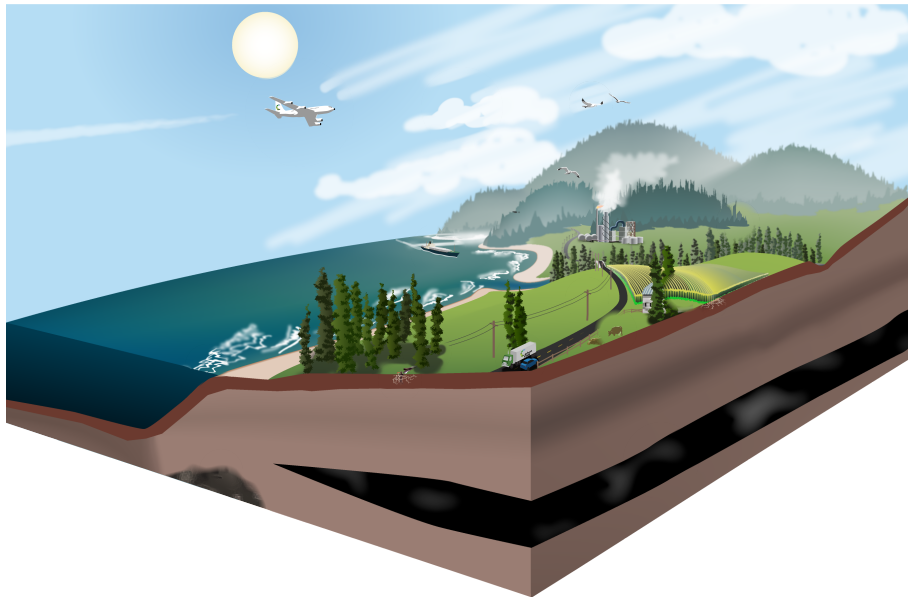


Human Energy Systems

Teacher's Guide



How humans use chemical energy

stored in *Carbon* bonds

**The Environmental Literacy Project
Carbon: Transformations in Matter and Energy
(Carbon TIME)
2012-2013**

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UNIT AND PROGRAM OVERVIEW

Human Energy Systems is one in a series of six units (*Systems and Scale, Animals, Plants, Decomposers, Ecosystems, Human Energy Systems*) developed by the *Carbon: Transformations in Matter, and Energy (Carbon TIME)* Project. In the *Carbon TIME* project we are developing a series of six teaching modules that can be used at the middle school or high school level. They are based on research focusing on learning progressions leading to environmental science literacy, described below. The purpose of these units is to enable students to *uncover the chemical basis of life and lifestyles*.

Key scientific ideas about carbon-transforming processes. The chemical basis of life and lifestyles lies in *carbon-transforming processes* in socio-ecological systems at multiple scales, including cellular and organismal metabolism, ecosystem energetics and carbon cycling, carbon sequestration, and combustion of fossil fuels. These processes: (a) create organic materials (*photosynthesis*), (b) transform organic materials (*biosynthesis, digestion*), and (c) oxidize organic materials (*cellular respiration, combustion*). We think that it is important for students to understand carbon-transforming processes for many reasons; among them: the primary cause of global climate change is the current worldwide imbalance among these processes.

The reason these processes are unbalanced lies in the nature of *organic materials*: foods, fuels, and biomass (the tissues of living and dead organisms). All organic materials contain carbon and hydrogen, and store chemical energy in their carbon-carbon and carbon-hydrogen bonds that can be released when those materials combine with oxygen.¹

Virtually all of the chemical energy on Earth is stored in organic materials, and we need that chemical energy to maintain our lifestyles, so we burn organic materials—especially fossil fuels. So understanding these process is essential for students to act as informed citizens—what we call *environmental science literacy*.

Describing student learning in terms of learning progression levels. We have found that in order to achieve our program goals, students must learn new *knowledge and practices*—the science content described above. Underlying those changes, however, is an even more fundamental kind of learning—what we refer to as mastering scientific *discourse*.

Our everyday accounts of carbon-transforming processes are based on *force-dynamic discourse* or reasoning. Force-dynamic reasoning construes the events of the world as caused by actors (including people, animals, plants, machines, and flames), each with its own purposes and abilities, or by natural tendencies of inanimate materials. In order to accomplish their purposes, the actors have needs or enablers that must be present. For example, force-dynamic reasoning explains the growth of a tree by identifying the actor (the tree), its purpose (to grow), and its needs (sunlight, water, air, and soil). Force-dynamic predictions involve identifying the most powerful actors and predicting that they will be able to overcome antagonists and achieve their purposes as long as their needs are met.

This approach to reasoning about socio-ecological processes contrasts sharply with *principled scientific discourse*, which construes the world as consisting of hierarchically organized systems at different scales. Rather than identifying the most powerful actors, scientific reasoning sees systems as constrained by fundamental laws or principles, which can

¹ This statement simplifies chemists' understanding of the nature of chemical potential energy. It would be more accurate to say that chemical potential energy is transformed to light and molecular motion (thermal energy) when organic materials are oxidized. In the Earth's oxidizing atmosphere, however, reduced materials that can be oxidized are the limiting reactants in most environments, and C-C and C-H bonds signal the presence of reduced carbon and hydrogen.

be used to predict the course of events. Each of our learning progressions involves students learning to apply fundamental scientific principles to the phenomena of the world around them.

So it is useful to think of learning science as like learning a second language. Students at the beginning of the learning progression are monolingual: They have mastered force-dynamic discourse but know little of the nature and power of scientific discourse. So our goal is to help students become “bilingual,” able to use force-dynamic or scientific discourse as the occasion demands. This is a difficult goal in part because force-dynamic and scientific discourse often use the same words (e.g., energy, growth, food, nutrient, matter) with different meanings. The differences can remain hidden to both teachers and students, creating the appearance of common understanding while profound differences remain.

We define students’ progress toward mastering scientific knowledge, practices, and discourse in terms of four *levels of achievement*, ranging from Level 1 (completely dependent on force-dynamic discourse) to Level 4 (able to choose between force-dynamic and principled scientific accounts of carbon-transforming processes). Very briefly, the levels we have identified are as follows:

Level 1: Pure force-dynamic accounts: Students have no choice but to rely on force-dynamic discourse. Their accounts focus on actors, enablers, and natural tendencies of inanimate materials, using relatively short time frames and macroscopic scale phenomena.

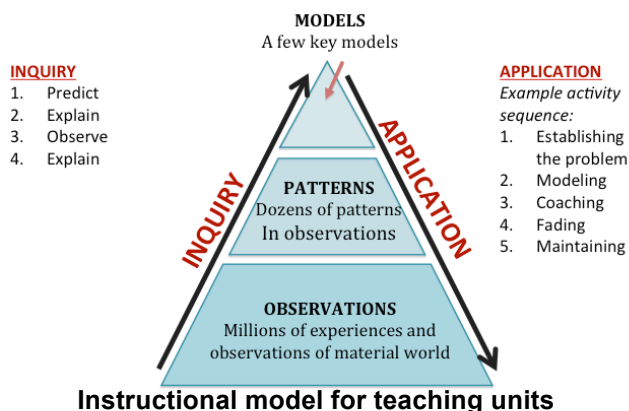
Level 2: Elaborated force-dynamic accounts: Students’ accounts continue to focus on actors, enablers, and natural tendencies of inanimate materials, but they add detail and complexity, especially at larger and smaller scales. They include ideas about what is happening inside plants and animals when they grow and respond, for example, and they show awareness of larger scale connections among phenomena such as food chains and how decay enriches the soil.

Level 3: Incomplete or confused scientific accounts: Students show awareness of important scientific principles and of models at smaller and larger scales, such as cells, atoms and molecules, and cycling of gases and materials in ecosystems. They have difficulty, though, connecting accounts at different scales and applying principles consistently. In particular, they often confuse matter and energy and fail to account for the mass of gases in their accounts.

Level 4: Coherent scientific accounts: Students successfully apply fundamental principles such as conservation of matter and energy to phenomena at multiple scales in space and time. In general, our descriptions of Level 4 performances are consistent with current national science education standards and with the draft framework for new standards.

Purpose and structure of Carbon TIME units. Each of our six units (*Systems and Scale, Animals, Plants, Decomposers, Ecosystems, Human Energy Systems*) focuses on familiar systems and events that involve carbon-transforming processes. Each unit is designed to help students at Level 2 in the learning progression (the most common starting point for middle school and high school students) advance to Level 3 or Level 4.

All of the units focus on *conservation of matter and energy as fundamental principles*, and all follow a general instructional model (see figure) that engages students in both inquiry and application (accounts)



practices. Teaching of application practices is based on a *cognitive apprenticeship* model: (a) students are put in situations where they can observe other people engaging in the activity—*modeling*, (b) the students engage in the practice with scaffolding or support from others—*coaching*, and (c) the support is gradually withdrawn until the students are independently engaged in the practice—*fading*.

The central role of the Three Questions. We believe that we can help students move to higher levels in the learning progression most effectively by focusing both the inquiry and application sequences on *Three Questions*. The *Three Questions* are slightly different in the large-scale units (*Ecosystems* and *Human Energy Systems*) than they are in the other units (*Systems & Scale*, *Animals*, *Plants*, *Decomposers*). These questions, along with rules that we will expect students to follow and evidence we will expect them to look for in answering them, are presented in Table 1 below.

Table 1: The Three Questions: Large-Scale Version

Question	Rules to Follow	Evidence to Look For
<p>The Location Question: Where are the available carbon atoms in our environment? What pools of materials are they in?</p>	<p>Atoms endure. Carbon atoms stay in pools unless a process moves them in or out.</p>	<p>The air has carbon atoms in CO₂ Organic materials are made of molecules with carbon atoms</p> <ul style="list-style-type: none"> • Fuels • Living and dead plants and animals (including foods)
<p>The Carbon/Movement Question: How/why do carbon pools change over time? How are carbon atoms moving?</p>	<p>Carbon-transforming processes move carbon atoms among pools Carbon atoms cycle within environmental systems</p>	<p>Evidence of carbon-transforming processes:</p> <ul style="list-style-type: none"> • organisms eating, growing, breathing, dying • decay • combustion <p>If a carbon pool size changes, that means carbon atoms moved</p>
<p>The Energy Question: What is happening to chemical energy? How does energy flow through environmental systems?</p>	<p>Carbon-transforming processes change energy from:</p> <ul style="list-style-type: none"> • sunlight to • chemical energy to • heat radiated into space <p>Energy flows through environmental systems</p>	<p>We can observe indicators of different forms of energy</p> <ul style="list-style-type: none"> • Organic materials with chemical energy • Light • Heat energy • Work or motion energy

Comments on goals based on the Three Questions. Our focus on the Three Questions arises from our reading of the data from the first pilot tests of our units during the 2011-12 school year, as well as our reading of data from other projects (e.g., Jin & Anderson, 2012). We are convinced that our first priority for student learning should be to engender a **sense of necessity** about conservation of matter and energy, along with the ability to apply these principles to carbon-transforming processes. The essential understandings that students should have from *Human Energy Systems* are summarized in the three columns of the Three Questions Poster—Table 1 above, which is available as a handout in Lesson 2, Activity 1.

SPECIFICATIONS FOR HUMAN ENERGY SYSTEMS UNIT

Human Energy Systems builds on student learning in *Systems and Scale*, *Animals*, *Plants*, *Decomposers*, and *Ecosystems* about organic and inorganic materials, how all systems exist at multiple scales, and transformation of materials and energy during chemical change. In *Human Energy Systems*, students focus on how the carbon-transforming processes of *photosynthesis*, *cellular respiration*, and *combustion* work in global systems to balance carbon pools and fluxes.

Overall, this unit has three important goals. These are a focus on:

1. Relating carbon emissions to energy use
2. Relating local systems, actions, and choices to global effects and outcomes
3. Relating changes in carbon pools to the balance of fluxes of carbon between these pools.

Because of the focus of large scale systems (as opposed to cellular or molecular systems) in the Human Energy Systems unit, we recommend that teachers complete the *Systems & Scale* and *Ecosystems* units before the *Human Energy Systems* unit. The foundational knowledge introduced in these units helps prepare students to engage in conversations and activities that require a basic understanding of photosynthesis, cellular respiration, and combustion of fossil fuels, and apply these concepts to carbon cycling and energy flow on a large scale. It may be difficult for students who do not have a notion about the difference between organic and inorganic forms of carbon to engage in these conversations and activities. It is through examining the pools and fluxes of carbon at a large scale that students will be able to make connections between energy use, combustion of fossil fuels, carbon emissions, and climate change.



Human Energy Systems Unit at a Glance

Lesson 1: The Keeling Curve: Introduction	Time Estimate
Activity 1: Unit Pre-Test	20 min
Activity 2: What's the CO ₂ Trend? Explaining the Keeling Curve	30 min
Activity 3: Why do we care about the Keeling Curve?	20 min
Lesson 2: Fossil Fuels and Carbon Pools	Time Estimate
Activity 1: Where is the carbon?	15 min
Activity 2: The Organic/Inorganic Swap	40 min
Activity 3: The Keeling Curve: Seasonal Cycle	20 min
Activity 4: Zooming Into Fossil Fuels	20 min
Activity 5: Follow the Carbon	25 min
Lesson 3: Consequences of our Lifestyles	Time Estimate
Activity 1: How do I use Organic Carbon?	20 minutes
Activity 2: Extreme Makeover: Lifestyle Edition	25 min
Activity 3: Secrets Revealed	25 min
Lesson 4: How does energy use create carbon emissions?	Time Estimate
Activity 1: How do carbon emissions happen? Jigsaw	60 min
Activity 2: Energy Scenarios	30 min
Activity 3: The Keeling Curve: Understanding the upward trend	30 min
Lesson 5: Global Implications	Time Estimate
Activity 1: Mitigation Strategies	30 min
Activity 2: The Ocean Pool	20 min
Activity 3: Post-test	20 min

LEARNING OBJECTIVES FOR MIDDLE AND HIGH SCHOOL STUDENTS

The overall goal for this unit is to help students *explain how human activities affect the concentration of CO₂ in the atmosphere*. The table below lists the specific goals for student learning in terms of inquiry, application, and citizenship practices and the challenges that those goals pose for Level 2 students (including most middle school students and many high school students) and Level 3 students (including some high school students). Note the organization of the table:



- There are three types of inquiry goals, focusing on measurement, using investigations to construct arguments from evidence, and collective validation of results of investigations.
- There are three types of application goals, focusing on the Three Questions: the Location Question (physical location of materials), the Movement/Carbon Question (movement and chemical change), and the Energy Question (transformations in forms of energy).
- This unit also has a citizenship/decision making goal, focusing on awareness of the consequences of our lifestyle decisions and policies.

Type of Objective	Learning Objective	Challenges for Level 2 Students	Challenges for Level 3 Students
Application: Location Question	Locate organic and inorganic carbon pools near the Earth's surface (atmosphere, biosphere, soil organic carbon, fossil fuels, oceanic carbon) Describe pools as changing in size over time.	Level 2 students will think of carbon a kind of material rather than as an atom in many carbon-containing molecules.	Level 3 students may not think of the same carbon atoms in the atmosphere, biomass, soil, and fossil fuels
Application: Movement/Carbon Question	Explain changes in atmospheric CO ₂ in terms of fluxes associated with carbon-transforming processes: combustion, photosynthesis, fossil fuel formation, cellular respiration. Describe carbon cycling within Earth and Human systems. Identify carbon fluxes associated with human economic activities.	Level 2 students will explain carbon-transforming processes as series of causally connected events (humans burn coal; plants take in CO ₂ ; oceans absorb CO ₂ , etc.)	Level 3 students will recognize fluxes as involving movements of matter, but not that fluxes BOTH make one pool larger AND make another pool smaller.
Application: Energy question	Identify energy transformations involved in carbon fluxes. Trace energy associated with human lifestyles to its sources, particularly combustion of fossil fuels. Describe energy as flowing through Earth systems, from sunlight to chemical energy to heat that is radiated into space.	Level 2 students will describe energy as a cause of events rather than a conserved entity that can be traced through systems.	Level 3 students are likely to be partially aware of connections between human activities, energy use, and combustion of fossil fuels. Level 3 students may also have difficulty tracing energy on its complete pathway from sunlight back into space

Type of Objective	Learning Objective	Challenges for Level 2 Students	Challenges for Level 3 Students
Citizenship decision making	Explain the consequences of lifestyle and energy system choices for changes in atmospheric CO ₂ concentration.	Level 2 students evaluate strategies as generically “good” or “bad” for the environment.	Level 3 students identify specific processes as affecting CO ₂ in the atmosphere, but not in terms of movement among carbon pools

TEACHING *HUMAN ENERGY SYSTEMS* TO MIDDLE AND HIGH SCHOOL STUDENTS

Human Energy Systems is designed for students who have completed the *Systems and Scale* unit, as well as the ecosystems unit. We also recommend that students complete at least one of the organism scale units (*Animals, Plants, and Decomposers*), but the activities of the *Human Energy Systems* unit are designed to be meaningful to students who have not completed those units. Students who have studied the *Ecosystems* unit will also be familiar with the Large Scale Three Questions and with seasonal trends in carbon exchange between biomass and atmospheric CO₂—the basis for the seasonal pattern in the Keeling Curve.

If you have **middle school students** or if most of your students are starting at Level 2, then **[need to complete]**.

If you have **high school students**, **[need to complete]**.

The optional activities include the Six Americas survey in Lesson 1 Activity 3. The Six Americas survey is an optional tool for anonymous assessment of your students’ climate profiles.

TARGETED GRADES: 6-12

KEY CONCEPTS: Human Impacts on Carbon Cycling, Keeling Curve, Carbon and Energy in Fossil Fuels, Carbon and Energy in Human Systems (Transportation, Electricity, Food, Buildings)

VOCABULARY:

- Biomass
- Calcium Carbonate
- Carbon Dioxide
- Carbon Emissions
- Chemical Energy
- Combustion
- Electrical Energy
- Fossil Fuel
- Gasoline
- Greenhouse Gases
- Heat Energy
- Keeling Curve
- Mitigation strategy
- Ocean Acidification

- Organic Carbon
- Inorganic Carbon

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LESSON 1: THE KEELING CURVE: INTRODUCTION

Role of this Lesson in the Application and Inquiry Sequences

Activity 1: (Pre-test)

Activity 2: Application: Establishing the Problem for The Keeling Curve

Activity 3: Application: Establishing the Problem for Climate Change

Time/Duration: About an hour and a half

Activity 1: Unit Pre-Test

~20 minutes

Activity 2: What's the CO₂ Trend? Explaining the Keeling Curve

~30 minutes

Activity 3: Why do we care about the Keeling Curve?

~20 minutes

Lesson Description:

Students use the Keeling Curve to document initial explanations about the trends in atmospheric CO₂, and then discuss the connection between the Keeling curve and climate change.

Guiding Questions:

1. How do we know CO₂ levels in the atmosphere increasing?
2. Why do we care about the Keeling Curve?

Background Information:

To help students to understand global carbon cycling, they should be able to explain the trends modeled in the Keeling Curve. The goal of this first lesson is to document student thinking about the Keeling Curve at the beginning of the unit so that this thinking can be revisited and revised as the unit progresses, and to begin to make initial connections between the trends in the Keeling Curve and climate change.

Lesson 1 Materials

For Activity 1:

- Human Energy Systems Unit Pre-test

For Activity 2:

- Worksheet: What's the CO₂ trend? Explaining the Keeling Curve

For Activity 3:

- Lesson 1 Activity 3.pptx
- <http://uw.kqed.org/climatesurvey/index-kqed.php> OR
- <https://apps.facebook.com/climatesurvey/>
- Climate Profile Cards

ACTIVITY 1: UNIT PRE-TEST**Learning Objectives:**

1. (Complete the pre-assessment)

Duration: 20 minutes

Activity Description:

Students complete a unit pre-assessment to document thinking about human energy systems at the beginning of the unit.

Background Information:

No background information is needed to administer the pre-test.

Materials:

- Human Energy Systems Unit Pre-Test

Directions:

1. **Administer the pre-test either with paper and pencil or on the testing website.**

The paper test will fit on the front and back of one page. Students can also take the test online at the testing website.

2. **Explain the purpose of the pre-test to your students.**

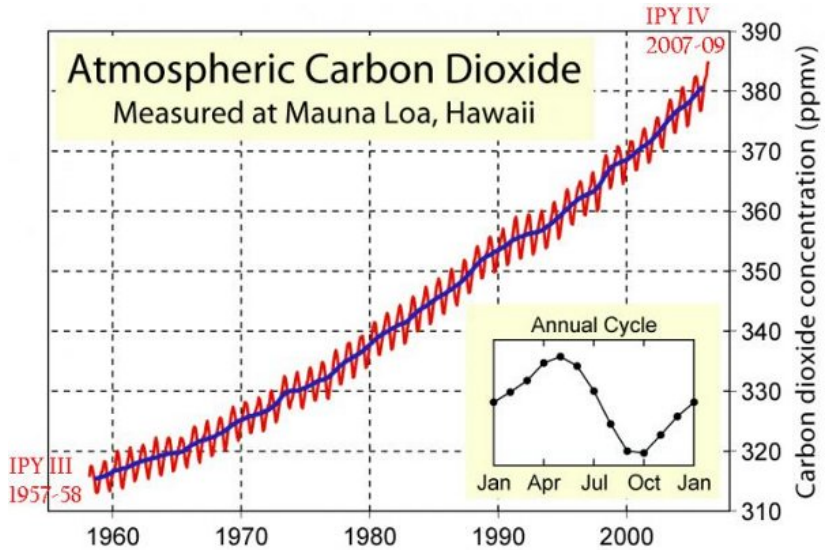
It will help you as a teacher understand how they think about the increase in CO₂ levels and what role people play in this increase. It will help our research project develop better teaching materials and activities by helping the researchers to understand how students think and learn. It will help students think about what they know and what they would like to learn.

3. **Give the students 20 minutes to complete the pre-test.**

Teacher _____ Period: ____ Grade ____ Date _____ Your initials _____

HUMAN ENERGY SYSTEMS PRE-TEST

1. This graph shows changes in carbon dioxide in the atmosphere over a 47-year span in Hawaii. Other measurements in different places on the Earth show the same pattern.



a. Why do you think carbon dioxide levels go down in the summer and go up in the winter? Circle the best choice to complete each of the statements. How much of the annual cycle is...

... caused by HUMANS BURNING COAL AND GASOLINE?	All or most	Some	None
... caused by CHANGES IN PLANT GROWTH?	All or most	Some	None
... caused by NUCLEAR POWER PLANTS?	All or most	Some	None
... caused by CHANGES IN WIND AND WEATHER?	All or most	Some	None

Explain your choices. Why does atmospheric carbon dioxide go down every summer and go up every winter?

b. Why do you think carbon dioxide in the atmosphere goes a little higher each year? Circle the best choice to complete each of the statements. How much of the continual rise is...

... caused by HUMANS BURNING COAL AND GASOLINE?	All or most	Some	None
... caused by CHANGES IN PLANT GROWTH?	All or most	Some	None
... caused by NUCLEAR POWER PLANTS?	All or most	Some	None
... caused by CHANGES IN WIND AND WEATHER?	All or most	Some	None

Explain your choices. Why is there a little more carbon dioxide in the atmosphere each year?

2. Do you think that *driving a car* causes carbon atoms to go into the atmosphere? Yes No

Where do the carbon atoms come from? Choose the best answer.

- | |
|---|
| a. Nowhere. Driving a car does not make carbon atoms move to the atmosphere. |
| b. Combustion: The carbon atoms come from the heat and light energy of burning. |
| c. Biomass: Recently living plants or animals. |
| d. Soil carbon: Dead plants or animals in the soil. |
| e. Fossil fuels: Petroleum, coal, or natural gas. |

Explain your choice. How does driving a car move carbon atoms from the source to the air?

--

2. Do you think that *turning on a light bulb* causes carbon atoms to go into the atmosphere? Yes No

Where do the carbon atoms come from? Choose the best answer.

- | |
|--|
| a. Nowhere. Turning on a light bulb does not make carbon atoms move to the atmosphere. |
| b. Combustion: The carbon atoms come from the heat and light energy of burning. |
| c. Biomass: Recently living plants or animals. |
| d. Soil carbon: Dead plants or animals in the soil. |
| e. Fossil fuels: Petroleum, coal, or natural gas. |

Explain your choice. How does turning on a light bulb move carbon atoms from the source to the air?

--

4. When someone eats a hamburger, which of the following processes are needed to produce the beef in the hamburger and deliver it to the person? Circle "needed" or "not needed" for each process.

Cellular respiration in plants	Needed	Not Needed
Cellular respiration in animals	Needed	Not Needed
Burning coal in power plants	Needed	Not Needed
Burning gasoline or diesel fuel in cars and trucks	Needed	Not Needed

Explain your answer. How is each of the processes that you chose "needed" or involved in producing and delivering beef?

--

5. For each of the choices below, circle the choice that produces fewer carbon emissions. Then explain your choice.

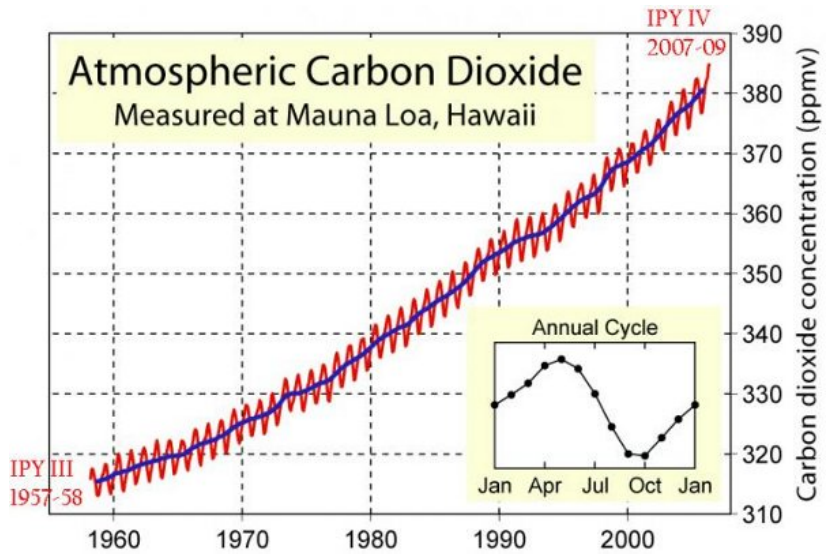
Your choice for fewer carbon emissions	Your explanation for your choice
Coal burning power plant, OR Nuclear power plant	
Heating your house with natural gas, OR Heating your house with electricity	
Eating meat, OR Eating vegetables	

6. Answer these true-false questions:

True	False	Carbon is a kind of atom.
True	False	Carbon is a kind of molecule.
True	False	There is carbon in the air.
True	False	There is carbon in pure water.
True	False	There is carbon in the soil.

ASSESSING THE HUMAN ENERGY SYSTEMS PRETEST

1. This graph shows changes in carbon dioxide in the atmosphere over a 47-year span in Hawaii. Other measurements in different places on the Earth show the same pattern.



a. Why do you think carbon dioxide levels go down in the summer and go up in the winter? Circle the best choice to complete each of the statements. How much of the annual cycle is...

