Understanding Climate Change

2012-2013

A comprehensive guide for learning about climate change through hands-on critical thinking activities.

EFFICIENCY CONSERVATION

SYNTHESIS

Grade Level:

- Intermediate

Subject Areas:

- Science
- Social Studies
- Language Arts
- Technology

NEED

National Energy Education Development Project

Teacher Advisory Board

NEED Mission Statement

The mission of The NEED Project is to promote an energy conscious and educated society by creating effective networks of students, educators, business, government and community leaders to design and deliver objective, multi-sided energy education programs.

Teacher Advisory Board Statement

In support of NEED, the national Teacher Advisory Board (TAB) is dedicated to developing and promoting standards-based energy curriculum and training.

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Energy Data Used in NEED Materials

NEED believes in providing the most recently reported energy data available to our teachers and students. Most statistics and data are derived from the U.S. Energy Information Administration's Annual Energy Review that is published in June of each year. Working in partnership with EIA, NEED includes easy to understand data in our curriculum materials. To do further research, visit the EIA web site at www.eia.gov. EIA's Energy Kids site has great lessons and activities for students at www.eia.gov/kids.

NEED
National Energy
Education Development

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Table of Contents

As America's policy-makers work toward developing public policy about carbon dioxide and climate change, it is important for the public to understand the technologies and techniques available to mitigate the release and impact of carbon dioxide. It is important to understand the science of climate and the way energy use and our consumer choices impact our environment, economics, and standard of living. The U.S. Department of Energy, the U.S. Environmental Protection Agency, the U.S. Department of Commerce, and other agencies have joined the nation's energy industry and the engineering and scientific community to find the best possible solutions to address climate change while reducing possible negative impacts on America's economy.

With this curriculum module, and other NEED activities, we hope to help students, teachers, and the local community understand more about energy, carbon dioxide, climate, and climate change. We hope that teachers and students will discuss and think about our use of energy and our personal energy choices with a global perspective too—recognizing that the choices made here in the United States have an impact on the global environment and that energy decisions made in other countries have an impact on us too. This curriculum module is meant to help distill a fairly complex and heavily politicized topic down to a level that our students can understand and comprehend—providing them with simulations and hands-on lessons and Informational Texts meant to provide a foundation for their learnings.

We are grateful to the Carbon Mitigation Initiative for their assistance with this project and we welcome feedback from teachers, students, and their families about the content and lessons found inside.

Cover image courtesy of Flavio Takemoto, contributor to the Stock.XCHNG website.

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Correlations to National Science Education Standards: Grades 5-8

This book has been correlated to National Science Education Content Standards.
For correlations to individual state standards, visit **www.NEED.org**.

Content Standard B | *PHYSICAL SCIENCE*

- **Properties and Changes of Properties in Matter**
  - Substances react chemically in characteristic ways with other substances to form new substances (compounds) with different characteristic properties. In chemical reactions, the total mass is conserved.

- **Transfer of Energy**
  - Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.
  - Heat moves in predictable ways, flowing from warmer objects to cooler ones, until both reach the same temperature.

Content Standard C | *LIFE SCIENCE*

- **Populations and Ecosystems**
  - For ecosystems, the major source of energy is sunlight. Energy entering ecosystems as sunlight is transferred by producers into chemical energy through photosynthesis. That energy then passes from organism to organism in food webs.
  - The number of organisms an ecosystem can support depends on the resources available and abiotic factors, such as quantity of light and water, range of temperatures, and soil composition. Given adequate biotic and abiotic resources and no disease or predators, populations (including humans) increase at rapid rates. Lack of resources and other factors, such as predation and climate, limit the growth of populations in specific niches in the ecosystem.

Content Standard D | *EARTH AND SPACE SCIENCE*

- **Structure of the Earth System**
  - Water, which covers the majority of the Earth's surface, circulates through the crust, oceans, and atmosphere in what is known as the "water cycle." Water evaporates from the Earth's surface, rises, and cools as it moves to higher elevations, condenses as rain or snow, and falls to the surface where it collects in lakes, oceans, soil, and in rocks underground.
  - Water is a solvent. As it passes through the water cycle it dissolves minerals and gases and carries them to the oceans.
  - The atmosphere is a mixture of nitrogen, oxygen, and trance gases that include water vapor. The atmosphere has different properties at different elevations.
  - Clouds, formed by the condensation of water vapor, affect water and climate.
  - Global patterns of atmospheric movement influence local weather. Oceans have a major effect on climate, because water in the oceans holds a large amount of heat.
  - Living organisms have played many roles in the Earth system, including affecting the composition of the atmosphere, producing some types of rocks, and contributing to the weathering of rocks.

Correlations to National Science Education Standards: Grades 5-8

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Content Standard E | *SCIENCE AND TECHNOLOGY*

- **Understandings About Science and Technology**
  - Scientific Inquiry and technological design have similarities and differences. Scientists propose explanations for questions about the natural world, and engineers propose solutions relating to human problems, needs, and aspirations. Technological solutions are temporary; technologies exist within nature and so they cannot contravene physical or biological principles; technological solutions have side effects; and technologies cost, carry risks, and provide benefits.
  - Technological solutions have intended benefits and unintended consequences. Some consequences can be predicted, others cannot.

Content Standard F | *SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES*

- **Populations, Resources, and Environments**
  - Causes of environmental degradation and resource depletion vary from region to region and from country to country.
- **Natural Hazards**
  - Human activities also can induce hazards through resource acquisition, urban growth, land-use decisions, and waste disposal. Such activities can accelerate many natural changes.
- **Risks and Benefits**
  - Important personal and social decisions are made based on perceptions of benefits and risks.
- **Science and Technology in Society**
  - Science influences society through its knowledge and world view. Scientific knowledge and the procedures used by scientists influence the way many individuals in society think about themselves, others, and the environment. The effect of science on society is neither entirely beneficial nor entirely detrimental.
  - Societal challenges often inspire questions for scientific research, and social priorities often influence research priorities through the availability of funding for research.
  - Technology influences society through its products and processes. Technology influences the quality of life and the ways people act and interact. Technological changes are often accompanied by social, political, and economic changes that can be beneficial or detrimental to individuals and to society. Social needs, attitudes, and values influence the direction of technological development.

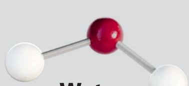
Teacher Guide

Time

- 10-15 class periods, depending on the activities selected

Background

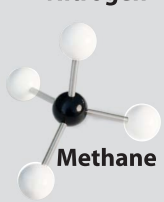
Through reading and hands-on activities, this guide examines the science behind climate change, the relationship between energy use and climate change, and personal choices that can be made to address climate change. It is recommended that teachers become familiar with activities and information included in this guide prior to use.


Water


Carbon Dioxide


Oxygen


Nitrogen


Methane

Activity 1: Introduction to Climate Change

Objective

- Students will outline their current understanding of climate change.

Time

- One class period

Materials

- Informational text, pages 20-31
- *Climate Change KWL Chart*, page 32

Procedure

1. Make copies of handouts for students.
2. Ask students, "What do you think you know about climate change?" Students should record their thinking on the *Climate Change KWL Chart*. Create a class chart on the board, if desired.
3. Have a class discussion about what students think they already know about climate change. Discuss where students developed these ideas, and what questions they may have about climate change. List any student questions in the KWL chart.
4. Students read the *Student Informational Text*. As they read they should take notes, specifically paying attention to new learning. Students should continue to add to their KWL charts as they read.

Activity 2: Greenhouse Gas Demonstration

Objective

- Students will understand why carbon dioxide, methane, and water vapor are three of the major greenhouse gases.

Time

- 10 minutes, or more, depending on depth of discussion

Materials

- Molecular models kit with spring attachments to act as bonds

Preparation

- Make models of the following (example photos in left margin):
  - carbon dioxide (CO_2)
  - water vapor (H_2O)
  - nitrogen (N_2)
  - methane (CH_4)
  - oxygen (O_2)

Procedure

1. Explain to your students:

   Carbon dioxide (CO_2), methane (CH_4), and water vapor (H_2O) are three of the major greenhouse gases. When the radiant energy from the sun travels through the Earth's atmosphere and strikes the surface of the Earth, much of that energy is radiated back as thermal energy and infrared energy that will leave the atmosphere, but much of it is absorbed by the greenhouse gases.

   The Earth's atmosphere is composed of around 78 percent nitrogen gas (N_2), which has a triple bond between the nitrogen atoms, and 21 percent oxygen gas (O_2), which has a double bond between the oxygen atoms. The energy is stored within the movement of those molecules. Nitrogen gas and oxygen gas do not have a great deal of flexibility in the vibrations, rotation, expansion, and contraction of the bonds within the molecule.

Demonstrate to students how there is a great deal of flexibility in the bonds of water, methane, and carbon dioxide, while there is very little in the flexibility of the other gases in the atmosphere. While holding the central atom in the structures of water, carbon dioxide, and methane, apply a slight force to the atoms attached to the central atom and show how the bonds are able to move freely indicating the ability to store more energy than the bonds within nitrogen gas or oxygen gas.

Activity 3: Properties of CO_2

Objective

- Students will identify properties of carbon dioxide.

Time

- One class period

Materials

- Plastic trash bags
- 5-10 lbs. of Dry ice (keep in foam cooler until ready to use)
- Pair of gloves
- Tongs
- Large, clear containers
- Plastic trays
- Bottles of bubbles
- Bottles of water
- Rubber gloves or rubber balloons
- Pipe cleaners
- Tea light candles
- Matches
- Plastic cups
- Safety glasses
- *Properties of CO_2 Gas*, page 33

Preparation

- Make copies of the student worksheet.
- Cover work surface with the plastic trash bags.
- Review the safety instructions for working with dry ice on page 18.
- You may conduct this activity as a demonstration, or gather enough containers, gloves, and tongs to allow small groups to work with the dry ice directly.

Procedure

1. Review the safety instructions for working with dry ice.
2. Place some dry ice on a plastic tray, place the tray of dry ice in the large container.
3. Explain that carbon dioxide (CO_2) is usually found in its gas form. However, it also can be found in a solid form and liquid form. Dry ice is frozen CO_2, or CO_2 in solid form.
4. Ask students, "What happens when frozen water warms up?" (It melts and turns into a liquid.) Next ask, "What do you think happens when frozen CO_2 warms up?" Have students record their predictions in their science notebooks. Have students observe the dry ice for a few minutes. Students should record observations using pictures and words in their science notebooks. Ask students to explain what they are seeing. Discuss that CO_2 does not exist as a liquid at atmospheric pressure. As frozen CO_2 thaws, or sublimes, it transforms directly into a gas. CO_2 exists as a liquid only under great pressure.
5. Pour water onto the dry ice until CO_2 gas fills the container. Blow bubbles into the large container. Have students record their observations on the *Properties of CO_2 Gas* worksheets, or in his/her notebook, and explain what is happening. After students have had time to write down their own thoughts, explain that CO_2 is more dense than air. Since the bubbles are filled with air, they float on top of the CO_2 gas collected in the container.

Science Notebooks

This curriculum is designed to be used in conjunction with science notebooks. Experimental questions, procedures, sample data tables, and conclusion questions are provided. If you do not use notebooks in your classroom, students may require paper for recording data and conclusions. If you use notebooks in your classroom, your students may choose to incorporate the activity sheets into their notebooks.

Additional Resources

Visit www.NEED.org for additional curriculum about energy sources as well as efficiency and conservation.

Recommended curriculum guides that will enhance your unit on climate change include:

- ***Carbon Capture, Utilization and Storage***
- ***Energy Conservation Contract***
- ***Great Energy Debate***
- ***Monitoring and Mentoring***
- ***Mission Possible***
- ***School Energy Survey***
- ***Intermediate Energy Infobook***

Dry Ice Safety

Carefully review the *Dry Ice Safety* sheet on page 18.

Dry ice can be obtained from many grocery stores. If you do not have access to dry ice, you can produce CO_2 gas by mixing equal parts baking soda and vinegar.

Note

During the experiment the temperature in the CO_2 rich beaker will rise for several minutes. Once a temperature peak is reached, the temperature will start to drop again rapidly. This is because the supply of CO_2 in the small water bottle has exhausted itself and because the natural convection currents in the beaker, driven by the heat from the light bulb, will disperse the CO_2.

6. Drop an ice cube sized piece of dry ice into a bottle of water. Place a rubber glove or balloon over the mouth of the water bottle. Use a pipe cleaner as a twist tie around the glove. Students should record observations in their science notebooks or on their worksheets and explain what happened.
7. Light a tea candle. Using the plastic cup, collect some CO_2 gas and pour it over the tea light. Using the *Properties of CO_2 Gas* worksheets or their science notebooks, students should record what happens and explain what they saw. Explain that CO_2 displaces lighter oxygen. The CO_2 is heavier than air and pushes the oxygen away. The fire needs oxygen to continue burning so the fire is extinguished. This is why CO_2 is used in fire extinguishers.

Activity 4: Greenhouse in a Beaker

Objective

- Students will understand that carbon dioxide speeds up the transfer of thermal energy.

Time

- One class period

Materials *FOR EACH GROUP*

- 2 600 mL Beakers
- 1 250 mL Flask
- 1 Rubber stopper with hole
- 1 Vinyl tubing, 3/16” diameter, 60 cm long
- 1 Clip light
- 1 Ruler
- 2 Probe thermometers
- 1 Small piece of masking tape
- 4 Alka-Seltzer tablets
- Safety glasses
- *Greenhouse in a Beaker* worksheets, pages 34-35
- Water (room temperature)
- 1000-1100 Lumen bulb, equivalent to 75 watt incandescent

Procedure

1. Introduce the investigation to students by asking, “What affect does adding carbon dioxide to the air have on the air’s temperature?”
2. Explain that students will be creating two models of our atmosphere (air inside of the beakers), and the lamp represents the sun. One beaker will contain a “normal” atmosphere. Carbon dioxide (CO_2) will be added to the second beaker, creating a CO_2 rich atmosphere. The CO_2 will be produced through a chemical reaction that occurs when Alka-Seltzer is added to water. The active ingredients in Alka-Seltzer are aspirin, citric acid, and sodium bicarbonate ($NaHCO_3$). When the tablet is placed in water, an acid-based reaction involving sodium bicarbonate and the citric acid takes place yielding sodium hydroxide, water, and carbon dioxide.

$$\mathbf{3NaHCO_3 + C_6H_8O_7 \longrightarrow Na_3C_6H_5O_7 + 3H_20 + 3CO_2(g)}$$

3. Divide students into small groups. Pass out the *Greenhouse in a Beaker* worksheets.
4. Circulate around the room assisting groups as needed.

Extension

Ask students what variables they can change in the investigation. Let students design new investigations and in their conclusions have them correlate their changes to actual conditions that may change in Earth’s climate system.

Activity 5: Carbon Cycle Simulation

Objective

- Students identify the basic ways carbon cycles throughout the Earth's systems.
- Students will be able to compare how carbon cycled through the Earth's systems prior to the Industrial Revolution and after the Industrial Revolution.

Time

- One to two class periods

Materials

- *Carbon Cycle Simulation Posters*, pages 37-40
- *Reservoir Instruction Sheets*, pages 41-49
- Two decks of playing cards, divided by suit
- 2 Copies of the *Carbon Tracking Sheet* for each student, page 50
- *Carbon Reservoir Comparison* worksheet, page 36

Pre-Industrial Round Preparation

- Make copies of student worksheets and posters.
- Hang up the carbon cycle posters and Pre-Industrial Round instruction sheets around the classroom (as shown in the diagram on page 10).
- Place a full suit of cards at each of the eight reservoirs.

Pre-Industrial Round Procedure

1. Pass out the *Carbon Reservoir Comparison* chart and have students use the *Understanding Climate Change Student Informational Text* to compare the four major carbon reservoirs. Review the information as a class.
2. Explain that in this activity students will become carbon atoms, and model the different forms carbon takes as it travels between these reservoirs.
3. Use the chart on page 11 to divide your students among the reservoirs. The natural exchange of carbon between the lithosphere and atmosphere pre-Industrial Revolution was negligible, so the lithosphere is not used in this round.
4. Pass out one *Carbon Tracking Sheet* to each student. Students will record which reservoirs they travel to in this round.
5. Assign students to their first reservoir. They should count how many people are at the reservoir and record the number on the sheet. Remind students that they should not pull cards until instructed. Students should not change reservoirs until given a signal to move. At that time, everyone who is changing reservoirs (based on the card they pulled) will move.
6. Students record the necessary information about their reservoir and carbon form on their *Carbon Tracking Sheet*.
7. Instruct students to each choose a card and use the directions on the sheet to determine who leaves the reservoir and who stays. Students return the cards to the original pile.
8. Signal students to change reservoirs. Once everyone has arrived where they need to be, the group counts how many people are at the reservoir and students write down the necessary information about the reservoir and carbon form on their worksheet.
9. Repeat steps seven and eight until you have completed 10 cycles in the Pre-Industrial Round.
10. Bring the students together and discuss what they noticed about carbon movement, the forms carbon comes in, and about the amount of carbon in each reservoir.

Online Resources

Samples of the reservoir posters and instruction sheets are on pages 37-49 To download full size color copies of the posters visit www.NEED.org.

Note

If you do not have enough students to make up the minimum number in either the Pre-Industrial or Present Day Rounds, you can create "proxy carbons" to fill up the needed spots. Assign one or two students to be "proxy managers" who will be responsible for drawing the cards for the proxy carbons, and moving them where they need to go.

Activity 5: Carbon Cycle Simulation *(CONTINUED FROM PAGE 9)*

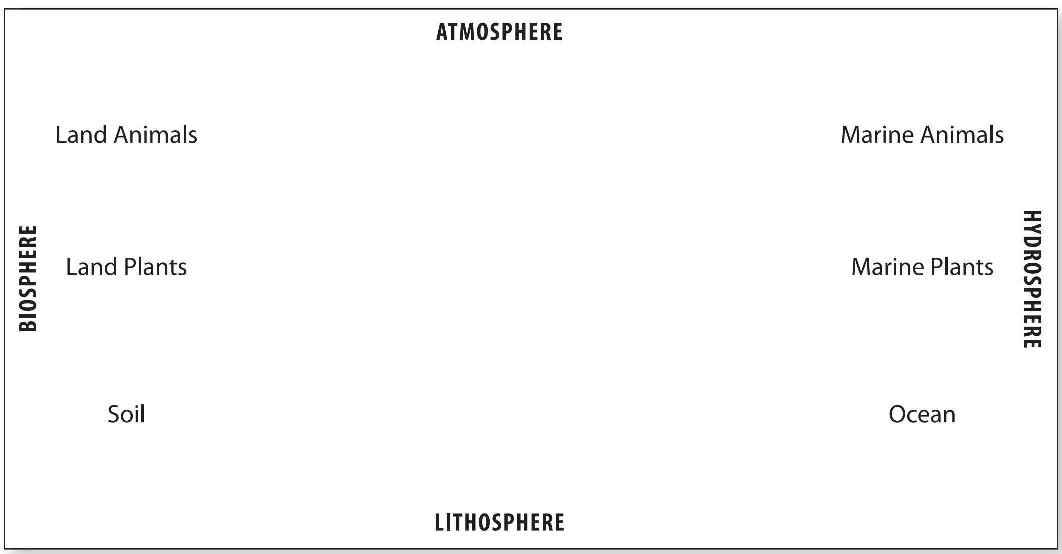
Present Day Round Preparation

- Place the *Atmosphere and Lithosphere: Present-Day Round* instruction sheets, pages 42 and 49, and the Lithosphere poster, page 40, around the room with the other materials from the Pre-Industrial Round, as shown in the diagram below.
- Make sure each reservoir has a full suit of cards.

