SYSTEMS & SCALE
HIGH SCHOOL

STUDENT PAGES
(Embedded Assessments)

Environmental Literacy Project

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Embedded Assessments

Please make copies of these student worksheets for your focus students and mail to the environmental literacy project.

- *Zooming In and Out*
- *Applying Powers of 10*
- *What is Air?*
- *Building Air Molecules*
- *How Can Machines Work?*
- *Burning Materials*
- *Does Burning Release Energy*
- *Energy-Rich Materials*

ACTIVITY 1. POWERS OF TEN

Name: ______________________________________ Hour: __________

Zooming In and Out

When thinking about different scales we can generally group systems and parts of systems into one of four groups: 1) atomic-molecular (things we cannot see even with a light microscope), 2) microscopic/cellular (we cannot see with our eyes, but can use a microscope to see), 3) macroscopic (things we can see with our eyes), and 4) large-scale (things that are too large to see with our eyes).

The following is a list of systems included in the Powers of Ten video. Try to sort these systems into one of the four categories described above.

Universe	Man or Woman	Cell Nucleus	United States
Hand	Earth	Lake Michigan	DNA molecule
Skin	Carbon Atom	Picnic Blanket	Galaxy
Capillaries	Skin Cell	Quarks	Chicago
City Park	White Blood Cell	Solar System	

1. What systems would you see at the atomic/molecular level?

2. What systems would you see at the microscopic or cellular level?

3. What systems would you see at the macroscopic level?

4. What systems would you see at the large-scale level?

5. Are there any systems that you are unsure about?

You will watch the Powers of Ten video again. However, this time your teacher will pause the video at each scale, and you will need to think about what appears and disappears when you zoom in or out. You will need to complete the table below, and as you watch the video again, think about the size of different systems and if they match the groups you made on the first page.

What You See When You Zoom In	Starting Point: What You See	What You See When You Zoom Out
	City Park	
	Chicago	
	United States	
	Solar System	
	Galaxy	
	Hand	
	Skin	
	Capillaries	
	DNA molecule	
	Carbon Atom	

After watching the video again, is there anything you would change from your groups on the first page?

ACTIVITY 3. USING POWERS OF TEN (OPTIONAL)

Name: ____ Hour: ____________

Applying Powers of 10

Now practice using the Powers of 10 to compare the sizes of two different systems.

Practice Question:

1. How much larger is the width of a human hand compared to an average particle of sand?

2. How much larger is an average particle of sand compared to an oxygen molecule (O_2)?

3. How much smaller is the smallest virus from the largest bacteria?

4. How much larger is the biggest piece of sand compared to the smallest piece of sand?

5. How much larger is a mosquito compared to a carbon dioxide molecule (CO_2)?

6. How much smaller is the smallest plant cell compared to a hand?

7. Try to think of two more comparisons using the Powers of 10 chart

   Comparison 1:

   Comparison 2:

ACTIVITY 4. WHAT IS AIR?

Name: ____ Hour: _________

What is Air?

We speak of air as light, "airy," or even as nothing. But what is air made of? Today you will learn more about the different molecules that make up air and have a chance to build these molecules using models.

Air is made of several gas molecules. The composition of air in the atmosphere changes slightly from moment to moment and place to place, but approximately 78% is nitrogen (N_2), 21 % is oxygen (O_2), 1% is argon (Ar), and .03% is carbon dioxide (CO_2). There are other trace gases in air, such as hydrogen, helium, and neon. Water vapor (H_2O) is also a gas found in air. Water vapor ranges between 0-3% depending on the temperature and humidity.

There are other substances in air, including dirt, germs, bacteria, smoke, and many others. Most substances that you can see in the air, like dust or smoke, are made of solid particles that contain *trillions of molecules* each (Remember the Powers of 10 chart!). These things are not air.

1. At the macroscopic level, how can you describe air? What things can we see and feel?

2. At the atomic-molecular level, how can you describe air?

3. Can you think of large-scale ways to describe air and how it is used and influenced by living organisms?

4. Can you think of microscopic things that may be found in air?

ACTIVITY 4. WHAT IS AIR?