... caused by HUMANS BURNING COAL AND GASOLINE?	All or most	Some	None
... caused by CHANGES IN PLANT GROWTH?	All or most	Some	None
... caused by NUCLEAR POWER PLANTS?	All or most	Some	None
... caused by CHANGES IN WIND AND WEATHER?	All or most	Some	None

Explain your choices. Why does atmospheric carbon dioxide go down every summer and go up every winter?

Level 4: In the summer, photosynthesis takes the CO₂ out of the atmosphere in summer, causing the concentration to go down. In winter, cellular respiration releases the carbon back into the atmosphere as the plants die and leaves fall, which causes the rise each winter.
Level 3: This happens because of all of the fossil fuels we are burning. Also, plants grow more in the summer, so they use more carbon from the air. Also, we use heaters more in the winter when it is cold to keep us warm, so that causes the spike in the winters.
Level 2: This happens because there is more pollution.

b. Why do you think carbon dioxide in the atmosphere goes a little higher each year? Circle the best choice to complete each of the statements. How much of the continual rise is...

... caused by HUMANS BURNING COAL AND GASOLINE?	All or most	Some	None
... caused by CHANGES IN PLANT GROWTH?	All or most	Some	None
... caused by NUCLEAR POWER PLANTS?	All or most	Some	None
... caused by CHANGES IN WIND AND WEATHER?	All or most	Some	None

Explain your choices. Why is there a little more carbon dioxide in the atmosphere each year?

Level 4: An increase in carbon emissions from the combustion of fossil fuels causes the overall increase in carbon dioxide in the atmosphere. Nuclear is not a cause of this because nuclear power plants do not emit carbon. Deforestation may also cause this rise, because there are not enough plants to sequester the carbon being taken out of the fossil fuel pool and put into the atmosphere.
Level 3: We are using more things like nuclear power plants and we use lots of energy that makes pollution. We should use less light bulbs and turn off our lights and drive less to make less pollution.
Level 2: There is more pollution in the air.

2. Do you think that driving a car causes carbon atoms to go into the atmosphere? Yes No
 Where do the carbon atoms come from? Choose the best answer.

- a. Nowhere. Driving a car does not make carbon atoms move to the atmosphere.
- b. Combustion: The carbon atoms come from the heat and light energy of burning.
- c. Biomass: Recently living plants or animals.
- d. Soil carbon: Dead plants or animals in the soil.
- e. **Fossil fuels: Petroleum, coal, or natural gas.**

Explain your choice. How does driving a car move carbon atoms from the source to the air?

Level 4: Engines in a car burn gasoline to make the cars move. When gasoline combusts, the carbon atoms in the gasoline are combined with oxygen atoms from the air. When this happens, carbon dioxide is formed and these molecules are released into the atmosphere.

Level 3: Driving cars causes pollution because it uses fossil fuels. Cars release exhaust into the atmosphere from the tailpipes. They also use energy. (Note: the Level 3 student may not be able to explain why the use of fossil fuels releases carbon into the air).

Level 2: Driving cars uses energy and causes pollution. This is from combustion and the energy of burning.

2. Do you think that *turning on a light bulb* causes carbon atoms to go into the atmosphere? Yes No

Where do the carbon atoms come from? Choose the best answer.

- a. Nowhere. Turning on a light bulb does not make carbon atoms move to the atmosphere.
- b. Combustion: The carbon atoms come from the heat and light energy of burning.
- c. Biomass: Recently living plants or animals.
- d. Soil carbon: Dead plants or animals in the soil.
- e. **Fossil fuels: Petroleum, coal, or natural gas.**

Explain your choice. How does turning on a light bulb move carbon atoms from the source to the air?

Level 4: When we use light bulbs, this uses electricity. Electricity is generated in power plants from the burning of coal. When coal is burned, the carbon atoms from the coal combine with oxygen atoms in the air, releasing carbon dioxide into the atmosphere.

Level 3: Level 3 students may connect energy use with fossil fuels, but cannot articulate how this use of fossil fuels releases carbon into the atmosphere.

Level 2: Level 2 students may not be able to connect light bulb use and release of carbon atoms. They may suggest that this uses energy only.

Note: these answers are assuming that the power plant from which students get their energy is coal-fired. If their electricity is generated from wind or solar, there would be fewer carbon emissions associated with turning on the light bulb. Because most electricity in the United States is generated using coal, we assume this in the question.

4. When someone eats a hamburger, which of the following processes are needed to produce the beef in the hamburger and deliver it to the person? Circle “needed” or “not needed” for each process.

Cellular respiration in plants	Needed	Not Needed
Cellular respiration in animals	Needed	Not Needed
Burning coal in power plants	Needed	Not Needed
Burning gasoline or diesel fuel in cars and trucks	Needed	Not Needed

Explain your answer. How is each of the processes that you chose “needed” or involved in producing and delivering beef?

Level 4: Cellular respiration in plants is needed to give the plants energy to function, which allows the plant to use CO₂ from the air to add biomass. The plants are eaten by the animals, which use cellular respiration to move and function as it grows. Doing cellular respiration allows the cow to function and move, adding biomass (or meat). The hamburger is sent to my house in a car or truck that uses gasoline. If I eat it in room that has lighting, or if the hamburger was cooked on a stove that uses electricity, and that electricity came from a coal-fired power plant, then I also needed to burn coal to eat the hamburger.

Level 3: Level 3 students may be able to suggest that cellular respiration is needed for plants to move and grow, and for animals to move and grow, and that gasoline is needed to transport the hamburger, but might not be able to connect the hamburger to the coal plants.

Level 2: Students may suggest that some of these processes are needed, but will not be able to articulate why or how. Level 2 students may suggest that cellular respiration in plants and animals is needed to keep them alive, or needed to survive.

5. For each of the choices below, circle the choice that produces fewer carbon emissions. Then explain your choice.

Your choice for fewer carbon emissions	Your explanation for your choice
Coal burning power plant, OR Nuclear power plant	<i>Nuclear power plants do not burn fossil fuels and do not release carbon</i>
Heating your house with natural gas, OR Heating your house with electricity	<i>Heating your house with natural gas releases less carbon than heating with electricity from a coal-fired power plant. OR If I use electricity and the source of the electricity does not emit carbon (wind, solar, nuclear), then this will have fewer emissions than burning natural gas, which always releases carbon.</i>
Eating meat, OR Eating vegetables	<i>Eating vegetables produces carbon emissions only from cellular respiration from the plants. If I eat meat, this requires carbon release from both cellular respiration in the plants that the cows eat, and also cellular respiration required by the cows. Most of the carbon from the plants is released back into the air during cellular respiration from the animals, so eating meat releases more carbon into the air than eating plants</i>

6. Answer these true-false questions:

True	False	Carbon is a kind of atom.
True	False	Carbon is a kind of molecule.
True	False	There is carbon in the air.
True	False	There is carbon in pure water.
True	False	There is carbon in the soil.

ACTIVITY 2: WHAT'S THE CO₂ TREND? EXPLAINING THE KEELING CURVE

Learning Objectives:

1. Explain changes in atmospheric CO₂ in terms of fluxes associated with carbon-transforming processes: combustion, photosynthesis, fossil fuel formation, cellular respiration
2. Describe carbon cycling within Earth and Human systems.
 - a. Explain the continual trend in the graph: carbon in the atmosphere is increasing over time due to combustion of fossil fuels.
 - b. Explain the seasonal trend in the graph: carbon levels in the atmosphere fluctuate with the seasons due to photosynthesis and cellular respiration.

Duration: 30 minutes

Activity Description:

Students share their ideas about why carbon dioxide levels are increasing in the atmosphere by interpreting data in the Keeling Curve.

Background Information:

The Keeling curve provides information that helps us understand two different trends in atmospheric carbon: the upward trend, and the seasonal trend.

The upward trend is represented by the straight line that continues from 1960 until 2010. This line shows that each year, carbon levels in the atmosphere are increasing. This is due to the fact that humans are burning fossil fuels that are releasing more carbon than the earth's plants and oceans can sequester.

The seasonal trend is represented by the light grey line that goes up and down between seasons each year. This line shows that each year, carbon levels in the atmosphere fluctuate from season to season. This is due to the fact that when it is summer in the northern hemisphere, some atmospheric carbon is sequestered in plant biomass like tree leaves, flowers, and grasses, which causes carbon dioxide concentration in the atmosphere to go down. When winter comes in the northern hemisphere, these plants drop their leaves (or die if they are annual plants). But cellular respiration continues in plants, animals, and decomposers, causing carbon dioxide concentration in the atmosphere to rise.²

Materials:

- Worksheet: [What's the CO₂ trend? Explaining the Keeling Curve](#)

Directions:

1. Pass out the worksheet.

Ask students to look at the graph on their worksheet. Tell them the purpose of this activity is to understand the trends in this graph and what they mean. Tell the students that there are

² Note: the opposite seasonal trend is observed in atmospheric carbon in the southern hemisphere; southern hemisphere summer (northern hemisphere winter), carbon levels in the atmosphere go down, but the decrease is less than in the northern hemisphere summer because there is less terrestrial biomass in the southern hemisphere (and terrestrial biomass varies much more with the seasons than ocean biomass). We do not address this in the unit, since the primary driver of the seasonal pattern is biomass in the northern hemisphere, and we expect students to be familiar with northern hemisphere seasons. For a graph showing the trend in the southern hemisphere, visit: <http://antarcticsun.usap.gov/science/contenthandler.cfm?id=2493>

two trends they will explain: the upward carbon dioxide trend, and the seasonal carbon dioxide trend. We will use what we know about the 4 pools of carbon to help us understand these two different trends. You may also want to point out that this graph is an important graph that scientists use to understand carbon in the atmosphere. But why is it so important? We will learn the answer to this question throughout the unit.

2. Discuss initial ideas about the cause of the trends in the Keeling Curve.

Ask students to complete questions 1-3 on their worksheet. Discuss their answers with the class. Tell students at this point, they are just sharing initial ideas about the data in the Keeling Curve, and that if they get the answers wrong, they will have a chance throughout the unit to change their ideas about the Keeling Curve.

3. Invite students to share beginning ideas about the Keeling Curve with the class.

Invite any students who are willing to offer ideas about the 2 trends to share with the class. Tell students that our explanations for these two separate trends may be incomplete at this point. Even if the ideas are incorrect at this point, we want to record some of our initial ideas in a public space so they can be revisited later in the unit—our ideas will change!

4. Transition to Activity 3.

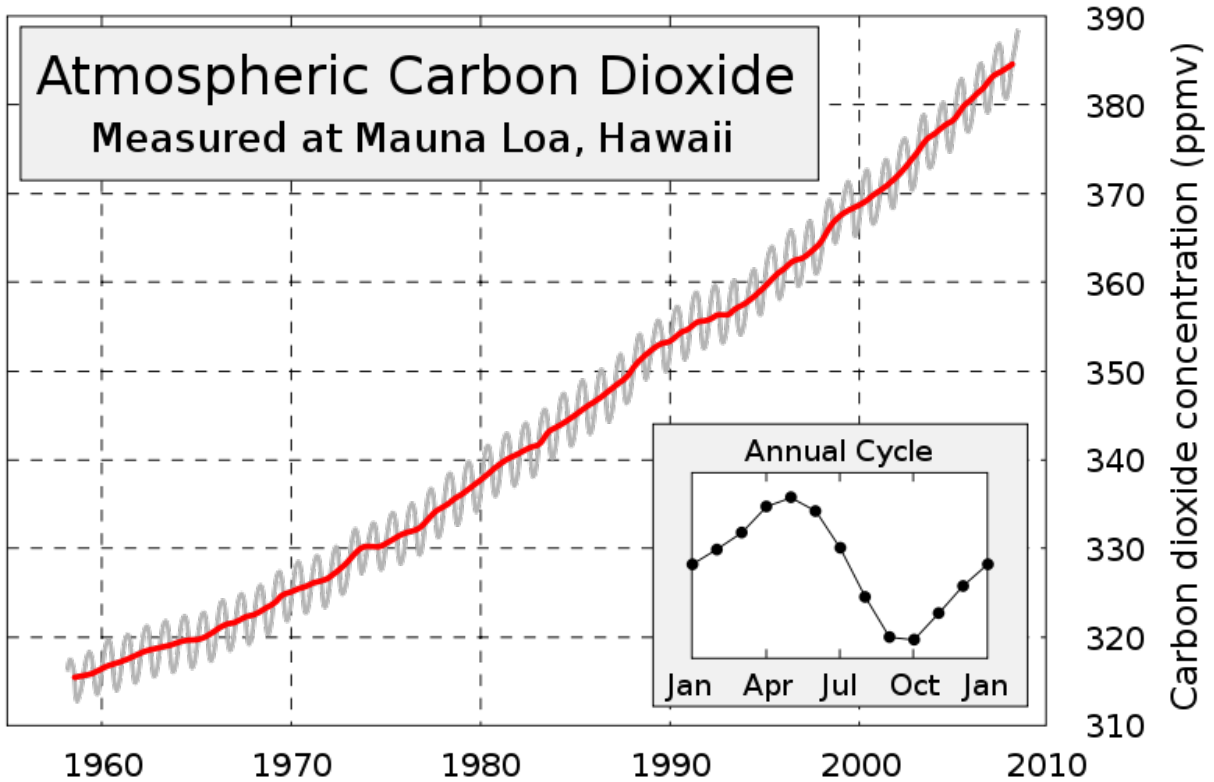
Now we know that carbon dioxide concentrations are increasing in the atmosphere. But why is this important? In the next activity, we will discuss what the Keeling Curve tells us about climate change.

Name: _____ Period: _____ Date: _____

WHAT'S THE CO₂ TREND? EXPLAINING THE KEELING CURVE

Human Energy Systems Lesson 1, Activity 2

This is a famous graph called the Keeling Curve. A scientist named Charles Keeling originally created this graph. Starting in the 1950s, Keeling studied levels of carbon dioxide in the atmosphere at Mauna Loa scientific observatory in Hawaii. Because it is located on an island in the middle of the Pacific Ocean (far away from most local sources of CO₂), Mauna Loa is a great place to sample the concentration of CO₂ in the whole atmosphere. The annual average CO₂ that is measured represents the entire globe, but Hawaii is located about 1300 miles north of the equator, and is thus also influenced by seasonal patterns of the Northern Hemisphere.



The Keeling Curve: Atmospheric CO₂ concentrations measured at Mauna Loa Observatory

1. Look at the Keeling Curve graph. Look at the long, straight line that begins before 1960 and goes to 2010. This line traces the average concentrations of carbon dioxide in the atmosphere for each year. Describe the general trend in the level of carbon dioxide in the atmosphere between 1958 and 2008. Is the level of carbon dioxide in the atmosphere going up, going down, or staying the same? Circle one.

Going Up	Going Down	Staying the Same
----------	------------	------------------

2. Why do you think this is happening? Record your ideas about this now (at the beginning of the unit: remember, your ideas about this might change!).

3. Look at the Keeling curve graph again. This time, look at the squiggly line that goes up and down each year. This line shows the concentration of carbon dioxide in the atmosphere each month.

- a. What are the seasons in the year when the carbon dioxide concentration is **going up?**

Spring	Summer	Fall	Winter
--------	--------	------	--------

- b. What are the seasons in the year when the carbon dioxide concentration is **going down?**

Spring	Summer	Fall	Winter
--------	--------	------	--------

4. Use what you have learned about plants and the text above to explain this line: **Why does the concentration of carbon dioxide in the atmosphere go up and down each year?** Try to explain both why the concentration goes up each year and why it goes down each year.

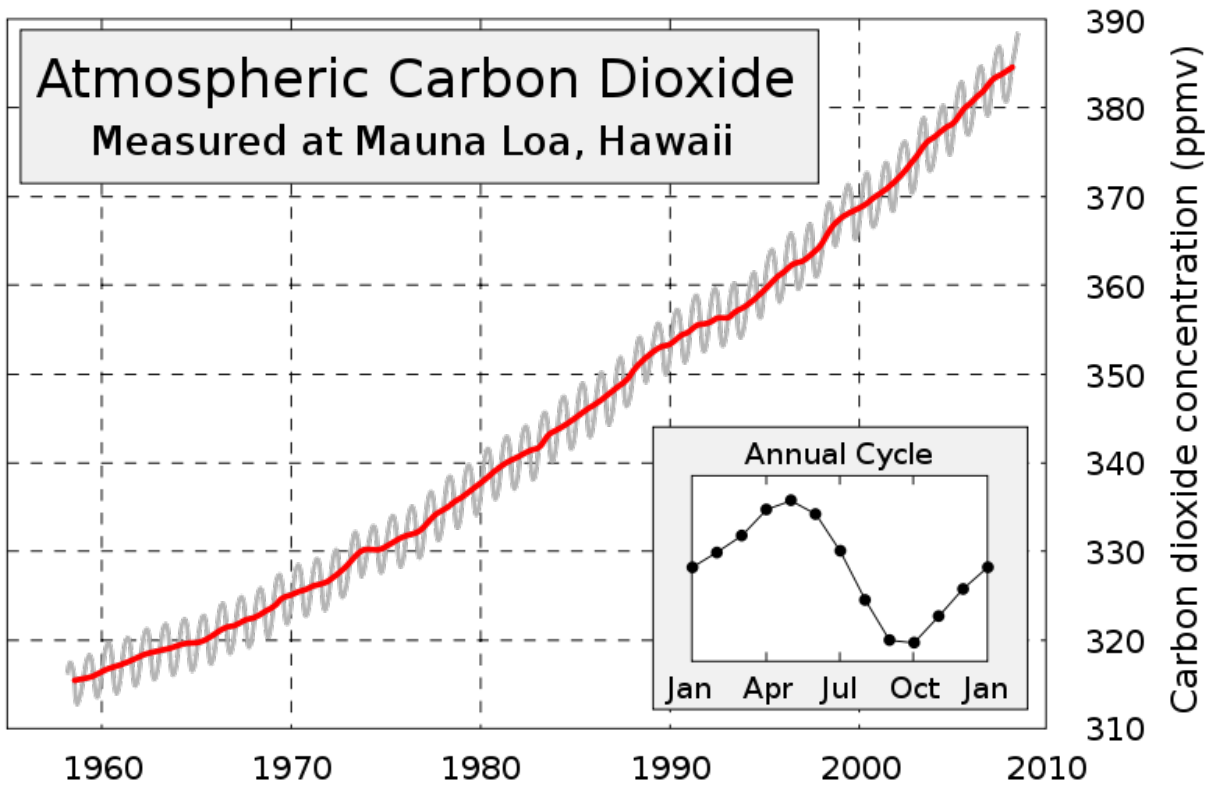
5. What unanswered questions do you have about the Keeling Curve?

ASSESSING WHAT'S THE CO₂ TREND? EXPLAINING THE KEELING CURVE

Human Energy Systems Lesson 1, Activity 2

We recommend that student responses to this worksheet be used for formative assessment rather than grading. The blue italic text below contrasts correct responses with common Level 2 and Level 3 responses.

This is a famous graph called the Keeling Curve. A scientist named Charles Keeling originally created this graph. Starting in the 1950s, Keeling studied levels of carbon dioxide in the atmosphere at Mauna Loa scientific observatory in Hawaii. Because it is located on an island in the middle of the Pacific Ocean (far away from most local sources of CO₂), Mauna Loa is a great place to sample the concentration of CO₂ in the whole atmosphere. The annual average CO₂ that is measured represents the entire globe, but Hawaii is located about 1300 miles north of the equator, and is thus also influenced by seasonal patterns of the Northern Hemisphere.



The Keeling Curve: Atmospheric CO₂ concentrations measured at Mauna Loa Observatory

1. Look at the Keeling Curve graph. Look at the long, straight line that begins before 1960 and goes to 2010. This line traces the average concentrations of carbon dioxide in the atmosphere for each year. Describe the general trend in the level of carbon dioxide in the atmosphere between 1958 and 2008. Is the level of carbon dioxide in the atmosphere going up, going down, or staying the same? Circle one.

Going Up Going Down Staying the Same

2. Why do you think this is happening? Record your ideas about this now (at the beginning of the unit: remember, your ideas about this might change! Right now, there are no right or wrong answers).

Student answers may vary at this point.

Level 4 students may describe an imbalance in the global carbon cycle, which leads to rising levels of carbon dioxide in the atmosphere due to humans taking carbon out of the ground and putting it into the atmosphere through combustion of these fossil fuels.

Level 3 students may describe several factors that contribute to rising carbon dioxide levels in the atmosphere, but may not be able to identify and explain how the imbalance in carbon entering and leaving the atmosphere is the core reason for rising CO₂ levels. Level 3 students will need scaffolding to focus not just on individual causes, but also on the big picture of balance and imbalance within the global carbon cycle.

Level 2 students may not be sure what is causing the level of carbon dioxide in the atmosphere to increase. Level 2 students may not understand the difference between weather and climate, or the mechanisms that regulate global climate. Level 2 students will need help learning about how carbon cycles between the atmosphere and other reservoirs, and help learning about how location of carbon relates to changes in climate.

3. Look at the Keeling curve graph again. This time, look at the squiggly line that goes up and down each year. This line shows the concentration of carbon dioxide in the atmosphere each month.

- a. What are the seasons in the year when the carbon dioxide concentration is **going up**?

Spring	Summer	Fall	Winter
--------	--------	------	--------

- b. What are the seasons in the year when the carbon dioxide concentration is **going down**?

Spring	Summer	Fall	Winter
--------	--------	------	--------

4. Use what you have learned about plants and the text above to explain this line: **Why does the concentration of carbon dioxide in the atmosphere go up and down each year?** Try to explain both why the concentration goes up each year and why it goes down each year.

This exchange is due to a relationship between photosynthesis (spring and summer) and cellular respiration (fall and winter). In summer in the northern hemisphere, plants grow new leaves and annual plants grow from seeds. Through photosynthesis, carbon is taken out of the atmosphere and used to build the biomass of plants. This lowers the overall amounts of carbon in the atmosphere. Then, in the fall and winter, the leaves fall off of the tree and the annual plants die. Decomposition of these plants releases the carbon back into the air as CO₂. This raises the levels of CO₂ in the atmosphere each winter.

Students at levels 1, 2, and 3 may incorrectly attribute the seasonal trend to the use of fossil fuels or "pollution."

5. What unanswered questions do you have about the Keeling Curve?

Answers may vary at this point. Students will likely not have complete explanations for either trend.

ACTIVITY 3: WHY DO WE CARE ABOUT THE KEELING CURVE?**Learning Objectives:**

1. Describe carbon cycling within Earth and Human systems.
2. Explain the consequences of lifestyle and energy system choices for changes in atmospheric CO₂ concentration.

Duration: 30 minutes

Activity Description:

Students share their initial ideas about climate change through an anonymous assessment and discuss the connection between the greenhouse effect and global warming.

Background Information:

Students in your classroom might respond differently to climate change curriculum depending on what “climate profile” they fall into. The Six Americas survey below will help you assess your classroom’s attitudes towards climate change. Having students anonymously share the results of the Six Americas quiz will give you as a teacher a sense of their attitudes towards climate change. If your classroom is majority “alarmed” or “concerned,” you may have different conversations than if your classrooms is majority “dismissive” or “doubtful.” It is important that this is anonymous so that students feel comfortable sharing their ideas, and are not ostracized for their attitudes about climate change, which could be largely dependent on the attitudes of their family and social community (and not based on scientific evidence). One goal of this unit is to encourage all students to discuss the scientific mechanisms behind climate change, regardless of their attitudes towards climate change are at the beginning of the unit.

It is important to stress in this activity that the greenhouse effect is a naturally-occurring phenomenon that maintains the earth’s temperature that allows for living things to survive on the planet. The greenhouse effect is the mechanism by which the earth maintains its temperature. This is able to happen because of the presence of greenhouse gases in the atmosphere.³ When the sun’s light energy (electromagnetic radiation) enters the atmosphere, it is able to pass through the greenhouse gases and reach the surface of the earth. At the surface, the sun’s light energy is transformed to thermal radiation, which is radiated from the earth back into the atmosphere in the form of infrared radiation.⁴ The infrared radiation excites the greenhouse gas molecules in the atmosphere, or “traps the heat.”

It is important to distinguish between this naturally occurring phenomenon (greenhouse effect) and the human-caused amplification of the greenhouse effect (global warming). Increase in greenhouse gases by fossil fuel combustion amplifies the greenhouse effect, which is not a naturally occurring phenomenon. When humans burn fossil fuels, CO₂ is emitted into the atmosphere. This increase in greenhouse gases traps more infrared radiation than is healthy for the planet, causing the average global temperatures to rise. This human-caused phenomenon is called global warming, which is what leads to global climate change.

Materials:

³ Although there are many different types of greenhouse gases in the atmosphere, we focus mainly on CO₂ in this unit.

⁴ Throughout the unit, we sometimes use the term “heat energy” as a substitution/simplification for thermal and infrared radiation.

- [Lesson 1 Activity 3.pptx](#)
- <http://uw.kqed.org/climatesurvey/index-kqed.php> OR <https://apps.facebook.com/climatesurvey/>
- [Climate Profile Cards](#)

Directions:

1. Introduce activity.

Display [Lesson 1 Activity 3.pptx](#) slide 1. Tell students we spend a lot of time discussing the Keeling Curve in this unit. But why is this important? In this unit, we will examine how the Keeling Curve is connected to Climate Change.

2. OPTIONAL: Anonymously collect initial ideas about climate change.⁵

Show Lesson 1 Activity 3.pptx slides 2-3 to explain the activity. Tell students to visit one of the two websites above to take a short 5-10 minute quiz (18 questions total). Give each student a [Climate Profile Card](#) and instruct them to return them to you anonymously (no names) after they complete the quiz.

FORMATIVE ASSESSMENT: Students in your classroom may represent a variety of understandings and viewpoints about climate change. The purpose of this activity is to invite students to give their initial (anonymous) ideas about climate change so you can assess where your students are in their understanding of climate change. Students may fall into a variety of climate “profiles:” alarmed, concerned, cautious, disengaged, doubtful, and dismissive. You should use the results of this quiz for your own assessment purposes.⁶

3. Introduce climate change.

The scientific community is concerned about the rising concentrations of CO₂ and what this means for the temperature of the planet. To understand why scientists are concerned, we have to talk about the greenhouse effect and fossil fuels.

4. Introduce the Greenhouse Effect.

Show [Activity 1 Lesson 3.pptx](#) slides 4-7. Walk students through the mechanism of the greenhouse effect. Stress that the greenhouse effect is a naturally occurring phenomenon that keeps our planet warm and allows us to survive. This is different from global warming and climate change, which are caused by humans.

5. Have students predict what will happen to the earth’s temperature if greenhouse gases are added.

Show slide 8 of [Activity 1 Lesson 3.pptx](#). Ask students to predict what will happen if we add more greenhouse gases to the atmosphere. Invite students to share their ideas with the class.

6. Discuss how fossil fuels impact the earth’s temperature.

Show [Activity 1 Lesson 4.pptx](#) slides 9-12 to explain how greenhouse gases (like CO₂) trap heat. Stress that when we burn fossil fuels, CO₂ is released into the atmosphere. Slide 12 displays data that shows a correlation between global temperatures and CO₂ in the atmosphere from 1880 to 2010. You can read the report that produced this graph at the National Climate Assessment website.⁷

7. Transition to Lesson 2.

⁵ The two surveys used in this activity are based on research from the Yale Project on Climate Change: <http://environment.yale.edu/climate/>

⁶ For more information about each profile, visit <http://environment.yale.edu/climate/> and click on [2012 Global Warming’s Six Americas Report](#).