☑ Present Day Round Procedure

1. Pass out a new *Carbon Tracking Sheet* to each student.
2. Assign students reservoirs using the Present-Day Round table on page 11.
3. Follow the same direction as the Pre-Industrial Round and complete 10 cycles in the Present-Day Round.
4. When complete, discuss with the students the differences between the Pre-Industrial Round and the Present-Day Round. Use the data collected on the posters to graph the movement between the reservoirs. What conclusions can students make about carbon cycling based on the data?

Suggested Placement of Reservoir Posters



Number of Students in Each Reservoir

PRE-INDUSTRIAL ROUND								
TOTAL NUMBER OF STUDENTS	ATMOSPHERE	BIOSPHERE LAND PLANT	BIOSPHERE LAND ANIMAL	BIOSPHERE SOIL	LITHOSPHERE	HYDROSPHERE OCEAN	HYDROSPHERE MARINE PLANT	HYDROSPHERE MARINE ANIMAL
18	5	3	2	1	0	4	2	1
19	5	3	2	1	0	5	2	1
20	5	4	2	1	0	5	2	1
21	6	4	2	1	0	5	2	1
22	6	4	2	1	0	5	3	1
23	6	4	3	1	0	5	3	1
24	7	4	3	1	0	5	3	1
25	7	4	3	1	0	5	3	2
26	7	4	3	2	0	5	3	2
27	8	4	3	2	0	5	3	2
28	8	4	3	2	0	6	3	2
29	8	5	3	2	0	6	3	2
30	9	5	3	2	0	6	3	2
31	9	5	3	2	0	6	4	2
32	9	5	4	2	0	6	4	2

PRESENT-DAY ROUND								
TOTAL NUMBER OF STUDENTS	ATMOSPHERE	BIOSPHERE LAND PLANT	BIOSPHERE LAND ANIMAL	BIOSPHERE SOIL	LITHOSPHERE	HYDROSPHERE OCEAN	HYDROSPHERE MARINE PLANT	HYDROSPHERE MARINE ANIMAL
28	5	3	2	1	10	4	2	1
29	5	3	2	1	10	5	2	1
30	5	4	2	1	10	5	2	1
31	6	4	2	1	10	5	2	1
32	6	4	2	1	10	5	3	1

Special Time Requirement

- The land-based ice cubes in this activity will take at least two hours to melt. Because of this, the activity can't be run during a standard class period. The activity works best in a self-contained classroom where students can check progress throughout the day. It could also work in an extended class period. As another option, students in early classes can start the experiment and students coming in later can observe the results. Photographs can also be taken by the teacher or other students throughout the day (and the time recorded for each photo) and then provided to the students the following day so they can complete the activity.
- To facilitate Part One of the activity, 'perfect cube' ice trays are recommended. These silicone trays produce 1" cubes which make it easy for students to measure the volume.

Activity 6: Land Ice/Sea Ice

Objective

- Students will be able to describe the effects sea and land ice have on sea level, when melted.

Time

- Two class periods (See "Special Time Requirement" note.)

Materials *FOR EACH GROUP*

- Non-absorbant materials to make a land form (e.g., rocks, clay, crumpled aluminum foil)
- 2 25 sq ft Rolls of aluminum foil (more if using foil for land forms)
- Rectangular tubs approximately 3-5" deep, and roughly 8" x 12"
- 11 Ice cubes
- Ruler
- 2 Liters of water
- Beaker
- *Land Ice/Sea Ice* worksheets, pages 51-52

Preparation

- Gather the materials necessary for the activity.
- Copy worksheets for each student.
- Make enough ice for all groups.

Procedure

1. Discuss the two contributors to sea level by reviewing page 29 in the informational text.
2. Ask students if they think that floating ice in the ocean would raise sea level if it melts. Also ask if they think that melting ice on land would raise sea level when it melts. Discuss student responses.
3. Tell students that they will be conducting two experiments to find out. Describe the experiments, showing them examples of each experimental set up. (See page 51 for directions.)
4. Direct students to run the experiments.
5. After students have run the experiments, ask students to discuss the results of Part One. Ensure students understand that water in its solid state unlike other liquids has a greater volume than in its liquid state.
6. Next, discuss the results of Part Two. Ask students to discuss why the water level did not rise in the sea ice tray. If necessary, explain that because this ice is floating it has displaced some of the water in which it floats. Because of this, even though some of the ice rises above the surface of the water, when it melts it does not affect the level of the water.
7. Relate this to rising sea levels ensuring students understand that it's the dynamic of melting land-based glaciers that is contributing to sea level rise. Thus, the polar ice cap, as it melts, does not contribute to sea level rise.
8. Finally, relate the results of Part Two to the results of Part One. Explain that because ice floats on water and is not completely submerged, ice does not displace an amount of water equal to its volume. Instead, it displaces less than its total volume of water. The water that floating ice displaces is equal to the volume that the ice would take up if it melted and became water again. So the difference between frozen and liquid water they calculated in Part One is the volume of

the ice cube that floats above the water line. As it melts, its volume becomes less thus leaving the water level in the tray in Part Two the same. When ice melts, the mass of the ice is conserved, but the crystal lattice structure of ice disappears and the volume decreases and becomes equal to the volume of water it displaced in its solid form.

9. Ensure that students can relate the rise in sea level to melting land-based ice to climate change and our use of fossil fuels. Ask them to go one step further and describe what causes the melting to occur in climate change (increased use of CO_2 emitting fossil fuels).

Activity 6 Extension: Ocean Currents and Sea Water Density

Materials

- Land forms and trays from *Activity 6: Land Ice/Sea Ice*
- Food coloring
- 10 Ice cubes
- Water
- Salt
- Balance

Procedure

1. Conduct the activity as before, but this time add food coloring to the water you use to make the ice cubes. You want the cubes to be strongly colored, so use a good amount of food coloring.
2. Since temperature is a factor in density, the trays should be filled with cold (refrigerated) water this time.
3. In addition, add salt to the water that students will use in the tubs. Mix 35 grams of salt per liter of water to achieve a similar concentration to that of sea water.
4. As the ice melts, ask students to observe the stratification that takes place. They should observe the colored, fresh water forming a layer on top of the clear, salt water.
5. After running the activity, lead a discussion on density and what caused the results. Have students write a paragraph describing what happened and why they think it happened.
6. Next discuss the role that density plays in the ocean currents and how these currents play a role in determining climate. Explain how fresh water from melting glaciers is causing changes in these currents.
7. Ask students to explain how this might affect climate.

Activity 7: Climate Web

Objectives

- Students will be able to identify components in the climate system and their functions.
- Students will be able to describe the connections between each component.

Time

- One class period

Materials

- Ball of yarn or string
- Scissors
- Single hole punch
- Climate web hang tags, pages 53-57
- *Climate Systems* worksheet, page 58

Preparation

- Copy the climate hang tags onto card stock and laminate for reuse.
- Cut apart the hang tags and use a single hole punch to make two holes in the top corner of each.
- Lace one length of yarn or string through each hang tag and tie off creating a necklace.
- Copy the *Climate Systems* worksheet for students.

Classroom Management Note

When handing out hang tags to students, some have descriptions that allow for easy identification of related components in the climate system. It may be wise to strategically assign cards to your students based on their knowledge.

☑ Procedure

1. Hand out the hang tag necklaces and ask students to read the backs of their cards aloud so other students in the group know the roles in the game. Give students a chance to ask any questions they have about what is written on their cards.
2. Direct students to put on their hang tags and stand in a circle.
3. Hand the ball of yarn to one of the students. Explain that he or she should look around the circle and identify another student representing a component of the system that is related to his or her role. Some of these relationships are spelled out on the descriptions on the backs of the hang tags.
4. Holding on to the end of the yarn, the first student passes the ball of yarn to that student, explaining how that part of the system relates to him or her. That student then repeats the process, holding onto the yarn and passing the ball on.
5. Continue passing the yarn around until everyone has their hands on the yarn. While connections can be made between each component, students may have trouble seeing all of them. Because of this, it is acceptable to pass to a student a second time before the yarn has made it all the way around the circle. In the end, the students will have created a web made of yarn connecting all of them.
6. Now choose a student to give a tug on the string. Explain that this tug represents an influence (positive or negative) being exerted by that part of the system. For instance, the person wearing the 'Coal' tag might give a tug, and you would say, "Coal is mined and processed for electrical energy. This process emits pollutants into the air and coal is a nonrenewable resource." Or solar energy might give a tug and you would say, "Increasing the use of solar PV's reduces our CO_2 emissions from generating electricity."
7. Ask students to raise their hands if they feel a pull when the string is tugged. Ask students why their component might be influenced due to the use of coal. Discuss the connections and why some students might feel stronger pulls than others.
8. Repeat this several times with different students tugging. For each tug, describe how that component is influencing the system.
9. Pass out the *Climate Systems* worksheet. Ask students to describe how the system is dependent on all of the components. Students should be able to explain that a change in one part of the system can affect all other parts of the system.

Activity 8: Carbon Footprint

Objective

- Students will quantify and describe their own individual carbon footprints.

Time

- One class period

Materials

- 5 lb. Bag of charcoal briquettes
- 1 Tall, white kitchen trash bag
- 1 Plastic grocery bag
- Paper towels
- All purpose cleaning solution
- 1 Sheet white 8 ½" x 11" paper
- *Carbon Footprint* worksheet, page 59
- *Carbon in My Life Informational Text*, pages 60-62

Preparation

Prior to this activity, have students research uses for CO_2 as homework. Encourage students to find ways CO_2 is used in residential, industry, and medical settings. Students should make a list and bring the list with them to class.

Procedure

1. Break students into small groups to brainstorm a list of uses for CO_2 based on their findings from the homework assignment.
2. Based on the previous activities, students should understand that CO_2 is released into the atmosphere during fossil fuel combustion. This includes combustion from fossil fueled power plants generating electricity, from manufacturing processes, and from the burning of fossil fuels as a fuel in vehicles.
3. Review that CO_2 is usually found in a gas form. It is colorless and transparent to light. Even though we know CO_2 impacts the environment, we do not always think about it because we cannot see it. Show students the bag of charcoal briquettes. The briquettes are made almost completely of carbon, so the briquettes will represent the amount of carbon in one gallon of gas. The average gallon of gasoline contains about five pounds of carbon. There are about 100 briquettes in the bag. By dividing five pounds of carbon by 100 briquettes, that means there are about 0.05 pounds of carbon per briquette.
4. Discuss how many miles each student drives (or is driven) to and from school each day. Calculate how many briquettes represent the carbon dioxide emissions related to transporting students to and from school. Use the bags to cover workspace and hold individual briquettes. Students will record their answers on the *Carbon Footprint* worksheet.
5. When students are done calculating their carbon footprint for transportation, ask students what else they might do to emit carbon. Make a list of other factors that might be included in one's carbon footprint. Explain to students that this is often called an ecological footprint.
6. If time permits, have students read the *Carbon In My Life Information Text*.
7. When students are done calculating and brainstorming their *Road Trip* carbon footprint, give them a separate piece of paper. Have students trace an outline of their shoe. Inside the footprint have students write at least three suggestions for reducing their carbon footprint. Students should also reflect on why it is important to understand their carbon footprint and why it matters.

Online Resources

- **Environmental Protection Agency's Emissions Calculator: www.epa.gov/climatechange/ghgemissions/ind-calculator.html**
- **Earth Day Network: www.earthday.org/footprint-calculator#.UMnKMqycny1**
- **Nature Conservancy: www.nature.org/greenliving/carboncalculator/**
- **Pacific Gas and Electric: www.pge.com/about/environment/calculator**
- **CarbonFootprint.com: http://calculator.carbonfootprint.com/calculator.aspx**
- **BP Energy Lab: www.bp.com**

Additional Resources

Students can find out exactly how much carbon is associated with the use of appliances and their favorite electronics. Check out *The Environment and You* activities in NEEDs's *Monitoring and Mentoring* guide for more information.

Activity 9: Carbon in My Life

Objectives

- Students will critically analyze commonplace items through the lens of the energy and materials that are involved in their use.
- Students will understand that CO_2 emissions occur throughout a product's life cycle.

Time

- Two to three class periods

Materials

- *Carbon in My Life Informational Text*, pages 60-62
- *Aluminum Can Life Cycle Comparison* worksheet, page 63
- *Carbon In My Life Survey*, page 64
- *Carbon In My Life Study Items* organizer, page 65
- *Carbon In My Life Item Analysis Organizer*, page 66
- *Carbon In My Life Questionnaire*, page 67
- *Carbon In My Life Action Planner*, page 68

Procedure

1. Present an overview of the activity and project expectations. Break into groups of three or four students.
2. Have students actively read the *Carbon in My Life Informational Text*. Select the best strategy for your students:
   - Read individually
   - Read aloud
   - Jigsaw read (teacher may work with emerging readers or pair students together)
3. Check for understanding of the *Informational Text* and explain that carbon contributors can include products, food items, behaviors, water and energy uses, transportation needs, or anything that can be associated with the need to use some form of energy.
4. Explain to students that the energy we use each day results directly in an increase in carbon in the atmosphere when electrical power is produced using fossil fuels, and when we operate motor vehicles or heat our homes and water with fossil fuels, and create products.
5. Review the *Aluminum Can Life Cycle Comparison* worksheet).
6. Have teams complete the *Carbon In My Life Survey.*
7. Brainstorm additional items on the *Carbon In My Life Study Items* organizer.
8. All teams will select an item from each category (food, energy, water, etc.) to study and use the *Carbon in My Life Item Analysis Organizer* and *Carbon In My Life Questionnaire* to identify Action Plan items.
9. Teams will select one item for each team member and develop an action plan for lowering their carbon footprint using the steps on the *Carbon In My Life Action Planner*.
10. If time allows, select one of the recommended extensions (on the next page) to reinforce the lesson and to give students opportunities to expand on their Action Plans.

Extensions

- Use this activity at your home to study items and to initiate action plans to reduce energy use and CO_2 impacts. Document your project from beginning to end and prepare a presentation to the class, to the community, or to other homeowners.
- Publish your action plan in a local newspaper article, an Internet article, or contact local radio or television media to conduct an interview.
- Develop a service-learning project that helps senior citizens or low-income citizens find ways to save money by using energy saving strategies that you've developed in this activity.
- Work with your local school board or city council to find ways that your strategies can be used at other schools, city parks, city owned businesses, etc.
- Research schools and buildings in other countries to see how needs are met differently and document the differences in energy use and CO_2 impacts.
- Research how schools and buildings in the year 1900 met the same needs you meet today and document the differences in energy use and CO_2 impacts.

Evaluation

Following the completion of your unit, evaluate the unit with your students using the *Evaluation Form* on page 71 and return it to The NEED Project.

Dry Ice Safety

What is Dry Ice?

Dry ice is frozen carbon dioxide. Unlike most solids, it does not melt into a liquid, but instead changes directly into a gas. This process is called sublimation. The temperature of dry ice is around -109° F! It sublimates very quickly so if you need dry ice for an experiment or project, buy it as close as possible to the time you need it.

Dry Ice Safety Rules

1. Students: Never use dry ice without adult supervision. Dry ice can cause serious injury if not used carefully!
2. Never store dry ice in an airtight container. As the dry ice undergoes sublimation from a solid directly into a gas, the gas will build up in the container until it bursts. Sharp pieces of container will go flying all over the place. Make sure your container is ventilated. The best place to store dry ice is in a foam chest with a loose fitting lid.
3. Do not touch dry ice with your skin! Use tongs, insulated (thick) gloves, or an oven mitt. Since the temperature of dry ice is so cold, it can cause severe frostbite. If you suspect you have frostbite, seek medical help immediately.
4. Never eat or swallow dry ice! Again, the temperature of dry ice is very, very cold. If you swallow dry ice, seek medical help immediately.
5. Never lay down in, or place small children or pets in, homemade clouds. The clouds are made of carbon dioxide gas. People and pets could suffocate if they breathe in too much gas.
6. Never place dry ice in an unventilated room or car. If you are traveling with dry ice in the car, crack a window open. The same rule applies if you are in a small room, crack a window open. You do not want too much carbon dioxide gas to build up around you.
7. Always wear safety glasses when doing experiments with dry ice.
8. Do not place dry ice directly on counter tops. The cold temperature could cause the surface to crack.
9. Leave the area immediately if you start to have difficulty catching your breath. This is a sign that you have inhaled in too much carbon dioxide gas.
10. Do not store dry ice in your freezer. It will cause your freezer to become too cold and your freezer may shut off. However, if you lose power for an extended period of time, dry ice is the best way to keep things cold in an ice chest or cooler.

Disposing of Dry Ice

To dispose of dry ice, place in a well ventilated container and take it outside where small children and pets cannot reach it. Simply let it sublimate away.

Data: NOAA and NWS

Resources

American Association for the Advancement of Science
http://www.aaas.org/news/press_room/climate_change/

Carbon Dioxide Information Analysis Center
http://cdiac.ornl.gov

Intergovernmental Panel on Climate Change
www.ipcc.ch

International Energy Agency
www.iea.org

NASA's Eyes on the Earth
http://climate.nasa.gov

National Center for Atmospheric Research
http://eo.ucar.edu/kids/green/index.htm

National Oceanic and Atmospheric Administration
www.noaa.gov/climate.html

U.S. Department of Energy
www.energy.gov/environment/climatechange.htm
www.eere.energy.gov
www.afdc.energy.gov/

U.S. Energy Information Administration
www.eia.gov
www.eia.gov/environment.html
www.eia.gov/kids
www.eia.gov/energyexplained/

U.S. Environmental Protection Agency
www.epa.gov/climatechange
www.epa.gov/cleanenergy/energy-resources/calculator.html
www.epa.gov/climatechange/ghgemissions/ind-calculator.html
www.epa.gov/statelocalclimate/resources/

United Nations Environment Programme
www.unep.org/climatechange

United Nations Environment Programme, GRID-Arendal
www.grida.no

United States Global Change Research Program
http://globalchange.gov

Understanding Climate Change

Student Informational Text

What is Energy?

Energy makes change; it does things for us. It moves cars along the road and boats over the water. It bakes a cake in the oven and keeps ice frozen in the freezer. It plays our favorite songs on the radio and lights our homes. Energy makes our bodies grow and allows our minds to think. Scientists define energy as the ability to do work.