Name: ____ Hour: _____________

Building Air Molecules

Your group will build the gas molecules that make up air and several important molecules for life. In order to do this, you will need to obtain a molecular model kit from your teacher. Before your group begins to build the molecules, you will need to know more about how to "bond" the molecules together.

Part I: Molecular Structure

Molecules are made of **atoms** bonded together. Today you will build several of the molecules in air and look at how the bonds hold the atoms together.

Single Bonds:

When two atoms share ONE pair of electrons, it is called a single bond. In water, for example, there are two single bonds.

Double and Triple Bonds:

When a pair of atoms share more than one set of electrons, these are called double or triple bonds, depending on the number of electron pairs. Oxygen and carbon dioxide molecules have double bonds.

Part II: Building Your Molecules

Familiarize yourself with the modeling kit. Open the bag/box and sort the pieces into similar piles. The round wooden pieces with holes in them represent various types of atoms. Each color represents a different element. To build your models you will need to use a color code to represent each type of atom:

Hydrogen- white

Oxygen- red

Carbon- black

Nitrogen- orange

The gray springs represent bonds. When you build molecules correctly, there should be no “empty” holes or bonding points.

Examine one of the hydrogen atoms. How many holes/bond points does it have?

______

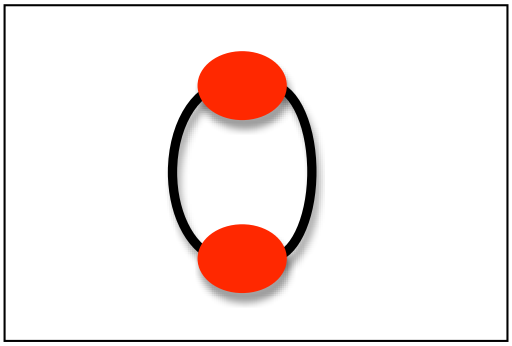
How many holes (bonding points) are in the carbon atoms? _______

How many holes (bonding points) are in the oxygen atoms? _______

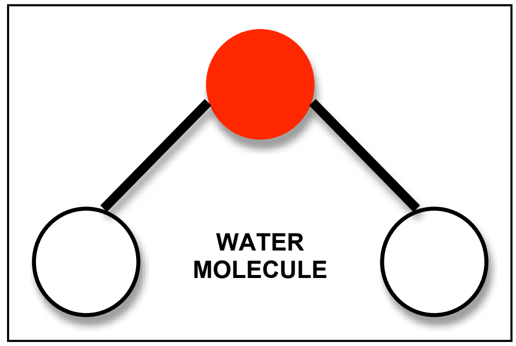
How many holed (bonding points) are in the nitrogen atoms? _______

Build and diagram the following molecules:

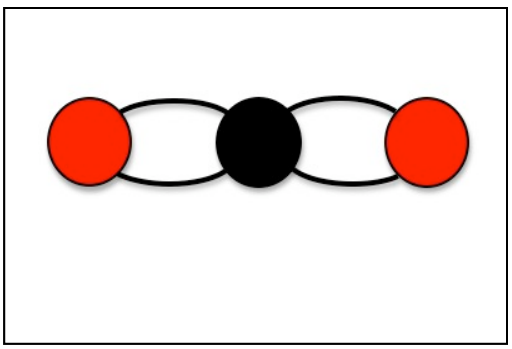
Oxygen (O_2)



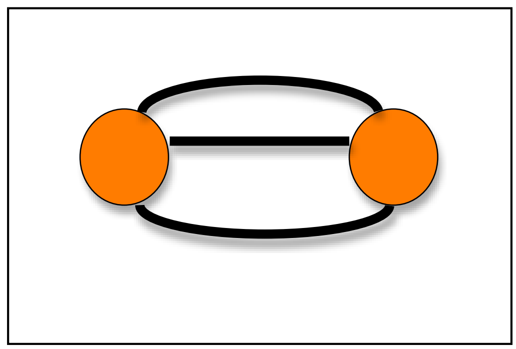
Water Vapor (H_2O)



Carbon Dioxide (CO_2)



Nitrogen (N_2)



1. Look at your carbon dioxide molecule. Which atoms are bonded to each other in this molecule?

2. Look at your water molecule. Which atoms are bonded to each other in this molecule?

3. Are air molecules matter? Why or why not?

ACTIVITY 5 ENERGY AND MACHINES

Name:____ Date:___________

How can machines work?