⁷ 2013 Draft National Climate Assessment Report: <http://www.globalchange.gov/what-we-do/assessment>

Now we know that fossil fuels amplify the greenhouse effect, causing the atmosphere to trap heat, which changes our climate. In the next activities, we will learn more about fossil fuels. How did they form? How do we use them? How does this add CO₂ to the atmosphere?

CLIMATE PROFILE CARDS

<p>My climate profile is (circle 1):</p> <p style="text-align: center;"> Alarmed Concerned Cautious Disengaged Doubtful Dismissive </p> <p>After you have taken the quiz, return this to your teacher (do not write your name on it).</p>	<p>My climate profile is (circle 1):</p> <p style="text-align: center;"> Alarmed Concerned Cautious Disengaged Doubtful Dismissive </p> <p>After you have taken the quiz, return this to your teacher (do not write your name on it).</p>
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LESSON 2: FOSSIL FUELS AND CARBON POOLS

Role of this Lesson in the Application and Inquiry Sequences

- Activity 1: Foundational Skills & Knowledge
- Activity 2: Review: Organic vs Inorganic Carbon⁸
- Activity 3: Modeling: Keeling Curve
- Activity 4: Foundational Skills & Knowledge
- Activity 5: Foundational Skills & Knowledge

Time/Duration: 45 minutes

Activity 1: Where is the Carbon?	~15 minutes
Activity 2: The Organic/Inorganic Swap	~40 minutes
Activity 3: The Keeling Curve: Seasonal cycle	~20 minutes
Activity 4: Zooming in to Fossil Fuels	~20 minutes
Activity 5: Follow the Carbon	~25 minutes

Lesson Description:

Students revisit the processes that form organic and inorganic carbon, examine the seasonal cycle in the Keeling Curve, and examine how fossil fuels are formed and how we use them.

Guiding Questions:

1. How are organic and inorganic carbon molecules formed?
2. How did fossil fuels form, and how do we use them?

Background Information:

Fossil fuels were made from once living things and are therefore composed of organic carbon. Humans can use this organic carbon because the bonds contain chemical energy. We use fossil fuels by first extracting them from deep in the ground and then burning them to release energy, transforming the organic carbon to inorganic carbon.

Lesson Materials:

For Activity 1:

- [Lesson 2 Activity 1.pptx](#)
- [Where is the Carbon? Worksheet](#)
- [3 Questions Handout](#)

For Activity 2:

- [Lesson 2 Activity 2.pptx](#)
- [Scenario Cards](#)

For Activity 3:

- [Lesson 2 Activity 3.pptx](#)
- Internet connection to show short film:
http://eoimages.gsfc.nasa.gov/images/globalmaps/data/mov/MOD17A2_M_PSN.mov
- [What causes the seasonal cycle in the Keeling Curve? Worksheet](#)

For Activity 4:

- [Lesson 2 Activity 4.pptx](#)

⁸ If you have not already completed the ecosystems unit, this activity will serve as an introduction to organic and inorganic carbon. If you have already completed the Ecosystems unit, this activity is review/optional.

- Worksheet: Zooming into Fossil Fuels

For Activity 5:

- Lesson 2 Activity 5.pptx
- Reading: Where Do Fossil Fuels Come From?
- Worksheet: Follow the Carbon

ACTIVITY 1: WHERE IS THE CARBON?

Learning Objectives:

1. Locate organic and inorganic carbon pools near the Earth's surface (atmosphere, biosphere, soil organic carbon, fossil fuels, oceanic carbon).

Duration: 15 minutes

Activity Description:

Students revisit the Three Questions and begin with the Location Question to identify pools of carbon: biomass, atmosphere, soil carbon, and fossil fuels.

Background Information:

This activity gathers student ideas about question 1: Where are the carbon atoms in our environment, and what pools are they in? At this point, we divide the carbon atoms into four pools: biomass, fossil fuels, soil carbon, and atmosphere. The **Biomass** pool includes carbon found in all living things: people, animals, plants, and decomposers. However, most biomass is stored in wood in trees. The **Fossil fuel pool** includes carbon in the form of oil, natural gas, and coal. The **atmosphere pool** includes carbon in the form of CO₂ (*Note: the atmosphere contains other carbon-based green house gases, but we focus only on CO₂ in this unit*). The **Soil carbon** pool contains carbon in the form of dead and living plant, animals, and decomposer materials. The soil pool is larger than than the atmosphere and biomass pools combined. Note: The ocean pool, which contains 1) biomass in the form of animals and plants, 2) carbon dioxide dissolved in the water, and 3) carbonate rocks, is explored in more detail in the last lesson of this unit. In this introductory lesson we focus only on the four pools mentioned above.

Materials:

- [Lesson 2 Activity 1.pptx](#)
- [Where is the Carbon? Worksheet](#)
- [3 Questions Handout](#)

Directions:

1. Discuss scale and how this unit frames our conversations about energy.

Tell students that this unit may be different from other Carbon TIME units because of the scale. Instead of looking at how carbon and energy move through an animal or a plant or a decomposer or an ecosystem, we are looking at how carbon and energy move around the entire world (i.e., at a large scale). By *world*, we mean the earth and atmosphere for matter; for energy, we also talk about the sun and space.

2. Introduce students to the main image for this unit.

Use Slide 1 of [Lesson 2 Activity 1.pptx](#) to introduce the main image for this unit. Tell students that we will use this picture to learn about how carbon and energy moves through our world. Ask students if they have initial ideas about what this picture has in it. What do they see in the picture?

3. Introduce the 3 rules: Atoms Endure! Carbon Cycles! Energy Flows!

Show [Lesson 2 Activity 1.pptx](#) slide 2. Say: Throughout this unit, we should always remember three important rules. Because of our first rule, "Atoms Endure," we know that atoms that are in our world are not created or destroyed. Because of the rule "Carbon Cycles," we know that carbon atoms move from pool to pool in our world, but never leave: they cycle. Because of our rule "Energy Flows," we know that energy can enter and exit our world (from the sun and then back into outer space): this is why we say energy flows.

Energy can change form, but can never be created or destroyed. We also say that energy “flows” instead of “cycles” because once energy is used it cannot be used again in the same form. We will try to remember these rules and use them throughout the unit. Introduce (or revisit) the 3 Questions using slide 3 of [Lesson 2 Activity 1.pptx](#). Give students copies of the [3 Questions Handout](#) (below). You may want to post the questions on the wall of your classroom.

4. Introduce Question 1: The Location Question.

Use slide 4 to introduce The Location Question. Look at the picture on slide 4. Say: “*Look at the picture on this slide. Where is the carbon in this picture?*” Take suggestions from students until you hear ideas that fall into all pools (biomass, atmosphere, soil carbon, and fossil fuels). Student suggestions may include: trees, birds, ocean, soil, fossil fuels, atmosphere, air, car exhaust, factory emissions, airplane emissions, and more. Encourage students to think about where this carbon came from.

5. Introduce the 4 pools of carbon.

Use slides 5-6 to introduce students to the language we will use to discuss pools of carbon in our world: **Biomass, soil carbon, atmosphere, and fossil fuels**⁹. Use the animation in slide 6 to make connections between the image and the more abstract “box diagrams” we use to represent the carbon pools.¹⁰ You may want to point out three interesting points about these pools: 1) the biomass pool contains carbon found in the form of living things and once-living things, but most biomass on the earth is stored in the wood of trees, and 2) The soil carbon pool is the largest (larger than the atmosphere and biomass pools combined!) and contains carbon in the form of dead plants, animals, and decomposers.

6. Introduce the task for this activity.

Ask students to suggest as a whole class which types of carbon are found in each of the 4 pools. Remind students that we sort carbon atoms into pools because according to Rule #2 (Carbon Cycles), carbon atoms can move from pool to pool. This means that if a carbon atom leaves one pool, it must enter another pool. It never disappears. It is transformed into a different form of carbon molecule. In this unit, we are mainly concerned with how carbon moves from the fossil fuel pool to the atmosphere pool and how this affects the climate.

7. Pass out the Where is the Carbon? worksheet.

Tell students to complete the worksheet, and that they can either write the names of carbon found in each pool, or draw pictures of carbon found in each pool. You may use slide 7 in [Lesson 2 Activity 1.pptx](#) to present directions for completing the worksheet.

⁹ Note: In the images in this unit, we use a picture of a **propane** tank to represent natural gas. The natural gas that is extracted from the grounds through hydraulic fracturing consists mostly of **methane** (and also traces of propane, ethane, and butane). These gases have different properties and uses. When we refer to “natural gas” in this unit, we are referring to methane.

¹⁰ Note: students may suggest that the ocean contains carbon as well, which is true! The ocean has carbon dioxide dissolved in the water, contains biomass in plants and animals, and also contains carbonate rocks and shells. We will address the ocean pool later in the unit. For now, our 4 pools will not address carbon in the ocean.

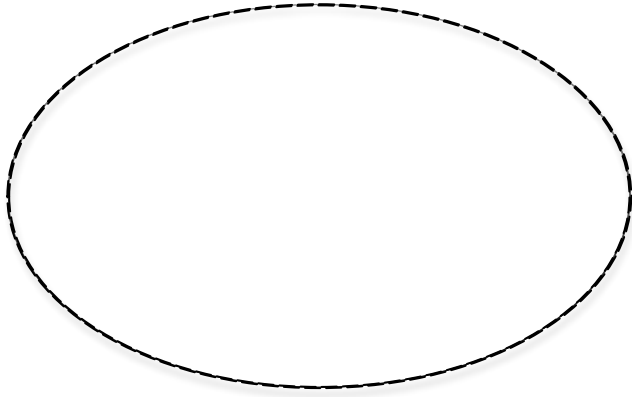
Name: _____ Period: ____ Date: _____

WHERE IS THE CARBON? WORKSHEET

Human Energy Systems Lesson 2, Activity 1

Carbon in our world is found in four pools. In each box or circle, **write** or **draw** examples of carbon found in each pool.

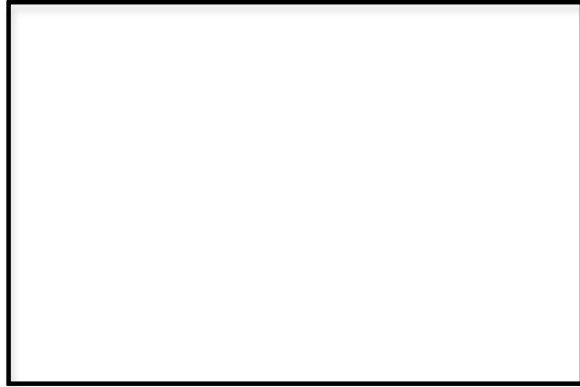
Atmosphere Pool



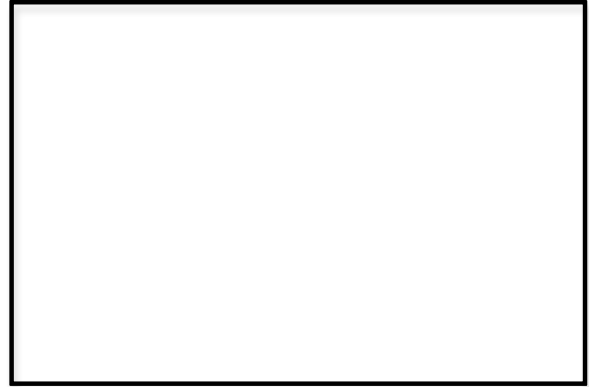
Biomass Pool



Soil Pool



Fossil Fuel Pool



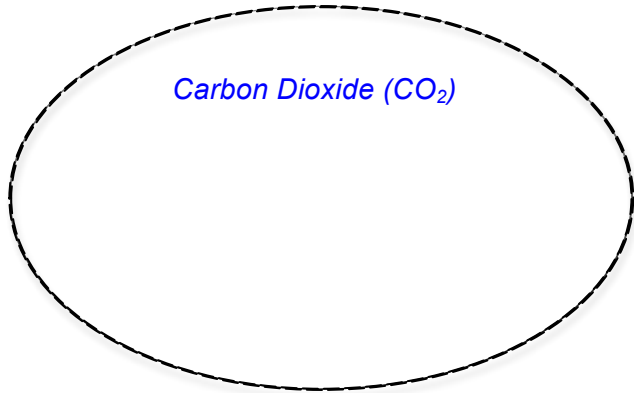
Remember Rule 1 and 2: **Atoms Endure! Carbon Cycles!** Carbon atoms can move between pools, but they are not created or destroyed.

ASSESSING WHERE IS THE CARBON? WORKSHEET

Human Energy Systems Lesson 2, Activity 1

Carbon in our world is found in four pools. In each box or circle, **write** or **draw** examples of carbon found in each pool.

Atmosphere Pool



Biomass Pool

*All kinds of plants and animals and decomposers (their bodies are built of organic carbon molecules).
Biomass-derived products such as wood, paper, and cotton also contain carbon and could be included in the Biomass Pool.*

Soil Pool

- Dead plants and animals waiting to decompose*
- Waste, feces*
- Insects, decomposers, worms, and detritivores that live in the soil*

Fossil Fuel Pool

*Coal
Natural Gas
Oil/Petroleum
Fossil-fuel derived products such as gasoline, asphalt, and plastics also contain carbon and could be included in the Fossil Fuel Pool*

Remember Rule 1 and 2: **Atoms Endure! Carbon Cycles!** Carbon atoms can move between pools, but they are not created or destroyed.

THE THREE QUESTIONS

Question	Rules to Follow	Evidence to Look For
<p>The Location Question: Where are the available carbon atoms in our environment? What pools of materials are they in?</p>	<p>Atoms endure. Carbon atoms stay in pools unless a process moves them in or out.</p>	<p>The air has carbon atoms in CO₂ Organic materials are made of molecules with carbon atoms</p> <ul style="list-style-type: none"> • Fuels • Living and dead plants and animals (including foods)
<p>The Carbon/Movement Question: How/why do carbon pools change over time? How are carbon atoms moving?</p>	<p>Carbon-transforming processes move carbon atoms among pools Carbon atoms cycle within environmental systems</p>	<p>Evidence of carbon-transforming processes:</p> <ul style="list-style-type: none"> • organisms eating, growing, breathing, dying • decay • combustion <p>If a carbon pool size changes, that means carbon atoms moved</p>
<p>The Energy Question: What is happening to chemical energy? How does energy flow through environmental systems?</p>	<p>Carbon-transforming processes change energy from:</p> <ul style="list-style-type: none"> • sunlight to • chemical energy to • heat radiated into space <p>Energy flows through environmental systems</p>	<p>We can observe indicators of different forms of energy</p> <ul style="list-style-type: none"> • Organic materials with chemical energy • Light • Heat energy • Work or motion energy

ACTIVITY 2: THE ORGANIC / INORGANIC SWAP¹¹**Learning Objectives:**

1. Explain changes in atmospheric CO₂ between seasons in terms of fluxes associated with carbon-transforming processes: photosynthesis and cellular respiration
2. Describe carbon cycling within Earth and Human systems.

Duration: 40 minutes

Activity Description:

Students examine how the balance between photosynthesis and cellular respiration impact the exchange of carbon between organic biomass and inorganic CO₂ in the atmosphere.

Background Information:

Plants play a big role in explaining the short-term rise and fall of carbon between summer and winter. Seasons on Earth are determined by the tilt of our planet on its axis. Due to this tilt, when it is summer in the northern hemisphere it is winter in the southern hemisphere, and vice versa. Consider how terrestrial plants are different in the winter versus the summer: Landmasses on Earth are not equally distributed all over the planet. In fact, the distribution is pretty different in the northern and southern hemispheres. The northern hemisphere is about 39% land and 61% water. The southern hemisphere is only about 19% land and 81% water.

During summer on the northern hemisphere, trees, grasses, and annual plants all engage in photosynthesis, moving carbon from CO₂ in the atmosphere to their biomass. This sequestering of carbon in biomass causes the level of CO₂ in the atmosphere to go down. During winter, there is much less photosynthesis. But cellular respiration continues in plants, animals, and decomposers, causing carbon dioxide concentration in the atmosphere to rise. This happens every year, which explains the seasonal cycle on the Keeling curve (the gray line).

The swap of carbon here also involves energy: when carbon is sequestered in plant biomass, energy from the sun is transformed from light energy into chemical energy and stored in the bonds of sugar molecules in the plant. Some of this energy eventually becomes stored in molecules in wood and roots. Some of this energy is released during cellular respiration for work/motion and as heat during the life of the plant. Some of this energy is stored in leaves. When the leaves drop in the fall, the energy stored in the leaves is released as heat during decomposition. Once this energy is released as heat or used for work/motion, this energy is lost to the atmosphere and cannot be re-used.

Materials:

- [Lesson 2 Activity 2.pptx](#)
- [Scenario Cards](#)

Directions:**1. Recall the Keeling Curve and identify the seasonal cycle.**

Ask students to verbally share accounts of the Keeling curve to activate their prior knowledge. Display slide 2 of [Lesson 2 Activity 2.pptx](#), which shows an image of the Keeling curve. Ask the students about the seasonal cycle. Say: *Who has an idea about why in the summer the atmospheric carbon goes down, but in the winter it goes up?*

2. Introduce Question 2: The Carbon/Movement Question.

¹¹ If your students have already completed the Ecosystems Unit, you may not feel the need to use this activity (unless you would like to refresh their memory about carbon cycling and energy flow during the seasons).

Show slide 3 of Lesson 2 Activity 2.pptx. Tell students that now that we know that carbon moves back and forth between the atmosphere and biomass pools during winter and summer, it is our job to figure out which carbon transforming processes cause this big swap.

3. Discuss the relationship between photosynthesis and cellular respiration.

Use slide 4 to pose the question about how photosynthesis and cellular respiration affect pool sizes. Invite them to explain how this relates to the seasonal cycle in the Keeling Curve. Ask the questions on slides 5, 6, 7, and 8 and give students an opportunity to explain their ideas using the diagram. They might want to make a sketch of the 4 pools in their notes and use this to draw arrows to explain their answers.

Formative Assessment: Check to see if students are making the connection that photosynthesis causes the inorganic pool to shrink and the organic pool to grow, whereas cellular respiration causes the opposite trend.

4. Scenario Cards Round 1: Carbon exchange between biomass and atmosphere

Divide the class into groups of 4. Pass out 1 scenario card to each group (below). Display Lesson 2 Activity 2.pptx slide 9. Have students discuss in groups what will happen to the organic and inorganic pools of carbon according to the scenarios on their cards. Which pool will get larger? Which pool will get smaller? Invite each group to share one of their scenarios and the result with the class.

Formative Assessment: Check to see if students are making the connection that photosynthesis causes the inorganic pool to shrink and the organic pool to grow, whereas cellular respiration causes the opposite trend. They might also suggest that photosynthesis causes a “flux” to the biomass pool, and cellular respiration causes a “flux” to the atmosphere pool.

5. Discuss energy flow through biological systems.

Display slide 10 of Lesson 2 Activity 2.pptx to introduce energy flow. Remind students of rule #3: energy flows. This means that energy can change form, but never be created or destroyed. This also means that once energy is used it degrades and cannot be reused in the same form. Ask question #3: how does energy flow through biological systems? Answer the questions about what happens to energy at a large scale using slides 10-12 of Lesson 2 Activity 2.pptx. For each slide, post the question on the slide and discuss the answer.¹²

6. Scenario Cards Round 2: Energy flow through biological systems¹³.

Display slide 13 of Lesson 2 Activity 2.pptx. Tell students to return to their small groups and think about what happens to energy in their scenario. Encourage students to explain how energy is transformed from **light** energy to **chemical** energy to **heat** energy in each scenario. Invite some groups to share a story of how energy is transformed during their scenarios.

7. Transition to Activity 3.

In this activity, we examined how carbon is transformed from organic to inorganic carbon, and we discussed how energy flows through systems. In the next activity, we will examine how we can use this knowledge to explain the seasonal cycle in the Keeling Curve.

¹² If students have already studied the Ecosystems Unit, you may want to skip this step.

¹³ Note: some of the scenarios are the same; not all groups will have unique scenarios cards.

SCENARIO CARDS FOR LESSON 2 ACTIVITY 2

(photosynthesis and cellular respiration)

<p><u>Round 1:</u> For each scenario, decide as a group what will happen to the organic and inorganic pools of carbon.</p> <ol style="list-style-type: none"> 1. It is summer in the northern hemisphere and annual flowers begin to grow. 2. Winter comes and the annual plants die and are digested by decomposers. <p><u>Round 2:</u> Explain how energy is transformed in the scenarios above.</p>	<p><u>Round 1:</u> For each scenario, decide as a group what will happen to the organic and inorganic pools of carbon.</p> <ol style="list-style-type: none"> 1. Winter comes and the deciduous trees lose their leaves. The leaves are decomposed on the forest floor by decomposers. 2. It is summer in the northern hemisphere and deciduous trees begin to grow new leaves. <p><u>Round 2:</u> Explain how energy is transformed in the scenarios above.</p>
<p><u>Round 1:</u> For each scenario, decide as a group what will happen to the organic and inorganic pools of carbon.</p> <ol style="list-style-type: none"> 1. It is summer in the northern hemisphere and tall grass prairies are at their peak. 2. Winter comes and the grasses die and are digested by decomposers. <p><u>Round 2:</u> Explain how energy is transformed in the scenarios above.</p>	<p><u>Round 1:</u> For each scenario, decide as a group what will happen to the organic and inorganic pools of carbon.</p> <ol style="list-style-type: none"> 1. It is summer in the northern hemisphere and shrubs and bushes begin to grow new leaves. 2. Winter comes and the shrubs and bushes drop their leaves, which are digested by decomposers. <p><u>Round 2:</u> Explain how energy is transformed in the scenarios above.</p>
<p><u>Round 1:</u> For each scenario, decide as a group what will happen to the organic and inorganic pools of carbon.</p> <ol style="list-style-type: none"> 1. It is summer in the northern hemisphere and annual flowers begin to grow. 2. Winter comes and the annual plants die and are digested by decomposers. <p><u>Round 2:</u> Explain how energy is transformed in the scenarios above.</p>	<p><u>Round 1:</u> For each scenario, decide as a group what will happen to the organic and inorganic pools of carbon.</p> <ol style="list-style-type: none"> 1. It is summer in the northern hemisphere and deciduous trees begin to grow new leaves. 2. Winter comes and the deciduous trees lose their leaves. The leaves are decomposed on the forest floor by decomposers. <p><u>Round 2:</u> Explain how energy is transformed in the scenarios above.</p>
<p><u>Round 1:</u> For each scenario, decide as a group what will happen to the organic and inorganic pools of carbon.</p> <ol style="list-style-type: none"> 1. Winter comes and grasses die and are digested by decomposers. 2. It is summer in the northern hemisphere and tall grass prairies are at their peak. <p><u>Round 2:</u> Explain how energy is transformed in the scenarios above.</p>	<p><u>Round 1:</u> For each scenario, decide as a group what will happen to the organic and inorganic pools of carbon.</p> <ol style="list-style-type: none"> 1. It is summer in the northern hemisphere and shrubs and bushes begin to grow new leaves. 2. Winter comes and the shrubs and bushes drop their leaves, which are digested by decomposers. <p><u>Round 2:</u> Explain how energy is transformed in the scenarios above.</p>

ACTIVITY 3: THE SEASONAL CYCLE

Learning Objectives:

1. Explain changes in atmospheric CO₂ in terms of fluxes associated with carbon-transforming processes: photosynthesis and cellular respiration
2. Describe the atmosphere and biomass pools as changing in size over time.
 - a. Explain the seasonal cycle in the Keeling Curve.

Duration: 30 minutes

Activity Description:

Students watch a short video about seasonal plant growth to help interpret the seasonal cycle on the Keeling Curve, and identify which carbon pools are affected by this cycle.

Background Information:

Plants play a big role in explaining the short-term rise and fall of carbon dioxide concentrations between summer and winter. Seasons on Earth are determined by the tilt of our planet on its axis. Due to this tilt, when it is summer in the northern hemisphere it is winter in the southern hemisphere, and vice versa. Consider how plants are different in the winter versus the summer: Landmasses on Earth are not equally distributed all over the planet. In fact, the distribution is pretty different in the northern and southern hemispheres. The northern hemisphere is about 39% land and 61% water. The southern hemisphere is only about 19% land and 81% water. The video below aims to give students a visual of this distribution of biomass on the planet, and how this looks during seasonal change.

During summer on the northern hemisphere, trees, grasses, and annual plants all engage in photosynthesis, moving carbon from CO₂ in the atmosphere to their biomass. This sequestering of carbon in biomass causes the level of CO₂ in the atmosphere to go down. During winter, there is much less photosynthesis. But cellular respiration continues in plants, animals, and decomposers, causing carbon dioxide concentration in the atmosphere to rise. This happens every year, which explains the seasonal cycle on the Keeling curve (the gray line).

Note: students may incorrectly attribute the seasonal flux to human actions, like the burning of fossil fuels. The use of fossil fuels is not the cause of the seasonal cycle. However, some human actions could contribute to small changes in this seasonal cycle. For example, deforestation and desertification could lower the overall biomass on the planet, thereby causing a smaller flux in the spring and summer from the atmosphere to the biomass pool.

Materials:

- [Lesson 2 Activity 3.pptx](#)
- Internet connection to show short film:
http://eoimages.gsfc.nasa.gov/images/globalmaps/data/mov/MOD17A2_M_PSN.mov
- [What causes the seasonal cycle in the Keeling Curve? Worksheet](#)

Directions:

1. Introduce the activity.

Project slide 1 of [Lesson 1 Activity 5.pptx](#) and say “In this activity, we want to understand the seasonal cycle of the Keeling Curve.”

2. Recall the Keeling Curve and identify the seasonal cycle.

Using slide 1 of [Lesson 2 Activity 3.pptx](#), identify the seasonal cycle in the Keeling Curve: the gray line that fluctuates up and down each year. Use the box called “Annual Cycle” for a

closer image of the rise and fall of carbon levels in one year. Tell students the purpose of this activity is to explain why this happens.

3. Watch a short video about seasonal plant growth (see link above).

Divide students into groups and have them consider what information from the video can help them understand the seasonal fluctuation of carbon concentration in the atmosphere. Ask students to share their ideas about how what they saw in the video helps explain what is happening in the Keeling Curve.

4. Pass out the group worksheet.

Display slide 2 with student instructions. Have students complete the worksheet in groups and share their responses with the class.

5. Discuss student accounts of the seasonal cycle on the Keeling Curve as a group.

Formative assessment: Use slides 3 in [Lesson 2 Activity 3.pptx](#) to discuss the trend as a class after the students have completed the worksheet. See if students have answers to any of the 3 questions that they can use to explain the seasonal cycle (they should be starting to form answers to questions 1 and 2 at this point, but their responses may still not be complete).

6. Transition to Activity 4.

Now that students have had a chance to develop explanations that explain the seasonal cycle in the Keeling Curve for carbon and energy, Activities 4 and 5 will provide some foundational knowledge needed to understand the upward trend. What are fossil fuels? Where do they come from? How do we use them? What happens to carbon and energy when we burn fossil fuels?

Name: _____ Period: _____ Date: _____

WHAT CAUSES THE SEASONAL CYCLE IN THE KEELING CURVE?