Forms of Energy

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

POTENTIAL ENERGY

Potential energy is stored energy or the energy of position. There are several forms of potential energy, including:

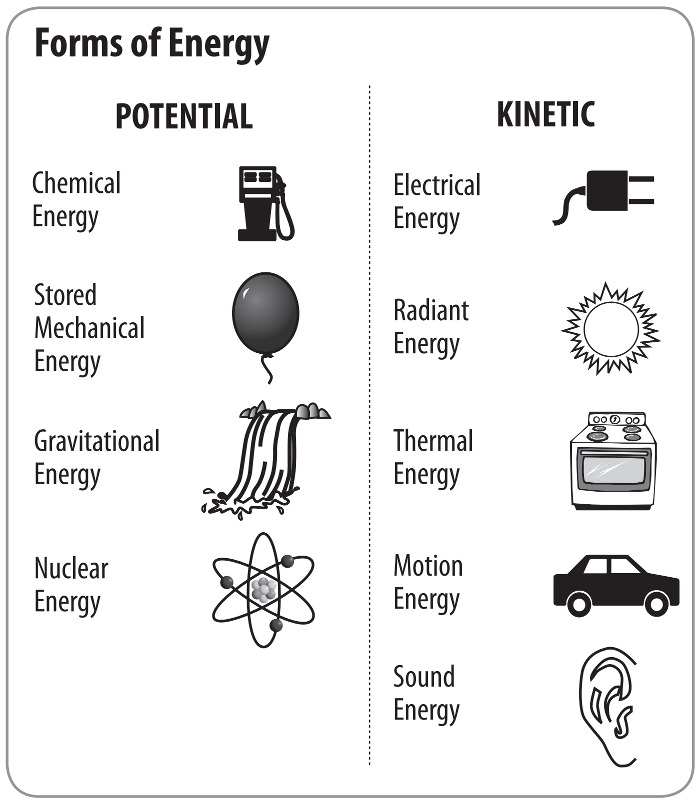
Chemical energy is energy stored in the bonds of atoms and molecules. It is the energy that holds these particles together. **Biomass**, petroleum, natural gas, and propane are examples of stored chemical energy.

- **Stored mechanical energy** is energy stored in objects by the application of a force. Compressed springs and stretched rubber bands are examples of items stored mechanical energy.
- **Nuclear energy** is energy stored in the nucleus of an atom; it is the energy that holds the nucleus together. The energy can be released when the nuclei are combined or split apart. Nuclear power plants split the nuclei of uranium atoms in a process called **fission**. The sun combines the nuclei of hydrogen atoms in a process called **fusion**.
- **Gravitational energy** is the energy of position or place. A rock resting at the top of a hill contains gravitational potential energy. Hydropower, such as water in a reservoir behind a dam, is an example of gravitational potential energy.

KINETIC ENERGY

Kinetic energy is motion; it is the motion of waves, electrons, atoms, molecules, substances, and objects.

- **Electrical energy** is the movement of electrons. Everything is made of tiny particles called atoms. Atoms are made of even smaller particles called electrons, protons, and neutrons. Applying a force can make some of the electrons move. Electrons moving through a wire is called circuit electricity. Lightning is another example of electrical energy.
- **Radiant energy** is electromagnetic energy that travels in transverse waves. Radiant energy includes visible light, x-rays, gamma rays, and radio waves. Solar energy is an example of radiant energy.
- **Thermal energy**, or heat, is the internal energy in substances; it is the vibration and movement of the atoms and molecules within substances. The more thermal energy in a substance, the faster the atoms and molecules vibrate and move. Geothermal energy is an example of thermal energy.
- **Motion energy** is the movement of objects and substances from one place to another. Objects and substances move when an unbalanced force is applied according to Newton's Laws of Motion. Wind is an example of motion energy.
- **Sound energy** is the movement of energy through substances in longitudinal (compression/rarefaction) waves. Sound is produced when a force causes an object or substance to vibrate; the energy is transferred through the substance in a longitudinal wave.



Conservation of Energy

To scientists, **conservation** of energy is not saving energy. The law of conservation of energy says that energy is neither created nor destroyed. When we use energy, it doesn't disappear. We change it from one form of energy into another. This is called an **energy transformation**.

A car engine burns gasoline, converting the chemical energy in gasoline into motion energy. Solar cells change radiant energy into electrical energy. Energy changes form, but the total amount of energy in the universe stays the same.

Efficiency

Energy efficiency is the amount of useful energy you get from a system. A perfect, energy efficient machine would change all the energy put in it into useful work—a technological impossibility today. Converting one form of energy into another form always involves a loss of usable energy.

Most energy transformations are not very efficient. The human body is a good example. Your body is like a machine, and the fuel for your machine is food. Food gives you the energy to move, breathe, and think.

Your body isn't very efficient at converting food into useful work. Your body's overall efficiency is about 15 percent most of the time. The rest of the energy is transformed into heat. You can really feel that heat when you exercise! Most electric power plants have the same efficiency problem as your body. Most are only about 35 percent efficient, meaning only 3-4 units of energy are created for every ten put in. The leftover energy is lost waste heat.

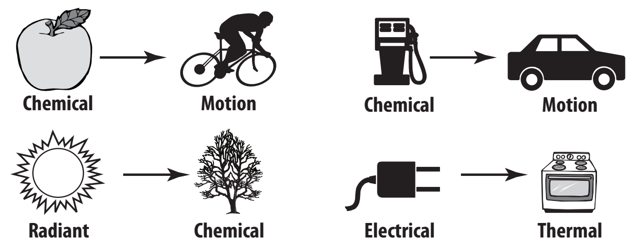
Sources of Energy

We use many different energy sources to do work for us. They are classified into two groups—renewable and nonrenewable.

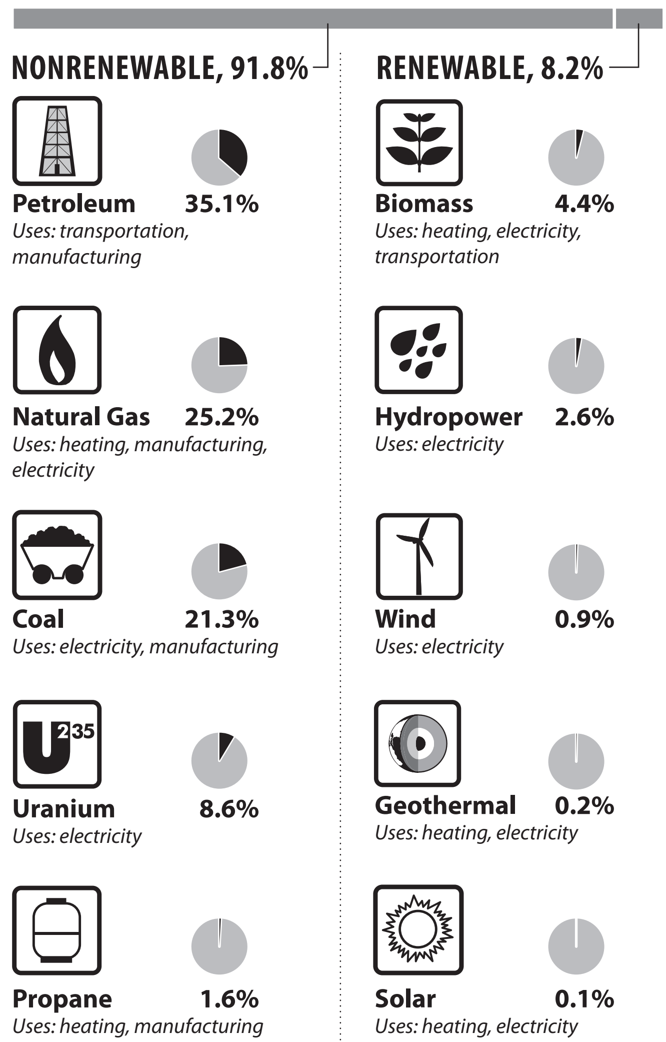
In the United States, most of our energy comes from **nonrenewable** energy sources. Coal, petroleum, natural gas, propane, and uranium are nonrenewable energy sources. They are used to make electricity, heat our homes, move our cars, and manufacture all kinds of products. These energy sources are called nonrenewable because their supplies are limited. Petroleum, for example, was formed hundreds of millions of years ago from the remains of ancient sea plants and animals. We can't make more crude oil deposits in a short time.

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

Energy Transformations



U.S. Energy Consumption by Source, 2010



Data: Energy Information Administration

Electricity

Electricity is different from the other energy sources because it is a **secondary energy source**. We must use another energy source to produce electricity. In the U.S., coal is the number one energy source used for generating electricity.

Electricity is sometimes called an energy carrier because it is an efficient and safe way to move energy from one place to another, and it can be used for so many tasks. As we use more technology, the demand for electricity grows.

Introduction to Climate Change

A Changing Climate

Since its formation, Earth's climate has been constantly changing. Many factors have altered the climate, including the Earth's orbit and changing proximity to the sun, as well as the amount of heat-trapping **gases** in the **atmosphere**.

Human societies have evolved during an extended period of favorable climatic conditions. In fact, some researchers believe that a period of favorable climate was the primary factor that allowed the rise of civilization.

Over the past several decades, scientists have collected an increasing amount of data indicating that, for the first time in Earth's history, the activities of one species—*homo sapiens*—are altering the climate. Research shows a significant increase in the **concentration** of heat-trapping gases, especially **carbon dioxide** (CO_2), in the Earth's atmosphere since the beginning of the Industrial Revolution. A rise in global temperatures relates to the rise in carbon dioxide.

There are many complex forces, both natural and man-made, that influence our climate. Should we be concerned if human activities are changing the climate? What effects might a change in climate have on us?

Weather and Climate

Climate and weather are not the same thing; the difference is simply a matter of time. **Weather** describes the conditions in the atmosphere over a short period of time, and is usually described in terms of its effects on human activities. Weather forecasts are focused on temperature, humidity, precipitation, atmospheric pressure, and wind conditions that occur over a time span of days.

Scientists use long-term averages and trends to describe **climate**. Russian Wladimir Köppen developed the most famous climate classification chart in 1884. Using annual and monthly temperatures, precipitation patterns, and native vegetation, Köppen categorized the Earth into five different climate groups. He refined it over his lifetime with the help of German scientist Rudolf Geiger. Their work is often called the Köppen-Geiger Classification System.

Climate Groups

A. **Tropical Moist Climates:** all months have average temperatures above 18° Celsius or 64.4° Fahrenheit.

B. **Dry Climates:** with deficient precipitation during most of the year.

C. **Moist Mid-Latitude Climates with Mild Winters**

D. **Moist Mid-Latitude Climates with Cold Winters**

E. **Polar Climates:** with extremely cold winters and summers.

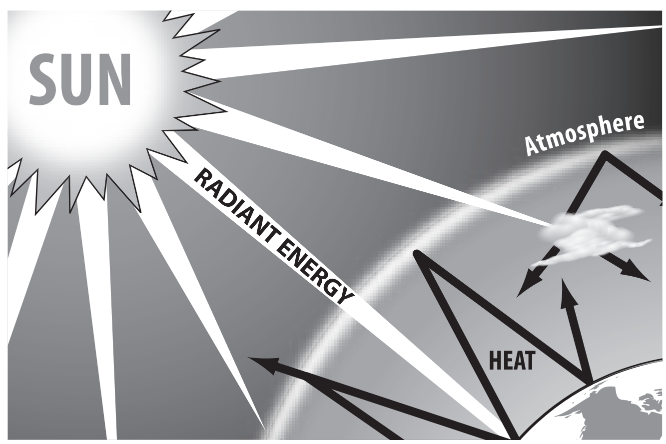
Climatologists have analyzed multiple sources to put together a history of Earth's climate. By looking at **ice cores**, boreholes, tree rings, glacier lengths, pollen remains, ocean sediments, and by studying Earth's orbit, they have determined that the climate naturally changes over time. There are multiple variables that affect Earth's natural climate patterns.

▪ Earth's Reflectivity

The reflectivity of the Earth's surface plays an important role in climate patterns. If you want to stay cooler on a hot, sunny day, you should wear light colors—especially white. We are kept cooler because more of the radiant energy from the sun that strikes us reflects off of lighter clothing. In darker clothing, more energy is transformed to thermal energy. Earth works the same way. Four percent of the sun's radiant energy that strikes Earth is reflected back into space. The amount of reflection that takes place at any given point of the Earth's surface varies widely. A dark surface like a parking lot or a body of water will reflect less than 10 percent of the light, while snow and ice can reflect 90 percent. Earth's atmosphere reflects 26 percent of the incoming radiation. The ability of a surface to reflect light is called its **albedo**.

During the ice ages, there were decreases in solar **radiation,** This allowed more snow to accumulate, and this high albedo surface reflected more solar radiation, keeping the ground and the air cooler. Scientists call this a 'positive feedback loop'. As this loop continued, it allowed snow and ice to accumulate for thousands of years until the **Milankovitch Cycles** increased solar radiation enough to promote warming of the climate.

The Greenhouse Effect



Radiant energy (light rays and arrows) shines on the Earth. Some radiant energy reaches the atmosphere and is reflected back into space. Some radiant energy is absorbed by the atmosphere and is transformed into heat (dark arrows).

Half of the radiant energy that is directed at Earth passes through the atmosphere and reaches the Earth, where it is transformed into heat.

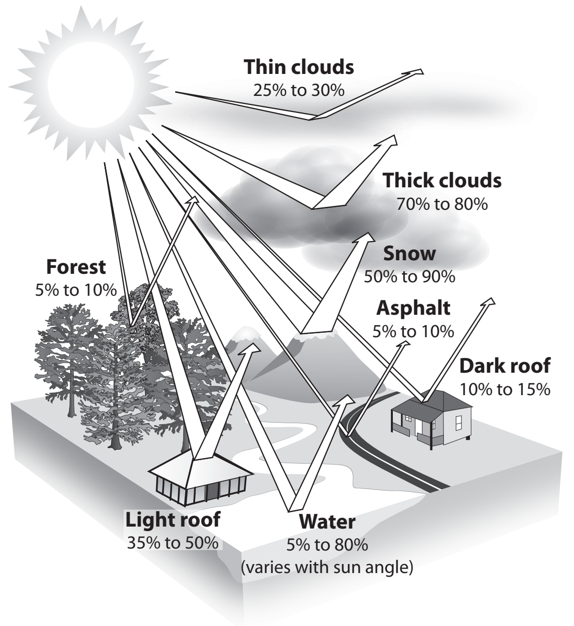
The Earth absorbs some of this heat.

Most of the heat flows back into the air. The atmosphere traps the heat.

Very little of the heat escapes back into space.

The trapped heat flows back to the Earth.

Albedo



Today, the opposite is occurring. As the climate has warmed, there has been a decrease in snow and ice coverage. Those surfaces which previously had a high albedo are revealing lower albedo surfaces, such as soil and water, as they melt. This feedback loop is predicted to increase the rate at which the Earth warms, as it will be able to absorb more heat.

Earth's Orbit

Serbian mathematician Mulitin Milanković (1879-1958) was the first to mathematically explain how the Earth's orientation to the sun and its orbital path changes over time.

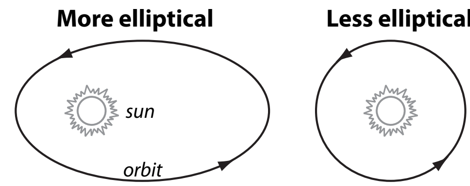
Milanković's calculations explained three Earth movements—Earth's orbit (**eccentricity**), angle of tilt (**obliquity**), and wobble on its axis (**precession**). These changes occur in cycles, called Milankovitch Cycles, which last thousands of years. These cycles affect the distribution of sunlight over the Earth's surface and the intensity of the seasons, and can slightly affect the total amount of radiation received. Milanković theorized that it is these cycles that are the driving force of ice ages.

The Earth is currently between ice ages, a time of warmer global average temperatures. According to Milanković's theory, and if human factors are not taken into account, this period of relative warmth is predicted to last at least another 50,000 years. Then, as the Milankovitch Cycles change, conditions favorable for another ice age would be created.

Sun's Intensity

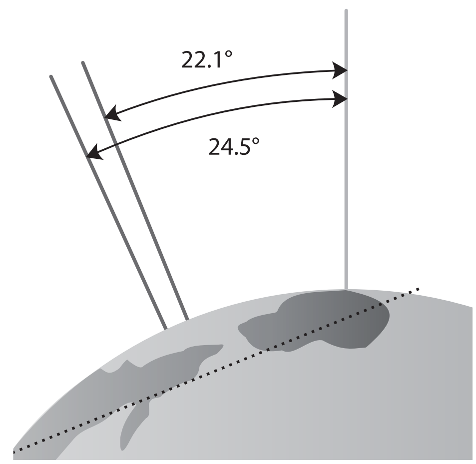
It is also believed that changes within the sun can affect the strength of the sunlight reaching Earth's surface. Low solar activity will cause cooling, while stronger solar activity can cause warming. Between the years 1350 and 1900, the Northern Hemisphere experienced cooler temperatures, approximately 1-2°C lower than present temperatures, which caused a time known as "The Little Ice Age." NASA research links the cooler temperatures in part to reduced solar intensity.

Eccentricity



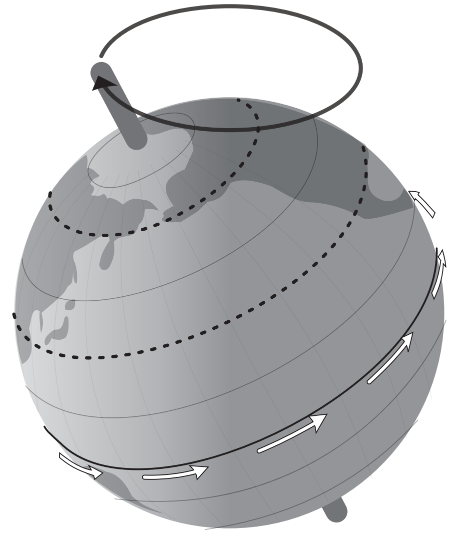
Eccentricity is the shape of the Earth's orbit around the sun. This constantly fluctuating, orbital shape ranges between more and less elliptical on a cycle of about 100,000 years.

Obliquity



Range of the tilt of Earth's axis of rotation (obliquity). Present tilt is 23.5º.

Precession



Precession is the change in direction of the Earth's axis of rotation caused primarily by the gravitational pull of the sun and moon.

- **Volcanic Eruptions**

Short term climate changes can occur with large, or multiple, volcanic eruptions. When a volcano erupts, **aerosols** and carbon dioxide are added to the air. Aerosols contribute to short term cooling because they block the sun's radiant energy. Aerosols do not stay in the atmosphere long, which is why their impact is only short term. Indonesia is a volcanic island nation. It is believed that some of its larger eruptions, Mount Toba 71,000 years ago, Tambora in 1815, and Krakatau in 1883, all contributed to world-wide cooling in the years immediately following the eruptions. Other **volcanism** along the Pacific Ring of Fire and Greenland may have also led to temporary cooler temperatures within longer climate cycles.

When volcanoes erupt, additional CO_2 is sent into the atmosphere. One theory is that numerous volcanic eruptions raised CO_2 levels enough to raise temperatures periodically over the last 400 million years. However, research into the relationship of volcanic CO_2 to climate change has not shown a strong connection between the two.

Natural Climate Change and Climate Change From Human Activity

It is estimated that ten thousand years ago there were five million humans on Earth. One thousand years ago the population had reached 254-245 million, and by 1900 the world's population had reached 1.6 billion. Today, there are more than seven billion people on Earth. Natural climate cycles provided warmer climates and allowed the human population to grow rapidly.

As some climatologists continued to analyze and record temperatures, they found a rising temperature trend—one that was moving faster than they would have expected based on normal Earth cycles. Climate scientists believe that the way humans are interacting with the Earth in their everyday lives is causing a faster than natural climate change.

