Your Climate, Your Future

An interdisciplinary approach to incorporating climate change in your classroom

15 lesson plans for grade 9-12

Written and edited by Kate Graves and Eliot Levine

WWF

Dear Educator,

The future of our planet lies in the hands of your students. We appreciate your interest in taking action and leading discussions about climate change in your classroom.

To develop the WWF curriculum, we pulled together and created the most engaging multisensory lesson plans available on the high school level. Climate change is, perhaps, the most pressing issue of our day and an integral part of your students' lives. We hope these materials will help elevate your students' knowledge about climate change and serve as a topical issue to engage them in the pedagogical process.

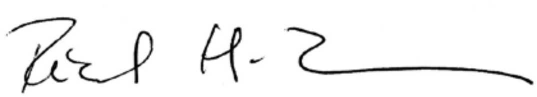
What you will find in this packet: Fifteen interdisciplinary lessons for the high school level, handouts and consent forms for lessons, a glossary containing need-to-know terms, additional resources for your own or student research, and discipline tracks that guide you to find lessons suitable for social studies, math, English science classes, and more. Also, the materials are available online to browse or download, as well as additional information that you might find helpful.

I would like to draw your attention to **Lesson 13: The Stabilization Wedges Game**. This game may look intimidating, but it will give your students the chance to use their critical thinking skills to create their own solutions and learn that while reducing emissions will not be easy, the solutions to do so are available now. We recently played the game with 24 students from the Gulf region, and the discussion engaged all of the students in thinking about the different possibilities. The students evaluated each other's arguments and kept everyone on their toes! When playing this game with other teachers, many felt they could adapt it for their middle school and junior high students. We encourage you to challenge your students with this activity!

We could not have produced this curriculum without the wonderful resources provided to us by other organizations. We thank the other groups who gave us permission to further distribute their lesson plans: Will Steger Foundation for the GlobalWarming101.com lessons, the Union of Concerned Scientists, and the Carbon Mitigation Initiative.

I encourage you to incorporate climate change into your classroom. It is necessary for future generations to understand climate change, because they will be the ones who live with its legacy and require the wisdom to know what actions to take. **Please feel free to contact the Climate Change Team at WWF if you have any further questions at (202)293-4800**

Sincerely,



Dr. Richard Moss

VP and Managing Director

Climate Change Program

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Lesson Eight: Climate Change and Ecosystems

Discipline: Natural Sciences
Research the interdependencies among plants and animals in an ecosystem and explore how climate change might affect those interdependencies and the ecosystem as a whole.

Lesson Nine: The Forecaster

Discipline: Natural Sciences, Social Sciences
Gather historical climate data for local regions and chart the trends over the past 100 years. Make climate predictions for the next month, semester, and year, and monitor these predictions over that period of time.

Lesson Ten: Car Quest

Discipline: Natural Sciences, Social Sciences
Assess the environmental impacts of a fleet of cars and then research and prepare a report about greener transportation choices.

Section C: What We Can Do!

Lesson Eleven: Energy Watch

Discipline: Natural Sciences, Social Sciences
Keep track of home-energy usage and develop a plan to reduce the home-energy consumption. Track the progress over a period of time, and present the results to the class.

Lesson Twelve: Write On!

Discipline: Social Sciences, English and Humanities
Express views and knowledge of climate change in the community by writing federal political officials, local political officials, and regional newspapers, giving students a voice on climate change and their concerns for their futures and the future of their community.

Lesson Thirteen: The Stabilization Wedges Game

Discipline: Natural Sciences
Learn about the technologies currently available that can substantially cut carbon emissions, develop critical reasoning skills as they create their own portfolio of strategies to cut emissions, and verbally communicate the rationale for their selections. Working in teams, students develop the skills to negotiate a solution that is physically plausible and politically acceptable, and defend their solution to a larger group.

Lesson Fourteen: The Great Climate Change Debate

Discipline: *Social Sciences, English and Humanities*
Develop arguments and positions to debate ways to address climate change politically, environmentally, and economically on the regional, national and international level.

Lesson Fifteen: Climate Witness Oral History Project

Discipline: *Social Sciences, English and Humanities*
Interview elder community members and write their stories of how they have noticed the climate changing over the years. Present these stories in class, offer suggestions to students, discuss relevance of material presented, and publish stories on a Web site.

Discipline Tracks

Climate Change should not be limited to science classes. There are lessons here suitable for English, Math, Economics, Theater, Civics, Social Studies, History, Technology, and Geography classes.

We encourage you to pick and choose lessons that you believe will be best for your classes. Here are our lessons separated for which disciplines they are most appropriate. However, please feel free to peruse all the lessons and incorporate any into your classroom which you believe your students will enjoy.