Human Energy Systems Lesson 2, Activity 3

1. Watch the video showing changes in plant growth with seasons. Discuss the video with your group. Which global carbon pool do you think are changing?

Atmosphere	biomass	soil organic carbon	fossil fuels
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2. What is happening to the size of the biomass pool during the summer and during the winter?

During Summer:
During Winter:

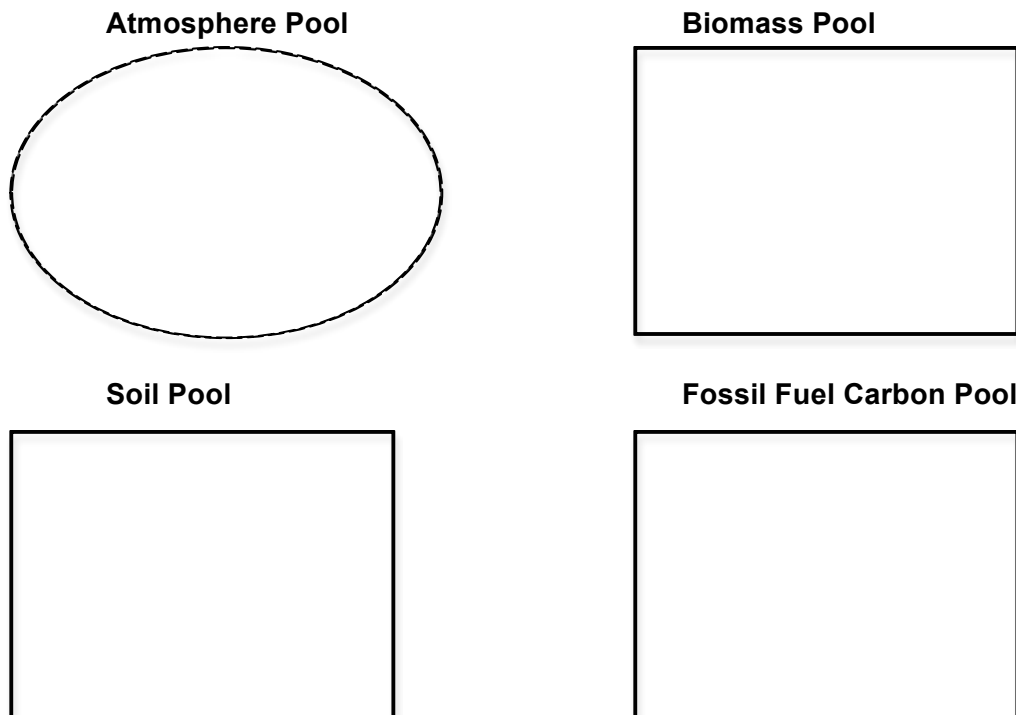
3. What processes might be changing the size of the biomass pool? (you can circle more than one process)

Combustion	Cellular respiration	Photosynthesis	Digestion	Biosynthesis
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4. Think about the Carbon/Movement question (Question #2). If the biomass pool is getting smaller, then some other pool **must** be getting larger, and vice versa. What other pool besides biomass is involved in these processes?

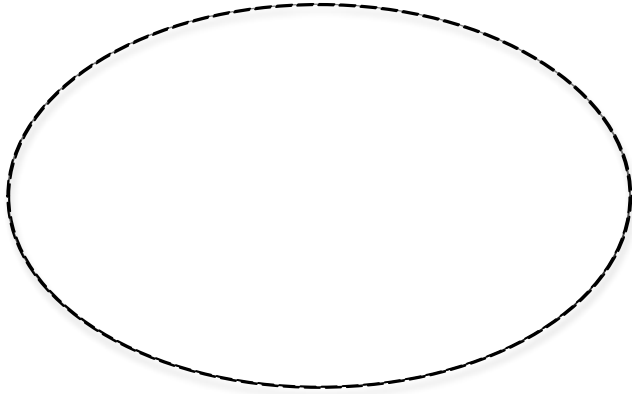
Atmosphere	Soil organic carbon	Fossil fuels
------------	---------------------	--------------

5. Draw and label arrows to show how each of the processes that you circled for Question 3 above moves carbon among the four pools (note that not all the pools are involved).

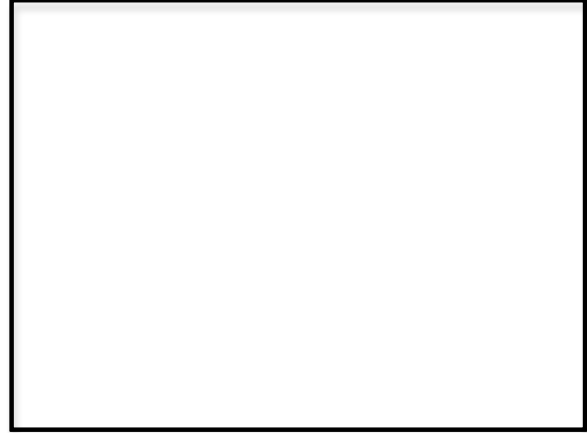


7. Draw arrows to show the main fluxes between the atmosphere and the biomass pool during the **summer**. Label the arrow that shows the **largest** flux.

Atmosphere Pool

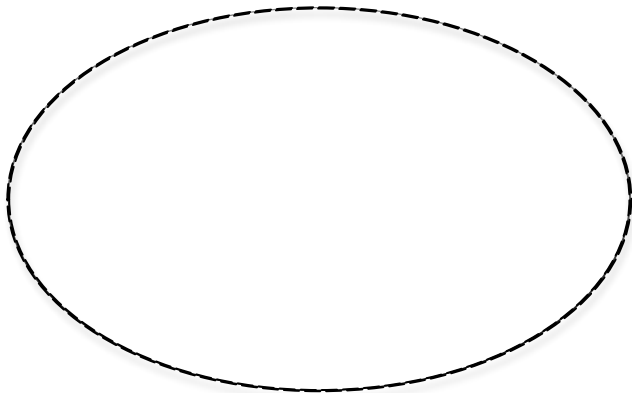


Biomass Pool

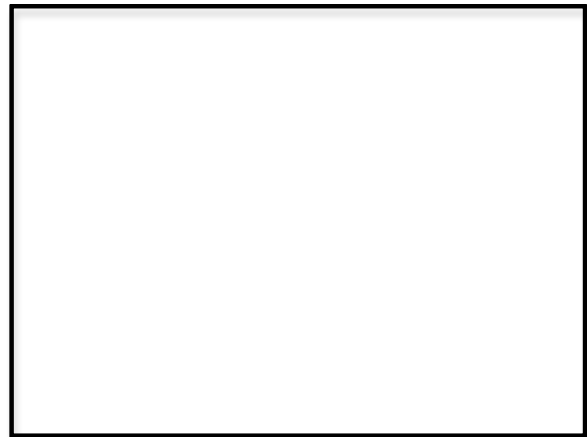


8. Draw arrows to show the main fluxes between the atmosphere and the biomass pool during the **winter**. Label the arrow that shows the **largest** flux.

Atmosphere Pool



Biomass Pool



8. Use what you have learned about seasonal differences in fluxes to explain the pattern in the Keeling curve: **Why does the concentration of carbon dioxide in the atmosphere go up and down each year?** Explain why the concentration goes up each year and why it goes down each year

ASSESSING WHAT CAUSES THE SEASONAL CYCLE IN THE KEELING CURVE?

Human Energy Systems Lesson 2, Activity 3

Students should have scientifically correct answers to this worksheet. Correct answers for grading purposes are in blue italics.

1. Watch the video showing changes in plant growth with seasons. Discuss the video with your group. Which global carbon pool do you think are changing?

Atmosphere	<i>biomass</i>	soil organic carbon	fossil fuels
------------	----------------	---------------------	--------------

2. What is happening to the size of the biomass pool during the summer and during the winter?

<i>Biomass pool is going up in the summer and down in the winter.</i>

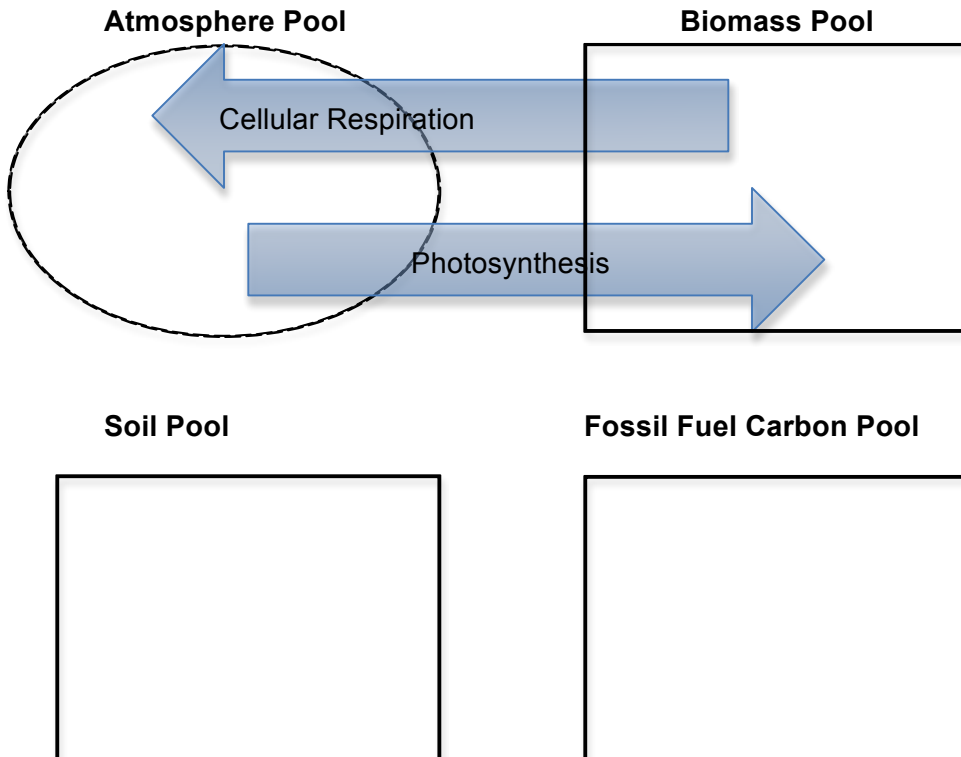
3. What processes might be changing the size of the biomass pool? (you can circle more than one process)

Combustion	<i>Cellular respiration</i>	<i>Photosynthesis</i>	Digestion	Biosynthesis
<i>Note that combustion, such as forest fires or using wood for fuel, does reduce the size of the biomass pool, though it is not a primary driver of the seasonal cycle. Digestion and biosynthesis change organic carbon from one form to another, but do not change the overall size of the biomass pool.</i>				

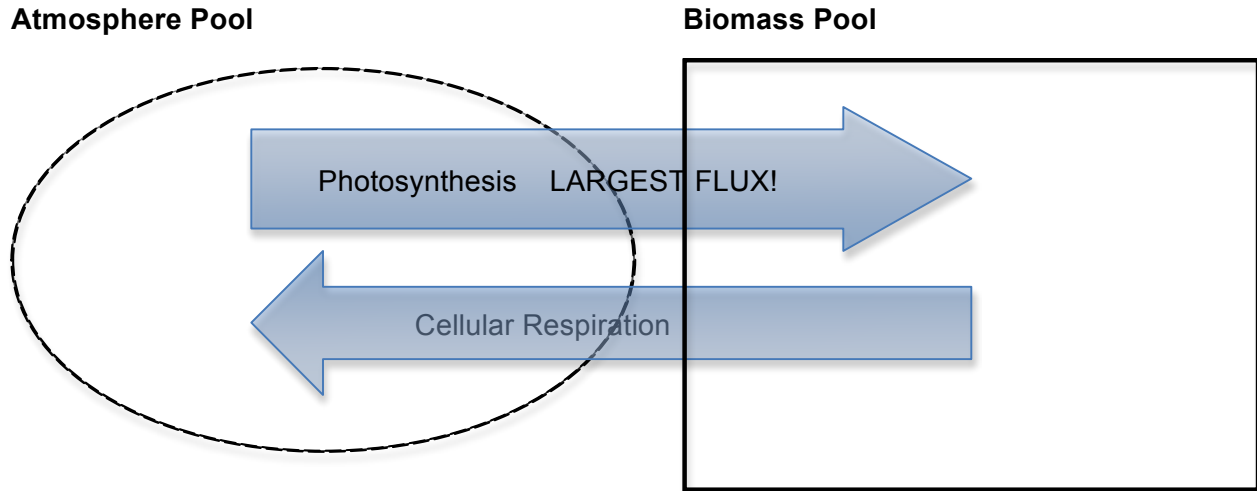
4. Think about the Carbon/Movement question (Question #2). If the biomass pool is getting smaller, then some other pool **must** be getting larger, and vice versa. What other pool besides biomass is involved in these processes?

<i>Atmosphere</i>	Soil organic carbon	Fossil fuels
-------------------	---------------------	--------------

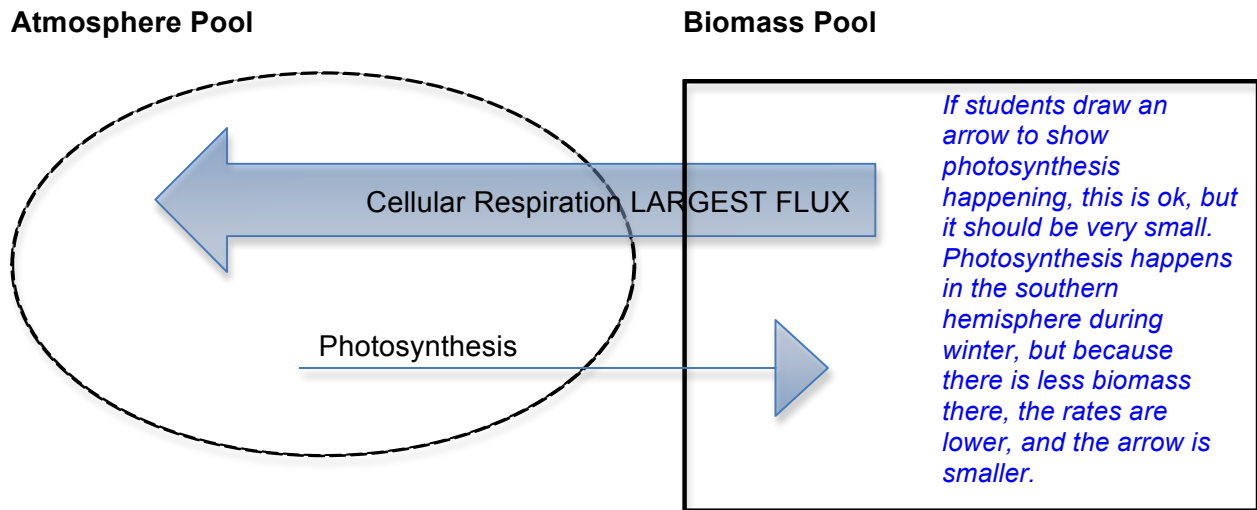
5. Draw and label arrows to show how each of the processes that you circled for Question 3 above moves carbon among the four pools (note that not all the pools are involved).



6. Draw arrows to show the main fluxes between the atmosphere and the biomass pool during the **summer**. Label the arrow that shows the **largest** flux.



7. Draw arrows to show the main fluxes between the atmosphere and the biomass pool during the **winter**. Label the arrow that shows the **largest** flux.



8. Use what you have learned seasonal differences in fluxes to explain the pattern in the Keeling curve: **Why does the concentration of carbon dioxide in the atmosphere go up and down each year?** Explain why the concentration goes up each year and why it goes down each year.

The main processes that cause the seasonal differences are photosynthesis and cellular respiration. During the summer, photosynthesis moves more carbon atoms from the atmosphere to biomass than cellular respiration moves the other way. During the winter, there is little photosynthesis, so cellular respiration is the more important process.

ACTIVITY 4: ZOOMING INTO FOSSIL FUELS

Learning Objectives:

1. Locate organic and inorganic carbon pools near the Earth's surface (atmosphere, biosphere, soil organic carbon, fossil fuels, oceanic carbon)
 - a. Identify the molecular structure of gasoline as an organic molecule, and all fossil fuels as originating as organic plant materials.

Duration: 20 minutes

Activity Description:

Students zoom into fossil fuels to examine how they were formed and why they store chemical energy. This serves as set up for the examination of the Keeling Curve's upward trend.

Background Information:

In the previous lesson, we examined the seasonal cycle in the Keeling curve, which is a result of the balance between photosynthesis and cellular respiration. The continuous upward trend in the Keeling Curve, however, is due to human consumption of fossil fuels for energy. When fossil fuels are burned, the energy released during combustion is used to generate electricity. In this process of combustion, CO₂ is released into the atmosphere. It is important for students to identify fossil fuels as organic material in order to understand how they were initially created and how they are now used in human energy systems. By zooming into a molecular level, students will see the similarity between fossil fuels and plant materials and other organic molecules. All organic molecules have stored chemical energy that is useful in human systems.

This foundational knowledge helps students make connections between fossil fuels and climate change by examining how carbon moves from the fossil fuel pool to the atmosphere pool.

Materials:

- [Lesson 2 Activity 4.pptx](#)
- Worksheet: [Zooming into Fossil Fuels](#)

Directions:

1. Recall the Keeling Curve.

Use slide 1 of Lesson 2 Activity 4.pptx to remind students what they already know about the Keeling Curve. At this point, they should have an understanding of the seasonal cycle, but not the upward trend. Tell them that this activity will give them clues to help answer this question: why is the concentration of carbon dioxide in the atmosphere increasing?

2. Discuss what fossil fuels are.

Ask students if they have ever heard of fossil fuels and to share with the class what they know about them. Use [Lesson 2 Activity 4.pptx](#) slides 2 and 3 to ask students if they know what fossil fuels are.

3. Compare the molecules of fossil fuels to other molecules.

Use slides 4-9 to "zoom" into fossil fuels at a molecular scale. Using the slides, lead the students through a discussion in which they compare the molecules of gasoline to other molecules to decide if gasoline is *organic* or *inorganic*. Tell students to use this information to answer questions 1-4 on their [Zooming into Fossil Fuels](#) worksheet.

4. Recall Question 3: The Energy Question

Tell students that fossil fuels contain chemical energy that is very useful to humans. Use [Lesson 2 Activity 4.pptx](#) slides 10-14 to discuss the energy question in the context of fossil

fuels. Have students complete question 5 of the Zooming into Fossil Fuels worksheet after this discussion.

FORMATIVE ASSESSMENT: Students will not have complete accounts of where the energy in fossil fuels comes from and where it goes after they are burned. Check during this activity to see where their ideas are as we begin to discuss fossil fuels.

5. Transition to Activity 5.

Tell students they will have an opportunity to learn more details about fossil fuels in the next activity.

Name: _____ Period: _____ Date: _____

Zooming In to Fossil Fuels Worksheet

Human Energy Systems Unit Lesson 2, Activity 4

Gasoline is a fossil fuel commonly used in transportation.

1) Think about the following materials: **gasoline, water, carbon dioxide, cellulose and ethanol**. Put the materials into two groups: one group that contains energy-rich (C-C and C-H) molecular bonds, and one group that doesn't. Describe each group.

Energy-rich bonds	No energy-rich bonds
<p>Materials in this group:</p> <p>The materials in this group are similar because:</p>	<p>Materials in this group:</p> <p>The materials in this group are similar because:</p>

3) Is gasoline organic or inorganic? Explain why or why not. Which material is it most similar to?

4) What are your ideas about where the **carbon atoms** in gasoline come from? Where were those atoms before they were in gasoline?

5) What are your ideas about where the **energy** for the C-C and C-H bonds in gasoline comes from? What form was the energy in before it was chemical energy?

ASSESSING ZOOMING IN TO FOSSIL FUELS WORKSHEET**Human Energy Systems Unit Lesson 2, Activity 4**

Gasoline is a fossil fuel commonly used in transportation.

1) Think about the following materials: **gasoline, water, carbon dioxide, cellulose and ethanol**. Put the materials into two groups: one group that contains energy-rich molecular bonds, and one group that doesn't. Describe each group.

<p>Materials in this group:</p> <p><i>Gasoline C_8H_{18}</i></p> <p><i>Ethanol C_2H_6O</i></p> <p><i>Glucose $C_6H_{12}O_6$</i></p> <p>This group is similar because:</p> <p><i>They have C-C and C-H bonds</i></p>	<p>Materials in this group:</p> <p><i>Water H_2O</i></p> <p><i>Carbon dioxide CO_2</i></p> <p>This group is similar because:</p> <p><i>They do not have C-C and C-H bonds</i></p>
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3) Is gasoline organic or inorganic? Explain why or why not. Which material is it most similar to?

Gasoline is organic because it has C-C and C-H bonds. It is the most similar in terms of atoms and bonds to glucose.

4) What are your ideas about where the **carbon atoms** in gasoline come from? Where were those atoms before they were in gasoline?

Students can share their own ideas, right or wrong, about this question. Take note of what students say so that you can help them compare their ideas to the explanations in the "Where Do Fossil Fuels Come From?" handout and slides 11-17 of the PowerPoint.

Level 4 students will suggest that carbon atoms in gasoline come from the carbon atoms in plant and animal biomass that was on the earth hundreds of millions of years ago. Over time, the organic material from the plants was exposed to heat and pressure in the ground, where it was turned into crude oil. This crude oil is refined and turned into gasoline that we use to power cars.

5) What are your ideas about where the **energy** for the C-C and C-H bonds in gasoline comes from. What form was the energy in before it was chemical energy?

Students can share their own ideas, right or wrong, about this question. Take note of what students say so that you can help them compare their ideas to the explanations in the "Where Do Fossil Fuels Come From?" handout and slides 11-17 of the PowerPoint.

Level 4 students will suggest that light energy from the sun was trapped as chemical energy in the biomass of plants, animals, and decomposers millions of years ago. This chemical energy was conserved in the ground as the biomass was exposed to heat and pressure over time. So, before it was chemical energy in the gasoline, it was chemical energy in the crude oil. Before that, it was chemical energy in plants and animals. Before that, it was light energy from the sun.

ACTIVITY 5: FOLLOW THE CARBON

Learning Objectives:

1. Trace energy associated with human lifestyles to its sources, particularly combustion of fossil fuels
2. Describe energy as flowing through Earth systems, from sunlight to chemical energy to heat that is radiated into space.
3. Describe the processes involved in fossil fuel formation and identify the time associated with each process.

Duration: 20 minutes

Activity Description:

Students trace carbon and energy through processes that lead to the formation of fossil fuels.

Background Information:

Having students follow a carbon atom from the air to plants and through the processes involved in forming and extracting fossil fuels will help them understand how fossil fuels were formed, when they were formed, and why they are a source of energy for humans.

During this discussion, focus on energy flow through the process of fossil fuel formation and combustion. Energy sequestered from the sun in the biomass pool millions of years ago was trapped in the form of chemical energy when fossil fuels formed (over time in the ground when exposed to pressure and heat). When fossil fuels are extracted from the ground and burned, the chemical energy stored in the fossil fuel molecules is released as heat energy. This heat energy is released into the atmosphere. Some of the energy radiates back out into outer space. Some of it is trapped in the greenhouse gases in the atmosphere, causing the global temperatures to rise.

During this discussion, also focus on carbon cycling through the process of fossil fuel formation and combustion. Carbon sequestered in the biomass pool millions of years ago was trapped in fossil fuel molecules when fossil fuels formed (over time in the ground when exposed to heat and pressure). Today, when fossil fuels are extracted from the ground and burned, the fossil fuels molecules are broken and the carbon from these molecules bonds with oxygen to creating CO₂ (and other emissions). This CO₂ is released into the atmosphere.

Materials:

- [Lesson 2 Activity 5.pptx](#)
- Reading: [Where Do Fossil Fuels Come From?](#)
- Worksheet: [Follow the Carbon](#)

Directions:

1. **Discuss as a class how fossil fuels were formed.**
Ask students if they know how fossil fuels were formed. Display [Lesson 2 Activity 5.pptx](#) slide 1 and pose the question: "How did fossil fuels form?" After students have shared ideas, display slides 2 and 3 for an overview about formation. Then, use the animation on slides 4-8 to trace carbon and energy separately through this large-scale system.
2. **Discuss the industrial revolution and its impacts on fossil fuel consumption.**
Use slides 9-10 to discuss changes in our history that lead to an increase in use of fossil fuels.
3. **Work individually to develop accounts of fossil fuel formation.**

Pass out copies of the Where Do Fossil Fuels Come From? handout to individuals or groups. Tell students to use this to complete the Follow the Carbon worksheet. Give students time to complete the worksheet in groups or individually.

4. Transition to Lesson 3.

Now that we have had a chance to talk about what fossil fuels are and how people use them, we are going to look more closely at how we use carbon as individuals and communities.

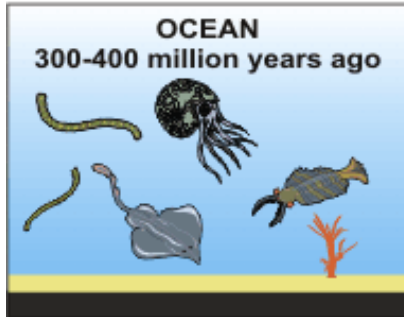
Name: _____ Period: _____ Date: _____

WHERE DO FOSSIL FUELS COME FROM? READING

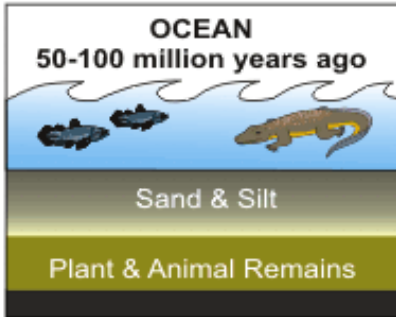
Human Energy Systems Lesson 2, Activity 5

Fossil fuels are formed over many millions of years from the remains of plants and animals. In this activity you will use the process tool to analyze how matter and energy transform in the process of fossil fuel formation.

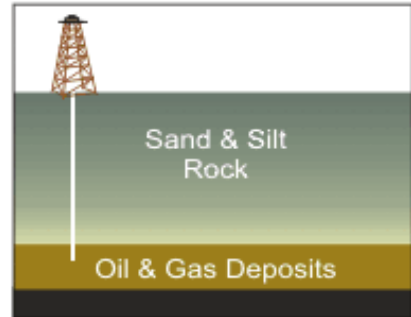
PETROLEUM AND NATURAL GAS FORMATION



OCEAN
300-400 million years ago
Tiny sea plants and animals died and were buried on the ocean floor. Over time, they were covered by layers of silt and sand.



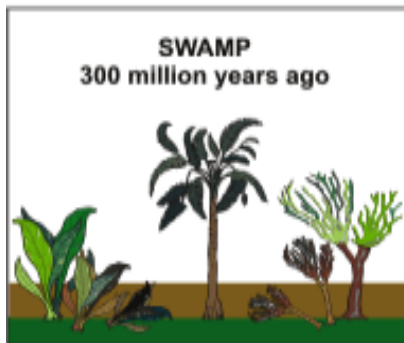
OCEAN
50-100 million years ago
Over millions of years, the remains were buried deeper and deeper. The enormous heat and pressure turned them into oil and gas.