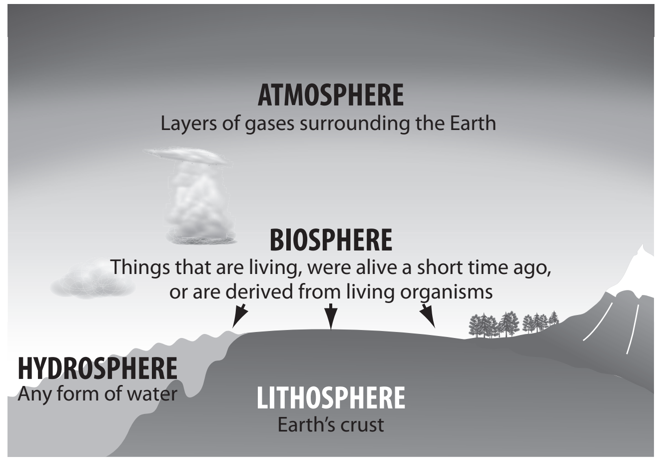
Earth's Systems

The Earth can be divided into four systems—the **lithosphere**, the **hydrosphere**, the **biosphere**, and the **atmosphere**. Each of these systems has a specific role in keeping the Earth going and in the storage of carbon. They each play a part in affecting the weather, which then affects the climate. These systems, and their **cycles**, replenish the Earth with water, supply energy, and create a climate that is able to sustain life. Each system has many inputs and outputs, which can affect the overall Earth system. Some of these systems are affected by natural inputs and outputs. Some of these systems are affected by inputs specifically from human activity.

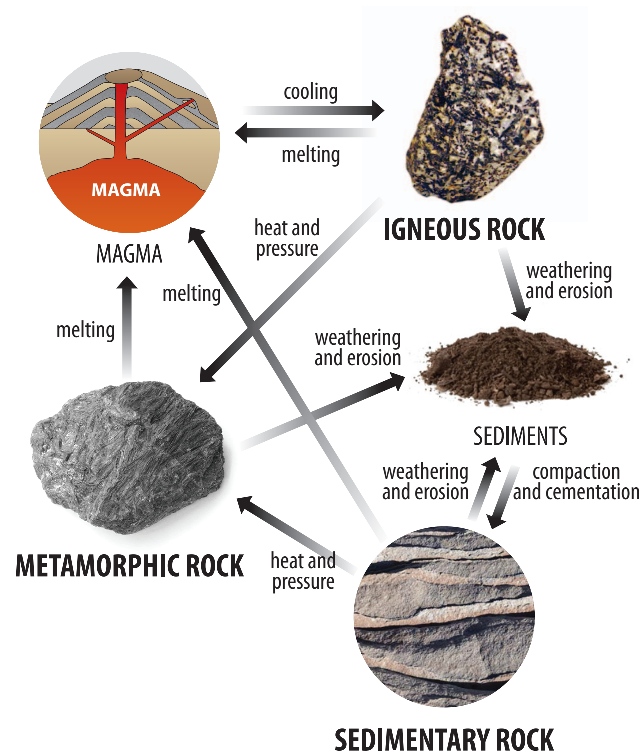
- **The Lithosphere**

Rocks, minerals, volcanoes, and **fossil fuels** make up the lithosphere. The major cycle within the lithosphere is the rock cycle. Slowly, over long periods of time, rocks can be changed from sedimentary rocks, to metamorphic rocks, to igneous rocks. By far, most of the carbon on Earth is found in the lithosphere—over 50,000 times as much as that found in the atmosphere. Carbon mainly takes the form of carbonates (combinations of **carbon**, calcium, and oxygen) and is found in rocks such as limestone and shale. Sedimentary rocks contain fossils of plants and animals. As the sedimentary rocks go through the rock cycle, these fossils are subjected to pressure and heat. Under these conditions some of the fossils transform into fossil fuels—petroleum, coal, and natural gas, which are all combinations of hydrogen and carbon called **hydrocarbons**.

Systems of the Earth



Lithosphere: The Rock Cycle



- **The Hydrosphere**

Over seventy percent of the Earth is covered by bodies of water—oceans, lakes, rivers, etc. Any form of water is included in the hydrosphere. Water is constantly on the move, flowing in a river, in the changing tides and currents of an ocean, and through the water cycle.

Water vapor is released to the atmosphere from all surface water sources, like oceans, lakes, and other fresh and salt water bodies. When water vapor in the atmosphere is cooled and has condensed, it falls back to the Earth as **precipitation** in the form of rain, snow, sleet, or hail. When water vapor condenses closer to the surface, precipitation is found in the form of dew or fog. Precipitation can fall onto land (the lithosphere) or back into a body of water, staying in the hydrosphere.

A very small percentage of the carbon in the hydrosphere is found in the fresh water sources (mostly in groundwater). Most of the carbon in the hydrosphere is found in the world's oceans. This carbon is found mainly in the form of carbonates. It is also found in the upper levels of the ocean where dissolved carbon dioxide is utilized by plants for photosynthesis. The carbon contained in marine and plant animals is also part of the carbon content of the hydrosphere.

The Biosphere

Plants, animals, fungi, and microorganisms are examples of parts of the biosphere. Included in this system are things that are living, were alive a short time ago, or are derived from living organisms. Cycles within the biosphere include the life cycle for both plants and animals. The food chain is also an important event taking place within the biosphere. Cycles from outside the biosphere are crucial to the continuation of the biosphere cycles. These cycles include the water cycle, nitrogen cycle, **carbon cycle**, and the flow of energy throughout them. The biosphere contains vast amounts of carbon. It is found in the form of **carbohydrates** and proteins primarily in both living and decaying organisms.

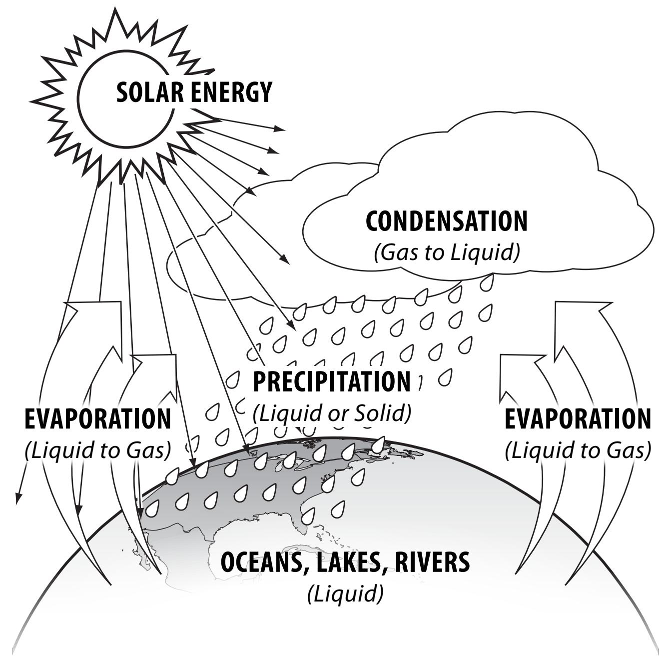
The Atmosphere

The atmosphere interacts with all of the other systems. The atmosphere acts like the glass of a greenhouse; it surrounds the Earth and keeps it warm, allowing an environment that promotes life. This is called the **Greenhouse Effect**. Composed of layers of gases surrounding the Earth, the atmosphere is made of roughly 78 percent nitrogen, 20 percent oxygen, and one percent argon. The remaining one percent is made of a mixture of carbon dioxide (CO_2), **methane** (CH_4), **nitrous oxide** (N_20), water vapor, and trace amounts of other gases. CO_2, CH_4, and water vapor have proven to be very efficient at trapping heat. These and several other gases are known as the **greenhouse gases** (GHGs). The atmosphere contains the smallest amount of carbon compared to the other Earth systems. Here, carbon primarily takes the form of CO_2, but also as CH_4. The atmosphere is the only Earth system that exchanges large amounts of carbon directly with all of the others.

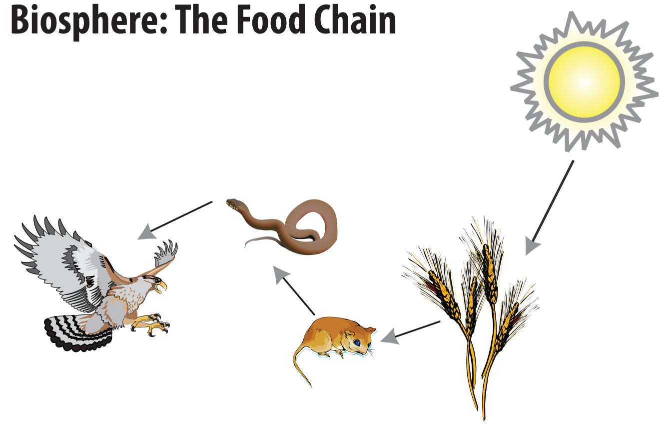
Greenhouse gases are molecules that are good at trapping thermal energy. They are able to absorb **infrared radiation** and then re-radiate it, most often to another greenhouse gas molecule. Eventually, the heat flows to the upper atmosphere and outer space, but the gases slow down this heat transfer, acting like a layer of insulation acting almost like plastic wrap on a plate of warm food. While oxygen and nitrogen make up 98 percent of the atmosphere, they are not affected by thermal energy in the same way that greenhouse gases are.

Even though GHGs make up less than one percent of the atmosphere, their heat trapping abilities are powerful, and small changes in their concentration appear to be making a significant difference to Earth's climate.

Hydrosphere: The Water Cycle



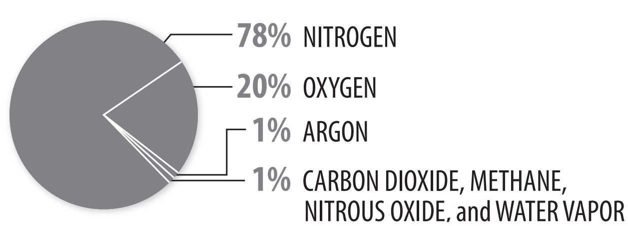
Biosphere: The Food Chain



The sun is part of the food chain. Plants turn sunlight directly into food, but animals cannot.

A mouse gets its energy from the plant, which got its energy from the sun. A snake gets its energy by eating the mouse. A hawk gets its energy by eating the snake.

Atmosphere Composition



A Closer Look at Greenhouse Gases

▪ Carbon Dioxide

Eighty-four percent of U.S. greenhouse gas emissions come in the form of carbon dioxide. Historically, natural levels of CO_2 in the atmosphere have been controlled by the carbon cycle that occurs between Earth's four systems. Today only five percent of atmospheric CO_2 levels are attributed to natural processes. Ninety-five percent of CO_2 emissions come from human activity—the **combustion** of fossil fuels in electricity generation, transportation, industrial, commercial, and residential uses.

▪ Methane

Methane is not as abundant in the atmosphere as CO_2; it only makes up ten percent of U.S. greenhouse gas emissions, but it is 20 times more effective at trapping heat than CO_2. However, methane has a short lifespan. It breaks down in the atmosphere after approximately 12 years. In the last 250 years, CH_4 concentrations have risen 148 percent. Methane emissions come from the digestive process of livestock, decomposition of waste in landfills, solid waste, producing and burning fossil fuels, biomass burning, and rice cultivation.

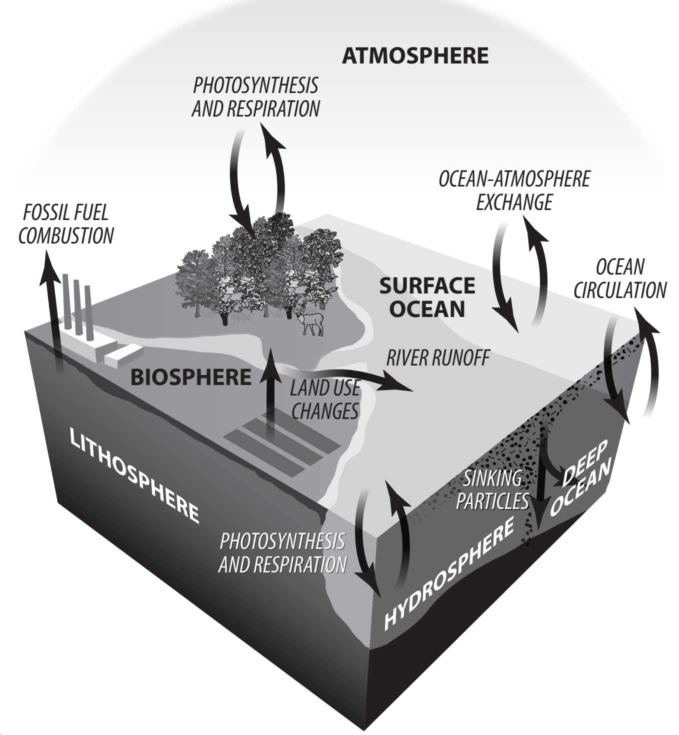
▪ Nitrous Oxide

Nitrous oxide makes up four percent of the U.S. greenhouse as emissions, yet N_2O is over 300 times more powerful than carbon dioxide at trapping heat. N_2O is naturally released into the atmosphere from natural processes in the soil and ocean. However, current agricultural practices release high levels of N_2O from the soil, as does fuel combustion in motor vehicles.

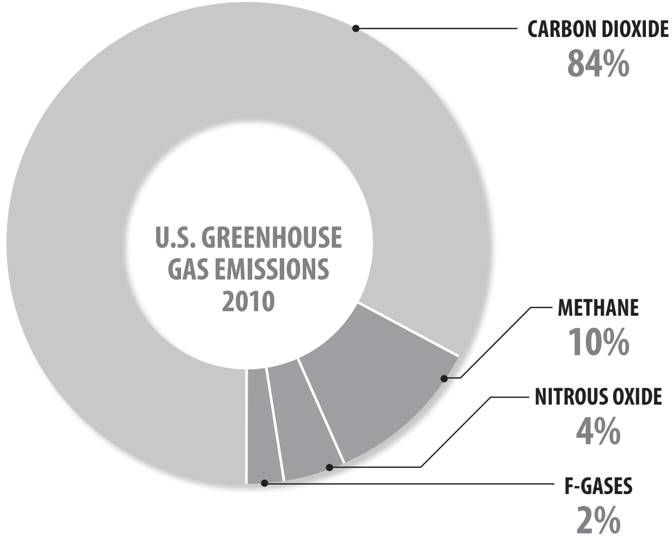
▪ Water Vapor

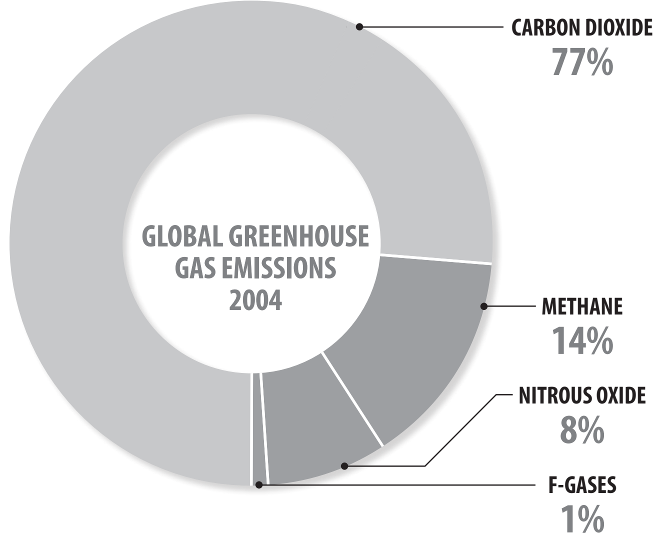
Climatologists who have been analyzing greenhouse gases have found that water vapor is the most abundant GHG. It accounts for two-thirds of all heat trapped in the atmosphere. Constantly moving between the hydrosphere, atmosphere, and biosphere in the water cycle, water vapor is a key player in the climate picture. Some climate scientists believe that rising atmospheric temperatures around the world may allow the atmosphere to hold more water vapor, which might, in turn, lead to more warming. However, water vapor levels have remained relatively constant through history, so it does not appear that increased water vapor is responsible for the changing climate.

The Carbon Cycle



Manmade Greenhouse Gas Emissions





Note: F-gases include HFCs, PFCs, and SF_6 which are used in many different industrial applications including as refrigerants, propellants, and tracer chemicals.
Data: U.S. Environmental Protection Agency, Intergovernmental Panel on Climate Change, Oak Ridge National Laboratory

Fossil Fuels Past and Present

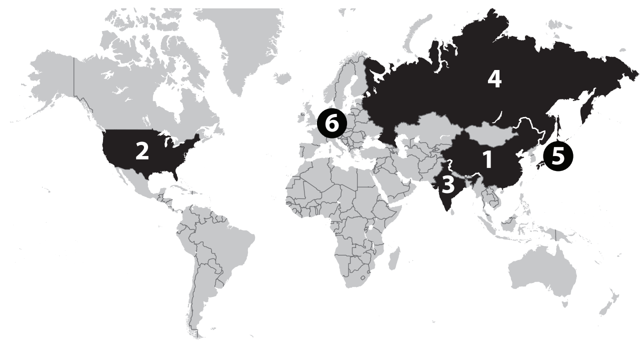
359 million to 299 million years ago the world had a more tropical and mild year-round climate than it does today. Called the Carboniferous Period, the climate during this time allowed the growth of large swamps and tropical forests filled with towering trees, massive ferns, large horsetails, and other leafy vegetation.

These plants all relied on the sun's radiant energy and the process of **photosynthesis** to grow and flourish. During photosynthesis, the plants use radiant energy from the sun to turn water and the carbon dioxide in the air into chemical energy. They store the energy in their leaves, fruits, stalks, and roots in the form of carbohydrates. Plants release oxygen back into the air. There were so many plants during this period that large amounts of carbon dioxide were removed from the atmosphere and large amounts of oxygen were released back into the atmosphere. During the Carboniferous Period, oxygen made up about 35 percent of the atmosphere.

Plants that grew in the swamps also died in the swamps. When the plants died the unused carbohydrates remained in the plant. Plant remains were covered by sand and clay and formed a layer of peat, which kept getting pushed farther and farther down as the land above shifted. Over millions of years the pressure and heat from the Earth squeezed out all of the water from the peat and it turned into coal.

Global Greenhouse Gas Emissions

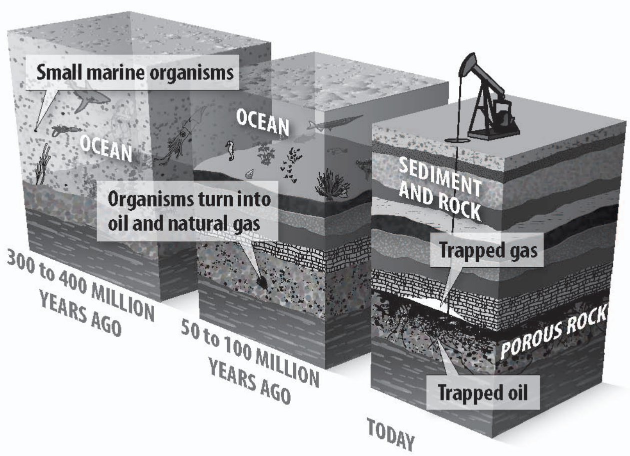
Only a few countries produce most of the global carbon dioxide emissions each year. A look at the top six:



RANK/COUNTRY	CO_2 EMISSIONS MILLION METRIC TONS	SHARE OF GLOBAL EMISSIONS
1. China	8320.9	**26.2%**
2. United States	5610.1	**17.7%**
3. India	1695.6	**5.3%**
4. Russia	1633.8	**5.1%**
5. Japan	1164.5	**3.7%**
6. Germany	793.7	**2.5%**
The Rest of the World		***39.5%***

Data: Energy Information Administration

How Petroleum and Natural Gas Were Formed

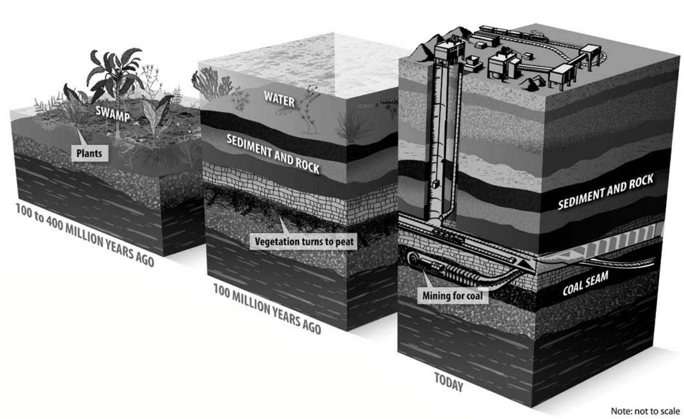


Tiny sea plants and animals died and were buried on the ocean floor. Over time, they were covered by layers of sediment and rock.