In this activity, you will use the *Process Tool* to analyze energy transformation in various events. The incoming wavy arrow represents the energy input to the machines. The outgoing wavy arrow represents the energy output from the machines. Please note that the process tool follows the two principles of energy:

- Energy conservation – Energy can transform from one energy form to other energy forms, but the total amount of energy conserves. (Energy cannot be converted into or from matter.)
- Energy degradation – Whenever energy transforms, heat is always released.

1. **Radiometer:** The radiometer is a light-bulb shaped device with a small weather vane in the middle of it. Place the radiometer under a lamp or sunlight and observe what happens when the light shines on it. Think about what happens inside the radiometer. Please use the process tool to analyze how energy transforms. Fill out the energy input and energy output in the table below.

	Energy Input	**Energy Output**
Radiometer spinning		

2. **Solar Car #1**: The solar car has a switch at the bottom. It can either run on battery or use solar cells. Put the switch on “solar”. Observe what happens when the car runs on solar cells. Please use the Energy Process Tool to analyze how energy transforms. Fill out the energy input and energy output in the table below.

	Energy Input	Energy Output
Toy car running on solar cells		

3. **Solar car #2**: Put the switch on “battery”. Observe what happens when the car uses the battery. What is the energy input? What is the energy output? Please use the process tool to analyze how energy transforms. Fill out the energy input and energy output in the table below.

	Energy Input	Energy Output
Toy car running on batteries		

4. **The Flashlight**: In order to make the flashlight work, you will need to squeeze the handle back-and-forth. Observe what happens when you squeeze and release the handle. What is the energy input? What is the energy output? Please use the process tool to analyze how energy transforms. Fill out the energy input and energy output in the table below.

	Energy Input	Energy Output
Toy car running on solar cells		

5. The four events are all about energy transformation. What patterns do you find in the processes of energy transformation?

____

____

____

____

ACTIVITY 6. WHAT HAPPENS WHEN FUELS BURN?

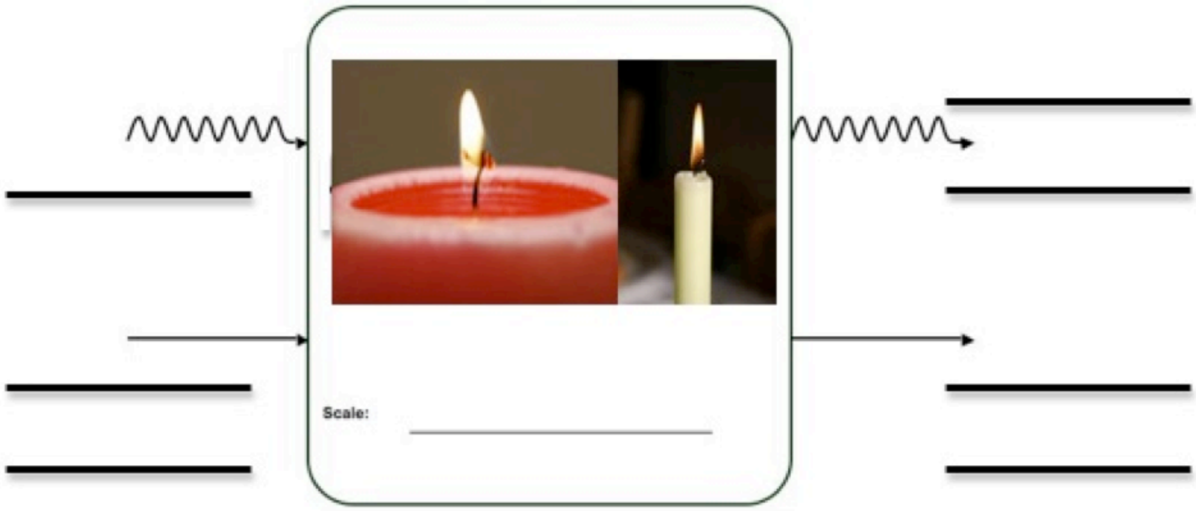
Name: ____ Date: _________________

Burning a Candle

Record your observations of the candle in the table below.