Science Classes

1. Climate Change Pretest
2. Our Unique Atmosphere
3. Emissions of Heat Trapping Gases
4. Communities of Living Things
5. Climate Change in My City
6. Climate Change and Disease
7. Climate Change and Ecosystems
8. The Forecaster
9. Energy Watch
10. Car Quest
11. The Stabilization Wedges Game
12. The Great Climate Change Debate

Humanities Classes

1. Communities of Living Things
2. Climate Change and People
3. Write On!
4. The Great Climate Change Debate
5. Climate Witness Oral History Project

Social Science Classes

1. Communities of Living Things
2. Climate Change and People
3. Climate Change in My City
4. Climate Change and Disease
5. The Forecaster
6. Energy Watch
7. Car Quest
8. Write On!
9. The Stabilization Wedges Game
10. The Great Climate Change Debate
11. Climate Witness Oral History Project

Lesson One:
The Climate Change Pretest

Subjects
Science, Current Events

Estimated Time
10 to 15 minutes

Grade Level
9-12

Objectives
This pretest is designed to evaluate students' knowledge of climate change. Teachers should use this pretest to determine how much time is needed to devote to background material.

Materials
- The Climate Change Pretest (provided)
- The Climate Change Pretest Key (provided)

Procedure
To understand climate change and its effects on Earth, it is necessary to have a basic understanding of some terms and definitions. This test should be used to help teachers get a better understanding of how much their students already know about weather and climate science, atmospheric structure, and terms used throughout the rest of the curriculum.

The Climate Change Pretest

Directions: Using what you have learned from other classes and resources, answer each question below.

1. **True or False:** The difference between climate and weather is that Earth's climate is the average condition in a given place over many years, whereas, weather includes only the immediate conditions for a specific place.

2. **True or False:** The atmosphere is a relatively thin layer of gas that scientists divide into four sections based only on chemical composition.

3. **True or False:** Greenhouse gases (GHGs) act like a blanket in the atmosphere, trapping heat and warming the planet.

4. **True or False:** The following gases are not GHGs: nitrous oxide (N2O), methane (CH4), water vapor (H20) and chlorofluorocarbons (CFCs).

5. **True or False:** Climate change refers only to the increasing temperature of the earth's surface.

6. **True or False:** Without the human race, GHGs would not exist.

7. **True or False:** Human-caused emissions of carbon come from both the burning of fossil fuels and from land-use changes such as deforestation and land-clearing.

8. **True or False:** The majority of human-caused carbon emissions come from the burning of fossil fuels.

9. **True or False:** Climate change is predicted to greatly affect the natural resources (such as water) that people depend on.

10. **True or False:** Individual actions, such as replacing all of your old light bulbs with Compact Fluorescent light bulbs, will help reduce the amount of GHGs in the atmosphere.

The Climate Change Pretest - Key

Directions: Using what you have learned from other classes and resources, answer each question below.

1. **True or False:** The difference between climate and weather is that Earth's climate is the average condition in a given place over many years, whereas, weather includes only the immediate conditions for a specific place.

2. **True or False:** The atmosphere is a relatively thin layer of gas that scientists divide into four sections based only on chemical composition.

   http://liftoff.msfc.nasa.gov/academy/space/atmosphere.html

3. **True or False:** Greenhouse gases (GHGs) act like a blanket in the atmosphere, trapping heat and warming the planet.

4. **True or False:** The following gases are not GHGs: nitrous oxide (N2O), methane (CH4), water vapor (H20) and chlorofluorocarbons (CFCs).

   http://www.pbs.org/wgbh/nova/ice/greenhouse.html

5. **True or False:** Climate change refers only to the increasing temperature of the earth's surface. See definitions for Climate and Climate Change in the WWF glossary or online here:

   http://www.pewclimate.org/global-warming-basics/full_glossary/glossary.php?term=a

6. **True or False:** Without the human race, GHGs would not exist.

   http://www.epa.gov/climatechange/emissions/index.html

7. **True or False:** Human-caused emissions of carbon come from both the burning of fossil fuels and from land-use changes such as deforestation and land-clearing.

8. **True or False:** The majority of human-caused carbon emissions today comes from the burning of fossil fuels.

9. **True or False:** Climate change is predicted to greatly affect the natural resources (such as water) that people depend on.

10. **True or False:** Individual actions, such as replacing all of your old light bulbs with Compact Fluorescent light bulbs, will help reduce the amount of GHGs in the atmosphere.

Lesson Two:
Our Unique Atmosphere

Subjects
Science, Current Events

Estimated Time
One forty-five minute class period

Grade Level
6-12

Objectives
- Students, working in groups, will each read different articles about our atmosphere.
- Students will be responsible for explaining what they have learned to members of the other groups.
- Students will be able to explain how heat-trapping gases work in the atmosphere.
- Students will be able to explain why carbon dioxide and other heat-trapping gases are necessary for life as we know it.