Over hundreds of millions of years, the remains were burried deeper and deeper. The enormous heat and pressure turned them into oil and gas.

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

How Coal Was Formed



Millions of years ago, dead plant matter fell into swampy water and overtime, a thick layer of dead plants lay decaying at the bottom of the swamps. Over time, the surface and climate of the Earth changed, and more water and dirt washed in, halting the decay process, forming peat.

The weight of the top layers of water and dirt packed down the lower layers of plant matter. Under heat and pressure, this plant matter underwent chemical and physical changes pushing out oxygen and leaving rich hydrocarbon deposits. What once had been plants gradually turned into coal.

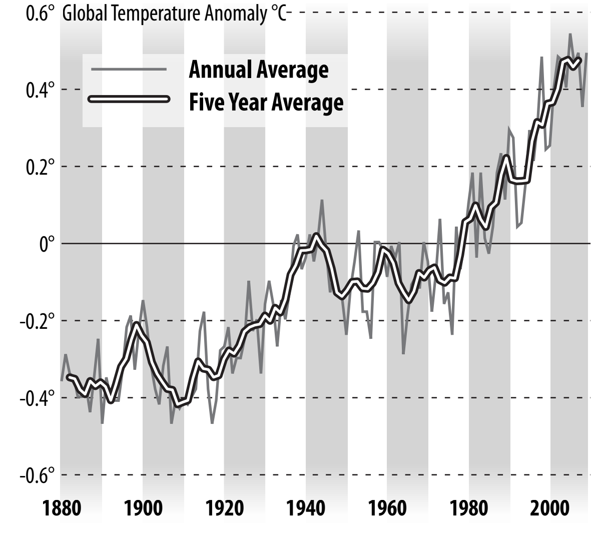
Coal can be found deep underground (as shown in this graphic), or it can be found near the surface.

Similarly, oil and natural gas are the result of small plants and animals that lived in the sea and died hundreds of millions of years ago before dinosaurs lived. Remains of the plants and animals fell to the sea floor, and over time were buried under sediment and other rock. The heat and pressure turned the carbon into oil and natural gas.

For millions of years the carbon dioxide found in fossil fuels was trapped deep below the ground. Levels of carbon dioxide in the atmosphere changed with Earth's natural processes of carbon cycling. Humans relied on solar energy or burning biomass, usually wood, for cooking, heating, and lighting. The relatively small addition of carbon dioxide into the atmosphere from the burning of wood does not seem to have had a significant impact on Earth's overall climate.

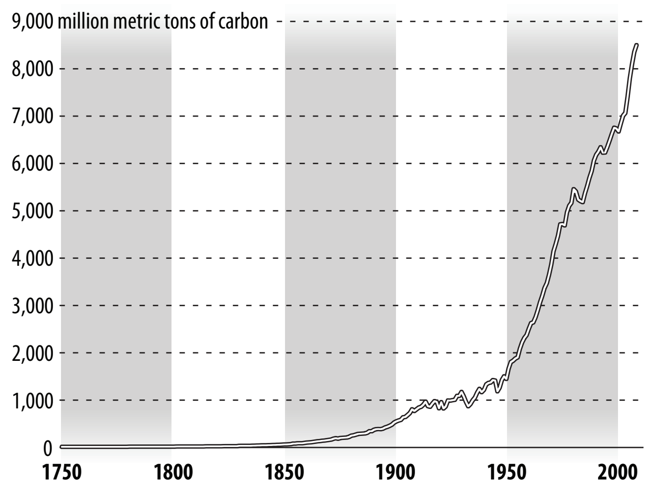
When the Industrial Revolution began in the mid 1700s, energy use began to change dramatically. In less than 200 years, coal, petroleum, and natural gas became the primary sources for industry, electricity, and transportation.

Global Temperature Change from Average, Since 1880



Data: NASA

Global Carbon Dioxide Emissions Since, 1750



Data: Oak Ridge National Laboratory

Effects of Climate Change

The use of fossil fuels allows humans to see at night, to stay comfortable in hot and cold weather, to cook food efficiently, to keep food for longer periods of time, and to travel quickly from place to place. Fossil fuels allow us to work, move goods and products to market, and to make technology work. The CO_2 concentration in the atmosphere before to the Industrial Revolution was about 280 ppm (parts per million). Currently, CO_2 concentration is about 390 ppm, a 39 percent increase. Levels of methane, nitrous oxide, and other greenhouse gases have also increased. Scientists are studying what effects these higher levels of gases are currently having on our climate and what the future effects may be.

▪ Temperature

Temperature varies in different regions. Some locations have seen a decrease in temperature rather than an increase; however, the global mean surface temperature has warmed by about 0.8°C since 1880. The **Intergovernmental** Panel on Climate Change (IPCC) concluded in 2007, "warming of the climate system is now unequivocal (clear), based on observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level." This rise in temperature is often called **global warming**.

In the United States, the National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center statistics show that temperatures in eight of the eleven climate regions have shown temperature increases of more than 0.74°C since 1901. The greatest increase is in Alaska, where temperatures have climbed up to 4°C. The Southeast has a slight cooling trend overall, but since 1979 has shown a warming trend.

Around the world scientists have recorded data that indicates land areas are warming faster than ocean areas, and winter months have warmed faster than summer months. Temperatures recorded in the arctic have increased at almost twice the rate as average global temperatures between 1965 to 2005.

Rising temperatures are believed to be having some very noticeable effects on the world. One of the most visible signs is the impact rising temperatures are having on snowfall, glaciers, ice thickness, and permafrost. In the Northern Hemisphere there has been a lessening of snow cover in most regions. Rivers and lakes are freezing later in the year and breaking-up earlier. Arctic Sea ice has been decreasing since the 1970s, while sea ice thickness has decreased since 1987. The IPCC believes that "late 20th-century glacier wastage [when glaciers melt and shrink] has most likely been a response to post-1970 warming." The largest losses of glaciers and ice caps have occurred in Patagonia (Southern Chile and Argentina), Alaska, Northwestern United States, and Southwest Canada. From 1993 to 2003, melting glaciers and ice caps are believed to have contributed approximately 2.8 mm each year to rising sea levels.

Permafrost is frozen ground that remains at or below 0°C for at least two consecutive years. Permafrost thickness ranges from less than one meter to more than 1500 meters. Nearly 25 percent of the Northern Hemisphere's land area is classified as permafrost.

Roads, railways, pipelines, houses, schools, and offices have all been built on permafrost in Alaska, Russia, and China. Since the 1980s temperatures at the surface of the permafrost have risen by 3°C. This has led to some thawing of the permafrost in the summer, changing the strength of the ground and putting man-made objects at risk.

▪ Sea Level Changes

In the last century, data shows that the sea level has risen worldwide approximately 12-22 centimeters. The rate and amount the sea level has changed varies greatly depending on the region. In some regions levels are quickly rising, while in others sea levels are actually falling. Monitoring devices are not as available outside of the U.S., Europe, and Japan, making it difficult to gather data about long-term trends in regional sea level rise. While scientists do not know all of the reasons behind the increased levels, they have a high confidence that they are indeed rising, and are confident in some of the primary factors.

First, the oceans are warming. From the surface to a depth of 700m, global ocean temperature has risen by 0.10°C between 1961 and 2010. When matter undergoes a temperature change its volume changes. In this case, when water is heated, the particles are more active and maintain a greater average separation, causing the sea level to rise due to expansion. The IPCC believes that **thermal expansion** accounts for about 57 percent of sea level rise each year.

The other factor the IPCC has confidence in is the loss of mass from glaciers and ice caps, and possibly the melting of the Greenland Ice Sheet and Antarctic Ice Sheet. Other factors that may be contributing to sea level changes include pumping of ground water for human use, reservoirs, wetland drainage, deforestation, and melting of polar ice sheets. Further research into these actions are needed to determine their relationship to sea levels.

▪ Weather Events

Climatologists hypothesize that an increase in greenhouse gases leads to an increase in temperatures, leading to an increase in evaporation, causing more precipitation. Globally there is no significant overall trend in increased precipitation; the data varies greatly from region to region. There is data that shows areas in eastern parts of North and South America, northern Europe, and northern and central Asia are considerably wetter than in the past.

Precipitation has declined in the African Sahel, the Mediterranean, southern Africa, and parts of southern Asia. Globally, research suggests that the total area affected by **drought** has likely increased since the 1970s.

Extreme weather events have been increasing. The number of heat waves per year has increased since 1950, and while the frequency of tropical storms and hurricanes has not noticeably increased, there is a trend towards increased storm intensity and duration. The number of Category 4 and 5 storms has increased by about 75 percent since 1970, driven by a rise in water temperature at the surface of the ocean. Worldwide there is a general increase in precipitation intensity. In North America, heavy downpours have become more frequent and more intense, while droughts in some regions are becoming more frequent and intense.

NASA's Theoretical Sea Level Change

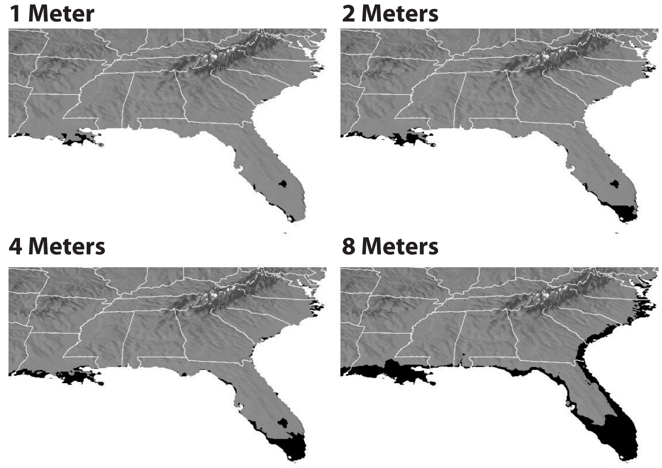


Image courtesy of NASA

Scientists are unsure about how much sea levels may rise due to global climate change. This map shows one model of areas in the southeastern United States that could be affected by a rise in sea level (black).

HURRICANE ISABEL

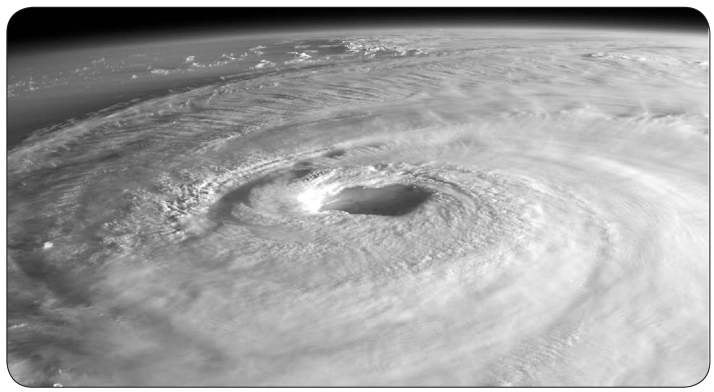


Image courtesy of NASA

This photo from the International Space Station shows Hurricane Isabel, a 2003 Category 5 storm. Climatologists believe climate change may generate more intense storms.

▪ Ocean Acidification

The oceans are a natural **carbon reservoir** and they have been able to absorb extra amounts of CO_2 being emitted. Between 1750 and 1994, the **inorganic** carbon content of the ocean has increased by about 118 **gigatons** of carbon (one gigaton is equal to one billion tons). The oceans are holding extra carbon dioxide that would likely be in the atmosphere if not in the oceans. This has made the oceans more acidic because carbon dioxide, when dissolved in water, creates an acid. Scientists predict that this higher acidity will make calcification more difficult, and affect the formation of corals and marine calcifiers including shells and skeletons by corals, crabs, marine snails, and clams. This could affect the entire reef ecosystem.

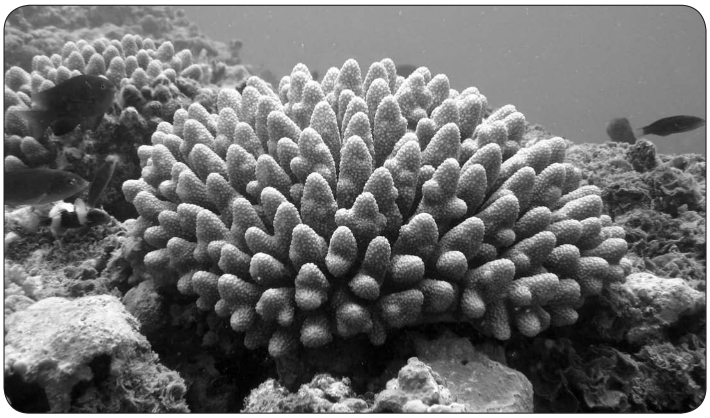


Image courtesy of National Oceanographic and Atmospheric Administration

Ocean acidification may affect the formation of coral and other marine calcifiers.

▪ Worldwide Impacts

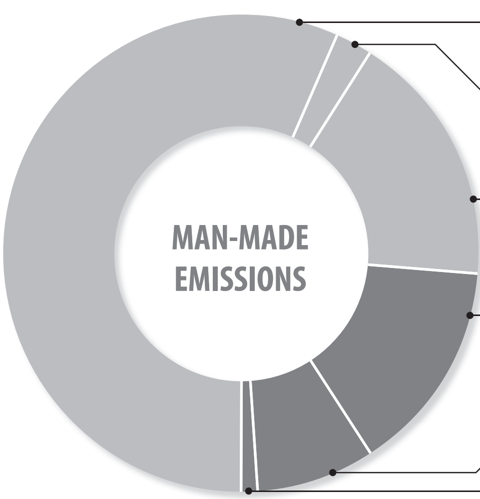
Scientists have data showing that GHGs, particularly CO_2, are more concentrated than ever before recorded in historical data. They have been observing different clues, including temperatures, weather events, sea levels, and ocean acidification to determine what affect greenhouse gases are having on Earth and its inhabitants; yet much is still unknown. When it comes to predicting the impact of this concentration of carbon dioxide, scientists are unsure of exactly what may happen, but by looking back through history and at current patterns, climatologists, biologists, **geologists**, **meteorologists**, and sociologists are making predictions. There is concern that the indicators mentioned above (as well as other impacts) could become more pronounced in the future. Because of these predictions, policy-makers worldwide have increased discussions on how to monitor, manage, and **mitigate** carbon dioxide **emissions** while maintaining quality of life and economic stability.

Mitgating Climate Change

Carbon dioxide stays in the atmosphere for a long time. The carbon dioxide we emit and continue to emit will be present in Earth's systems for some time to come. While emissions can be slowed, it will take time before actions that reduce emissions turn into a reduction of carbon dioxide in the system. With this knowledge, policy-makers must consider ways to **adapt** to any future impacts of climate change while planning ways to reduce emissions today. Throughout history, societies around the world have adapted to changes in their environment, and have taken steps to reduce the impact of those changes on their communities.

Global Greenhouse Gas Emissions

Carbon dioxide accounts for more than 75 percent of all global greenhouse gas emissions, mainly due to the increased use of fossil fuels. Since the industrial Revolution, the concentration of all greenhouse gasses has increased.



		ATMOSPHERIC CONCENTRATIONS	
	2007	PRE-INDUSTRIAL (1750)	2011
CARBON DIOXIDE FROM FOSSIL FUELS	56.6%	278 parts per million (ALL CARBON DIOXIDE)	388.5 parts per million (ALL CARBON DIOXIDE)
OTHER CARBON DIOXIDE	2.8%		
CARBON DIOXIDE FROM DEFORESTATION AND BIOMASS DECAY	17.3%		
METHANE	14.3%	0.72 parts per million	1.7 parts per million
NITROUS OXIDE	7.9%	0.27 parts per million	0.32 parts per million
F-GASES*	1.1%	0 parts per trillion	84.5 parts per trillion

* F-gases include HFCs, PFCs, and SF_6, which are used in many different industrial applications including as refrigerants, propellants, and tracer chemicals.

Data: U.S. Environmental Protection Agency, Intergovernmental Panel on Climate Change, Oak Ridge National Laboratory

▪ Mitigation

To mitigate climate change means to make its impact less severe. Many scientists believe that climate change can be mitigated through advances in technology and individual lifestyle modifications. To reduce carbon emissions to sustainable levels, we will need to turn to more energy sources that do not emit carbon dioxide such as uranium, solar, hydropower, and wind.

A combination of these types of actions will need to be taken on the international and governmental level, and at the individual level as well.

International Awareness

Climate change impacts every person around the globe, so climate change is an international issue. There has been a history of the international community coming together to try and make plans to combat rising greenhouse gases. In 1997, the Kyoto Protocol was a first step in coming to an international agreement on greenhouse gas levels. The United States has not ratified the Kyoto Protocol because it did not have targets or timetables outlined for developing nations as well as industrialized nations.

This agreement expires in 2012. World leaders continue to meet to discuss the topic of emissions. Some members of the Kyoto Protocol have signed and agreed to an extension through 2020. Debate continues about an international system for monitoring and lowering emissions.

Personal Awareness

Part of battling climate change means having a better awareness and understanding of how individual actions affect climate change. People often talk about having a "carbon footprint." A carbon footprint refers to the greenhouse gas emissions caused directly and indirectly by an individual, a product, an organization, or an event. Each person has an individual carbon footprint. Each classroom, school, family, and home have specific carbon footprints. A total carbon footprint is based on several factors—how much energy is used, the way electricity is generated, water use, the types of transportation used, foods that are eaten, and products and services used. By decreasing your carbon footprint you can help decrease the production of carbon dioxide.

GHG emissions from electricity production vary depending upon the sources of energy your utility provider uses for generation. Fossil fuels used to generate electricity produce carbon dioxide; however, hydropower, solar, and nuclear energy are considered **carbon neutral**. Using less energy, more efficient appliances, and using electricity from low or no-carbon sources are among ways to decrease your carbon footprint.

Transportation is a major part of your carbon footprint, because energy is needed for almost every form of transportation. Cars and buses use gasoline or diesel fuel and produce GHGs as they combust. Carpooling and using public transportation are more efficient ways to use energy and thus contribute less GHGs than other transportation options. Walking or using a bicycle has no carbon impact.

Water usage is another area that influences the size of your carbon footprint. The processes of finding, purifying, treating, and transporting water involve energy and procedures that have a carbon footprint. When we are done with water, if it goes to a sewage or water treatment plant, these steps also add to water's carbon footprint.

It is harder for people to think of individual products, like games or pencils, as adding to their carbon footprint, but our product choices impact our carbon footprint as well. Every product has a "life cycle" that includes everything that had to happen to make, deliver, and dispose of the item. Recycling products is an easy way to decrease the size of your footprint. For example, if you recycle your aluminum can you are helping save energy. Using recycled aluminum requires about 95 percent less energy than used in the original process of converting bauxite into metal. The size of your carbon footprint is adjusted based on if you reuse products, recycle them, or throw them away.

