemical Energy (photosynthesis—light waves to sugar)

Rechargeable battery being charged and then running a portable game system
Electrical Energy (from the wall socket) ➔ Chemical Energy (chemistry of the battery stores electricity) ➔ Electrical Energy (Chemical reaction converted to electricity)

Electricity making a speaker in a phone work
Chemical Energy (phone battery) ➔ Electrical Energy ➔ Sound Energy

Electricity lighting the phone screen
Chemical Energy (battery) ➔ Electrical Energy ➔ Radiant Energy (light on phone screen)

Fire keeping you warm
Chemical Energy (stored in wood) ➔ Radiant Energy (infrared waves) ➔ Thermal Energy (skin warming)

There are many, many more. Once you get the hang of it you can see the transfers and conversions taking place all around you. See if your students can come with their own.

READING PASSAGE

Work done by animals and machines requires a quantity of energy. Energy is around us all the time in many forms. Energy is the ability to perform work. Work is a force than can cause an object to move.

For an animal or machine to do something that requires energy, the energy must be changed from one form to another during the process of work. This happens all the time and is called an energy conversion or energy transfer. When energy is changed from one form to another, it is called energy conversion (eg. potential energy to kinetic energy—water behind a dam to flowing water) but when it changes to the same form it is called an energy transfer (eg. chemical energy to chemical energy—energy stored in fat is transferred to energy in sugar so it can be used).

Your body is capable of converting energy from one form to another. For example, if you eat a hamburger and then play Frisbee, all the movements that it takes to catch and throw a Frisbee require you to convert the energy in the hamburger into the energy to make your muscles move. After a while, you will get tired because you have converted all the energy that was made available to you by the hamburger. You need to refuel by eating more food or burning some of the energy stored in your body as fat.

The energy of the hamburger can only be converted once from its original form. Once the body has transformed the energy in the hamburger, the rest is excreted as waste. You constantly need a source of energy in a form that your body can use.

The First Law of Thermodynamics, loosely interpreted, states that energy can neither be created nor destroyed; it changes from one form to another. During a conversion or transfer, some of the available energy is used to cause work to happen, and in the process the energy changes to a different form.

Table 1. Forms of energy

POTENTIAL ENERGY **Stored Energy or Energy of Position**	**KINETIC ENERGY** **Energy of Motion**
Chemical – Energy stored in chemical bonds. Some examples are coal, natural gas, petroleum.	**Radiant** – Energy that travels in electromagnetic waves such as x-rays, UV waves, visible light waves, radio waves, infrared (heat) waves.
Nuclear – Energy in the nucleus of an atom. Extraction through fission (splitting atoms) or through fusion (fusing atoms).	**Mechanical** – Movement of things or objects from one place to another. Wind is a movement of air molecules.
Stored – Energy in a mechanical item such as a spring that is compressed or rubber band that has been stretched.	**Electrical** – Movement of electrons such as in lightening or electrons in electrical wires.
Energy of Position or Gravitational Energy Things that have mass and have height above the surface of the Earth have stored energy due to gravity. Water above a dam or a rock held above your head has stored gravitational energy.	**Thermal** – Internal energy of vibrating molecules. Temperature is a measure of this internal energy. The faster molecules within a substance vibrate, the higher the temperature
	Sound – Movement of energy through objects.

Wind blowing through the blades of a wind turbine causes the blades to rotate due to the orientation and shape of the blade. The blades are attached to a driveshaft, which will also rotate. The energy transfer from the wind to the turbine is kinetic energy.

The spinning driveshaft causes magnets to rotate in the generator, which are situated near copper coils. This arrangement converts the kinetic energy of the shaft into electrical energy that then travels along power lines to your home or school.

If you toast a piece of bread in your toaster, you have converted the energy one more time from electrical energy to thermal energy, which, after you have eaten the toast, will be converted to mechanical energy when you throw a Frisbee.

The energy conversions and transfers involved are shown in the chain below.

Mechanical Energy (wind blowing) ➔ Mechanical Energy (blades rotating) ➔ Mechanical Energy (driveshaft rotating) ➔ Electrical Energy (magnets and wires in generator) ➔ travels down wires ➔ Thermal Energy (heating toaster element) ➔ Chemical Energy (converting toast to sugar for the body to use) ➔ Mechanical Energy (body converting sugar to muscles moving)

When energy changes form, not all the energy present at the beginning of the process is converted into the product at the end of the process. What happens to it? Some energy is "lost."