What happens to materials as the candle burns?	**What happens to the energy as the candle burns?**
1. What does the flame need in order to keep burning? ***2. What happens to the weight of the wax and wick of the candle?*** ***3. What is produced when the flame burns?***	***1. What form of energy do you identify before the candle burns?*** ***2. What forms of energy is released when the candle burns?***

Fill out the matter and energy inputs and outputs in the blanks below.



1. When you use digital scale to measure the weight of the candle, what did find? Does it lose weight? If yes, where do the lost materials go?

____

____

2. Wood and wax can burn, but water, sand, and stone cannot burn. Some materials are called fuels. Fuels can burn, which means energy must come from fuels. What type of energy do fuels have?

____

____

____

3. How does the energy change as the fuel burns?

____

____

____

ACTIVITY 6. WHAT HAPPENS WHEN FUELS BURN?

Name: ____ Hour: ________

Burning Materials

1. Please record your observations.

	Reactants of Combustion		Products of Combustion	
	What is the substance that is burning?	Invert the beaker over the flame. What do you observe? What substance is required to keep the flame burning?	Put a cold glass (beaker) over the flame, what do you observe? What substance is released?	There is another product of burning. Do you know what it is?
Burning methane				
Burning butane				
Burning propane				
Burning ethanol				

2. You have observed burning different types of fuels. You have also gained some information about different substances involved in burning. What are the patterns?

3. What are the forms of energy involved in these events of burning different materials? What are the evidences of different forms of energy?

Part 2. Explain Combustion by the Process Tool

1. How does matter transform in burning? How does energy transform in burning? Please use the process tool to analyze and then explain how matter and energy transform in the table below.

	Process	Scale	Energy Input	Energy Output	Matter Input	Matter Output
Burning Methane						
Burning Butane						
Burning Propane						
Burning Ethanol						

2. Inside a car engine, the gasoline burns in order to provide energy for the car to run.

What does the car need in order to run? Please use the process tool to analyze and then explain how matter and energy transform as gasoline burns inside the engine in the table below.

	Process	Scale	Energy Input	Energy Output	Matter Input	Matter Output
Car Running						

3. When the car is running, where does the motion energy come from?

4. When the car runs out of gasoline and stops, where has the matter of the gasoline gone?

5. When the car runs out of gasoline and stops, where has the **ENERGY** of the gasoline gone? Please note that when the car stops running, there is no motion energy.

6. Why do people use gasoline instead of water to run their cars?

7. Is it possible that all the energy of gasoline can be transformed into the energy of car running? Why?

ACTIVITY 7. DOES BURNING RELEASE ENERGY: MODELING COMBUSTION

Name:____ Hour: ______________

Questions

Part 1. Why Can Fuels Burn? – Molecules of Fuels

1. Read the article *Part 1. Why Can Fuels Burn? – Molecules of Fuels.* The article provides information about molecules of different types of fuels. These molecules all belong to a class of substances – **hydrocarbons**. What is the similarity among the molecules? Please draw a picture to show the characteristic structure of hydrocarbons.

2. Hydrocarbons are energy-rich materials, because they all contain certain chemical bonds. Please examine the molecules of different types of hydrocarbons. What are the chemical bonds that are associated with high-energy?

3. Examine the different molecules. How many bonds can one carbon atom form?

ACTIVITY 7. DOES BURNIGN RELEASE ENERGY: MODELING COMBUSTION

Name:____ Hour: _______________

Part 2. Modeling Combustion

Directions for Building Models:

Step 1: First build the “fuel” molecule.

Step 2: Use the remaining oxygen molecules to build O_2

Step 3: Once you have the reactants built, think about the atoms in each molecule and the bonds between atoms and complete part of the table.

Step 4: Use the reactants to “simulate” combustion of the fuel source. Recombine the atoms from the fuel molecule and oxygen molecules to make carbon dioxide and water.

Step 5: Look at the atoms in the products (carbon dioxide and water) and the bonds between atoms. Complete the rest of the table.

Step 6: Do steps 1-5 for each of the fuel molecules.