Like products, the food you eat plays a role in determining your carbon footprint. When analyzing food's impact you also have to look at the life cycle of the food you consume, the amount of water and type of fertilizer used, and the machinery and vehicles used to pack and transport food from where it is grown to where it is consumed. What happens to that plate of leftovers in the refrigerator? Does it go in the trash, to a compoast pile, or through the garbage disposal?

Energy Sustainability

Efficiency and conservation are key components of energy **sustainability**. Every generation should meet its energy needs without compromising the needs of future generations.

Sustainability focuses on long-term strategies and policies that ensure adequate energy to meet today's needs and the needs of tomorrow. Sustainability also includes investing in research and development of advanced technologies for producing conventional energy sources, promoting the use of renewable energy sources, and encouraging responsible environmental policies and practices.

Looking to the Future

Our environment provides us with all of the essential resources we need. It provides us with sources of food, water, and oxygen, as well as reservoirs that can store and process the waste or byproducts created by our activities. How do we balance our need for energy with the importance of efficiency and conservation? While this issue is very complex, creative solutions by government and industry can lead to a thriving economy and stable climate. It is the choice of individuals that makes the most difference. Using energy wisely and conserving our resources is a good idea.

Climate Change KWL Chart

What I Think I KNOW	What I WANT to Know	What I LEARNED

Properties of CO_2 Gas

What are the properties of CO_2 as a solid and a gas? Record your observations below.

Greenhouse in a Beaker

Question

What affect does adding carbon dioxide to the air have on the air's temperature during the day and during the night?

Hypothesis

In your science notebook, record your hypothesis in an "If....then....because...." format.

Materials

- 2 600 mL Beakers
- 1 250 mL Flask
- 1 Rubber stopper with hole
- 1 Vinyl tubing, 3/16" diameter, 60 cm long
- 1 Clip light
- 1 Ruler
- 2 Probe thermometers
- 1 1,000-1,100 Lumen bulb (equivalent to a 75 watt incandescent)
- Small piece of masking tape
- 4 Alka-Seltzer tablets
- Safety glasses
- 240 mL Water (room temperature)

Procedure

Part 1—Day

1. Set up the light source 15 cm in front of the two beakers. The beakers should be receiving equal light.
2. Insert the tubing through the hole in the 250 mL flask. Place the other end of the hose near the bottom of one of the beakers. Secure the tubing inside the beaker with a small piece of masking tape.
3. Add 120 mL of water to the flask.
4. Turn on the clip light. Wait for the temperature in each beaker to stabilize. The temperatures in the beakers should be similar, but they do not have to be exactly the same.
5. Record the stable temperature of each beaker in the data table.
6. Break two Alka-Seltzer tablets in half and drop the pieces into the flask. Secure the rubber stopper.
7. Record the temperature of each beaker every 30 seconds for three minutes.

Part 2—Night

1. After you have data to model temperatures during the day, empty out your beakers and flask. Refill the flask with 120 mL water. Resecure the tubing inside one of the beakers.
2. Turn on the clip light. Wait for the temperature to stabilize. The temperatures in the beakers should be similar, but they do not have to be exactly the same.
3. Record the stable temperature of each beaker in the data table.
4. Break two more Alka-Seltzer tablets in half and drop the pieces into the flask. Secure the rubber stopper.
5. Turn off the light.
6. Record the temperature of each beaker every 30 seconds for three minutes.

Data

Record your data in these tables or into your science notebook.

Simulated Day Data

	BEAKER 1 (WITHOUT CO_2)	BEAKER 2 (WITH CO_2)
Beginning Temperature		
30 seconds		
1 minute		
1 minute, 30 seconds		
2 minutes		
2 minutes, 30 seconds		
3 minutes		

Simulated Night Data

	BEAKER 1 (WITHOUT CO_2)	BEAKER 2 (WITH CO_2)
Beginning Temperature		
30 seconds		
1 minute		
1 minute, 30 seconds		
2 minutes		
2 minutes, 30 seconds		
3 minutes		

Create a graph displaying both the day and night temperatures for both beakers.

Conclusion

1. Do you accept or reject your hypothesis? What were the results of your investigation? Use data to explain what happened.
2. Why do you think this happened?
3. How does this demonstration relate to climate change?

Carbon Reservoir Comparison

Atmosphere	Biosphere
Hydrosphere	**Lithosphere**

Atmosphere — CO_2 Gas

You are a CO_2 molecule in the atmosphere.

You came from

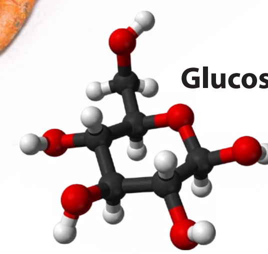
- the hydrosphere by **degassing**, or
- land animals or soil through **respiration**, or
- from the lithosphere through the **combustion** of fossil fuels.

CO_2

Biosphere — Land Plant

You are now part of a glucose molecule in a carrot.

You came as a **carbon dioxide molecule** from the atmosphere by the **photosynthesis** process.



Through photosynthesis, a plant combined carbon, water, and solar energy to create a molecule of glucose.

$$6CO_2 + 6H_2O + \text{Energy} \longrightarrow C_6H_{12}O_6 + 6O_2$$

Biosphere — Soil

You are now part of an organic molecule in the soil.

You came as part of a **protein molecule** in a plant or animal that died and decomposed.

You became part of an organic molecule in the soil through the process of respiration in soil microbes.

Biosphere — Land Animal

You are now part of a protein molecule in a rabbit.

You came as a **glucose molecule** from a carrot in the biosphere through the **consumption** process.

Glucose: $C_6H_{12}O_6$

The rabbit ate a carrot and through digestion and respiration broke down the glucose molecule, which released energy for her to use to hop around. The glucose molecule broke down into molecules of carbon dioxide and water and the carbon eventually became part of a protein molecule.

$$\mathbf{C_6H_{12}O_6 + 60_2 \longrightarrow 6CO_2 + 6\,H_2O + Energy}$$

Hydrosphere — Ocean

You are part of a dissolved CO_2 molecule in the ocean.

You came as part of a **carbon dioxide molecule** from the atmosphere by the **dissolution** process or from a marine animal through **respiration**.

CO_2

Hydrosphere — Marine Plant

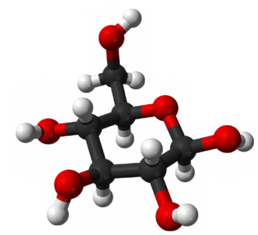
You are now part of a glucose molecule in seaweed.

You came as part of a **carbon dioxide molecule** from the hydrosphere-ocean through the **photosynthesis** process.

Through photosynthesis, a plant used water and energy from the sun to create a molecule of glucose.

$$6CO_2 + 6H_2O + \text{Energy} \longrightarrow C_6H_{12}O_6 + 6O_2$$

Glucose



Hydrosphere — Marine Animal

You are now part of a protein molecule in a sea turtle.

You came as part of a **glucose molecule** from seaweed in the hydrosphere through the **consumption** process.

The turtle ate seaweed and through digestion and respiration, broke down the glucose molecule, which released energy for her to use to swim around. The glucose molecule broke down into molecules of carbon dioxide and water and the carbon eventually became part of a protein molecule.

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{Energy}$$

Lithosphere — Fossil Fuel

You are now part of a hydrocarbon molecule in fossil fuels.

You are part of a **hydrocarbon molecule** in the lithosphere. You are a part of all fossil fuels. Fossil fuels took millions of years to form.

Fossil fuels are made up of hydrocarbon molecules, which are made up of carbon, hydrogen, and oxygen atoms. Fossil fuels include coal, petroleum, and natural gas. Until people discovered how to burn fossil fuels to create energy and for other uses, the hydrocarbons stayed underground for millions of years.

CARBON CYCLE SIMULATION

The Atmosphere: CO_2 Gas Pre-Industrial Round

You are now part of a carbon dioxide molecule in the atmosphere.

1. When you arrive, use the *Carbon Tracking Sheet* and the poster to fill in the “I arrived here by the process of …" and “What I am now” columns of your worksheet.
2. Record the total number of carbons in this reservoir in the space provided below.
3. When directed, each person draws a card. Use the chart below to figure out where each person goes next. Then each person fills in the “Next I am going to the…” column on their worksheet.
4. Return cards to the pile and shuffle.
5. WAIT UNTIL YOU ARE DIRECTED TO MOVE TO YOUR NEW RESERVOIR.

	GO TO THE LAND PLANT RESERVOIR	GO TO THE OCEAN RESERVOIR	STAY IN THE ATMOSPHERE RESERVOIR	NUMBER OF CARBONS IN THIS RESERVOIR
Start				
1	Two Highest Cards	Next Three Highest Cards	All Others	
2	Two Highest Cards	Next Three Highest Cards	All Others	
3	Two Highest Cards	Next Three Highest Cards	All Others	
4	Two Highest Cards	Next Three Highest Cards	All Others	
5	Two Highest Cards	Next Three Highest Cards	All Others	
6	Two Highest Cards	Next Three Highest Cards	All Others	
7	Two Highest Cards	Next Three Highest Cards	All Others	
8	Two Highest Cards	Next Three Highest Cards	All Others	
9	Two Highest Cards	Next Three Highest Cards	All Others	
10	Two Highest Cards	Next Three Highest Cards	All Others	

CARBON CYCLE SIMULATION

The Atmosphere: CO_2 Gas Present-Day Round

You are now part of a carbon dioxide molecule in the atmosphere.

1. When you arrive, use the *Carbon Tracking Sheet* and the poster to fill in the "I arrived here by the process of …" and "What I am now" columns of your worksheet.
2. Record the total number of carbons in this reservoir in the space provided below.
3. When directed, each person draws a card. Use the chart below to figure out where each person goes next. Then each person fills in the "Next I am going to the…" column on their worksheet.
4. Return cards to the pile and shuffle.
5. WAIT UNTIL YOU ARE DIRECTED TO MOVE TO YOUR NEW RESERVOIR.

	GO TO THE LAND PLANT RESERVOIR	GO TO THE OCEAN RESERVOIR	STAY IN THE ATMOSPHERE RESERVOIR	NUMBER OF CARBONS IN THIS RESERVOIR
Start				
1	Two Highest Cards	Next Three Highest Cards	All Others	
2	Two Highest Cards	Next Three Highest Cards	All Others	
3	Two Highest Cards	Next Four Highest Cards	All Others	
4	Two Highest Cards	Next Three Highest Cards	All Others	
5	Two Highest Cards	Next Four Highest Cards	All Others	
6	Two Highest Cards	Next Three Highest Cards	All Others	
7	Two Highest Cards	Next Four Highest Cards	All Others	
8	Two Highest Cards	Next Four Highest Cards	All Others	
9	Two Highest Cards	Next Four Highest Cards	All Others	
10	Two Highest Cards	Next Three Highest Cards	All Others	

The Biosphere: Land Plant All Rounds

You are now part of a glucose molecule in a carrot.

1. When you arrive, use the *Carbon Tracking Sheet* and the poster to fill in the "I arrived here by the process of …" and "What I am now" columns of your worksheet.
2. Record the total number of carbons in this reservoir in the space provided below.
3. When directed, each person draws a card. Use the chart below to figure out where each person goes next. Then each person fills in the "Next I am going to the…" column on their worksheet.
4. Return cards to the pile and shuffle.
5. WAIT UNTIL YOU ARE DIRECTED TO MOVE TO YOUR NEW RESERVOIR.

	GO TO THE LAND ANIMAL RESERVOIR	GO TO THE SOIL RESERVOIR	STAY IN THE LAND PLANT RESERVOIR	NUMBER OF CARBONS IN THIS RESERVOIR
Start				
1	High Card	Low Card	All Others	
2	Two Highest Cards		All Others	
3	High Card	Low Card	All Others	
4	Two Highest Cards		All Others	
5	High Card	Low Card	All Others	
6	Two Highest Cards		All Others	
7	High Card	Low Card	All Others	
8	Two Highest Cards		All Others	
9	High Card	Low Card	All Others	
10	Two Highest Cards		All Others	

CARBON CYCLE SIMULATION

The Biosphere: Land Animal All Rounds

You are now part of a protein molecule in a rabbit.

1. When you arrive, use the *Carbon Tracking Sheet* and the poster to fill in the "I arrived here by the process of …" and "What I am now" columns of your worksheet.
2. Record the total number of carbons in this reservoir in the space provided below.
3. When directed, each person draws a card. Use the chart below to figure out where each person goes next. Then each person fills in the "Next I am going to the…" column on their worksheet.
4. Return cards to the pile and shuffle.
5. WAIT UNTIL YOU ARE DIRECTED TO MOVE TO YOUR NEW RESERVOIR.

	GO TO THE ATMOSPHERE	GO TO THE SOIL RESERVOIR	STAY IN THE LAND ANIMAL RESERVOIR	NUMBER OF CARBONS IN THIS RESERVOIR
Start				
1	High Card		All Others	
2	High Card	Low Card	All Others	
3	High Card		All Others	
4	High Card	Low Card	All Others	
5	High Card		All Others	
6	High Card	Low Card	All Others	
7	High Card		All Others	
8	High Card	Low Card	All Others	
9	High Card		All Others	
10	High Card	Low Card	All Others	

CARBON CYCLE SIMULATION

The Biosphere: Soil All Rounds

You are now part of an organic molecule in the soil.

1. When you arrive, use the *Carbon Tracking Sheet* and the poster to fill in the "I arrived here by the process of …" and "What I am now" columns of your worksheet.
2. Record the total number of carbons in this reservoir in the space provided below.
3. When directed, each person draws a card. Use the chart below to figure out where each person goes next. Then each person fills in the "Next I am going to the…" column on their worksheet.
4. Return cards to the pile and shuffle.
5. WAIT UNTIL YOU ARE DIRECTED TO MOVE TO YOUR NEW RESERVOIR.

	GO TO THE ATMOSPHERE RESERVOIR	STAY IN THE SOIL RESERVOIR	NUMBER OF CARBONS IN THIS RESERVOIR
Start			
1	High Card	All Others	
2	High Card	All Others	
3	High Card	All Others	
4	High Card	All Others	
5	High Card	All Others	
6	High Card	All Others	
7	High Card	All Others	
8	High Card	All Others	
9	High Card	All Others	
10	High Card	All Others	

CARBON CYCLE SIMULATION

The Hydrosphere: Ocean All Rounds

You are now part of a carbon dioxide molecule dissolved in the ocean.

1. When you arrive, use the *Carbon Tracking Sheet* and the poster to fill in the "I arrived here by the process of …" and "What I am now" columns of your worksheet.
2. Record the total number of carbons in this reservoir in the space provided below.
3. When directed, each person draws a card. Use the chart below to figure out where each person goes next. Then each person fills in the "Next I am going to the…" column on their worksheet.
4. Return cards to the pile and shuffle.
5. WAIT UNTIL YOU ARE DIRECTED TO MOVE TO YOUR NEW RESERVOIR.

	GO TO THE ATMOSPHERE RESERVOIR	GO TO THE MARINE PLANT RESERVOIR	STAY IN THE OCEAN RESERVOIR	NUMBER OF CARBONS IN THIS RESERVOIR
Start				
1	Three Highest Cards	Low Card	All Others	
2	Three Highest Cards	Low Card	All Others	
3	Three Highest Cards	Low Card	All Others	
4	Three Highest Cards	Low Card	All Others	
5	Three Highest Cards	Low Card	All Others	
6	Three Highest Cards	Low Card	All Others	
7	Three Highest Cards	Low Card	All Others	
8	Three Highest Cards	Low Card	All Others	
9	Three Highest Cards	Low Card	All Others	
10	Three Highest Cards	Low Card	All Others	

The Hydrosphere: Marine Plant All Rounds

You are now part of a glucose molecule in seaweed.

1. When you arrive, use the *Carbon Tracking Sheet* and the poster to fill in the "I arrived here by the process of …" and "What I am now" columns of your worksheet.
2. Record the total number of carbons in this reservoir in the space provided below.
3. When directed, each person draws a card. Use the chart below to figure out where each person goes next. Then each person fills in the "Next I am going to the…" column on their worksheet.
4. Return cards to the pile and shuffle.
5. WAIT UNTIL YOU ARE DIRECTED TO MOVE TO YOUR NEW RESERVOIR.

	GO TO THE MARINE ANIMAL RESERVOIR	STAY IN THE MARINE PLANT RESERVOIR	NUMBER OF CARBONS IN THIS RESERVOIR
Start			
1	High Card	All Others	
2	High Card	All Others	
3	High Card	All Others	
4	High Card	All Others	
5	High Card	All Others	
6	High Card	All Others	
7	High Card	All Others	
8	High Card	All Others	
9	High Card	All Others	
10	High Card	All Others	

CARBON CYCLE SIMULATION

The Hydrosphere: Marine Animal All Rounds

You are now part of a protein molecule in a sea turtle.

1. When you arrive, use the *Carbon Tracking Sheet* and the poster to fill in the "I arrived here by the process of …" and "What I am now" columns of your worksheet.
2. Record the total number of carbons in this reservoir in the space provided below.
3. When directed, each person draws a card. Use the chart below to figure out where each person goes next. Then each person fills in the "Next I am going to the…" column on their worksheet.
4. Return cards to the pile and shuffle.
5. WAIT UNTIL YOU ARE DIRECTED TO MOVE TO YOUR NEW RESERVOIR.

	GO TO THE OCEAN RESERVOIR	STAY IN THE MARINE ANIMAL RESERVOIR	NUMBER OF CARBONS IN THIS RESERVOIR
Start			
1	High Card	All Others	
2	High Card	All Others	
3	High Card	All Others	
4	High Card	All Others	
5	High Card	All Others	
6	High Card	All Others	
7	High Card	All Others	
8	High Card	All Others	
9	High Card	All Others	
10	High Card	All Others	

CARBON CYCLE SIMULATION

The Lithosphere: Fossil Fuel Present-Day Round

You are now part of a hydrocarbon molecule in a coal deposit.

1. When you arrive, use the *Carbon Tracking Sheet* and the poster to fill in the "I arrived here by the process of …" and "What I am now" columns of your worksheet.
2. Record the total number of carbons in this reservoir in the space provided below.
3. When directed, each person draws a card. Use the chart below to figure out where each person goes next. Then each person fills in the "Next I am going to the…" column on their worksheet.
4. Return cards to the pile and shuffle.
5. WAIT UNTIL YOU ARE DIRECTED TO MOVE TO YOUR NEW RESERVOIR.

	GO TO THE ATMOSPHERE RESERVOIR	STAY IN THE LITHOSPHERE RESERVOIR	NUMBER OF CARBONS IN THIS RESERVOIR
Start			
1	High Card	All Others	
2	High Card	All Others	
3	High Card	All Others	
4	High Card	All Others	
5	High Card	All Others	
6	High Card	All Others	
7	High Card	All Others	
8	High Card	All Others	
9	High Card	All Others	
10	High Card	All Others	

CARBON CYCLE SIMULATION

Carbon Tracking Sheet

Name: ______________________________ Round: ____________________

Use the posters and playing cards to help complete the table.