Materials
The following readings should be made available to the class:
- Reading Number 1: The structure of the atmosphere
- Reading Number 2: Heat-trapping gases in the atmosphere
- Reading Number 3: The greenhouse effect

(Note: All of these are provided for you in this curriculum, but can also be found at the following website free of charge: www.Globalwarming101.com.)

Lesson designed by Elizabeth K. Andre for the Will Steger Foundation.

Our Unique Atmosphere

How does our atmosphere keep the earth warm?

Procedure

Have students count off from one to three. Each student must then find another student who has the same number. For example, a student with the number one would find another student who is also a number one. In these pairs, the students cooperatively read the following passages:

Reading Number 1: The structure of the Atmosphere
Reading Number 2: Heat-trapping gases in the atmosphere
Reading Number 3: The greenhouse effect (10 min)

Each pair then plans a way to teach their topic to other students. Their lesson will need to include an explanation of the major concepts in the passage and an explanation of the visuals that accompany the passage. Students will also need to include in their lesson an original analogy and an original visual that help explain the concepts in their passage.

Make sure students understand that an analogy is a comparison based on a similarity between two things that are otherwise dissimilar. For example, students who read the passage about the layers of the atmosphere could compare the layers of the atmosphere to the different colored layers on a gobstopper candy, an onion, or a layer cake. They would then draw a visual that helps clarify their analogy.

These pairs then split and each student finds another student who also has the same number. For example, a student with the number one will find a different student who is also a number one. These new pairs then share with each other the lesson they prepared with their first partner, including the analogy and original visual. These new partners give each other feedback on aspects of their lesson that were especially good. Each can then decide to incorporate certain aspects of the partner's lesson into his or her lesson to strengthen it. (5 min)

Next, students find new groups that comprise a student with each number. For example, a student with the number one would find a student with the number two and also a student with the number three. Starting with the student with the number one, the students teach their lessons to the other two students in their group. (10 min)

The teacher then picks one student from each passage to share his or her analogy and visual with the class. (5 min)

Notes to the teacher:

As the students are cooperatively reading, planning and practicing their lessons and presenting their lessons to each other, circulate between the groups and listen at each group for a few moments to gauge the progress of the groups and to make certain that students are focusing their efforts on the task.

Before dividing the students into groups, explain the entire activity to them and let them know how much time they will have for each section of the activity.

Explain to the students that you will be circulating between the groups during this activity and that you may ask any student at any time to explain any aspect of the passages. Let them know that it is the responsibility of each group to make sure that each group member understands all the concepts and would be ready to explain any of the topics.

National Standards Alignment

National Science Education

Unifying Concepts and Processes (5-12): Systems, order, and organization; Change, constancy, and measurement
Earth and Space Science (5-12): Energy in the earth system
Science in Personal and Social Perspectives (5-12): Populations, resources, and environments; Environmental quality

Environmental Education Guidelines for Learning (K-12)

Strand 1: Questioning and Analysis Skills: Organizing information; Working with models and simulations; Developing explanations
Strand 2: Knowledge of Environmental Processes and Systems: Processes that shape the earth; Energy
Strand 2.2: The Living Environment: Systems and Connections

Standards for the Language Arts

Standard 4: Students adjust their use of spoken, written, and visual language (e.g. conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.

Standard 12 : Students use spoken, written, and visual language to accomplish their own purposes (e.g. for learning, enjoyment, persuasion, and the exchange of information).