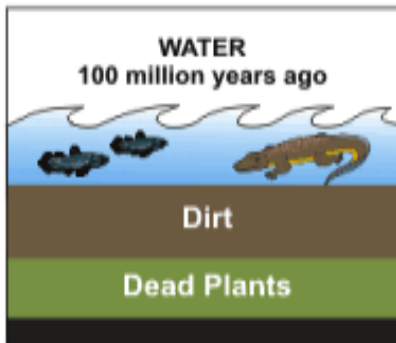
Today, we drill down through layers of sand, silt, and rock to reach the rock formations that contain oil and gas deposits.

Oil (petroleum) and natural gas are formed from the remains of animals and plants that lived millions of years ago in a marine (water) environment that existed on Earth before the dinosaurs. Over the years, layers of mud covered the remains of these animals and plants. Heat and pressure from these layers transformed the remains into what we today call crude oil. The word "petroleum" means "rock oil" or "oil from the Earth." Oil and natural gas are composed primarily of carbon and hydrogen atoms.

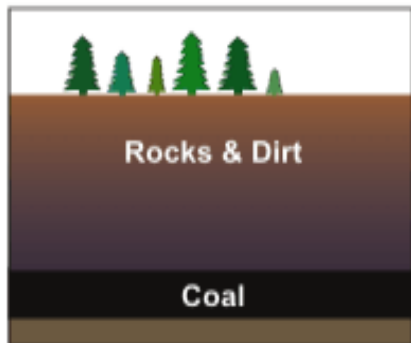
COAL FORMATION



SWAMP
300 million years ago
Before the dinosaurs, many giant plants died in swamps.



WATER
100 million years ago
Over millions of years, the plants were buried under water and dirt.



Heat and pressure turned the dead plants into coal.

Coal was formed in a similar way, mainly from the plants that lived hundreds of millions of years ago, when the Earth was partly covered with swampy forests. Layers of water and dirt covered layers of dead plants. The heat and pressure from the top layers helped the plant remains transform into what we today call coal. Coal is composed primarily of carbon, hydrogen, and oxygen atoms.

Name: _____ Period: _____ Date: _____

FOLLOW THE CARBON WORKSHEET

Human Energy Systems Lesson 2, Activity 5

Fossil fuels were around for a long time before they ended up in a gas tank or in a power plant. Use the table below to answer the Carbon/Movement Question and the Location Question as you describe how a carbon atom became part of the gasoline used in a car.

- 1) In the first column labeled “**Carbon/Movement Question: What Process?**” put the following processes listed in order with those that happened longest ago at the top and those that happened most recently at the bottom:

Extracted	CO₂ gas enters plant leaves	Heated and compressed
Buried	Photosynthesized	Combusted

- 2) In the second column labeled “**Location Question: Where did it happen?**” describe where the process happened, or where the carbon atom moved during the process.

- 3) In the third column labeled “**When Did it Happen?**” write when the process happened. (Hint: choose from a time scale of “Millions of years ago,” “Within last hundred years,” “Ten years ago,” or “Today”)

Carbon/Movement Question: What Process?	Location Question: Where did it happen?	When did it happen?

- 4) How did energy get from the sun 300 million years ago into a coal-burning power plant today? Explain the path that energy took in this process, including how energy was transformed along the way.

ASSESSING FOLLOW THE CARBON

Human Energy Systems Lesson 2, Activity 5

This worksheet could be graded using the answers below or assessed informally for formative assessment

Fossil fuels were around for a long time before they ended up in a gas tank or in a power plant. Use the table below to answer the Carbon/Movement Question and the Location Question as you describe how a carbon atom became part of the gasoline used in a car.

- 3) In the first column labeled “**Carbon/Movement Question: What Process?**” put the following processes listed in order with those that happened longest ago at the top and those that happened most recently at the bottom:

Extracted	CO₂ gas enters plant leaves	Heated and compressed
Buried	Photosynthesized	Combusted

- 4) In the second column labeled “**Location Question: Where did it happen?**” describe where the process happened, or where the carbon atom moved during the process.

- 3) In the third column labeled “**When Did it Happen?**” write when the process happened. (Hint: choose from a time scale of “Millions of years ago,” “Within last hundred years,” “Ten years ago,” or “Today”)

Carbon/Movement Question: What Process?	Location Question: Where did it happen?	When did it happen?
<i>CO₂ gas enters plant leaves</i>	<i>In the air</i>	<i>Millions of years ago</i>
<i>Photosynthesized</i>	<i>In a plant</i>	<i>Millions of years ago</i>
<i>Buried</i>	<i>Underground</i>	<i>Millions of years ago</i>
<i>Heated and compressed</i>	<i>Underground</i>	<i>Millions of years ago</i>
<i>Extracted</i>	<i>Underground to aboveground</i>	<i>Within last 100 years</i>
<i>Combusted</i>	<i>In human energy systems In car engines In factories In power plants In buildings (etc)</i>	<i>Today</i>

- 4) How did energy get from the sun 300 million years ago into a coal-burning power plant today? Explain the path that energy took in this process, including how energy was transformed along the way.

Level 4: Light energy from the sun entered plants that were alive 300 million years ago through photosynthesis and was transformed into chemical energy. This chemical energy was stored in plants, and transferred (not transformed) to animals that ate the plants. When these plants and animals died, some materials were trapped in ocean floors or swamps. This biomass was exposed to heat and pressure underground, and turned into fossil fuels, like coal, oil, and gas,

that is full of organic carbon and chemical energy. Since the industrial revolution started and today, humans extract these fossil fuels from the ground and burn them. During combustion, the carbon atoms in the fossil fuels are oxidized. When the carbon atoms bond with oxygen, energy is released in the form of heat. This heat is used to generate electricity or make engines work.

LESSON 3: CONSEQUENCES OF OUR LIFESTYLES

Role of this Lesson in the Application and Inquiry Sequences

Activity 1: Establishing the Problem: Making connections between human energy use and the movement of carbon atoms

Activity 2: Establishing the Problem: Making connections between human energy use and the movement of carbon atoms

Activity 3: Establishing the Problem: Making connections between human energy use and the movement of carbon atoms

Time/Duration: 70 minutes

Activity 1: How do I use organic carbon?	~20 minutes
Activity 2: Extreme Makeover: Lifestyle Edition	~25 minutes
Activity 3: Secrets Revealed!	~25 minutes

Lesson Description:

Students examine ways they use carbon as individuals and compare how people around the globe use carbon for transportation, food, housing, and electricity.

Guiding Questions:

1. How do we use organic carbon in our lives?
2. If you had a choice, what lifestyle would you choose for your housing, the food you eat, the amount of electricity you use, and your transportation?

Background Information:

Major lifestyle sectors of transportation, food, housing and electricity use contribute greatly to carbon emissions. Average lifestyles for individuals in different countries vary greatly; per capita carbon emissions are particularly high in developed countries --- especially the United States.

Lesson Materials:

For Activity 1:

- Worksheet: [How Do I Use Organic Carbon?](#)

For Activity 2:

- [Lifestyle Cards.pdf](#)
- 4 stations (set up one transportation section with all 4 transportation cards, one food station with all 4 food cards, etc).
- [Extreme Makeover: Lifestyle Edition](#) worksheet
- [Consequences Revealed! Worksheet](#) (important: do not handout this worksheet until **after** students make their lifestyle choices)
- Calculator for each student (optional)

For Activity 3

- [Lesson 3 Activity 3.pptx](#)

ACTIVITY 1: HOW DO I USE ORGANIC CARBON?**Learning Objectives:**

1. Trace energy associated with human lifestyles to its sources, particularly combustion of fossil fuels.
2. Describe carbon cycling within Earth and Human systems.
3. Describe energy as flowing through Earth systems, from sunlight to chemical energy to heat that is radiated into space.

Duration: 20 minutes

Activity Description:

Students share their initial ideas about how they use organic carbon and illustrate how these uses cause movement of carbon between pools.

Background Information:

The level of carbon dioxide in our atmosphere is increasing primarily because human activity in the past century has moved significant amounts of carbon that had been sequestered in fossil fuels buried underground for millions of years into the atmosphere. The global carbon cycle includes processes that both release carbon dioxide into the air (e.g., decomposition, combustion, respiration) and that remove carbon dioxide from the air (e.g., photosynthesis). The rate at which humans burn fossil fuels for various activities means that more carbon is being added to the atmosphere than removed.

Energy is also involved in this process: mainly, we use fossil fuels because we need the energy stored in their bonds. When we burn fossil fuels, energy is released in the form of heat, which is used to generate electricity, make our engines run, or give us heat for our stoves and houses. Our lifestyles require us to use energy in a variety of ways. This activity gets students thinking about how they use energy, and how this moves carbon out of the fossil fuels pool and into the atmosphere pool.

Materials:

- Worksheet: [How Do I Use Organic Carbon?](#)

Directions:**1. Recall the difference between organic and inorganic carbon.**

As a review, ask students to explain the difference between organic and inorganic carbon. This should serve as a reminder that organic carbon stores useful chemical energy in C-C or C-H bonds. Pass out worksheets to the students and have them record their ideas for number 1.

2. Brainstorm about how we use organic carbon in every day life.

Have students think of organic carbon they use in everyday life. If students are having a difficult time coming up with ideas, have them look around the classroom or think about what they have done during the day for more ideas.

3. Record ideas as a group.

Create a T-chart on the board, with headings “Organic carbon that I use” and “How I use it.” Have students take turns sharing one way they use organic carbon during their day. Continue adding different ways that organic carbon is used until there are a large variety of responses. Spend time allowing students to discuss these questions aloud as a whole group, probing what they already know about the uses of organic carbon in everyday life.

4. Record ideas as individuals.

Pass out [How Do I Use Organic Carbon](#) and tell students to complete the worksheet.

5. Formative Assessment: Come together as a class after students have completed the worksheet. As a class, have students offer their ideas about how carbon moves from pool to

pool in question #6, and how energy is transformed in #7 on the worksheet. Check to see if they understand what each pool represents, and how carbon-transforming processes cause atoms to move from pool to pool, and how energy is transformed and lost as heat to the environment.

6. Transition to Activity 2.

Now that we have examined ways we use carbon in our own lives, the next activity will help us examine ways people use fossil fuels around the world.

Name: _____ Period: _____ Date: _____

HOW DO I USE ORGANIC CARBON? WORKSHEET

Human Energy Systems Lesson 3, Activity 1

There are lots of ways that people use organic carbon.

1. Can you list at least five materials that are organic and five that are inorganic?

Organic Materials:	Inorganic Materials:
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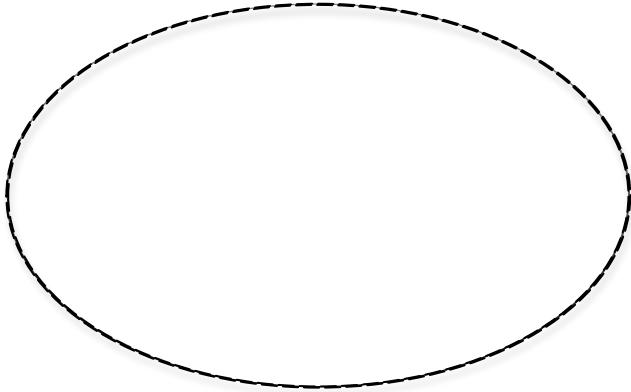
2. What is the difference between organic and inorganic materials?

3. Can you name at least five types of organic carbon that you use? List them in the left-hand column. How do you use that organic carbon? Explain how for each type of organic carbon in the right hand column.

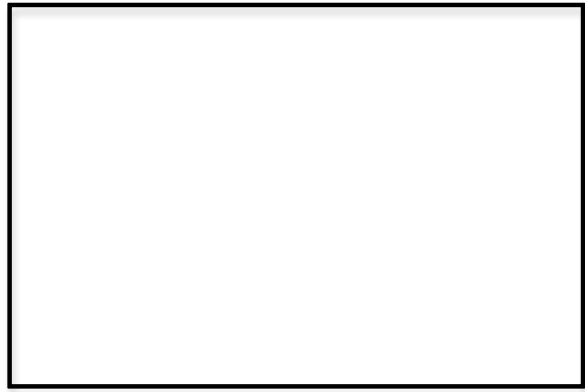
Organic carbon that I use	How I use it

4. Choose **one** of the forms of carbon you use above. Write it in this line: _____
5. In the picture below, draw arrows to show how carbon moves between pools when you use this form of carbon.

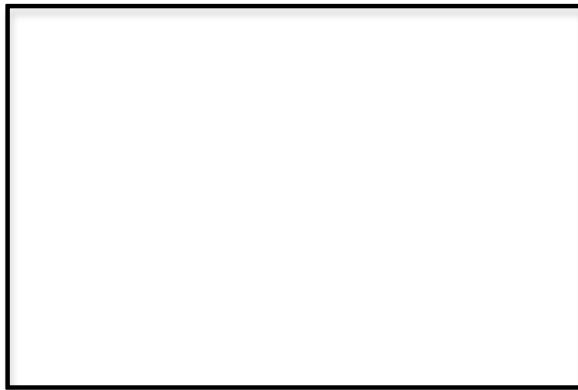
Atmosphere Pool



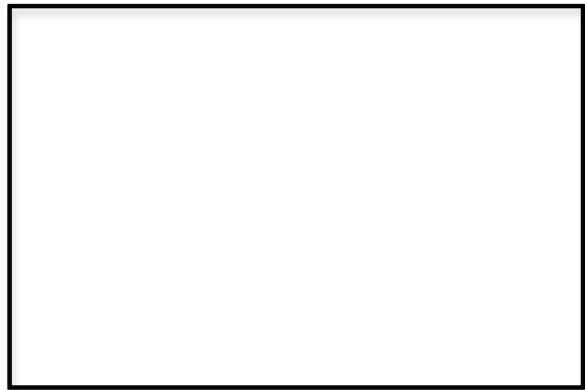
Biomass Pool



Soil Pool

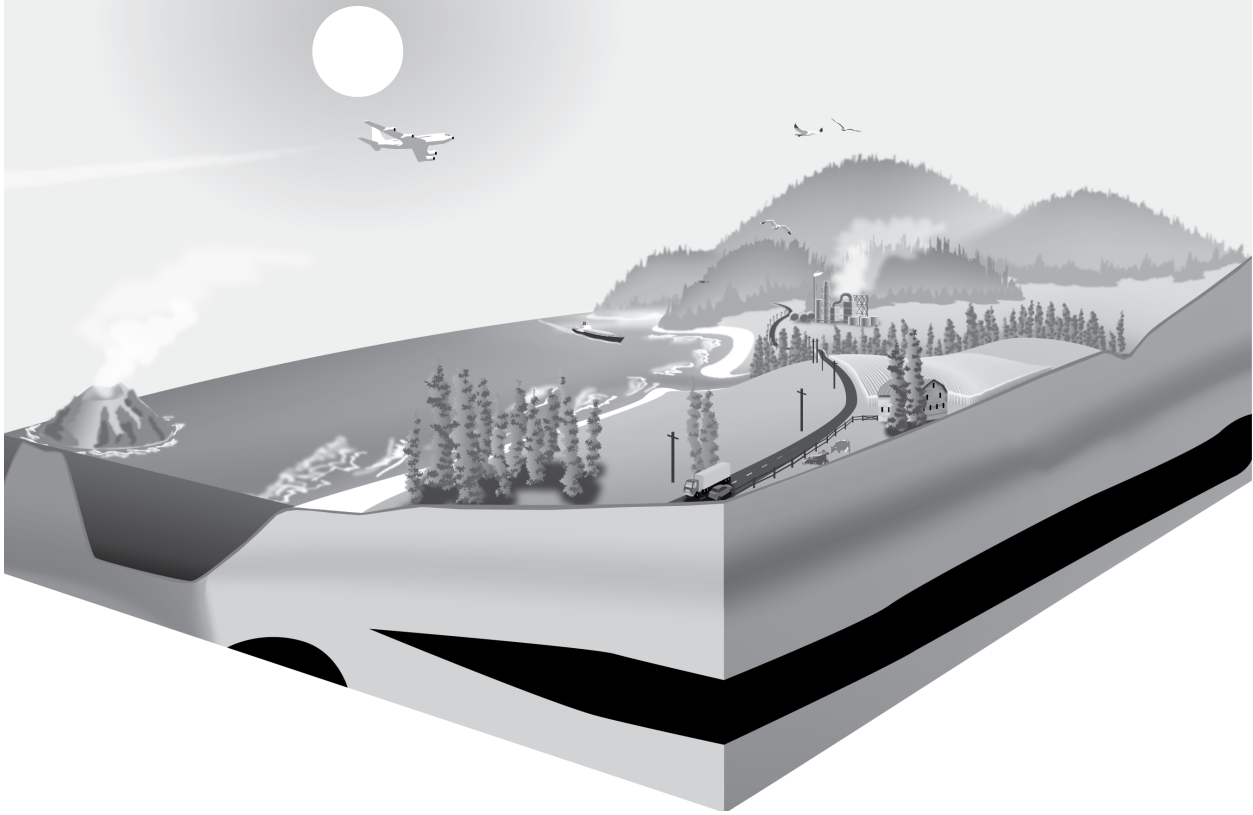


Fossil Fuels Pool



6. Now consider the following actions that cause carbon to move from pool to pool. Describe how each action below makes carbon move from one pool to another.
 - When I **burn gasoline in my car**, carbon moves from the _____ pool to the _____ pool.
 - When I **exercise**, carbon moves from the _____ pool to the _____ pool.
 - When I **grow plants in my garden**, carbon moves from the _____ pool to the _____ pool.
 - When a **tree grows and gains mass**, carbon moves from the _____ pool to the _____ pool.
 - When I **ride a bike to school**, carbon moves from the _____ pool to the _____ pool.
 - When a **forest burns**, carbon moves from the _____ pool to the _____ pool.
 - When an **animal dies and falls on the ground**, carbon moves from the _____ pool to the _____ pool.

7. Draw arrows on this picture to trace the energy that is released when you **take a ride in a bus that uses gasoline**. In your drawing, include arrows for: light energy, chemical energy, and heat energy.



8. Explain what is happening in the picture you drew above. Remember the rule: energy flows!

ASSESSING THE HOW DO I USE ORGANIC CARBON? WORKSHEET

Human Energy Systems Lesson 3, Activity 1

This worksheet is best used for formative assessment. Appropriate answers are suggested below.

1. Can you list at least five materials that are organic and five that are inorganic?

<p>Organic Materials:</p> <ul style="list-style-type: none"> <i>Food</i> <i>Plants</i> <i>Animals</i> <i>Fossil fuels</i> <i>Paper</i> <i>Wood</i> <i>Leather</i> 	<p>Inorganic Materials:</p> <ul style="list-style-type: none"> <i>Water</i> <i>Carbon dioxide</i> <i>Rocks</i> <i>Sand</i> <i>Metal</i> <i>Glass</i>
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2. What is the difference between organic and inorganic materials?

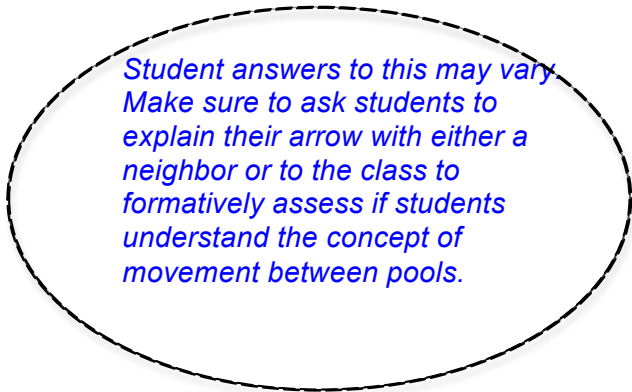
Organic materials store chemical energy in C-C and C-H bonds; inorganic materials do not. They have different bonds that have energy in them too, but there are no Carbon-hydrogen or Carbon-carbon bonds in inorganic materials.

3. Can you name at least five types of organic carbon that you use? List them in the left-hand column. How do you use that organic carbon? Explain how for each type of organic carbon in the right hand column.

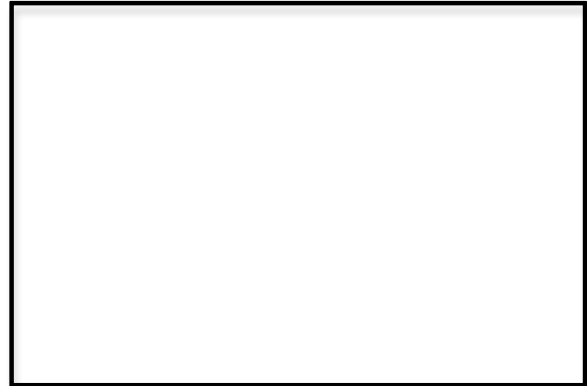
Organic carbon that I use	How I use it
<ul style="list-style-type: none"> <i>1. Vegetables</i> <i>2. Wood</i> <i>3. Fuel (gasoline)</i> <i>4. Fuel (coal)</i> <i>5. Paper</i> <p><i>Other examples of organic carbon include:</i></p> <ul style="list-style-type: none"> <i>Other food types</i> <i>Wood or gas for heating</i> <i>Fibers in clothing</i> <i>Wood in tables or cabinets</i> 	<ul style="list-style-type: none"> <i>1. I eat it for mass and energy</i> <i>2. I live and go to school in buildings made of wood</i> <i>3. I use gasoline when I drive or ride in a car or bus</i> <i>4. I use fuel that has been turned into electricity for lights in school</i> <i>5. I use paper that I write on during school</i>

4. Choose **one** of the forms of carbon you use above. Write it in this line: answers will vary
6. In the picture below, draw arrows to show how carbon moves between pools when you use this form of carbon.

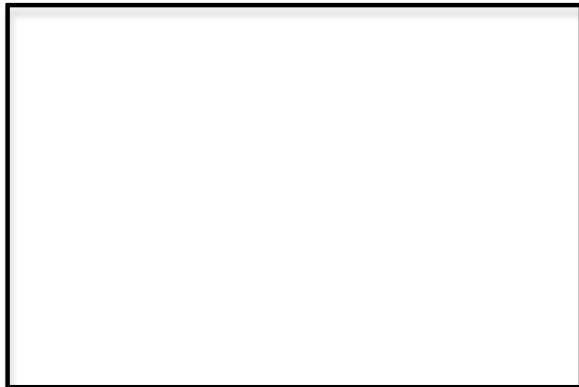
Atmosphere Pool



Biomass Pool



Fossil Fuel Pool



Soil Carbon Pool

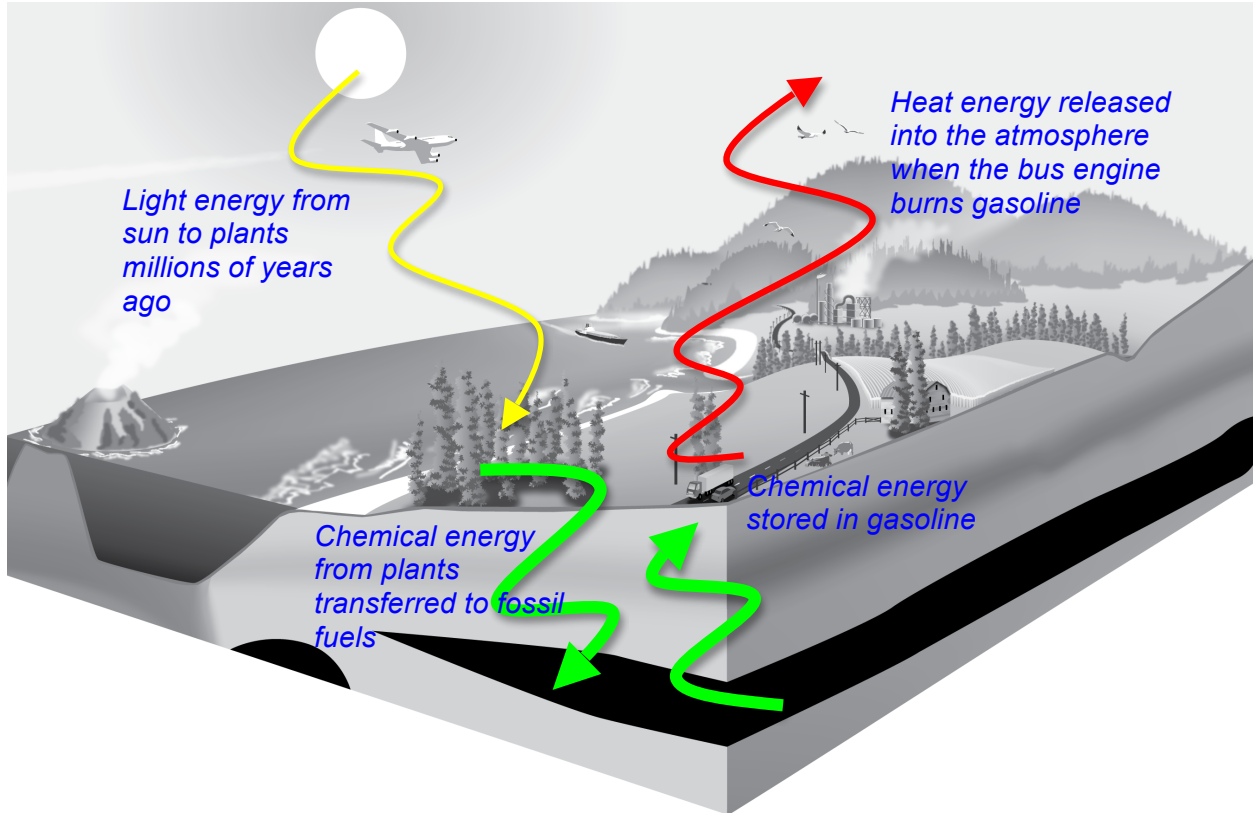


7. Now consider the following actions that cause carbon to move from pool to pool. Describe how each action below makes carbon move from one pool to another.

- When I **burn gasoline in my car**, carbon moves from the Fossil Fuel pool to the Atmosphere pool.
- When I **grow plants in my garden**, carbon moves from the Atmosphere pool to the Biomass pool.
- When a **tree grows and gains mass**, carbon moves from the Atmosphere pool to the Biomass pool.
- When I **ride a bike to school**, carbon moves from the Biomass pool to the Atmosphere pool.
- When a **forest burns**, carbon moves from the Biomass pool to the Atmosphere pool.
- When an **animal dies and falls on the ground**, carbon moves from the Biomass pool to the Atmosphere/Soil Carbon pool.

Note: If the students are thinking about decomposition, they might suggest that the carbon from the dead animal goes into the atmosphere when decomposers engage in cellular respiration. If the students are thinking about the movement of dead animal matter that has yet to be decomposed, they might suggest that the carbon from the dead animal goes into the soil carbon where it waits to be decomposed.

7. Draw arrows on this picture to show how energy is transformed when you **take a ride in a bus that uses gasoline**. In your drawing, include arrows for: light energy, chemical energy, and heat energy.



8. Explain what is happening in the picture you drew above. Remember the rule: energy flows!

Light energy from the sun is sequestered in plants millions of years ago. The chemical energy in plants is buried underground when it is exposed to pressure and heat.

Energy stored in the bonds of gasoline is burned in the engine of a car. The combustion of fossil fuels releases heat that is used to power the engine. The heat is lost the atmosphere and cannot be reused.

Note: the gasoline is made through a process of refining crude oil (petroleum) that is extracted from the ground. This takes place at an oil refinery. The gasoline does not go from the ground directly into the tank of the car.