TURN	I ARRIVED HERE BY THE PROCESS OF…	WHAT I AM NOW	NEXT I AM GOING TO THE…
START		I am part of a(n) ______________molecule in _______________	
1		I am now part of a(n) ______________molecule in _______________	
2		I am now part of a(n) ______________molecule in _______________	
3		I am now part of a(n) ______________molecule in _______________	
4		I am now part of a(n) ______________molecule in _______________	
5		I am now part of a(n) ______________molecule in _______________	
6		I am now part of a(n) ______________molecule in _______________	
7		I am now part of a(n) ______________molecule in _______________	
8		I am now part of a(n) ______________molecule in _______________	
9		I am now part of a(n) ______________molecule in _______________	
10		I am now part of a(n) ______________molecule in _______________	

Land Ice/Sea Ice

Question

How does melting ice affect sea level?

Materials

- Landform materials
- Tubs
- Foil
- Ice cubes
- Water
- Beaker
- Ruler
- Food coloring
- Balance

Part One: Ice Cube Volume

1. Using the ruler, measure the volume of one ice cube in cubic centimeters. Enter the volume in the space provided below.
2. Set the ice cube inside the graduated beaker.
3. When instructed by your teacher, measure the volume of the water in the beaker once the ice cube has melted. Record the volume in cubic centimeters in the space provided below. (Remember, 1 cm^3 = 1 mL)

   Ice cube volume: ____________

   Melted ice cube volume: ____________

   Difference: ____________
4. Write a paragraph describing the results. Describe why you think the experiment turned out the way it did.

Part Two: Land Ice / Sea Ice

1. Read the entire procedure. Develop and write a hypothesis on the outcome of the experiment on the space provided on the data sheet.
2. Put half of your materials in each tub, creating a form for a land mass against one end of each tray.
3. Spread a sheet of aluminum foil (approximately 12" x 12") over each of the land mass forms to create a land mass. Land masses can include hills and valleys.
   - One of the land masses will need to hold five ice cubes. Be sure to design it so that it can do this, and so the water that collects as the ice melts can run into the tub.
4. Place five ice cubes in the bottom of the empty tub.
5. Pour enough water into this tub so that the ice floats. Measure the depth of the water. This is your sea ice tub.
6. Pour water into the other tub to the same depth.
7. Place the other five cubes on the land mass in the other tub. This is your land ice tub.
8. Record the initial water levels on the data sheet.
9. Record additional measurements as instructed by your teacher over time.

Hypothesis

Record your hypothesis in an "If....then....because...." format.

Data

TIME	SEA ICE WATER LEVEL	LAND ICE WATER LEVEL

Conclusion

Write a paragraph explaining the results, using what you know about the properties of water in its different states.

Climate Web

Energy Efficiency and Conservation	In using energy wisely we decrease CO_2 emissions from power plants and vehicles.
Atmosphere	Our atmosphere keeps us alive and warm. Gases in the atmosphere control amounts of ultraviolet radiation reaching the planet and determine the Earth's temperature, keeping us warm. Without gases in the atmosphere, it would be so cold, almost nothing could survive. Increasing CO_2 levels can warm the atmosphere making it less stable.
Transportation	Transportation is very important to us. We use it to travel and ship products. We must have transportation to get people and products to places throughout the world, but different modes of transportation need fuel to work and emit CO_2 and other emissions into our atmosphere.
Trees	Humans could not survive without trees and other plants. Trees take in CO_2 and through the process of photosynthesis produce oxygen for us to breathe, as well as shade, wood products, and beauty. Trees are a renewable resource.

Climate Web

Animals	Animals exhale CO_2 through natural respiration. We must have animals for food and equilibrium in ecosystems. Animals are used extensively for food and other products.
People	We need and use a lot of energy daily. Our homes, communities, and modes of transportation all use energy in various ways. We use more energy today than ever before. Much of our energy use comes from fossil fuels. Energy production from fossil fuels emits CO_2 and other emissions into the atmosphere.
Solar Energy	Solar energy is radiant energy emitted by the sun. Through the use of solar panels, we can harness this energy to power our homes and heat water. Solar energy is a renewable resource that does not produce CO_2 emissions.
Carbon Capture, Utilization and Storage	New technology allows us to store CO_2 emissions from power plants underground to be used later. This may be an effective way to limit the amount of CO_2 we put into the atmosphere. We do not know yet how effective this strategy is at storing CO_2 in the long term.

Climate Web

Nuclear Plant	Uranium ore is mined then processed at nuclear power plants to produce electrical energy we need for homes and industry. Nuclear energy is a nonrenewable resource that produces no CO_2 emissons. Using nuclear power is controversial because of potential risk of radiation, if it is not contained.
Mining	Through mining, we extract ore and minerals from the Earth. We extract coal and uranium in this way to use for electricity production. Machinery used in mining emits CO_2 and other emissions. By removing vegetation, the ability of the land to remove CO_2 from the atmosphere is decreased.
Soil	Soil is the top layer of the Earth's surface, consisting of rock and mineral particles mixed with organic matter. We need healthy soil for growing food. Soil stores carbon, keeping it from the atmosphere. Developing and tilling and other activities that disturb the soil release this stored carbon into the atmosphere.
Crops	The crops we grow are essential to our survival. Growing crops also produces CO_2 emissions through the use of farm equipment, pesticides, fertilizers, and tilling the soil. Crops also remove CO_2 from the atmosphere as they grow.

Climate Web

Petroleum	Petroleum is a nonrenewable fossil fuel formed hundreds of millions of years ago. We use more petroleum than any other energy source. Some product benefits include transportation fuels, fertilizers, plastics, and medicines. Petroleum must be burned to release the energy, which emits CO_2.
Refineries	Refineries are industrial plants that refine petroleum into useable products. We refine crude oil for fuels such as gasoline, jet fuel, and fuel oils needed for transportation. Production, distribution, and consumption release CO_2.
Coal	Coal is a nonrenewable fossil fuel created from the remains of plants that lived and died hundreds of millions of years ago. We extract coal from the Earth to use as fuel for electricity, industry, and heating, as well as in making iron and steel. We burn coal to release energy. Burning coal releases CO_2.
Coal Plants	Coal plants clean, process, and burn coal to generate electricity. Burning coal releases CO_2 into the atmosphere.

Climate Web

Oceans	Oceans are carbon reservoirs, which means they have the ability to absorb CO_2. This process of absorption helps keep our planet cooler. However, adding CO_2 to the ocean makes it more acidic, which impacts ocean ecosystems.
Natural Earth Events	Geological evidence tells us that the Earth's climate has changed a lot over time. Natural Earth events are factors that can contribute to climate change. Earth's position relative to the sun, volcanic eruptions, forest fires, and ocean currents are factors that can affect climate.
Economy	A growing economy demands more energy and electricity, and can increase CO_2 emissions if fossil fuels are used. Energy efficiency and conservation reduces CO_2 emissions and energy bills for families, schools, and companies.

Climate Systems

✪ Concepts

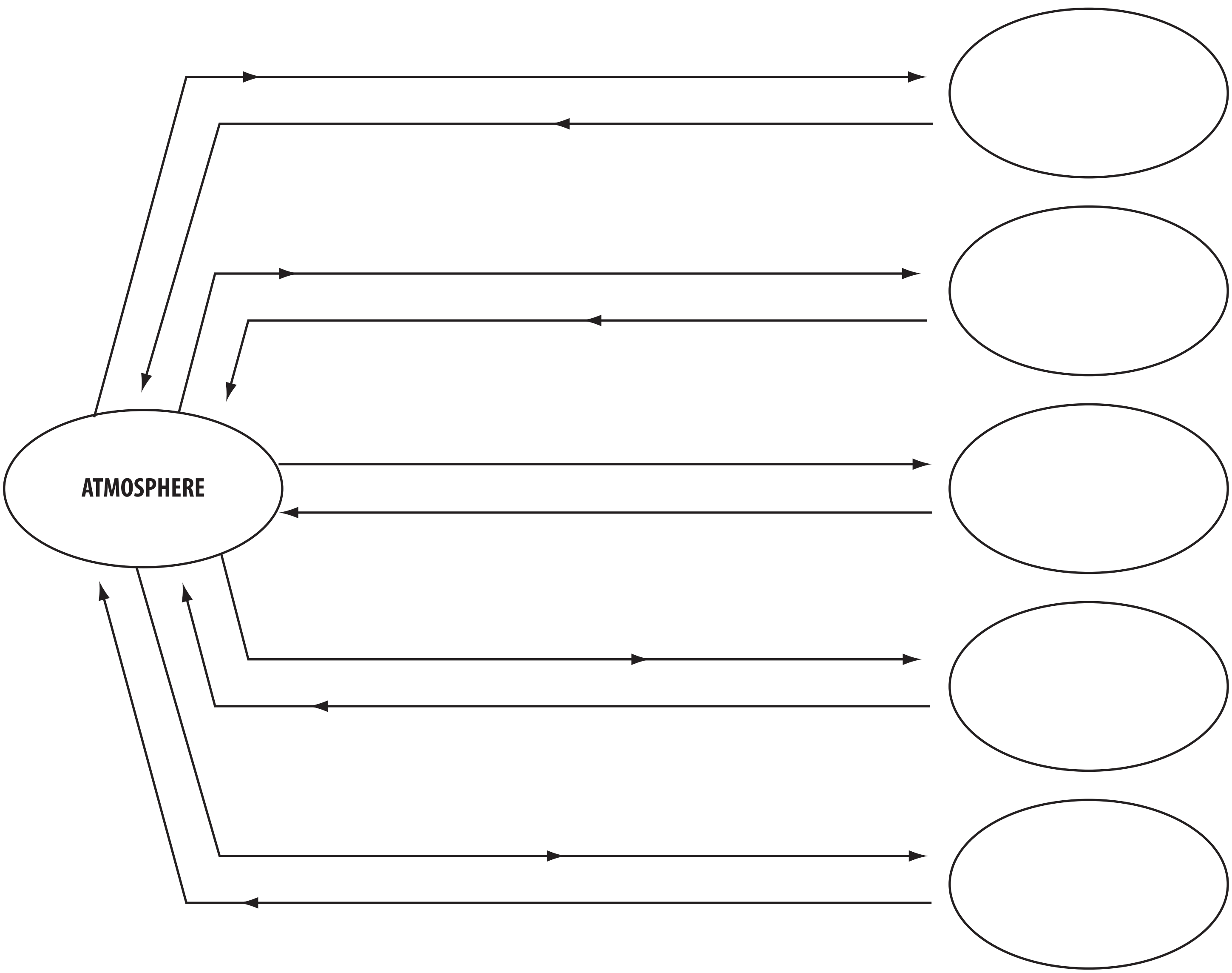
Each of the components listed below affects the atmosphere, which in turn affects the other components of the climate system.

Some Components of the Climate System

Animals
Coal
Coal Plants
Crops
Economy
Energy Efficiency/Conservation
Carbon Capture, Utilization and Storage
Mining
Natural Earth Events
Nuclear Plant
Oceans
People
Petroleum
Refineries
Soil
Solar Energy
Transportation
Trees

☑ Procedure

Atmosphere has been filled in for you. Select five (5) components from the list above and write them in the bubbles on the right. On the lines between the bubbles, write how the atmosphere affects the climate system component, and how the component affects the atmosphere, using the arrows as a guide.



Carbon Footprint

Given

- The average gallon of gas contains about 5 lbs. of carbon.
- One five-pound bag of charcoal briquettes contains approximately 100 briquettes.
- 5 lbs. of carbon/100 briquettes = 0.05 lbs. carbon per briquette

Sample

1. If you drive a vehicle that averages 25 mpg, how many briquettes per mile would you be emitting?

2. If each briquette contains 0.05 lbs. of carbon, how many lbs. of carbon are emitted each mile?

Questions

1. How many miles per gallon does your car (or your family car) average?

2. How many briquettes per mile would be emitted while driving your vehicle?

3. If each briquette contains 0.05 lbs. of carbon, how many lbs. of carbon are you emitting per mile?

4a. How many miles do you drive to school?

4b. Calculate how much carbon dioxide you are emitting as you travel to school.

5a. How many miles do you drive on the average day? Think about everywhere you go.

5b. Calculate how much carbon dioxide you are emitting as you travel on an average day.

Conclusions

1. Do you think people would change their behavior if carbon dioxide was emitted in a visible way, such as charcoal briquettes, rather than as a gas? Why or why not?
2. What are challenges in decreasing carbon dioxide emitted from our vehicles?
3. What might be some options for reducing the amount of carbon dioxide emitted from the transportation sector?

$ EFFICIENCY CONSERVATION

Carbon In My Life Informational Text

Carbon is one of the most common elements in the world and is in nearly everything. Carbon dioxide is also often released as a byproduct in the manufacturing, transportation, and use of products, food, individual transportation, and daily energy consumption. Remember that our “carbon footprint” is the total amount of carbon dioxide contributed by all of the things we do and all of the things we use, at home or at school.

You can probably think of a few ways to reduce your carbon footprint, including walking instead of driving, switching to compact fluorescent lamps, and recycling. Today people are looking closely at new ways to reduce their carbon footprint, or the carbon in their lives.

In this activity, you’ll learn how to investigate the carbon impacts of the products you use, the foods you eat, the energy and water you use, and of the different forms of transportation you use. You will select items to study and develop strategies to reduce your carbon footprint at school. Later, you can apply some of the same strategies at home.

Products

To determine the carbon impact for any product we buy or use, we have to look at the “life cycle” for that product. The product life cycle includes everything that had to happen to make that item, deliver it to you, and what happens to it when you’re done. Thinking about a product’s life cycle can tell us a lot about its carbon impact.

It is also important to think about whether a product is disposable or not. Disposable products can include everyday items like bottles, plates, and silverware. Diapers, writing utensils, cameras, and even items like gift cards are considered disposable. If you receive a gift card or give a gift card as a present, what do you do with it? Many people use a gift card and when the value has been used completely, they throw it away. These gift cards often come with different types of packaging around them, and we often go even further and wrap them more decoratively. Some gift cards can be reloaded with value added to them. Many disposable products can even be used twice or several times. There are also many reusable alternatives to disposable products. Whether you use disposable or reusable products, either option involves the mining, extraction, refining, manufacture, and shipping of parts and packaging, often including plastics. Each of these individual steps involves energy use and carbon impacts. Many disposable products can be made from recycled materials, which means less energy and carbon were involved in their manufacture. Try to use products made from recycled content as much as possible. When recyclable and reusable alternatives to disposable products are used, they can reduce your carbon impact by a significant amount. If you purchase a reusable cup to fill each time you stop for a beverage, you will have created far less waste and reduced your carbon footprint. Purchasing online “e”-gift cards, or reloading a used card can save on waste and impacts as well. Some businesses even reward customers for using reusable options or for environmentally-friendly purchases. If stores can cut costs on supplies like cups, because their customers use refillable ones, it often leads to discounts for those customers.

Foods

The foods you eat also have an impact on the amount of carbon in your life. Where does most of your food come from? There are many places our food and food products can come from. Some people eat foods that they have grown and produced themselves. Many people buy all of their foods at the grocery store or local market. Does all of the food we eat get produced locally? In many cases, the items we eat are shipped in from all over the country, and sometimes the world! Not all foods can be grown year-round, or in all climates, but we eat them anyway to supplement our diets. If it is cold and wintry where you live, the produce you buy at the store is probably not produced locally, it is shipped in from other areas. Some foods like animal products, or foods with multiple ingredients, require more energy to produce and keep them healthy for those who eat them. Items that must be transported long distances or require more energy to produce will have a much greater carbon impact.

Some foods use a lot of packaging. This packaging has a carbon footprint all its own and is different for plastic wrapping, paper boxes, or foam containers. Usually, the less packaging any product has, the lower its carbon footprint. What do we do with the packaging? Is it recycled?

Like products, leftover food has a life after we’re done with it. Are we sending leftover food items down the drain, into a landfill, or are we sending it to a compost pile to be turned into rich soil for a garden?

Think about the life cycle for every plastic fork or disposable plate you might use in one year. Would it be better to use plates and utensils that are used over and over again, or would it require too much water and energy to clean and dry them? Compostable utensils and containers are now available. Would these be better for the environment than disposable utensils?

How many different ways is carbon involved in the refrigeration, preparation, handling, and transportation of food at your school or home?

CREDIT CARD

Energy

We all use many forms of energy at school and at home, including our lights and computers, heating and cooling rooms, running our refrigerators and phones, and more.

There are two main ways to reduce the carbon footprint of the energy we use. The easiest way to reduce our energy use is by changing our behaviors—to remember to turn off lights and other electrical devices when not in use and to set thermostats to use less energy to heat and cool rooms. Look around your classroom to see how many different items are plugged in and using electricity.

Another way to use less energy is by using better equipment, like switching light bulbs to compact fluorescents (CFLs) or light-emitting diode (LED) bulbs and buying EnergyStar appliances, as well as insulating and weather-stripping our homes.

The second way to reduce the carbon footprint of the energy we use is in using renewable resources or less carbon-rich forms of energy. Coal is a nonrenewable resource that makes most of our electricity but has a significant carbon footprint. Electricity can come from using renewable resources—wind, solar, geothermal, and hydroelectric power. These sources create no CO_2 during energy production and are called "carbon neutral." While nuclear energy is nonrenewable, there are no emissions associated with electricity generation, so electricity generated from nuclear power is also carbon neutral.

Some utility companies give customers the opportunity to request that most or all of their electricity comes from carbon neutral sources. Some schools and homes are equipped with solar photovoltaic systems or wind turbines that generate as much electricity throughout the year as the buildings use. There are many ways to decrease your energy carbon footprint.

Water

You might not think that the water we use can add to our carbon footprint, but it does. The processes of finding, purifying, treating, and transporting water involve energy and have a carbon footprint.

When we are done with the water it goes to a sewage or water treatment plant and these steps add to water's carbon footprint. So, using less water reduces your carbon footprint on the input side and on the output side of your use.

It takes energy to heat our water, and this process creates carbon dioxide. If the water heater settings are too high, lowering the setting can lower your carbon footprint.

The two greatest ways we can reduce the carbon footprint of the water we use are to use less and to manage the water we're using differently. There are many ideas for using less water: take short showers instead of baths, don't let the water run while you brush your teeth or wash dishes, and be sure that your sprinkler systems are not wasting water. Installing low-flow toilets and showerheads will save a lot of water and lower your carbon footprint.

When our wastewater leaves our house or school, it goes to a treatment plant that uses energy and where more carbon dioxide is created. Whenever you can, don't send water down the drain; use it to water plants or trees instead.

Think of all the places water is used at your school and try to think of ways to take action to reduce your carbon footprint.

CFL LIGHT BULB

LED BULB

WIND TURBINES

WATER FAUCET

Transportation

For Americans, transportation choices make up a large part of our carbon footprint. Over long distances we can travel by car, by bus, by train, or by plane. Train travel tends to have the lowest carbon impact and air travel has the highest.

Most of us need to use some form of transportation every day. The choices for most people are to use a car, a bus, a local rapid transit, a bicycle, or to walk. Some ways to reduce our carbon footprint include driving less by combining errands into fewer trips, driving slower on the highway, and carpooling.

Four people carpooling to school or work in one car use a fraction of the energy of four people in separate cars. Whenever possible, walk, bike, or use public transportation. When we have to use a car, we should remember that some cars, like hybrids, are much more efficient than others, and maintaining proper tire pressure and keeping the car tuned-up leads to better fuel economy and reduced carbon emissions.

At school, we can encourage students to walk or bike, or find ways for students to carpool. Some schools have a "no-idling" rule when students are being picked up after school, which cuts down on the amount of fuel burned and the amount of emissions released.

What are the different ways students and teachers use transportation at your school? What are some ways you can reduce your carbon footprint in the ways you use transportation?