But wait—energy cannot be *lost*! Recall that energy can neither be created nor destroyed, so how can energy be lost? The only way, according to the First Law, is that some must be converted to another form.

When the blades of a wind turbine rotate in the wind, only about 40-50% of the available kinetic energy in the wind is converted to rotation of the blades due the following factors:

- Wind must flow through the device for it to work properly. All the wind's energy cannot be used by the turbine. A famous physicist named Alfred Betz determined that the most perfect turbine in the world could only convert 59% of the energy in the wind to usable energy.
- Imperfection in the design of the blades.
- Friction caused by the moving parts of the wind turbine as they spin and rub against each other.

Friction creates heat, which is a form of thermal energy. Heat energy is the most common form of energy loss during an energy conversion. You have felt waste heat before. Playing Frisbee makes you hot and sweaty—that is the heat energy wasted when your body converts calories from your food to motion of your body. Other examples include car engines heat up when they are running and light bulbs give off heat when they are emitting light.

Energy being lost or wasted during energy conversions is so universal that it is described in the Second Law of Thermodynamics. This law is complicated, but can be simply stated like this: while the quantity of energy remains the same, the quality of energy deteriorates over time. Another way to think of it, is that as we convert or transform one form of energy to another some of the usable energy is converted into unusable energy that is "lost" to our use.

This Second Law has frustrated human engineers throughout history. The word "efficiency"—how much of the energy available to a machine can be converted to useful work—is tied to this frustration.

Many of the machines that you use every day are less than 20% efficient (i.e., they convert less than 20% of the energy available to them into useful work).

One of the biggest challenges facing engineers of energy conversion devices is to try to overcome the Second Law and come up with more efficient machines.

Will you be the person to solve this challenge?

Name______________________________________ Date________________ Class_________

PART 1: TYPES OF ENERGY

1. Write down some forms of energy.

2. Classify the forms of energy you have written down into one of the categories discussed in the reading passage. If you are not sure how to classify them, take a guess.

PART 2: ENERGY CONVERSION DEMONSTRATION

For this part of the lesson you will need your Forms of Energy Table in the reading passage.

1. Which lamp is the hottest?

2. Which lamp is more efficient at converting electricity to light? What is your evidence?

3. What is waste heat? Provide some examples.

4. Calculate the improvement in efficiency for a CFL over an IB by dividing the watts for the IB by the watts for the CFL.

$\frac{IB}{CFL}$ = _________ times more efficient

PART 3: ENERGY TRANSFER & ENERGY CONVERSION CHAINS

For this part of the lesson you will need your Forms of Energy Table in the reading passage.

1. Write down the Energy Chain that converts the energy in gasoline to a car moving.

2. Write down the Energy Chain that converts the energy from the sun to gasoline.

3. Your teacher has written a few common energy conversions on the board. Complete Energy Chains for at least three of them. If you have more time you can do more!

Name______________________________________ Date________________ Class_________

PART 4: POWERING A CELL PHONE

Your teacher has provided two energy sources and a cell phone. Using the index cards, create energy chains from each source to power the cell phone.

After you have used the index cards to create your energy chains, draw them here. Be sure to include the energy chain used to power the phone and the chain that shows where the fuel originated.

Answer the following questions:

1. How many conversions or transfers did each chain have? How many forms?

2. Which one created more waste heat?

3. Do you have all the conversions or transfers accounted for? Are there any additional "hidden" ones?

4. Do you think that all conversions/transfers have the same efficiency? What factors might cause them to be different? Can you list one or two?

PART 5: ENERGY MATH

1. If you started with 100 units for each of your energy chains, how many did you have left at the end once your phone was powered?

2. What percentage of energy was left to power the phone?

3. Which of your chains seems most efficient?

For more realistic conversion percentages see the table for Extension 1.

EXTENSION 1

Table 1. Efficiencies of some common energy conversion devices

ENERGY CONVERSION DEVICE	TYPICAL EFFICIENCY %
Electric heater	100
Hair dryer	100
Electricity to heat (Kitchen Range)	80
Electric generator	95
Wind generator	30
Hydroelectric generator	21
Electric motor (large)	90
Battery	90
Steam boiler (power plant)	85
Steam turbine	45
Home gas furnace	85
Home oil furnace	65
Electric motor (small)	65
Automobile engine	25
Incandescent bulb	5
Natural gas to electricity	33
Natural gas to heat	40
Natural gas to hot water	60
Natural gas to electricity (fuel cell)	90
Steam boiler (power plant)	85
Gasoline to mechanical energy (car)	22
Diesel to mechanical energy (car)	35
Hydrogen to electricity (fuel cell)	50
Sun to electricity	15
Sun to heat	40

1. What are some very efficient conversions?

2. What are some very inefficient conversions?

3. Solar to electricity is only 15% efficient, but natural gas to electricity is 33% efficient, which one is better? What does this type of comparison leave out?