ACTIVITY 2: EXTREME MAKEOVER: LIFESTYLE EDITION**Learning Objectives:**

1. Explain the consequences of lifestyle and energy system choices for changes in atmospheric CO₂ concentration.
2. Trace energy associated with human lifestyles to its sources, particularly combustion of fossil fuels

Duration: 25 minutes

Activity Description:

Students visit four stations representing the four lifestyle sectors, choose a lifestyle preference for each sector, and calculate the CO₂ emissions associated with their lifestyle choices.

Background Information:

Many carbon footprint calculators available on the internet examine how many pounds of CO₂ individuals emit as a result of their lifestyle choices and energy use. While this is a valuable exercise, these tools often frame energy and carbon use as a *choice*. While it is important to focus on how individual choices in energy reduction can lead to fewer carbon emissions, it is also important to examine how the places where we live, the transportation that is available to us, the food that is available to us, and the ways our electricity is produced all impact how much carbon we emit. While some of these we can change through lifestyle choices, others are determined for us by the infrastructure, resources, and systems where we live. Changing these systems is not as simple as making a personal choice: this takes change to policy and infrastructure.

It is important to discuss the fact that individual energy use is a result of two factors: the ways we use carbon as *individual* consumers, and the ways we use carbon as a *society*. Examining the roles of both individual and societal carbon use can help students realize that solutions to lowering carbon emissions will take a combination of 1) individual choices to lower individual carbon use (i.e., turn the lights off when we can; riding bikes when we can) and 2) cooperation from groups of people to lower carbon use at a societal level (i.e., replace coal plants with solar and wind; building more public transportation to reduce the need to drive cars).

Materials:

- [Lifestyle Cards.pdf](#)
- 4 stations (set up one transportation section with all 4 transportation cards, one food station with all 4 food cards, etc).
- [Extreme Makeover: Lifestyle Edition worksheet](#)
- [Consequences Revealed! Worksheet](#) (important: do not handout this worksheet until **after** students make their lifestyle choices)
- Calculator for each student (optional)

Directions:**1. Make connections to previous activity.**

Tell students in this activity we examine how we as individuals use organic carbon, and how others use carbon around the globe. In this activity, we are going to examine how people from all parts of the world use carbon and energy.

2. Visit Stations and make lifestyle choices.

Give each student a copy of [Extreme Makeover: Lifestyle Edition worksheet](#). Tell students to visit each station, read each lifestyle card at each station, and select a lifestyle for each station (They should record their choice in Table 1: Lifestyle Choices). Give students 10 minutes to visit each station.

3. Ask for reflections on the activity as a whole class.

Ask students to share any reflections they have on their choices for each station. Ask: *Who would like to share the choice they made for each station? And Why did you make the choices you did? And What did you think about as you were making your decisions? And What was your motivation for choosing these?* Students were likely to have chosen various lifestyles for a variety of reasons. Answers will vary at this point. Use the discussion to highlight the fact that different people use carbon in different ways depending on their needs, wants, and what kinds of resources are available to them.

4. Calculate carbon emissions associated with the students' chosen lifestyles.

Pass out Consequences Revealed! Worksheets and tell students to use the information in Table 2 to calculate how much carbon emissions are associated with their lifestyle choices.

5. Share results with partner/table.

Ask students to look at their individual carbon emissions based on their choices and share their results with their partners. Encourage students to notice which lifestyle choices lead to the highest emissions and to look for similarities and differences in the choices they made.

6. Transition to Activity 3.

Tell students now that they know the emissions associated with their choices, we will learn which country is represented by each choice and discuss how *where you live* can affect how much carbon you use as well as the choices you make.

Name: _____ Period: _____ Date: _____

EXTREME MAKEOVER: LIFESTYLE EDITION WORKSHEET

Human Energy Systems Lesson 3, Activity 2

How Would You Like To Live?

How do peoples’ lifestyles contribute to the rise in the Keeling Curve? In this activity, you will choose what lifestyle you would prefer for four different aspects of life including the transportation you use, the house you live in, the electricity you use, and the food you eat.

In table 1, indicate which lifestyle you choose (A, B, C, or D) for each category.

Table 1. Lifestyle Choices

Station	Write your lifestyle choice for each station here ↓
Transportation	
Home	
Electricity	
Food	

Name: _____ Period: _____ Date: _____

CONSEQUENCES REVEALED! WORKSHEET

Human Energy Systems Lesson 3, Activity 2

How Much Carbon Dioxide Emissions Will Your Chosen Lifestyle Produce?

Carbon emissions represent the amount of carbon dioxide that is released into the atmosphere. Many carbon dioxide emissions come from human activities that involve combustion of fossil fuels. However, fossil fuels are not the only source of carbon emissions in the global carbon cycle. Other sources of carbon dioxide emissions into the atmosphere include respiration by plants and animals and decomposition of dead plants and animals. Often though, when you read about carbon emissions in the media, this term refers to carbon dioxide that is emitted through human activity.

Use tables 2 and 3 below to calculate a rough estimate of the carbon dioxide emissions that your lifestyle choices for these four categories will lead to.

Table 2. Carbon Dioxide Emissions For Different Lifestyle Choices

Lifestyle Category	Choice A (lbs CO ₂ /yr)	Choice B (lbs CO ₂ /yr)	Choice C (lbs CO ₂ /yr)	Choice D (lbs CO ₂ /yr)
Transportation	11,570	780	110	4,240
Home	2,790	410	30	2,960
Electricity	15,700	5,460	10	1,790
Food	6,580	1,420	30	2,190

Table 3. Carbon Dioxide Emissions For Your Lifestyle Choices

Lifestyle Category	Your Choice (A, B, C or D)	Emissions For Your Choice (lbs CO ₂ /yr)
Transportation		
Home		
Electricity		
Food		
Total carbon dioxide emissions for your choices →		

ACTIVITY 3: SECRETS REVEALED!**Learning Objectives:**

1. Explain the consequences of lifestyle and energy system choices for changes in atmospheric CO₂ concentration.
2. Discuss how personal choices *and* where we live can determine how we use organic carbon in our lives.

Duration: 25 minutes

Activity Description:

Students learn that the lifestyle choices in Activity 1 are associated with average lifestyles in four countries around the world (United States, China, Ethiopia, and France) and then engage in a short discussion about how lifestyles relate to carbon dioxide emissions.

Background Information:

When we talk about carbon emissions, we often discuss actions that we can take to help reduce our carbon footprint. However, people use carbon in different ways around the world, and these are not always choices. This activity helps students think about how much of their carbon footprint is a choice and what aspects of their carbon footprint is determined by where they live. This may help students think about how their individual choices can determine how much

Materials:

- [Lesson 3 Activity 3.pptx](#)

Directions:**1. Recall lifestyle choices game.**

Tell students that in the last activity, we learned that people who live in different geographical regions in the world use carbon in different ways. In this activity, we are going to reveal which places these and discuss what this means.

2. Ask students for guesses about which country matches which letter in the cards.

Display [Lesson 3 Activity 3.pptx](#) slide 2. Ask students: *Which countries do you think are represented by lifestyles A, B, C, and D?* Give students an opportunity to suggest ideas about this question.

3. Reveal the answers!

Use [Lesson3 Activity 3.pptx](#) slide 3 to show which country is associated with which lifestyle. Ask students if this is what they were expecting. Use [Lesson3 Activity 3.pptx](#) slide 4 to ask *Why do you think these countries have different carbon emissions?* Invite students to share ideas with the class.

4. Think-Pair-Share Discussion .

Display [Lesson3 Activity 3.pptx](#) slide 5. Give students an opportunity to think about each question on the slide individually, share with a neighbor, and then share with the class.

5. Transition to Lesson 5

Tell students that in this lesson we examined how our individual choices and where we live determine how we use energy and carbon. In the next lesson, we will talk about how these lifestyles move carbon from pool to pool in the world. We will finally answer our unanswered questions about the Keeling Curve.

LESSON 4: HOW DOES ENERGY USE CREATE CARBON EMISSIONS?

Role of this Lesson in the Application and Inquiry Sequences

Activity 1: Coaching: Making connections between human energy use and the movement of carbon atoms

Activity 2: Coaching: Making connections between human energy use and the movement of carbon atoms

Activity 3: Modeling and Coaching: The Keeling Curve

Time/Duration: 60 minutes

Activity 1: How do carbon emissions happen? Jigsaw ~45 minutes

Activity 2: Energy Scenarios ~45 minutes

Activity 3: Interpreting the upward trend in the Keeling Curve ~20 minutes

Guiding Question: Where does our energy come from? How does carbon move from pool to pool when we use energy?

Lesson Description:

Students discuss how organic carbon from the ground is transformed into inorganic carbon (CO₂) in the atmosphere, and relate carbon emissions to human consumption of fossil fuels and energy.

Background Information:

Nearly all the energy humans use comes from energy stored in the bonds of organic carbon. Some students may not be aware of how important organic carbon is to human energy systems. Without this understanding, they may not comprehend how humans could add so much inorganic carbon to the atmosphere. Energy use is directly related to carbon emissions.

Lesson 4 Materials

For Activity 1

Per Group

- [GroupA_Electricity.pdf](#)
- [GroupB_Transportation.pdf](#)
- [GroupC_Buildings.pdf](#)
- [GroupD_Food.pdf](#)

Per Student

- [Group A Questions: Where does electricity come from? Worksheet](#)
- [Group B Questions: How do we use energy for transportation? Worksheet](#)
- [Group C Questions: How do we use energy in our homes and buildings? Worksheet](#)
- [Group D Questions: How do we make and move food? Worksheet](#)
- [JigsawCards.pdf](#)

For Activity 2

- [Energy Scenario Cards \(below\)](#)
- [Energy Scenario Handout \(below\)](#)
- [Lesson 4 Activity 2.pptx](#)

For Activity 3

- [What causes the upward trend in the Keeling Curve? Worksheet](#)

ACTIVITY 1: HOW DO CARBON EMISSIONS HAPPEN? (JIGSAW)

Learning Objectives:

1. Explain the consequences of lifestyle and energy system choices for changes in atmospheric CO₂ concentration.

Duration: 45 minutes

Activity Description:

Students participate in a jigsaw activity designed to create a student-led discussion about human consumption of fossil fuels and energy through transportation, food consumption, electricity use, and buildings.

Background Information:

Humans use energy in a variety of different ways. We use energy through electricity generation, transportation, housing, and agriculture/food distribution. Tracing matter and energy through these processes is an important piece of envisioning matter cycle and energy flow at large scale. Learning about how we need energy in various actions in our lives helps students examine the relationship between energy use and carbon emissions.

Materials:

Per Group

- [GroupA_Electricity.pdf](#)
- [GroupB_Transportation.pdf](#)
- [GroupC_Buildings.pdf](#)
- [GroupD_Food.pdf](#)

Per Student

- [Group A Questions: Where does electricity come from? Worksheet](#)
- [Group B Questions: How do we use energy for transportation? Worksheet](#)
- [Group C Questions: How do we use energy in our homes and buildings? Worksheet](#)
- [Group D Questions: How do we make and move food? Worksheet](#)
- [JigsawCards.pdf](#)

Directions:

1. Activate Prior Knowledge about Question 3: Energy.

Remind students of rule #3: Energy flows! Invite students to share what they think this means. You may want to recall the [3 Questions Handout](#) from Lesson 1.

2. Introduce the jigsaw to the students.

Tell students they are going to participate in a jigsaw to discuss how we use fossil fuels for our energy needs. First, they will divide into **home** groups. In their **home** group, they will read one handout and discuss the questions on their handout. They will have 10 minutes to read, and 10 minutes to write down their answers to the questions. Then, they will move to **expert** groups. In their expert groups, it is their job to share with their expert group members what was discussed in their home groups. They will have 15 minutes as a group to share with each other what they learned in their home groups.

3. Pass out Jigsaw Cards.

Distribute one jigsaw card to each student. For large classes with 25 students or more or more use the “Jigsaw cards for large classes” in [Jigsawcards.pdf](#). For classes under 25 students, use the “Jigsaw cards for smaller classes” in [JigsawCards.pdf](#)

4. Divide students into home groups.

Tell students to divide by letter to form home groups (i.e., all students with the same letter on their cards should group together, etc.). These are their **home** groups. Distribute

readings and questions to each home group. Students should take time to read (10 minutes), and then discuss and answer questions as a group (15 minutes). Each student should be prepared to provide a summary/report to their **expert** group about what they discussed in their home group. They can use their answers written down on their questions worksheets to help them remember what to say in their expert groups.

5. **Divide students into expert groups.**

Instruct students to regroup according to image to form expert groups (i.e., students with gas tanks should all form one group, etc.). These are their **expert** groups. In their expert groups, it is each student's job to provide a summary or report of what s/he discussed in his/her home group. Give students 15 minutes to share what they discussed in their home groups. (15 minutes)

6. **Whole Class Discussion**

Regroup as an entire class. Ask students to share observations and patterns they noticed with the class. Do a comprehension check to see if students are on board with the following ideas:

- a. Which type of energy use leads to carbon emissions?
- b. Which type of energy use produces the lowest carbon emissions?
- c. How do humans transform organic carbon to inorganic carbon?
- d. What is one way that eating food produces carbon emissions?
- e. How does our school building produce carbon emissions?
- f. What types of transportation produce the least carbon emissions?
- g. What are some actions humans could take to reduce their carbon emissions at school? At home?

7. **Transition to Activity 2**

Tell students that in this activity, we discussed ways that we use fossil fuels for energy. In the next lesson, we will examine how carbon and energy are transformed when we do these things by playing a tracing game.

Name: _____ Period: _____ Date: _____

GROUP A QUESTIONS: WHERE DOES ELECTRICITY COME FROM?

Driving question: Does turning on lights cause carbon emissions?

1. List all the ways you can think of that you use electricity at home and at school.

2. Other forms of energy are transformed into electrical energy at power plants. What kinds of power plants can you think of? Try to list at least five different types of power plants.

3. Each type of power plant has inputs of energy that are transformed into electrical energy. We know this because energy cannot be created or destroyed. For each power plant you named, identify the energy that is the input for that type of power plant. Solar power plants are given as an example. See if your group can name five more.

Type of energy input	Type of power plant	Type of energy output
<u>Light energy</u>	<u>Solar power plant</u>	<u>electrical energy and heat energy</u>
_____	_____	<u>electrical energy and heat energy</u>
_____	_____	<u>electrical energy and heat energy</u>
_____	_____	<u>electrical energy and heat energy</u>
_____	_____	<u>electrical energy and heat energy</u>
_____	_____	<u>electrical energy and heat energy</u>

4. Do you think any of the above energy transformation processes involve carbon? Make two lists.

Power plants that use energy transformations that involve carbon:	Power plants that use energy transformations that DO NOT involve carbon:
Explain how power plants involve carbon:	Explain how these power plants DO NOT involve carbon:

5. Do you think turning on lights could cause carbon emissions? Why or why not?

6. Do you think that turning off lights when you're not using them or switching to a more efficient light bulb will reduce carbon emissions? Explain why or why not.

7. What type of power plant is most commonly used in the United States?

Name: _____ Period: _____ Date: _____

GROUP B QUESTIONS: HOW DO WE USE ENERGY FOR TRANSPORTATION?

Driving question: Does transportation cause carbon emissions?

1. List all the ways that people travel locally or long distance. Consider what you know about transportation options in other countries too.

2. Each type of transportation has inputs of energy that are transformed into motion energy. We know this because energy cannot be created or destroyed. For each type of transportation you named, trace the energy that is the input. Airplanes are given as an example. See if your group can name five more.

Type of energy input	Type of transportation	Type of energy output
<u>Chemical energy</u>	<u>airplanes</u>	<u>motion energy and heat energy</u>
_____	_____	<u>motion energy and heat energy</u>
_____	_____	<u>motion energy and heat energy</u>
_____	_____	<u>motion energy and heat energy</u>
_____	_____	<u>motion energy and heat energy</u>
_____	_____	<u>motion energy and heat energy</u>

4. Do you think any of the above energy transformation processes involve carbon? Explain why or why not.

5. Which type of transportation creates the most carbon emissions for one person to go one mile? Rank the types of transportation listed above from 1 to 6, with 1 being the type that leads to the most carbon emissions and 6 to the least carbon emissions.

- 1.
- 2.
- 3.
- 4.
- 5.
- 6.

6. Below, write the reason why you think these types of transportation are different in terms of carbon emissions.

Name: _____ Period: _____ Date: _____

GROUP C QUESTIONS: HOW DO WE USE ENERGY IN OUR HOMES AND BUILDINGS?

Driving question: Does daily use of homes and buildings cause carbon emissions?

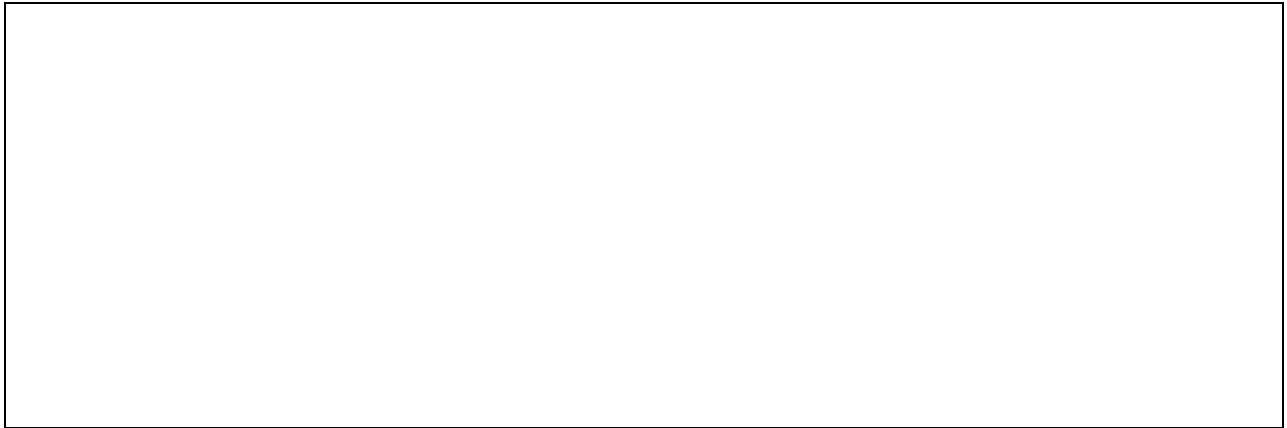
1. Think about the building that you are in. How big do you think it is in square feet?

2. Think about the school building you are in right now. In the box on the left, make a list of all the systems within the school (hint: these may be things like lighting, heating/cooling, maintenance, school grounds, waste management, etc.). In the box on the right, explain how these systems use energy. Which systems do you think use the most energy? Place a star next to the systems you think use larger amounts of energy.

Systems that use energy	How the energy is used

3. Do any of these systems within the building require energy that involves carbon? Which ones? How do they use carbon?

4. Do you think the daily use of buildings can cause carbon emissions? How? Explain in words or by drawing and labeling a picture.

A large, empty rectangular box with a thin black border, intended for a student to draw and label a picture related to the question above.

Name: _____ Period: _____ Date: _____

GROUP D QUESTIONS: HOW DO WE MAKE AND MOVE FOOD?

Driving question: How much energy and carbon is required to produce and transport the food we eat?

Think about two items that a student at your school may have for lunch: an apple and hamburger meat. Have you ever thought about where these food items come from? Discuss the following questions with your group.

APPLE

Was the apple purchased at a grocery store?

How did the apple get to the grocery store?

Where was the apple grown?

How was the apple grown? Did the tree need water? Fertilizer? Pesticide? Pruning?

HAMBURGER MEAT

Was the hamburger meat purchased at a grocery store?

How did the hamburger meat get to the grocery store?

Where was the hamburger meat made?

Where did the hamburger meat come from?

What was the cow fed?

How was the food grown that the cow ate?

Did production of the food for the cow require water? Fertilizer? Pesticide?

1. Draw and label two pictures, one that traces steps required to produce and get the apple to you, and one that does the same for the hamburger meat. Trace as far back as you can go. Connect each stage of the picture with arrows.

Apple	Meat
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3. Think of all the different types of energy that may be used during food production and label them on your pictures of the apple and the meat.

4. Do any of the stages in food production emit carbon? How? Which ones?

5. Do you think food production can cause carbon emissions? How? Which types of foods lead to more carbon emissions? Which types of food lead to less carbon emissions?

ACTIVITY 2: ENERGY SCENARIOS

Learning Objectives:

1. Describe energy as flowing through Earth systems, from sunlight to chemical energy to heat that is radiated into space.
2. Describe carbon cycling within Earth and Human systems.
3. Explain the consequences of lifestyle and energy system choices for changes in atmospheric CO₂ concentration.
4. Make an explicit connection between energy use and carbon emissions.

Duration: 45 minutes

Activity Description:

Students work in small groups to develop stories to share with the class that trace carbon and energy through large-scale systems. Classmates hold them accountable to the three rules.

Background Information:

Tracing carbon and energy through large-scale systems requires students to think about how carbon and energy are transformed as they cycle and flow through these systems. For carbon, this requires students to think about how carbon moves from pool to pool, as well as the carbon transforming processes that cause these fluxes. Photosynthesis causes a flux from the atmosphere pool to the biomass pool. Cellular respiration causes a flux from the biomass pool to the atmosphere pool. Combustion causes a flux from the fossil fuel pool to the atmosphere pool.

Tracing energy requires students to think about how energy flows and is transformed from the time it enters in the form of light energy until it leaves our atmosphere and goes into outer space in the form of infrared radiation. Carbon transforming processes are involved here, too: Photosynthesis transforms light energy from the sun and transforms it into chemical energy that is stored in the bonds of organic molecules in plants. The chemical energy in these bonds can be either conserved (as the bonds become part of other molecules) or degraded (as the bonds are broken and form new bonds, releasing the energy as work, motion, or heat).

Materials:

- [Energy Scenario Cards](#) (below)
- [Energy Scenario Handout](#) (below)
- [Lesson 4 Activity 2.pptx](#)

Directions:

1. Activate Prior Knowledge.

Remind students of the three rules: *Atoms endure! Carbon Cycles! Energy Flows!* Tell them it is their job today to tell stories about how energy use causes carbon atoms to move. Their stories will be expected to follow the rules!

2. Divide students into pairs.

Tell students to find their groups. Pass out [Energy Scenario Handout](#) to each group. Tell them to use the handout to help them tell their story—they should draw arrows to help illustrate their story.

3. Play the energy scenario game.

Pass out one Energy Scenario Card to each group. Give the students 5 minutes to discuss as a group how the energy use on their card causes carbon atoms to move between pools. Then ask each group to select a “spokesperson” to share their story with the class. The spokesperson should read the energy use to the class, and use the handout to tell the story of how carbon moves and is transformed. For each story that is told, invite the rest of the

class to “fact check.” Do all parts of the story follow the rules? Do carbon atoms ever disappear? When carbon leaves one pool, does it always enter another?

4. Play another round.

This time tell students to come up with a form of energy use that has not already been mentioned in class and to determine how carbon atoms move from between pools as a result of this energy use. In this round, use slide 1 in EnergyScenarios.pptx to illustrate student stories of carbon movement as a result of their energy use. Ask students: which scenarios cause carbon to move from the biomass pool to the atmosphere pool? Which scenarios cause carbon to move from the fossil fuels pool to the atmosphere pool? Point out that for each energy use on the cards, carbon was transformed from organic to inorganic carbon.

5. Discuss the increasing atmosphere pool.

Ask students to think about how carbon moved as a result of all of these energy uses. Which pool is getting bigger as a result of these energy uses? Display Lesson 4 Activity 2.pptx slide 2. Use the animation to show how the atmosphere pool grows as a result of fossil fuel consumption. Pose the question: What will happen to the climate if we continue to burn fossil fuels at the same rate?

6. Transition to Activity 3.

Tell students the last activity in this unit will use what we have learned so far to answer the final question: Why is there an upward trend in the Keeling Curve?