NATURAL GAS BUS

Image courtesy of United States Environmental Protection Agency

PAPER BAG

PLASTIC BAG

REUSABLE GROCERY BAG

Comparing Carbon Footprints

▪ Paper or Plastic Shopping Bags?

Which product do you think uses less energy and has a lower carbon footprint? Both have impacts in their manufacture, transportation, and disposal, but a life cycle analysis shows that neither is perfect. Paper bags are made of a renewable resource, wood, and they are recyclable. Plastic bags are made of nonrenewable petroleum but use less energy in their manufacture and transportation. They don't decompose well in a landfill, but they are recyclable too. It actually takes more than four times the energy to make a paper bag and because they take up more space, it takes more energy to transport them in bulk.

Recycling paper and plastic bags will help decrease your carbon footprint, but the very best choice is to use a reusable shopping bag made of canvas or recycled plastic. These are becoming widely available at stores and are, by far, more environmentally friendly than any disposable bag.

▪ Polystyrene or Paper Drinking Cups?

Polystyrene, often called Styrofoam, has many uses including drinking cups. Polystyrene cups are recyclable, but they are not biodegradable. If styrene is not properly disposed of and ends up in the environment, it can remain there for hundreds of years. Paper cups are recyclable and will break down in the environment more quickly than polystyrene, but in landfills both take up space and will not readily decompose. Studies show that it actually takes more energy to produce paper cups, so the carbon footprint for these is greater than for polystyrene cups.

A third type of cup becoming available is compostable drinking cups. These can be made of organic materials like cornstarch, and they break down harmlessly when composted with plant and vegetable materials. Other compostable eating utensils are available, like forks and knives, but they are more expensive to purchase.

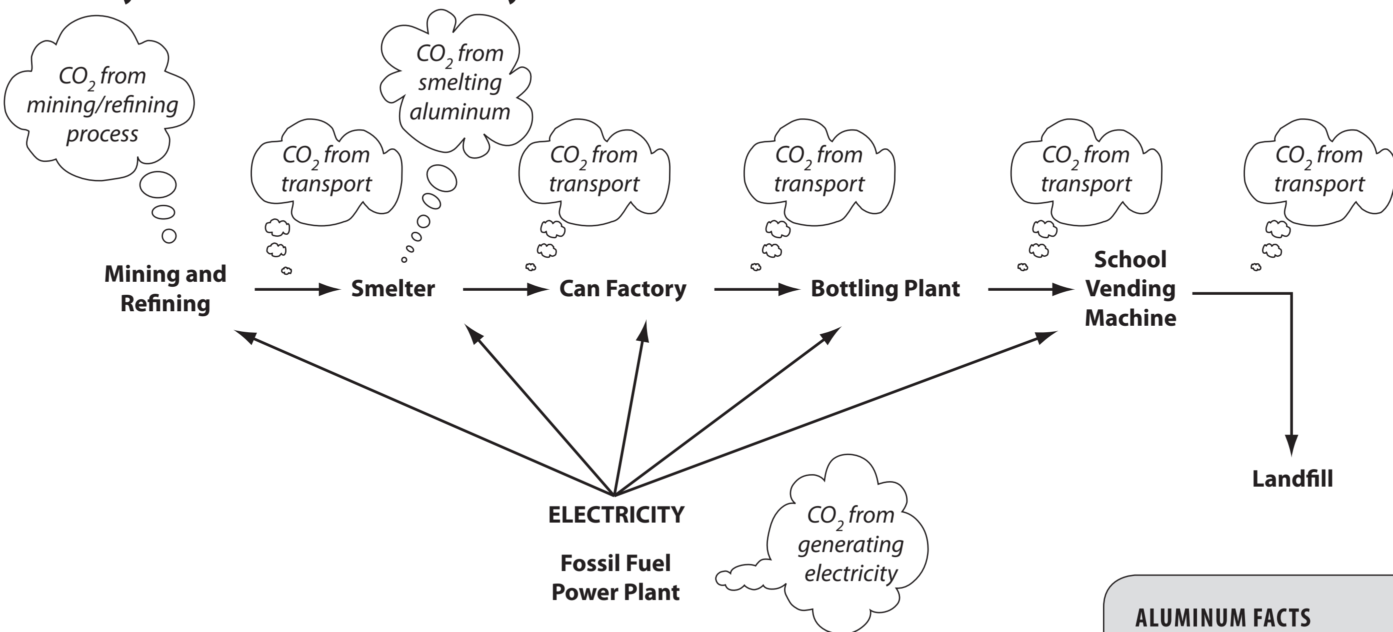
As we found with shopping bags, an alternative to disposable cups is to use washable glass, plastic, ceramic, or metal drinking containers. When we wash them we use some energy and water, but we do not have to make them over and over and we create less of a problem with waste.

As you study the carbon footprint for any of the items in your everyday life, remember that there are misconceptions about what choices are better for the environment. New products and ideas are being created every day, and it's important to do a little research to be sure that you make the best choices.

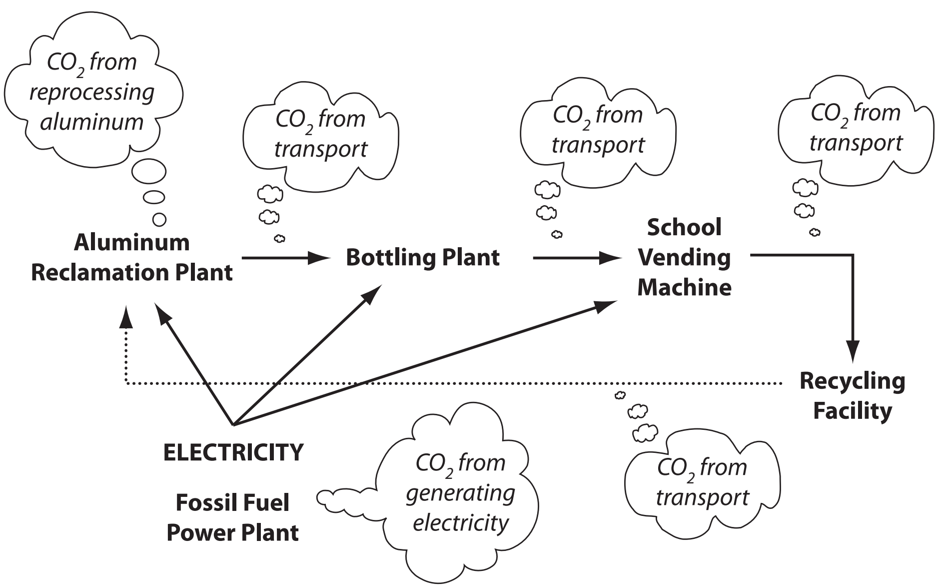
Aluminum Can Life Cycle Comparison

Several steps are needed to create a new product. When we use recycled materials we eliminate several steps, and the reduction of processes and transportation means less energy is used during the life cycle. This also results in fewer emissions of carbon dioxide due to electricity use and transportation.

Non-Recycled Aluminum Can Life Cycle



Recycled Aluminum Can Life Cycle



ALUMINUM FACTS

- In the U.S., 100 billion aluminum beverage cans are produced annually; about half of those are returned for recycling.
- The energy used to make one aluminum beverage can is about 7,000 Btu. Recycling saves 95 percent of the energy it would take to make new metal from ore.
- It takes about 60 days for aluminum beverage containers to be recycled and reappear on store shelves.

Data: Alcoa

Every product you use has a life cycle and associated carbon dioxide impacts before and after its use. With a little research you can find out where the energy use and CO_2 emissions occur.

Try to draw a life cycle chart like the one above for some other items you use at home or at school. Ask yourself where the product, or water, or energy comes from. Then think about where the product, or water, or energy goes when you are done using it.

$ EFFICIENCY CONSERVATION

Carbon In My Life Survey

Discuss the items below. Are these occurrences happening at your school?

Do you think that CO_2 emissions are involved (yes or no)?

Brainstorm additional items observed at your school that you think can be improved upon.

OBSERVED ITEM TO STUDY	NEVER	SOMETIMES	OFTEN	CO_2 EMISSIONS
Cans and bottles are being used, then thrown in the trash.				
Paper and cardboard recycling drives occur at school.				
Parents' cars are seen idling in morning and afternoon.				
Buses are often idling for a long time.				
Sprinklers are watering the street and running too long.				
Lights in the gym are left on all day.				
Computers are left on when not being used.				
Students are encouraged to bike and walk to school.				
The cafeteria uses disposable plates, cups, and utensils.				
Classrooms are too cold on hot days, too warm in the winter.				
Schools distribute lots of paper handouts.				
Classrooms and offices are equipped with occupancy sensors.				
Vending machines are using energy, creating trash.				
Science class goes through a lot of disposable batteries.				
Students bring their lunch in disposable bags and containers.				
Waste material that could be composted is sent to a landfill.				
Other:				
Other:				
Other:				
Other:				

Carbon In My Life Study Items

Think about all of the ways carbon cycles in and out of your life. What products do you use on a daily basis? What do you eat? What types of energy (electrical or gas) and water uses do you have? How do you travel?

List a few items in each column.

CONSUMABLE PRODUCTS I USE	FOODS I EAT	ENERGY AND WATER I USE	TRANSPORTATION I USE	OTHER

Your team should discuss each of these items and try to identify opportunities to implement changes in their use that might lower the carbon footprint.

Critical Questions

Does this item apply at school, at home, or at both?

Does taking action require individual action or group cooperation?

What obstacles might be encountered in taking action to lower the carbon footprint of this item?

Select four or five items, one from each category above, to study using the *Item Analysis Organizer* on page 66.

Develop an action plan for one or more items studied using the *Questionnaire*, page 67, and *Action Planner*, page 68.

$ EFFICIENCY CONSERVATION

Carbon In My Life Item Analysis Organizer

Answer the questions in this organizer to find opportunities to reduce your carbon footprint.

Item: ______________________________

What purpose does this item serve? ______________________________

Can you do without this item?
YES → **Item is not essential: Explain how not using it will save energy or lower your energy carbon footprint.**
NO ↓

If item is essential, is there a better, less carbon intensive way to meet the same need?
YES → **Describe an alternative way to meet this need and how it will lower your carbon footprint.**
NO ↓

Is there a better source for this item, a renewable, more local, or more efficient source?
YES → **Describe the alternative source and how it will lower your carbon footprint.**
NO ↓

Can you use less of this item?
YES → **Explain your plan to use less of this item and how it will lower your carbon footprint.**
NO ↓

Is this item being wasted or disposed of carelessly?
YES → **Describe your suggestion for proper disposal and how it will lower your carbon footprint.**
NO ↓

If you answered "NO" to every question, select a different item to study until you can answer "YES" to one of the questions. Once you've identified items that offer an opportunity to conserve energy or reduce your carbon footprint, complete pages 67 and 68 to develop an Action Plan.

Carbon In My Life Questionnaire

You can lower your carbon footprint if you learn to ask these questions of every thing you use:

- Is it essential, do I have to use it or can I live without it?
- What purpose does it serve, what need does it fill? Can I fill that need in a different way?
- If I have to use it, can I use less of it or use it more wisely?
- Where does it come from, and is there a better or more local source for it?
- When I'm done with this item, where does it go, is it recycled or reused?

Choose one item from each category on page 65. Use this questionnaire to analyze your use of the product and think about what steps you might take in order to lessen your own carbon footprint. Compose detailed answers on separate paper.

Item description: ______________________________

Need met: ______________________________

Item's current energy use impact: ______________________________

Item's current CO_2 impact: ______________________________

Complete as many of the questions below as apply to the item being studied:

This item comes from (what materials, where): ______________________________

An alternate source is: ______________________________

The energy needed would be lower because: ______________________________

The CO_2 impact would be lower because: ______________________________

Other ways I could meet the same need include: ______________________________

The energy needed would be lower because: ______________________________

The CO_2 impact would be lower because: ______________________________

Ways to use less of this item include: ______________________________

The energy needed would be lower because: ______________________________

The CO_2 impact would be lower because: ______________________________

Where this item goes after it's used is: ______________________________

An alternative for this item after it is used: ______________________________

Energy is saved because: ______________________________

The CO_2 impact might be lower because: ______________________________

Actions I can take include: ______________________________

Actions others can take include: ______________________________

If you are unable to find ways to lower energy use or the CO_2 impact, select another item to analyze. When you've found ways to lower energy use or CO_2 impact, complete the Action Planner on the next page.

Carbon In My Life Action Planner

$ EFFICIENCY CONSERVATION

Select one of the items analyzed that offers an opportunity for you to reduce your personal carbon footprint or the carbon footprint of your school.

Use this planner to plan and execute your carbon reduction strategy.

Compose detailed answers on separate paper.

Item Description: ____

Problem Description: ____

How is energy related to this item?

How is CO_2 related to this item?

How are behaviors and choices related to this item?

The action you plan to take:

What you need to learn before you can take action:

Who might need to give permission for you to take this action?

Who can help you make this action successful?

List any difficulties you might encounter:

What will determine "success" for your action and when will success be met?

Explain how this action might save money, cost money, or have no financial impact.

Does action on this item give you ideas for other items to study? List these below.

Describe how you could encourage others to take similar actions.

Develop a timeline for each step you plan to take.

Take notes and document your progress in your science notebook.

Glossary

adapt	to make changes or modifications
aerosols	the suspension of tiny particles or droplets in a gas; smog and volcanic ash are examples
albedo	the ability of any surface to reflect light
atmosphere	the surrounding gaseous state of the air around the Earth
biomass	living organic matter that can be converted to fuel as an energy source
biosphere	the parts of Earth that support life—water, atmosphere, land
carbohydrates	organic compounds produced through photosynthesis that contain sugar, starch, and cellulose that are consumed by animals for energy
carbon	a basic building block of matter that exists naturally; C on the periodic table of elements
carbon cycle	the organic circulation of carbon atoms in the biosphere exchanged between organisms and the environment
carbon dioxide	an odorless, colorless, noncombustible gas produced from respiration, organic decomposition, and combustion
carbon neutral	no carbon dioxide gas production going into the atmosphere
carbon reservoir	area between major carbon sinks including the biosphere, lithosphere, hydrosphere, and atmosphere
carbon sinks	a reservoir that accumulates and stores carbon
climate	meteorological conditions in the atmosphere of a certain region over a relatively long period of time including temperature, winds, and precipitation
climatologist	a scientist that works in the field of climatology dealing with climate and climate conditions
climatology	a field of science that deals with climate or climate conditions
combustion	a burning process where a substance reacts with oxygen to emit heat and light
concentration	the amount of a specific substance within another substance
conservation	saving or preserving to prevent depletion, loss, or extinction
consumption	to use or destroy
cycle	a repeating pattern
drought	a long period of dry weather with abnormally low precipitation
eccentricity	the amount an orbit deviates from a perfect circle or its shape
electricity	the presence and flow of electric charge, moving electrons
emissions	substances released or emitted into the atmosphere
energy	the ability to produce change or do work
energy efficiency	using less energy to produce the same (equivalent) amount of something
energy transformation	any process of energy conversion from one form to another form of energy
erosion	the wearing down of the surface of the Earth by movement from water, wind, waves, or glaciers
fission	splitting into parts; splitting or fragmenting the nucleus of atoms to release energy
fossil fuels	the remains of plants and animals that died millions of years ago
fusion	the joining of nuclei of atoms to form heavier, more stable nuclei
gas	a state of matter in which the molecules are in random order and motion that takes on the shape of the available space; air is a mixture of gases
geologists	scientists who study the science that deals with the dynamics and physical history of Planet Earth structures such as rocks, and the processes that cause change in the Planet Earth
gigatons	a unit of measure equal to one billion tons

global warming	the increase of Earth's average atmospheric temperature
greenhouse effect	The result of water vapor, carbon dioxide, and other atmospheric gases trapping radiant (infrared) energy, thereby keeping the Earth's surface warmer than it would otherwise be. Greenhouse gases within the lower levels of the atmosphere trap this radiation, which would otherwise escape into space, and subsequent re-radiation of some of this energy back to the Earth maintains higher surface temperatures than would occur if the gases were absent.
greenhouse gases	(GHGs) naturally occurring gases in the atmosphere that blanket the Earth keeping it warm
hydrocarbon	an organic compound consisting of hydrogen and carbon
hydrosphere	all water on or around the Earth including surface, ground, ice, and water vapor
ice core	a drilled sample from an ice sheet
impact	an impression or force one thing has on another
infrared radiation	electromagnetic waves produced from very hot objects, which are longer than visible light and shorter than radio waves and we can feel them produced from an incandescent bulb
inorganic	compounds not containing carbon
intergovernmental	work that combines two or more levels of governments
lithosphere	the solid portion of the crust and upper mantle of the Earth
meteorologists	scientists who study the science dealing with the atmosphere and its phenomena, including weather and climate
methane	colorless, odorless, flammable gas used as fuel that is naturally released during decomposition of organic materials; consists of one carbon and four hydrogens—the major component of natural gas; it is a greenhouse gas
Milankovitch Cycles	changes in the Earth's movements that affect climate
mitigate	to lessen or make milder
nitrous oxide	also known as laughing gas, N_2O is a sweet-smelling and tasting, nonflammable, colorless gas
nonrenewable	energy or natural resources that cannot be replaced once they have been used up
obliquity	the axial tilt of an object; difference between orbital and equatorial planes
photosynthesis	process utilizing light as the energy source, in which green plants produce carbohydrates from carbon dioxide and water and release oxygen as a byproduct
precession	the rotational motion of an axis (such as a wobbling top), caused by gravitational forces
precipitation	rain, snow, sleet, or hail that are products of condensation in the atmosphere that fall to Earth
radiation	the emitting of particles or waves giving off energy; energy from the sun in rays or waves
renewable	energy or natural resources that are never used up or can be replaced
reservoirs	a natural storage; an extra supply
respiration	inhaling and exhaling air; breathing
secondary energy source	requires the use of another energy source for production
smog	atmospheric emissions in fog
sustainability	support; keep in existence or maintain
thermal expansion	the tendency of matter to change in volume due to a change in temperature
volcanism	relating to volcanic activity or volcanic force
weather	describes the meteorological conditions in the atmosphere over a short period of time
weathering	chemical and mechanical processes that decompose or break down rock

Understanding Climate Change Evaluation Form

State: ____________ **Grade Level:** ____________ **Number of Students:** ___________

1. Did you conduct the entire unit?	❑ Yes	❑ No
2. Were the instructions clear and easy to follow?	❑ Yes	❑ No
3. Did the activities meet your academic objectives?	❑ Yes	❑ No
4. Were the activities age appropriate?	❑ Yes	❑ No
5. Were the allotted times sufficient to conduct the activities?	❑ Yes	❑ No
6. Were the activities easy to use?	❑ Yes	❑ No
7. Was the preparation required acceptable for the activities?	❑ Yes	❑ No
8. Were the students interested and motivated?	❑ Yes	❑ No
9. Was the energy knowledge content age appropriate?	❑ Yes	❑ No
10. Would you teach this unit again?	❑ Yes	❑ No

Please explain any 'no' statement below.

How would you rate the unit overall?	❑ excellent	❑ good	❑ fair	❑ poor
How would your students rate the unit overall?	❑ excellent	❑ good	❑ fair	❑ poor

What would make the unit more useful to you?

Other Comments:

Please fax or mail to: **The NEED Project**
P.O. Box 10101
Manassas, VA 20108
FAX: 1-800-847-1820

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National Ocean Industries Association
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New Mexico Oil Corporation
New Mexico Landman's Association
New Orleans Solar Schools Initiative
New York Power Authority
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