EXTENSION 2

If you or your teacher measured the difference in temperature between the IB and CFL, calculate whether the difference in temperature (caused by waste heat) is about the same as the efficiency difference you just calculated.

See if this function is roughly correct:

$$\frac{\text{Temp IB} - \text{Ambient Temperature}}{\text{Temp CFL} - \text{Ambient Temperature}} = \frac{\text{Watts IB}}{\text{Watts CFL}}$$

PART 1: TYPES OF ENERGY

1. Write down some forms of energy.
   Student Observations

2. Classify the forms of energy you have written down into one of the categories discussed in the reading passage. If you are not sure how to classify them, take a guess.
   Student Observations

PART 2: ENERGY CONVERSION DEMONSTRATION

For this part of the lesson you will need your Forms of Energy Table in the reading passage.

1. Which lamp is the hottest?
   Student Observations

2. Which lamp is more efficient at converting electricity to light? What is your evidence?
   The CFL is more efficient. It takes less energy to activate the mercury gas inside the bulb than it does to heat the wire in an IB. The IB gets hotter because more of the energy is released as heat representing waste.

3. What is waste heat? Provide some examples.
   Waste heat represents energy that is released during an energy conversion or transfer and is energy that is released that has not done any work.

4. Calculate the improvement in efficiency for a CFL over an IB by dividing the watts for the IB by the watts for the CFL.
   Answer depends upon the bulbs used.

PART 3: ENERGY TRANSFER & ENERGY CONVERSION CHAINS

For this part of the lesson you will need your Forms of Energy Table in the reading passage.

1. Write down the Energy Chain that converts the energy in gasoline to a car moving.

2. Write down the Energy Chain that converts the energy from the sun to gasoline.

3. Your teacher has written a few common energy conversions on the board. Complete Energy Chains for at least three of them. If you have more time you can do more!
   Student draw chains copied from the board here.

PART 4: POWERING A CELL PHONE

Your teacher has provided two energy sources and a cell phone. Using the index card, create energy chains from each source to power the cell phone.

After you have used the index cards to create your energy chains, draw them here. Be sure to include the energy chain used to power the phone and the chain that shows where the fuel originated.

Students draw the chains they developed here.

Answer the following questions:

1. How many conversions or transfers did each chain have? How many forms?
   Student Observations

2. Which one created more waste heat?
   Student Observations

3. Do you have all the conversions or transfers accounted for? Are there any additional "hidden" ones?
   Student Observations

4. Do you think that all conversions/transfers have the same efficiency? What factors might cause them to be different? Can you list one or two?
   Some examples of observations:
   Appliances that generate heat have no “waste” in their conversion
   Wherever friction is involved, it will reduce the efficiency of conversion

PART 5: ENERGY MATH

1. If you started with 100 units for each of your energy chains, how many did you have left at the end once your phone was powered?
   Student observations – 100 x (0.5)n where n = the number of conversions

2. What percentage of energy was left to power the phone?
   Student observations – the number of beans at the end expressed directly as a percentage

3. Which of your chains seems most efficient?
   Student observations – the one with the highest percentage of the original energy left = the one with the fewest number of conversions

For more realistic conversion percentages see the table for Extension 1.

EXTENSION 1

1. What are some very efficient conversions?

   Student Observations

2. What are some very inefficient conversions?

   Student Observations

3. Solar to electricity is only 15% efficient, but natural gas to electricity is 33% efficient, which one is better? What does this type of comparison leave out?

   Student observations.

EXTENSION 2

If you or your teacher measured the difference in temperature between the IB and CFL, calculate whether the difference in temperature (caused by waste heat) is about the same as the efficiency difference you just calculated.

See if this function is roughly correct:

$$\frac{\text{Temp IB} - \text{Ambient Temperature}}{\text{Temp CFL} - \text{Ambient Temperature}} = \frac{\text{Watts IB}}{\text{Watts CFL}}$$

This ratio should be roughly equal. It will be unlikely to be exact given the limitations on inaccuracy of how the temperature was measured.