ENERGY SCENARIO CARDS

<p style="text-align: center;"><i>Scenario Card 1</i></p> <p>Energy Use: Turning the lights on in your classroom.</p> <p><i>Read the energy use above to your group. As a group, your job is to answer 3 questions:</i></p> <ol style="list-style-type: none">1. <i>Why is this an energy use?</i>2. <i>What is the source of this energy?</i>3. <i>How do carbon atoms move as a result of this?</i> <p><i>Remember: your story must follow the rule: Carbon Cycles! If carbon leaves one pool, it must enter another pool.</i></p>	<p style="text-align: center;"><i>Scenario Card 2</i></p> <p>Energy Use: Buying a hamburger to eat</p> <p><i>Read the energy use above to your group. As a group, your job is to answer 3 questions:</i></p> <ol style="list-style-type: none">1. <i>Why is this an energy use?</i>2. <i>What is the source of this energy?</i>3. <i>How do carbon atoms move as a result of this?</i> <p><i>Remember: your story must follow the rule: Carbon Cycles! If carbon leaves one pool, it must enter another pool.</i></p>
<p style="text-align: center;"><i>Scenario Card 3</i></p> <p>Energy Use: Riding in a bus (which burns gasoline)</p> <p><i>Read the energy use above to your group. As a group, your job is to answer 3 questions:</i></p> <ol style="list-style-type: none">1. <i>Why is this an energy use?</i>2. <i>What is the source of this energy?</i>3. <i>How do carbon atoms move as a result of this?</i> <p><i>Remember: your story must follow the rule: Carbon Cycles! If carbon leaves one pool, it must enter another pool.</i></p>	<p style="text-align: center;"><i>Scenario Card 4</i></p> <p>Energy Use: Buying a salad to eat</p> <p><i>Read the energy use above to your group. As a group, your job is to answer 3 questions:</i></p> <ol style="list-style-type: none">1. <i>Why is this an energy use?</i>2. <i>What is the source of this energy?</i>3. <i>How do carbon atoms move as a result of this?</i> <p><i>Remember: your story must follow the rule: Carbon Cycles! If carbon leaves one pool, it must enter another pool.</i></p>

<p style="text-align: center;"><i>Scenario Card 5</i></p> <p>Energy Use: Drying clothes in a dryer</p> <p><i>Read the energy use above to your group. As a group, your job is to answer 3 questions:</i></p> <ol style="list-style-type: none"> 1. <i>Why is this an energy use?</i> 2. <i>What is the source of this energy?</i> 3. <i>How do carbon atoms move as a result of this?</i> <p><i>Remember: your story must follow the rule: Carbon Cycles! If carbon leaves one pool, it must enter another pool.</i></p>	<p style="text-align: center;"><i>Scenario Card 6</i></p> <p>Energy Use: Washing clothes in a washing machine.</p> <p><i>Read the energy use above to your group. As a group, your job is to answer 3 questions:</i></p> <ol style="list-style-type: none"> 1. <i>Why is this an energy use?</i> 2. <i>What is the source of this energy?</i> 3. <i>How do carbon atoms move as a result of this?</i> <p><i>Remember: your story must follow the rule: Carbon Cycles! If carbon leaves one pool, it must enter another pool.</i></p>
<p style="text-align: center;"><i>Scenario Card 7</i></p> <p>Energy Use: Washing dishes in hot water</p> <p><i>Read the energy use above to your group. As a group, your job is to answer 3 questions:</i></p> <ol style="list-style-type: none"> 1. <i>Why is this an energy use?</i> 2. <i>What is the source of this energy?</i> 3. <i>How do carbon atoms move as a result of this?</i> <p><i>Remember: your story must follow the rule: Carbon Cycles! If carbon leaves one pool, it must enter another pool.</i></p>	<p style="text-align: center;"><i>Scenario Card 8</i></p> <p>Energy Use: Buying a pizza to eat</p> <p><i>Read the energy use above to your group. As a group, your job is to answer 3 questions:</i></p> <ol style="list-style-type: none"> 1. <i>Why is this an energy use?</i> 2. <i>What is the source of this energy?</i> 3. <i>How do carbon atoms move as a result of this?</i> <p><i>Remember: your story must follow the rule: Carbon Cycles! If carbon leaves one pool, it must enter another pool.</i></p>

<p style="text-align: center;"><i>Scenario Card 9</i></p> <p>Energy Use: Buying a bottle of water.</p> <p><i>Read the energy use above to your group. As a group, your job is to answer 3 questions:</i></p> <ol style="list-style-type: none"> 1. <i>Why is this an energy use?</i> 2. <i>What is the source of this energy?</i> 3. <i>How do carbon atoms move as a result of this?</i> <p><i>Remember: your story must follow the rule: Carbon Cycles! If carbon leaves one pool, it must enter another pool.</i></p>	<p style="text-align: center;"><i>Scenario Card 10</i></p> <p>Energy Use: Using the air conditioning.</p> <p><i>Read the energy use above to your group. As a group, your job is to answer 3 questions:</i></p> <ol style="list-style-type: none"> 1. <i>Why is this an energy use?</i> 2. <i>What is the source of this energy?</i> 3. <i>How do carbon atoms move as a result of this?</i> <p><i>Remember: your story must follow the rule: Carbon Cycles! If carbon leaves one pool, it must enter another pool.</i></p>
<p style="text-align: center;"><i>Scenario Card 11</i></p> <p>Energy Use: Using your gas stove.</p> <p><i>Read the energy use above to your group. As a group, your job is to answer 3 questions:</i></p> <ol style="list-style-type: none"> 1. <i>Why is this an energy use?</i> 2. <i>What is the source of this energy?</i> 3. <i>How do carbon atoms move as a result of this?</i> <p><i>Remember: your story must follow the rule: Carbon Cycles! If carbon leaves one pool, it must enter another pool.</i></p>	<p style="text-align: center;"><i>Scenario Card 12</i></p> <p>Energy Use: Using your electric stove.</p> <p><i>Read the energy use above to your group. As a group, your job is to answer 3 questions:</i></p> <ol style="list-style-type: none"> 1. <i>Why is this an energy use?</i> 2. <i>What is the source of this energy?</i> 3. <i>How do carbon atoms move as a result of this?</i> <p><i>Remember: your story must follow the rule: Carbon Cycles! If carbon leaves one pool, it must enter another pool. .</i></p>

<p style="text-align: center;"><i>Scenario Card 13</i></p> <p>Energy Use: Taking a hot shower.</p> <p><i>Read the energy use above to your group. As a group, your job is to answer 3 questions:</i></p> <ol style="list-style-type: none"> 1. <i>Why is this an energy use?</i> 2. <i>What is the source of this energy?</i> 3. <i>How do carbon atoms move as a result of this?</i> <p><i>Remember: your story must follow the rule: Carbon Cycles! If carbon leaves one pool, it must enter another pool.</i></p>	<p style="text-align: center;"><i>Scenario Card 14</i></p> <p>Energy Use: Riding a bike.</p> <p><i>Read the energy use above to your group. As a group, your job is to answer 3 questions:</i></p> <ol style="list-style-type: none"> 1. <i>Why is this an energy use?</i> 2. <i>What is the source of this energy?</i> 3. <i>How do carbon atoms move as a result of this?</i> <p><i>Remember: your story must follow the rule: Carbon Cycles! If carbon leaves one pool, it must enter another pool.</i></p>
<p style="text-align: center;"><i>Scenario Card 15</i></p> <p>Energy Use: Flying in an airplane.</p> <p><i>Read the energy use above to your group. As a group, your job is to answer 3 questions:</i></p> <ol style="list-style-type: none"> 1. <i>Why is this an energy use?</i> 2. <i>What is the source of this energy?</i> 3. <i>How do carbon atoms move as a result of this?</i> <p><i>Remember: your story must follow the rule: Carbon Cycles! If carbon leaves one pool, it must enter another pool.</i></p>	<p style="text-align: center;"><i>Scenario Card 16</i></p> <p>Energy Use: Eating a chicken sandwich.</p> <p><i>Read the energy use above to your group. As a group, your job is to answer 3 questions:</i></p> <ol style="list-style-type: none"> 1. <i>Why is this an energy use?</i> 2. <i>What is the source of this energy?</i> 3. <i>How do carbon atoms move as a result of this?</i> <p><i>Remember: your story must follow the rule: Carbon Cycles! If carbon leaves one pool, it must enter another pool. .</i></p>

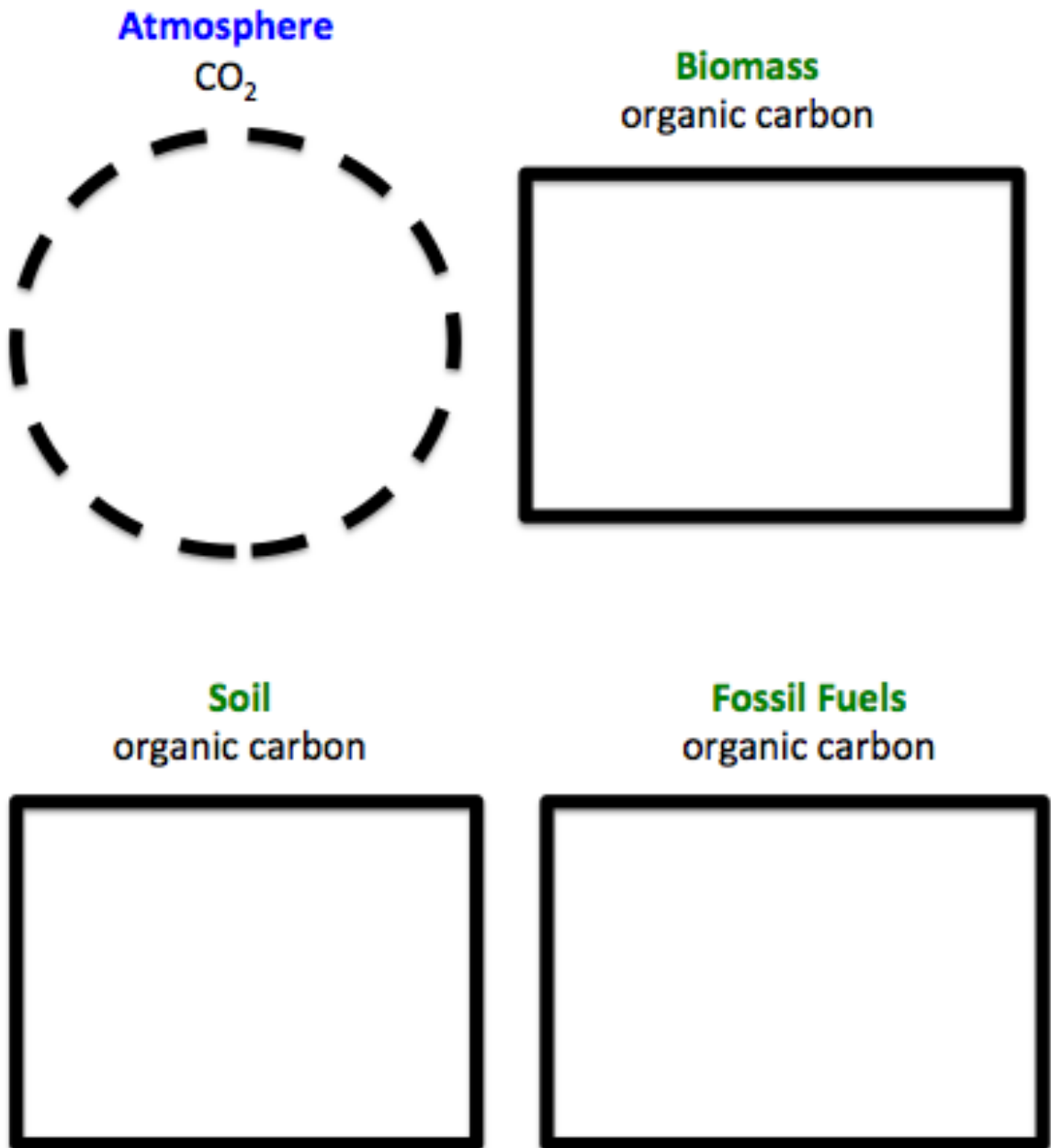
<p style="text-align: center;"><i>Scenario Card 17</i></p> <p>Energy Use: Charging a cell phone.</p> <p><i>Read the energy use above to your group. As a group, your job is to answer 3 questions:</i></p> <ol style="list-style-type: none"><i>1. Why is this an energy use?</i><i>2. What is the source of this energy?</i><i>3. How do carbon atoms move as a result of this?</i> <p><i>Remember: your story must follow the rule: Carbon Cycles! If carbon leaves one pool, it must enter another pool.</i></p>	<p style="text-align: center;"><i>Scenario Card 18</i></p> <p>Energy Use: Burning wood in a fireplace.</p> <p><i>Read the energy use above to your group. As a group, your job is to answer 3 questions:</i></p> <ol style="list-style-type: none"><i>1. Why is this an energy use?</i><i>2. What is the source of this energy?</i><i>3. How do carbon atoms move as a result of this?</i> <p><i>Remember: your story must follow the rule: Carbon Cycles! If carbon leaves one pool, it must enter another pool.</i></p>
<p style="text-align: center;"><i>Scenario Card 19</i></p> <p>Energy Use: walking.</p> <p><i>Read the energy use above to your group. As a group, your job is to answer 3 questions:</i></p> <ol style="list-style-type: none"><i>1. Why is this an energy use?</i><i>2. What is the source of this energy?</i><i>3. How do carbon atoms move as a result of this?</i> <p><i>Remember: your story must follow the rule: Carbon Cycles! If carbon leaves one pool, it must enter another pool.</i></p>	<p style="text-align: center;"><i>Scenario Card 20</i></p> <p>Energy Use: Turning the heat on in winter.</p> <p><i>Read the energy use above to your group. As a group, your job is to answer 3 questions:</i></p> <ol style="list-style-type: none"><i>1. Why is this an energy use?</i><i>2. What is the source of this energy?</i><i>3. How do carbon atoms move as a result of this?</i> <p><i>Remember: your story must follow the rule: Carbon Cycles! If carbon leaves one pool, it must enter another pool.</i></p>

<p style="text-align: center;"><i>Scenario Card 21</i></p> <p>Energy Use: Mowing a lawn.</p> <p><i>Read the energy use above to your group. As a group, your job is to answer 3 questions:</i></p> <ol style="list-style-type: none"><i>1. Why is this an energy use?</i><i>2. What is the source of this energy?</i><i>3. How do carbon atoms move as a result of this?</i> <p><i>Remember: your story must follow the rule: Carbon Cycles! If carbon leaves one pool, it must enter another pool.</i></p>	<p style="text-align: center;"><i>Scenario Card 22</i></p> <p>Energy Use: Feeding a pet.</p> <p><i>Read the energy use above to your group. As a group, your job is to answer 3 questions:</i></p> <ol style="list-style-type: none"><i>1. Why is this an energy use?</i><i>2. What is the source of this energy?</i><i>3. How do carbon atoms move as a result of this?</i> <p><i>Remember: your story must follow the rule: Carbon Cycles! If carbon leaves one pool, it must enter another pool.</i></p>
<p style="text-align: center;"><i>Scenario Card 23</i></p> <p>Energy Use: Drinking milk.</p> <p><i>Read the energy use above to your group. As a group, your job is to answer 3 questions:</i></p> <ol style="list-style-type: none"><i>1. Why is this an energy use?</i><i>2. What is the source of this energy?</i><i>3. How do carbon atoms move as a result of this?</i> <p><i>Remember: your story must follow the rule: Carbon Cycles! If carbon leaves one pool, it must enter another pool.</i></p>	<p style="text-align: center;"><i>Scenario Card 24</i></p> <p>Energy Use: Playing soccer.</p> <p><i>Read the energy use above to your group. As a group, your job is to answer 3 questions:</i></p> <ol style="list-style-type: none"><i>1. Why is this an energy use?</i><i>2. What is the source of this energy?</i><i>3. How do carbon atoms move as a result of this?</i> <p><i>Remember: your story must follow the rule: Carbon Cycles! If carbon leaves one pool, it must enter another pool.</i></p>

ENERGY SCENARIO HANDOUT

Human Energy Systems Lesson 4, Activity 2

For your tracing scenario, use the image below to show how carbon moves from one pool to another. Make sure your story follows the rules. When carbon atoms leave one pool, do they always enter another? Is energy either conserved or degraded in each step?



Remember the rules:

- Atoms Endure!
- Carbon Cycles!
- Energy Flows!

ACTIVITY 3: THE KEELING CURVE: UNDERSTANDING THE UPWARD TREND

Learning Objectives:

1. Explain changes in atmospheric CO₂ in terms of fluxes associated with carbon-transforming processes: combustion, photosynthesis, fossil fuel formation, cellular respiration
2. Describe pools as changing in size over time
3. Contrast the upward trend of the Keeling curve with the seasonal cycle.

Duration: 30 minutes

Activity Description:

Students use what they have learned in the unit to answer the final question about the Keeling Curve: Why are concentrations of carbon dioxide increasing in the atmosphere?

Background Information:

While the balance between cellular respiration and photosynthesis is the cause of the seasonal flux between the atmosphere and biomass pools, the upward trend in the Keeling curve is caused by the burning of fossil fuels. This causes a flux of carbon atoms from the fossil fuel pool to the atmosphere pool. The producers (plants) and oceans on the planet are unable to sequester all carbon that is released by the combustion of fossil fuels, so the rise of atmospheric carbon continues.

At this point, students have examined many ways in which humans use energy that contribute to the growing size of the atmosphere pool. This activity is designed to help them make connections to the ways humans use fossil fuels for energy, and the increase of CO₂ in the atmosphere.

Materials:

- [What causes the upward trend in the Keeling Curve? Worksheet](#)

Directions:

1. Recall the Keeling Curve and identify the seasonal cycle.

Pass out the worksheets and have students look at the Keeling Curve. Recall the seasonal cycle, which is caused by the seasonal shift in photosynthesis and cellular respiration rates. Identify the upward trend in the Keeling Curve: the (red) line that moves continuously upward over time. The purpose of this activity is to explain why this line is going up.

2. Ask for ideas about the upward trend.

Ask students if any of them have ideas about why there is an upward trend in the Keeling Curve. Ask them how this is different from the seasonal trend.

3. Students complete worksheet in groups.

Have students complete the worksheet in groups and share their responses with the class.

4. Discuss student accounts of the upward trend on the Keeling Curve as a class.

Formative assessment: Check to see if students recognize that the upward trend is caused by a carbon flux from the fossil fuel pool to the atmosphere pool as a result of combustion of fossil fuels.

5. Transition to Lesson 5.

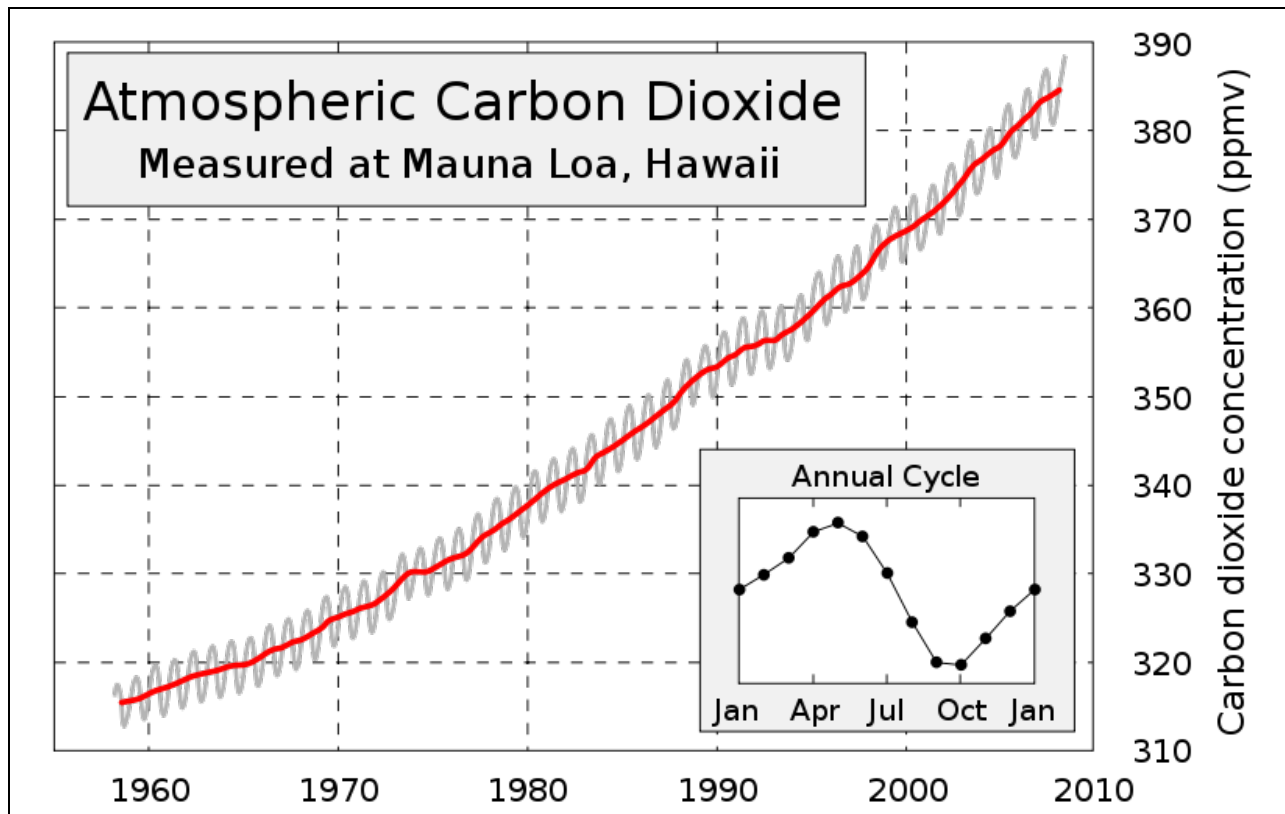
Now that we understand how our energy uses lead to an increase in atmospheric carbon, we are ready to discuss the consequences of this for both people and the planet. What can we do to make the future safe for future generations? There are steps we can take as both individuals and societies to reduce carbon emissions and energy use.

Name: _____ Period: _____ Date: _____

WHAT CAUSES THE UPWARD TREND IN THE KEELING CURVE?

Human Energy Systems Lesson 4, Activity 3

You've seen this graph before, right? In Lesson 1, we learned that the seasonal flux of carbon between the atmosphere and biomass pools causes the small rise and fall each year (the light grey line). In this Lesson we will be talking about what causes the overall upward trend.



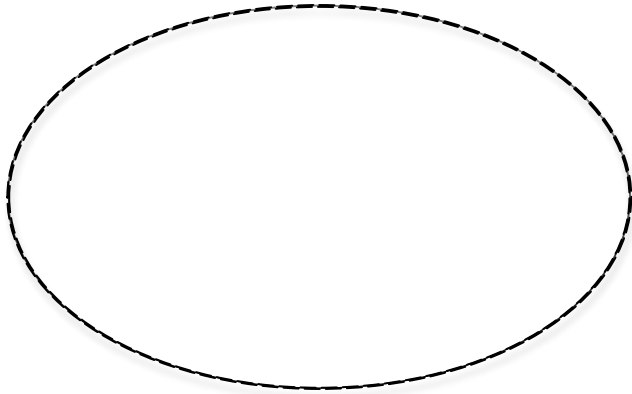
The Keeling Curve: Atmospheric CO₂ concentrations measured at Mauna Loa Observatory

1. **With your group, look at the graph. What does the upward trend tell you? What does this part of the graph mean? Describe the trend in your own words.**

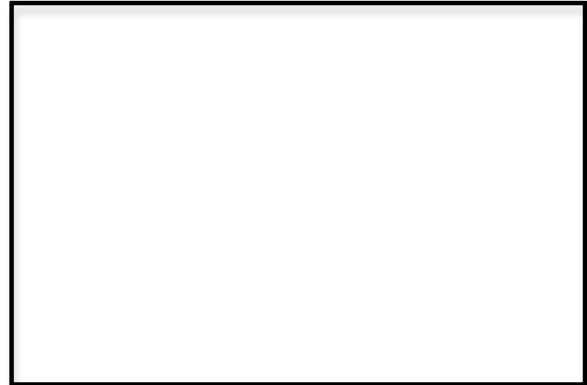
2. Remember rule #2: **Carbon cycles!** This means that if CO₂ concentration is increasing in the atmosphere, then the carbon must be coming from somewhere else. Where do you think this carbon is coming from that causes this increasing trend?

3. The dark line in the Keeling Curve above tells us something about how carbon is moving in the world. Use the pools below to show how carbon is moving. This line tells us that some pools are getting smaller and some pools are getting larger. Draw an arrow to show how carbon atoms are moving from pool to pool to account for both the seasonal cycle and the upward trend.

Atmosphere Pool



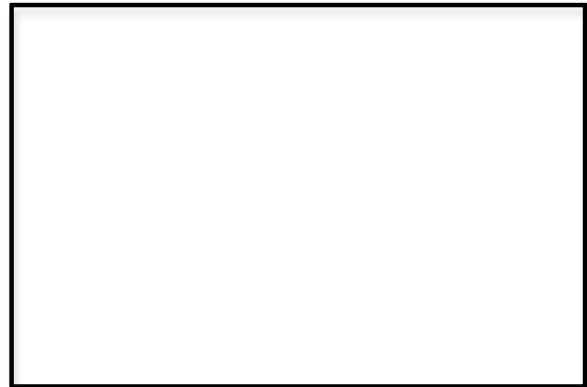
Biomass Pool



Soil Pool



Fossil Fuel Pool



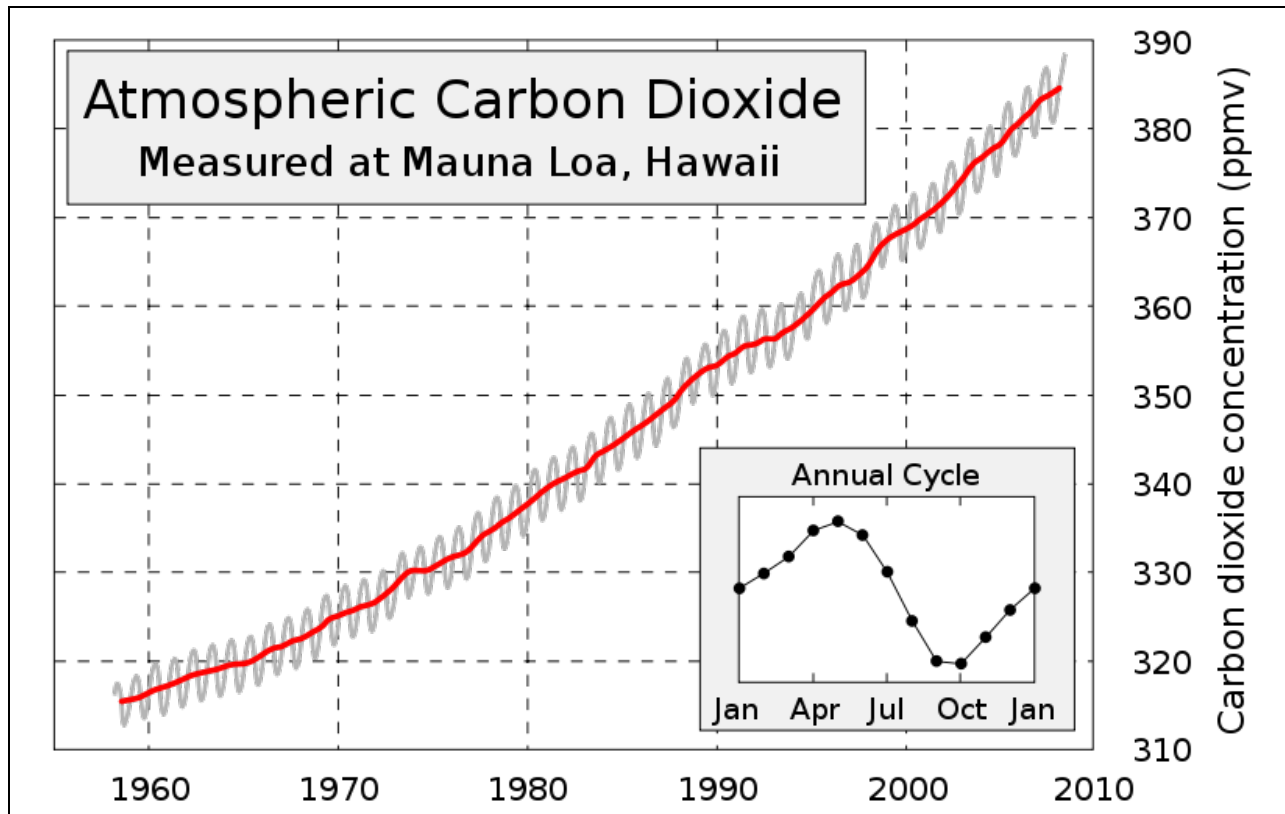
4. Which carbon transforming process is causing the upward trend in the Keeling Curve?
(Circle One)

Photosynthesis Biosynthesis Cellular Respiration Combustion Digestion

Explain your choice. How does this carbon-transforming process cause the upward trend in the Keeling Curve?

5. In this unit, we have discussed how energy use causes this upward trend. What are three ways humans use energy that cause carbon to enter the atmosphere?

GRADING THE WHAT CAUSES THE UPWARD TREND IN THE KEELING CURVE?