Step 7: Once you have completed all the fuel sources and tables, discuss and respond to the questions on the last page.

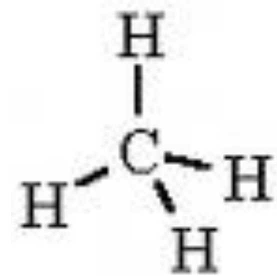
1. You have already burned some of these fuels and observed macroscopic changes in matter and energy. You will show what is really happening at the atomic-molecular level as these fuels burn. Matter transformation is described by the chemical equation of combustion as below.

Fuel + oxygen ⟶ carbon dioxide + water

You will now use your model kits to demonstrate this equation for each fuel source. As you build your models, make sure to complete the tables.

Chemical Change #1: Methane

Methane burns by combining with oxygen in the air to make carbon dioxide and water vapor. One methane molecule reacts with 2 oxygen molecules:



$$CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$$

	Reactants and Products of the Chemical Change			**Does the substance contain Energy**	
	How many carbon atoms does it have?	How many oxygen atoms does it have?	How many hydrogen atoms does it have?	What type of bonds does the substance contain? (C-C, C-H, O-H, C-O, O=O)	Is this substance energy-rich? (yes or no)
Begin with…					
Methane					
Oxygen					
End with…					
Carbon Dioxide					
Water					

Total amount of different atoms in reactants:

Carbon Atoms: _________ Oxygen Atoms: ___________ Hydrogen Atoms: _________

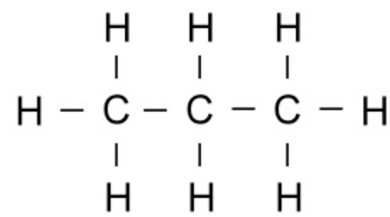
Total amount of different atoms in products:

Carbon Atoms: ________ Oxygen Atoms: __________ Hydrogen Atoms: _________

Which molecule(s) contain(s) energy? _________.

Chemical Change #2: Propane

Propane burns by combining with oxygen in the air to make carbon dioxide and water vapor. One propane molecule reacts with 5 oxygen molecules:



$$C_3H_8 + 5\ O_2 \rightarrow 3\ CO_2 + 4\ H_2O$$

	Reactants and Products of the Chemical Change			**Does the substance contain Energy**	
	How many carbon atoms does it have?	How many oxygen atoms does it have?	How many hydrogen atoms does it have?	What type of bonds does the substance contain? (C-C, C-H, O-H, C-O, O=O)	Is this substance energy-rich? (yes or no)
Begin with…					
Propane					
Oxygen					
End with…					
Carbon Dioxide					
Water					

Total amount of different atoms in reactants:

Carbon Atoms: _________ Oxygen Atoms: __________ Hydrogen Atoms: _________

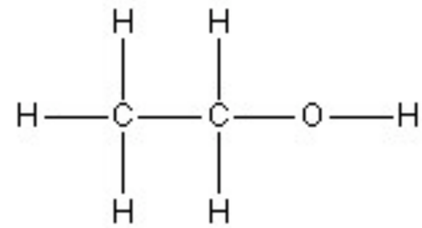
Total amount of different atoms in products:

Carbon Atoms: _________ Oxygen Atoms: _________ Hydrogen Atoms: _________

Which molecule(s) contain(s) energy? _________.

Chemical Change #3: Ethanol

Ethanol burns by combining with oxygen in the air to make carbon dioxide and water vapor. One ethanol molecule reacts with 3 oxygen molecules:



$$C_2H_5OH + 3\ O_2 \rightarrow 2\ CO_2 + 3\ H_2O$$

	Reactants and Products of the Chemical Change			**Does the substance contain Energy**	
	How many carbon atoms does it have?	How many oxygen atoms does it have?	How many hydrogen atoms does it have?	What type of bonds does the substance contain? (C-C, C-H, O-H, C-O, O=O)	Is this substance energy-rich? (yes or no)
Begin with…					
Ethanol					
Oxygen					
End with…					
Carbon Dioxide					
Water					

Total amount of different atoms in reactants:

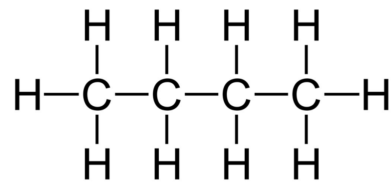
Carbon Atoms: _________ Oxygen Atoms: __________ Hydrogen Atoms: _________

Total amount of different atoms in products:

Carbon Atoms: _________ Oxygen Atoms: __________ Hydrogen Atoms: _________

Which molecule(s) contain(s) energy? _________.