The Keeling Curve: Atmospheric CO₂ concentrations measured at Mauna Loa Observatory

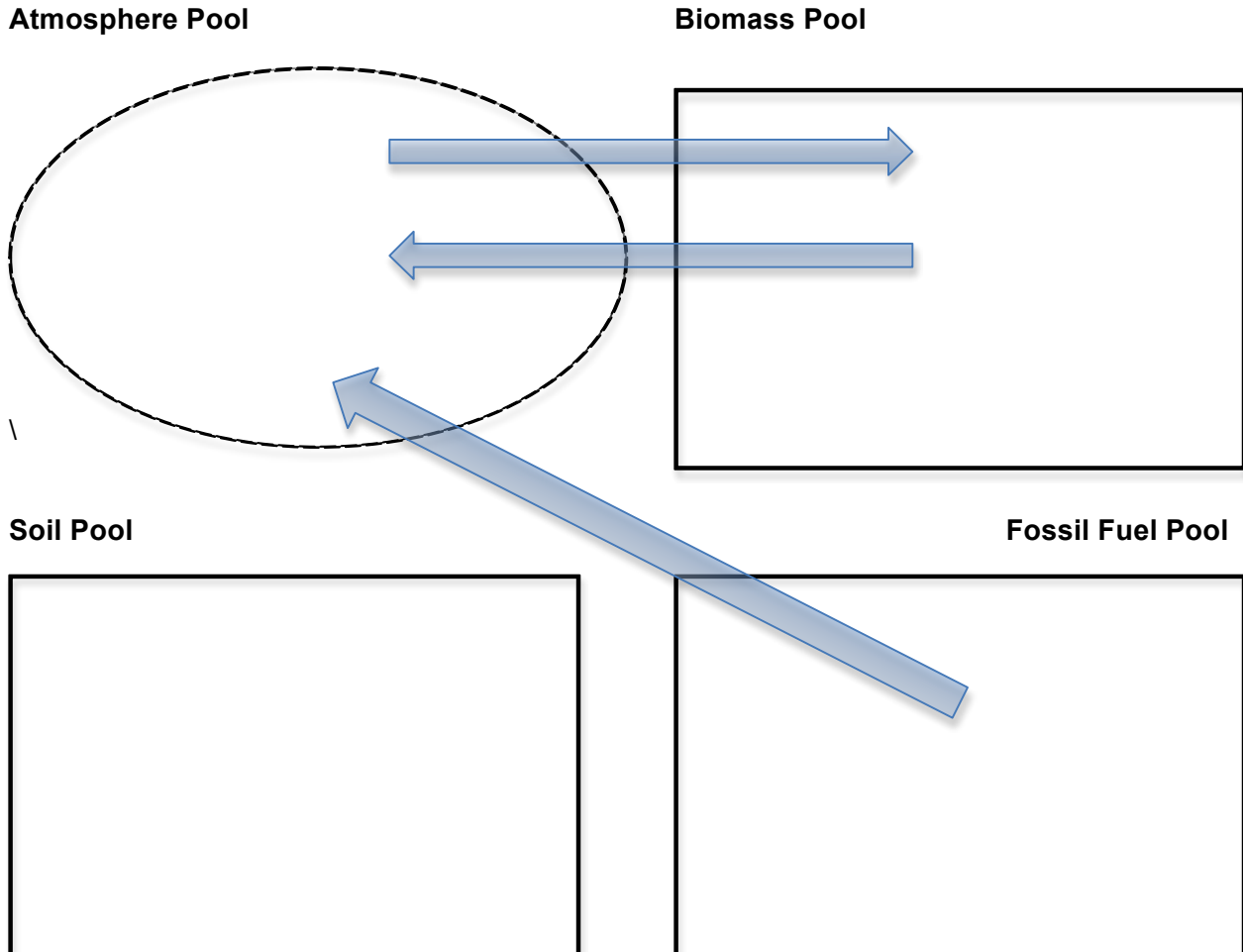
1. With your group, look at the graph. What does the upward trend tell you? What does this part of the graph mean? Describe the trend in your own words.

Level 4: This part of the graph means that since 1960, there has been an increase in carbon in our atmosphere.

2. Remember rule #2: **Carbon cycles!** This means that if CO₂ concentration is increasing in the atmosphere, then the carbon must be coming from somewhere else. Where do you think this carbon is coming from that causes this increasing trend?

Level 4: Carbon is moving from the fossil fuel pool to the atmosphere pool.

3. The dark line in the Keeling Curve above tells us something about how carbon is moving in the world. Use the pools below to show how carbon is moving. This line tells us that some pools are getting smaller and some pools are getting larger. Draw an arrow to show how carbon atoms are moving from pool to pool to account for both the seasonal cycle and the upward trend.



4. Which carbon transforming process is causing the upward trend in the Keeling Curve?
(Circle One)
Photosynthesis Biosynthesis Cellular Respiration Combustion Digestion

Explain your choice. How does this carbon-transforming process cause the upward trend in the Keeling Curve?

Combustion of fossil fuels causes the carbon in the organic molecules to oxidize and bond with oxygen. When this happens, energy is released in the form of heat, which humans use for energy. As a result of combustion, CO₂ is released into the atmosphere, causing the atmosphere pool to grow.

5. In this unit, we have discussed how energy use causes this upward trend. What are three ways humans use energy that cause carbon to enter the atmosphere?

Answers may vary: any reduction in energy use that would reduce the use of fossil fuels is an acceptable answer.

LESSON 5: GLOBAL IMPLICATIONS

Role of this Lesson in the Application and Inquiry Sequences

Activity 1: Coaching/Fading: Making connections between human energy use and the movement of carbon atoms

Activity 2: Fading: Making connections between human energy use and the movement of carbon atoms

Activity 3: (Post-Test)

Time/Duration: About 2 hours total across 4 weeks

Activity 1: Mitigation Strategies

~45 minutes

Activity 2: The Ocean Pool

~20 minutes

Activity 3: Post Test

~20 minutes

Lesson Description:

Students suggest mitigation strategies for climate change and take a post-test to document how their thinking has changed about human energy systems during the unit.

Guiding Questions:

1. What can people do to lower carbon emissions on the planet?

Background Information:

Once the *hows* and *whys* of the Keeling Curve are examined, students can discuss strategies for mitigation of the upward carbon trend in the atmosphere.

Lesson 5 Materials

For Activity 1

- [Lesson 5 Activity 1.pptx](#)
- **Global Warming Video:** <http://video.nationalgeographic.com/video/environment/global-warming-environment/global-warming-101/>
- [Strategy Cards](#)

For Activity 2

- [Lesson 5 Activity 2.pptx](#)
- Carbon Tracing Cards
- <http://www.youtube.com/watch?v=cAwZ7VCYn44>

For Activity 3

- [Human Energy Systems Unit Post Test](#)

ACTIVITY 1: STRATEGIES TO LOWER CARBON EMISSIONS

Learning Objectives:

1. Explain the consequences of lifestyle and energy system choices for changes in atmospheric CO₂ concentration.
2. Suggest mitigation strategies for lowering carbon emissions.

Duration: 30 minutes

Activity Description:

Students watch a video from National Geographic that gives an overview of the evidence scientists have of the causes and affects of climate change and suggest ways humans can mitigate climate change.

Background Information:

Using complex climate models, scientists predict that a continual increase in carbon in our atmosphere will lead to negative impacts for both the environment and people. Considering this, societies across the globe must work together to solve this problem. Students may be able to make this connection more clearly if they realize that taking efforts to decrease carbon in the atmosphere now would make life better for people, now and in the future.

Materials:

- [Lesson 5 Activity 1.pptx](#)
- **Global Warming Video:** <http://video.nationalgeographic.com/video/environment/global-warming-environment/global-warming-101/>
- [Strategy Cards](#)

Directions:

1. Watch a video from National Geographic about Global Warming.**

Ask students: *This video shows that scientists predict that the rise in temperature is a result of a rise in green house gases and carbon emissions. They suggest that there are things people can do to lower our green house gas emissions. What did you hear them say in the video?* Students may suggest that using less electricity and driving less miles in a car each week are two mitigation strategies for reducing carbon emissions.

2. Introduce activity.

Display [Lesson 5 Activity 1.pptx](#). Use slide 2 to remind students of the problem we face: an imbalance in carbon transforming processes leads to too much carbon in the atmosphere (this slide is repeated from Lesson 4 Activity 2). Next, display slide 3: This graph shows 2 projections of atmospheric carbon concentrations about 85 years from now. The pink dot (near 1,000) shows a scenario if we do not lower carbon emissions. The purple dot (around 400) shows a scenario if we lower carbon emissions. Tell students in today's activity we will spend time thinking about strategies people have suggested could help keep atmospheric carbon from rising to near 1000 ppm.

3. Pass out strategy cards.

Have students form small groups of 3-4 and discuss the strategies on their cards. How would this strategy lower carbon emissions?

4. Whole class discussion.

Have students suggest 1) how their strategies lower carbon emissions, and 2) other strategies for energy use that may curb carbon emissions.

5. Think Pair Share: Individual Action & Societal Action

Instruct students to take 60 seconds to divide their ideas into two categories: things they can do as individuals, and things that must be done as a society. Then, share their ideas for individual action and societal action with their partners.

6. Whole class discussion.

Display slide 4 of Lesson 5 Activity 1.pptx. Input student suggestions into the two columns of the T-chart. For example, students may suggest that “eating less meat” is something they can do as individuals, but that “using electricity from nuclear power plants instead of coal” is something that society has to change (through policy change and consumer action). Stress that lowering carbon emissions will take *a combination of* individual action and societal changes.

**This video states that “Energy is reflected by greenhouse gases and sent back into the atmosphere.” This is a simplification that we think might be misleading. A more accurate statement would be that “Energy is absorbed by greenhouse gases and retained in the atmosphere.”

**This video states that only some climate scientists predict sea level rise. It is more accurate to say that all climate change models predict sea level rise.

STRATEGY CARDS

Drive less miles in your car each week	Increase Building Insulation	Using electricity from nuclear power plants instead of coal
Built wind-turbines	Use solar panels instead of fossil fuels	Use biofuels instead of fossil fuels
Plant trees	Protect and conserve existing forests	Use public transportation (buses, subway, etc)
Eat less meat	Turn lights off when we're not using them	Replace appliances with energy-efficient appliances
Eat food that was grown locally	Drink tap water instead of bottled water	Reuse things instead of buying new things
Eat food with little or no packaging	Grow food in your garden	Lower the heat in the winter and wear warm clothes inside
Add insulation to the walls and ceiling of your home	Ride your bike to work or school	Close doors and windows in the summer to keep air conditioning from escaping
Use wind turbines instead of coal	Drive a car that gets 35 or more miles per gallon	Replace incandescent light bulbs with LEDs

ACTIVITY 2: OCEANS-- THE OTHER CARBON POOL**Learning Objectives:**

1. Locate organic and inorganic carbon pools near the Earth's surface (atmosphere, biosphere, soil organic carbon, fossil fuels, oceanic carbon)
2. Describe pools as changing in size over time
3. Explain the consequences of lifestyle and energy system choices for changes in atmospheric CO₂ concentration.

Duration: 20-30 minutes

Activity Description:

Students identify oceans as carbon pools and discuss the implications of large amounts of carbon in the oceans, specifically ocean acidification.

Background Information:

Although previously in the unit we have focused on the soil, atmosphere, biomass, and fossil fuel pools, another important carbon pool is the oceans. When humans release an excess of CO₂ into the atmosphere from the combustion of fossil fuels, the oceans absorb this CO₂. Oceans absorb about 25% of the CO₂ emissions from fossil fuels each year, which can affect the oceans in many ways. For one, this can lead to ocean acidification, or a lowering of pH in the ocean's water when carbonic acid is formed. This can harm coral reefs, which are sensitive to ocean acidification and change in ocean temperatures. Ocean acidification negatively impacts other ocean organisms as well, including organisms that use calcium carbonate to build shells (like krill, oysters, crabs, etc).

The ocean pool is important in this discussion because it is a large carbon sink. Although the oceans help remove carbon dioxide from the atmosphere, the excess of CO₂ released by humans is a problem. Therefore, to help prevent ocean acidification, humans should work together to curb carbon emissions.

Materials:

- [Lesson 5 Activity 2.pptx](#)
- Carbon Tracing Cards
- <http://www.youtube.com/watch?v=cAwZ7VCYn44>

Directions:

1. **Review the four pools of carbon used throughout the unit.**
Display [Lesson 5 Activity 2.pptx](#). Using slide 2, introduce a new carbon pool that we have not discussed: the ocean pool.
2. **Share foundational knowledge about the ocean pool.**
Using slides 3-6 of [Lesson 5 Activity 2.pptx](#), discuss where the carbon is in the oceans, how climate change affects the oceans, and how these effects impact people.
3. **Conduct a Think Pair Share activity using Carbon Tracing Scenarios.**
Tell student pairs it is their job to develop a story about what happens to a carbon molecule in a scenario on a card. Pass out one Carbon Tracing Game sheet to each pair. Give the students 5-10 minutes to discuss as a pair. Then ask four pairs to share their story with the class. The spokesperson should read the scenario, and use the handout to tell the story of how carbon moves and is transformed. For each story that is told, invite the rest of the class to "fact check." Do all parts of the story follow the rules? Do carbon atoms ever disappear? When carbon leaves one pool, does it always enter another?
4. **Connect the Keeling Curve's upward trend and with carbon in the ocean pool.**

Display Lesson 5 Activity 2.pptx slide 7. Look at the Keeling Curve and ask students to recall why the Keeling Curve shows an upward trend. Ask students how the Keeling Curve would be different if there weren't oceans? What would the trend look like? Have the students draw the trend and describe the change. Continue talking until a consensus is reached that the trend would get steeper, because the oceans would not absorb as much carbon, thereby leaving more in the atmosphere.

5. Transition to Activity 3

Time for the post-test!

OCEAN SCENARIO CARDS

<p style="text-align: center;"><i>Carbon Tracing Card A</i></p> <ol style="list-style-type: none"> 1. Create a story that traces carbon from its starting location to its ending location. 2. In your story, include what carbon-transforming processes the carbon goes through on its journey, and which pools it goes through. 3. Select one person in your group to be the “spokesperson” who will tell your story to the class. <p><i>Remember: your story must follow the rule: Carbon Cycles! If carbon leaves one pool, it must enter another pool.</i></p> <p>Starting location: The atmosphere, 4 years ago. Ending location: The shell of a mollusk in the ocean.</p>	<p style="text-align: center;"><i>Carbon Tracing Card B</i></p> <ol style="list-style-type: none"> 1. Create a story that traces carbon from its starting location to its ending location. 2. In your story, include what carbon-transforming processes the carbon goes through on its journey, and which pools it goes through. 3. Select one person in your group to be the “spokesperson” who will tell your story to the class. <p><i>Remember: your story must follow the rule: Carbon Cycles! If carbon leaves one pool, it must enter another pool.</i></p> <p>Starting location: Coal stored in a cave in West Virginia. Ending location: Dissolved in the ocean.</p>
<p style="text-align: center;"><i>Carbon Tracing Card C</i></p> <ol style="list-style-type: none"> 1. Create a story that traces carbon from its starting location to its ending location. 2. In your story, include what carbon-transforming processes the carbon goes through on its journey, and which pools it goes through. 3. Select one person in your group to be the “spokesperson” who will tell your story to the class. <p><i>Remember: your story must follow the rule: Carbon Cycles! If carbon leaves one pool, it must enter another pool.</i></p> <p>Starting location: The gas tank of a car. Ending location: Dissolved in the ocean.</p>	<p style="text-align: center;"><i>Carbon Tracing Card D</i></p> <ol style="list-style-type: none"> 1. Create a story that traces carbon from its starting location to its ending location. 2. In your story, include what carbon-transforming processes the carbon goes through on its journey, and which pools it goes through. 3. Select one person in your group to be the “spokesperson” who will tell your story to the class. <p><i>Remember: your story must follow the rule: Carbon Cycles! If carbon leaves one pool, it must enter another pool.</i></p> <p>Starting location: The fuel of an airplane taking off. Ending location: A coral in the Great Barrier Reef.</p>

ACTIVITY 3: POST TEST**Learning Objectives:**

1. Complete Post-Test

Duration: 20 minutes

Activity Description:

Students document their thinking and ideas at the end of the unit.

Background Information:

No background information is needed to administer the post-test.

Materials:

- Human Energy Systems Unit Post Test

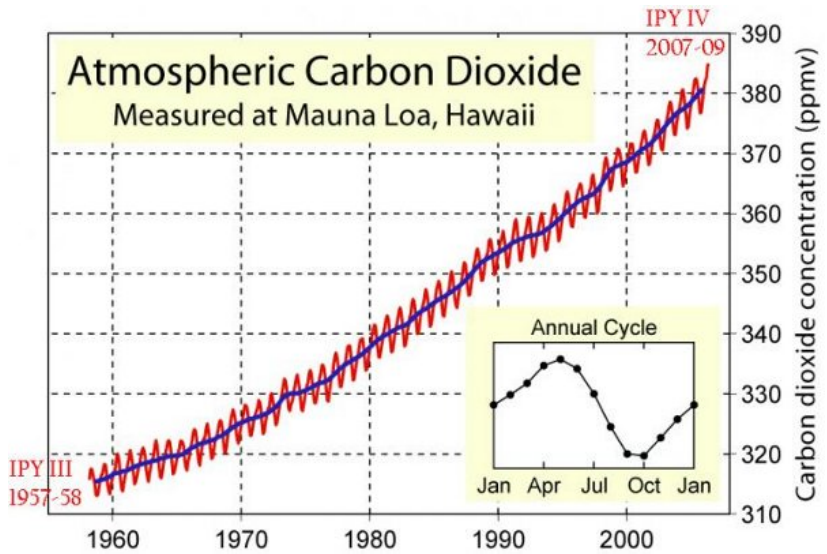
Directions:

1. **Pass out** Human Energy Systems Unit Post-Test to each student.
Remind them to put their initials only on the test (no names).
2. **Students take post test.**
Give students 20 minutes to complete the post test.

Teacher _____ Period: _____ Grade _____ Date _____ Your initials _____

HUMAN ENERGY SYSTEMS POST-TEST

1. This graph shows changes in carbon dioxide in the atmosphere over a 47-year span in Hawaii. Other measurements in different places on the Earth show the same pattern.



a. Why do you think carbon dioxide levels go down in the summer and go up in the winter? Circle the best choice to complete each of the statements. How much of the annual cycle is...

... caused by HUMANS BURNING COAL AND GASOLINE?	All or most	Some	None
... caused by CHANGES IN PLANT GROWTH?	All or most	Some	None
... caused by NUCLEAR POWER PLANTS?	All or most	Some	None
... caused by CHANGES IN WIND AND WEATHER?	All or most	Some	None

Explain your choices. Why does atmospheric carbon dioxide go down every summer and go up every winter?

b. Why do you think carbon dioxide in the atmosphere goes a little higher each year? Circle the best choice to complete each of the statements. How much of the continual rise is...

... caused by HUMANS BURNING COAL AND GASOLINE?	All or most	Some	None
... caused by CHANGES IN PLANT GROWTH?	All or most	Some	None
... caused by NUCLEAR POWER PLANTS?	All or most	Some	None
... caused by CHANGES IN WIND AND WEATHER?	All or most	Some	None

Explain your choices. Why is there a little more carbon dioxide in the atmosphere each year?

2. Do you think that *driving a car* causes carbon atoms to go into the atmosphere? Yes No

Where do the carbon atoms come from? Choose the best answer.

- | |
|---|
| a. Nowhere. Driving a car does not make carbon atoms move to the atmosphere. |
| b. Combustion: The carbon atoms come from the heat and light energy of burning. |
| c. Biomass: Recently living plants or animals. |
| d. Soil carbon: Dead plants or animals in the soil. |
| e. Fossil fuels: Petroleum, coal, or natural gas. |

Explain your choice. How does driving a car move carbon atoms from the source to the air?

--

2. Do you think that *turning on a light bulb* causes carbon atoms to go into the atmosphere? Yes No
 Where do the carbon atoms come from? Choose the best answer.

- | |
|--|
| a. Nowhere. Turning on a light bulb does not make carbon atoms move to the atmosphere. |
| b. Combustion: The carbon atoms come from the heat and light energy of burning. |
| c. Biomass: Recently living plants or animals. |
| d. Soil carbon: Dead plants or animals in the soil. |
| e. Fossil fuels: Petroleum, coal, or natural gas. |

Explain your choice. How does turning on a light bulb move carbon atoms from the source to the air?

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4. When someone eats a hamburger, which of the following processes are needed to produce the beef in the hamburger and deliver it to the person? Circle "needed" or "not needed" for each process.

Cellular respiration in plants	Needed	Not Needed
Cellular respiration in animals	Needed	Not Needed
Burning coal in power plants	Needed	Not Needed
Burning gasoline or diesel fuel in cars and trucks	Needed	Not Needed

Explain your answer. How is each of the processes that you chose "needed" or involved in producing and delivering beef?

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5. For each of the choices below, circle the choice that produces fewer carbon emissions. Then explain your choice.

Your choice for fewer carbon emissions	Your explanation for your choice
Coal burning power plant, OR Nuclear power plant	
Heating your house with natural gas, OR Heating your house with electricity	
Eating meat, OR Eating vegetables	

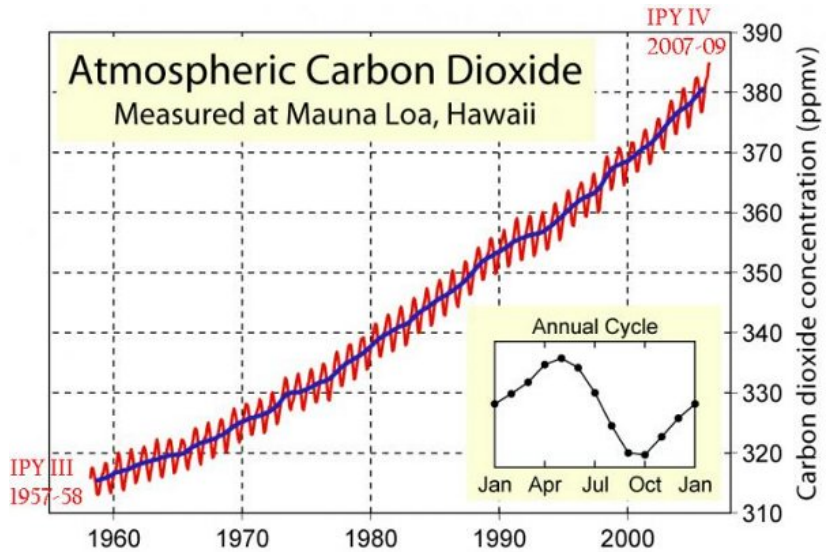
6. Answer these true-false questions:

True	False	Carbon is a kind of atom.
True	False	Carbon is a kind of molecule.
True	False	There is carbon in the air.
True	False	There is carbon in pure water.
True	False	There is carbon in the soil.

GRADING THE HUMAN ENERGY SYSTEMS POSTTEST

Correct responses are in bold blue italics.

1. This graph shows changes in carbon dioxide in the atmosphere over a 47-year span in Hawaii. Other measurements in different places on the Earth show the same pattern.



a. Why do you think carbon dioxide levels go down in the summer and go up in the winter? Circle the best choice to complete each of the statements. How much of the annual cycle is...

... caused by HUMANS BURNING COAL AND GASOLINE?	All or most	Some	None
... caused by CHANGES IN PLANT GROWTH?	All or most	Some	None
... caused by NUCLEAR POWER PLANTS?	All or most	Some	None
... caused by CHANGES IN WIND AND WEATHER?	All or most	Some	None

Explain your choices. Why does atmospheric carbon dioxide go down every summer and go up every winter?

In the summer, photosynthesis takes the CO₂ out of the atmosphere, causing the concentration to go down. In winter, cellular respiration releases the carbon back into the atmosphere as the plants die and leaves fall.

b. Why do you think carbon dioxide in the atmosphere goes a little higher each year? Circle the best choice to complete each of the statements. How much of the continual rise is...

... caused by HUMANS BURNING COAL AND GASOLINE?	All or most	Some	None
... caused by CHANGES IN PLANT GROWTH?	All or most	Some	None
... caused by NUCLEAR POWER PLANTS?	All or most	Some	None
... caused by CHANGES IN WIND AND WEATHER?	All or most	Some	None

Explain your choices. Why is there a little more carbon dioxide in the atmosphere each year?

Carbon emissions from the combustion of fossil fuels cause the overall increase in carbon dioxide in the atmosphere. (Nuclear is not a cause of this because nuclear power plants do not emit carbon. Deforestation may also cause this rise, because forest biomass and soil carbon are oxidized and rates of photosynthesis decrease.)

2. Do you think that *driving a car* causes carbon atoms to go into the atmosphere? **Yes** No

Where do the carbon atoms come from? Choose the best answer.

- a. Nowhere. Driving a car does not make carbon atoms move to the atmosphere.
- b. Combustion: The carbon atoms come from the heat and light energy of burning.
- c. Biomass: Recently living plants or animals.
- d. Soil carbon: Dead plants or animals in the soil.
- e. ***Fossil fuels: Petroleum, coal, or natural gas.***

Explain your choice. How does driving a car move carbon atoms from the source to the air?

Engines in a car burn gasoline to make the cars move. When gasoline combusts, the carbon atoms in the gasoline are combined with oxygen atoms from the air, forming CO₂ in the atmosphere.

2. Do you think that *turning on a light bulb* causes carbon atoms to go into the atmosphere? Yes No
 Where do the carbon atoms come from? Choose the best answer.

- a. Nowhere. Turning on a light bulb does not make carbon atoms move to the atmosphere.
- b. Combustion: The carbon atoms come from the heat and light energy of burning.
- c. Biomass: Recently living plants or animals.
- d. Soil carbon: Dead plants or animals in the soil.
- e. **Fossil fuels: Petroleum, coal, or natural gas.**

Explain your choice. How does turning on a light bulb move carbon atoms from the source to the air?

When we use light bulbs, this uses electricity. Electricity is generated in power plants from the burning of coal or natural gas. When these fossil fuels are burned, the carbon atoms from the fuel combine with oxygen atoms in the air, releasing carbon dioxide into the atmosphere.

Note: Coal-fired power plants produce the most carbon emissions; natural gas plants produce fewer emissions. Nuclear, wind, and solar plants do not generate carbon emissions as they run (though building the plants produces carbon emissions).

4. When someone eats a hamburger, which of the following processes are needed to produce the beef in the hamburger and deliver it to the person? Circle “needed” or “not needed” for each process.

Cellular respiration in plants	Needed	Not Needed
Cellular respiration in animals	Needed	Not Needed
Burning coal in power plants	Needed	Not Needed
Burning gasoline or diesel fuel in cars and trucks	Needed	Not Needed

Explain your answer. How is each of the processes that you chose “needed” or involved in producing and delivering beef?

Cellular respiration in plants is needed to give the plants energy to function, which allows the plant to use CO₂ from the air to add biomass. The plants are eaten by the animals, which use cellular respiration to move and function as it grows. Doing cellular respiration allows the cow to function and move, adding biomass (or meat). The hamburger is sent to my house in a car or truck that uses gasoline. If I eat it in a room that has lighting, or if the hamburger was cooked on a stove that uses electricity, and that electricity came from a coal-fired power plant, then I also needed to burn coal to eat the hamburger.

5. For each of the choices below, circle the choice that produces fewer carbon emissions. Then explain your choice.

Your choice for fewer carbon emissions	Your explanation for your choice
Coal burning power plant, OR Nuclear power plant	Nuclear power plants do not burn fossil fuels and do not release carbon
Heating your house with natural gas , OR Heating your house with electricity	Heating your house with natural gas releases less carbon than heating with electricity from a coal-fired power plant. OR If I use electricity and the source of the electricity does not emit carbon (wind, solar, nuclear), then this will have fewer emissions than burning natural gas, which always releases carbon.
Eating meat, OR Eating vegetables	Eating vegetables produces carbon emissions only from cellular respiration from the plants. If I eat meat, this requires carbon release from both cellular respiration in the plants that the cows eat, and also cellular respiration required by the

	<p><i>cows. Most of the carbon from the plants is released back into the air during cellular respiration from the animals, so eating meat releases more carbon into the air than eating plants. Meat also usually requires more refrigeration than vegetables.</i></p>
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6. Answer these true-false questions:

True	False	Carbon is a kind of atom.
True	False	Carbon is a kind of molecule.
True	False	There is carbon in the air.
True	False	There is carbon in pure water.
True	False	There is carbon in the soil.