Chemical Change #4: Butane



Butane burns by combining with oxygen in the air to make carbon dioxide and water vapor. Two butane molecules react with 13 oxygen molecules:

$$2\ C_4H_{10} + 13\ O_2 \rightarrow 8\ CO_2 + 10\ H_2O$$

	Reactants and Products of the Chemical Change			**Does the substance contain Energy**	
	How many carbon atoms does it have?	How many oxygen atoms does it have?	How many hydrogen atoms does it have?	What type of bonds does the substance contain? (C-C, C-H, O-H, C-O, O=O)	Is this substance energy-rich? (yes or no)
Begin with…					
Butane					
Oxygen					
End with…					
Carbon Dioxide					
Water					

Total amount of different atoms in reactants:

Carbon Atoms: _________ Oxygen Atoms: __________ Hydrogen Atoms: ________

Total amount of different atoms in products:

Carbon Atoms: _________ Oxygen Atoms: __________ Hydrogen Atoms: ________

Which molecule(s) contain(s) energy? _________.

Summary Questions:

1. Each carbon dioxide molecule that is given off during combustion contains 1 carbon. Where was this carbon atom before it was in the carbon dioxide molecule?

2. Combustion is a process where energy-rich substances react with oxygen to make substances without high-energy bonds. What happens to energy in this process if it is no longer found as chemical energy?

3. Compare the reactants and products of combustion. Are there high-energy bonds (C-C and C-H) contained in reactants? Are there high-energy bonds contained in the products?

4. You have made models of energy-rich materials that we burn. How do the molecules change when they are burned? What happens to the atoms?

5. Please use two equations to show how matter transforms and how energy transforms during combustion. Then answer the following questions:

a) Compare the amount of different types of atoms before and after the chemical change. What pattern do you find?

b) Does the total amount of energy change after the chemical reaction?

QUESTION YOU MAY STILL HAVE:

Do you have questions about how matter or energy change during combustion? In the space below, write down new things you learned about combustion, or questions you have that were not answered during the previous activities.

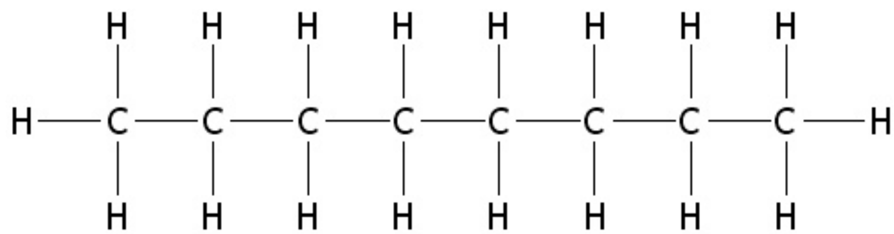
ACTIVITY 8. IDENTIFYING ENERGY-RICH MATERIALS

Name:____ Hour: ___________

Energy-Rich Materials

N≡N	O=O	O=C=O	O-H-O
Nitrogen	Oxygen	Carbon Dioxide	Water

1. Look at the molecules that make up most of our air. Do you think these molecules are sources of chemical energy? Explain why or why not.



2. a. This is an octane molecule found in gasoline. Is this molecule similar to or different from the fuel molecules you built in the previous lesson? Explain why it is similar or different.

b. Which of the molecules in the reading (glucose, propane, lipid) is most similar to the octane molecule? What might this mean in terms of energy storage for plant and animal cells?

Think back over all the molecules you built using your model kits, and other molecules you read about today. Which molecules have chemical energy and which do not? Complete the table below.

Which molecules have chemical energy?	Which are NOT sources of chemical energy?

Summary Questions:

1. What makes the molecules with chemical energy similar?

2. How are molecules with chemical energy different from the molecules without chemical energy?