Reading Number 1:
The structure of the Atmosphere

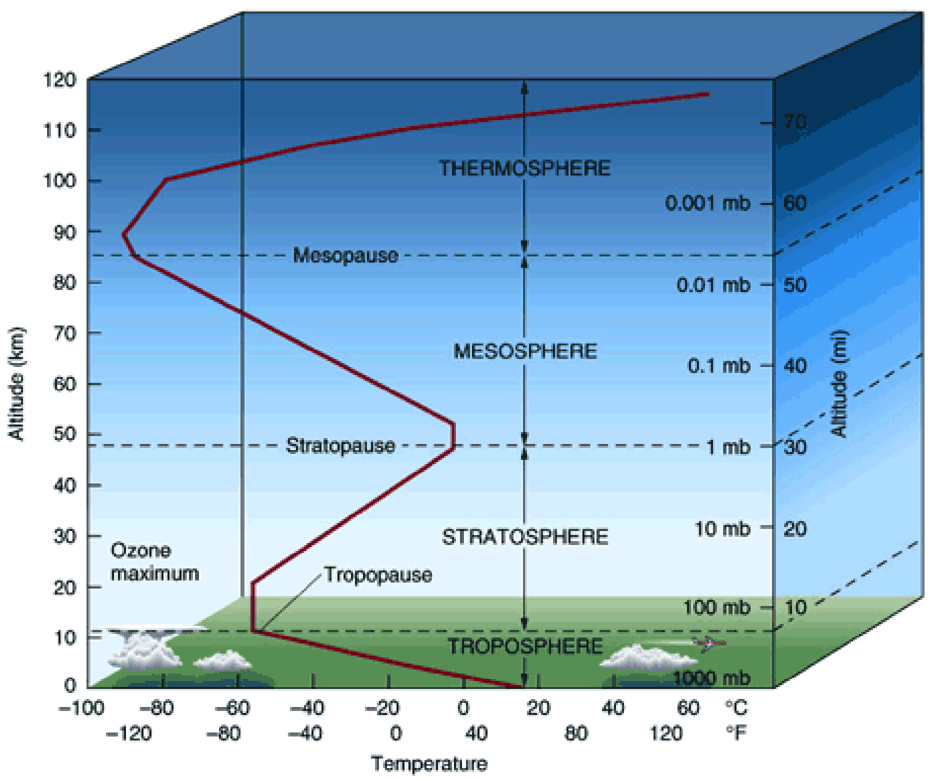
© NASA

The atmosphere is about 372 miles (600 kilometers) thick. While this may seem like a lot, when compared to the size of the earth, the atmosphere is a relatively thin layer of gases. In the photo to the right you can see how relatively thin the atmosphere is.

Based on temperature, the atmosphere is divided into four layers. The layer closest to earth's surface is the troposphere. The troposphere is thickest in the tropics (about 9 miles/14.5 kilometers thick) and thinnest at the poles (about 5 miles/8 kilometers thick). Most weather happens in the troposphere. The troposphere is the densest of all the layers of the atmosphere and it contains about 80% of the mass of the atmosphere and almost all of the water in the atmosphere. The average temperature in the troposphere is highest at ground level and decreases to about negative 57 degrees F (-52 degrees C) in the uppermost parts of the troposphere.

At the very top of the troposphere is the tropopause. This layer is very stable and separates the troposphere from the next layer, the stratosphere. Have you ever seen a thunderhead (cumulonimbus cloud) with a flat top? Sometimes this flat top is caused by winds, but sometimes it is caused by the top of the cloud reaching the tropopause and not being able to go up any further.

Together, the troposphere and the tropopause are known as the *lower atmosphere*. It is in the lower atmosphere that heat-trapping gases (some people refer to these as *greenhouse gases*) accumulate.



Source: globalwarming101.com

Above the tropopause is the stratosphere and the mesosphere. Together they are known as the *middle atmosphere*. Chemicals in the middle atmosphere absorb and scatter the ultraviolet radiation coming in from the sun.

Above the middle atmosphere is the thermosphere or *upper atmosphere*. Temperatures increase the higher you go up in the thermosphere because of the incoming energy from the sun. Temperatures can reach over 3,140 degrees F (1,700 degrees C).

Study the graph to the left. The red line represents the average temperature.

Reading Number 2:
Heat-trapping gases in the atmosphere

Heat-trapping gases collect in the troposphere and include carbon dioxide (CO2), nitrous oxide (N20), methane (CH4), water vapor (H20), ozone (O3), and chlorofluorocarbons (CFCs). These gases act like a blanket in the atmosphere, trapping heat and warming the planet. Some scientists have also called these gases "greenhouse" gases, because akin to an actual greenhouse made of glass and used to grow plants when it is too cold outside, these gases trap heat and help regulate the temperature on earth.

Air is made up of different gases, and gases are made up of molecules (which are, in turn, made up of atoms). These molecules are so small that they cannot be seen with the naked eye and there is a lot of space between individual molecules; that is why air is transparent.

Based on the structure of the molecules, some gases are more effective at trapping heat than others and stay in the atmosphere for longer. The better a gas is at trapping heat and the longer it stays in the atmosphere, the more potential it has for aiding global warming (we will learn more about how this works in the next lesson).

We use the global warming potential of carbon dioxide (CO2) as a standard against which we can compare other trace gases. To make comparisons easily, we label carbon dioxide (CO2) as having a Global Warming Potential (GWP) of 1. We can compare this to other greenhouse gases. Methane (CH4) has a GWP of 23 (measured over a 100 year period). Other gases have much longer atmospheric residence times, like sulfur hexafluoride which has a GWP of 22,000 over 100 years. We don't hear much about hexafluoride, however, because it has very low concentrations in the atmosphere.

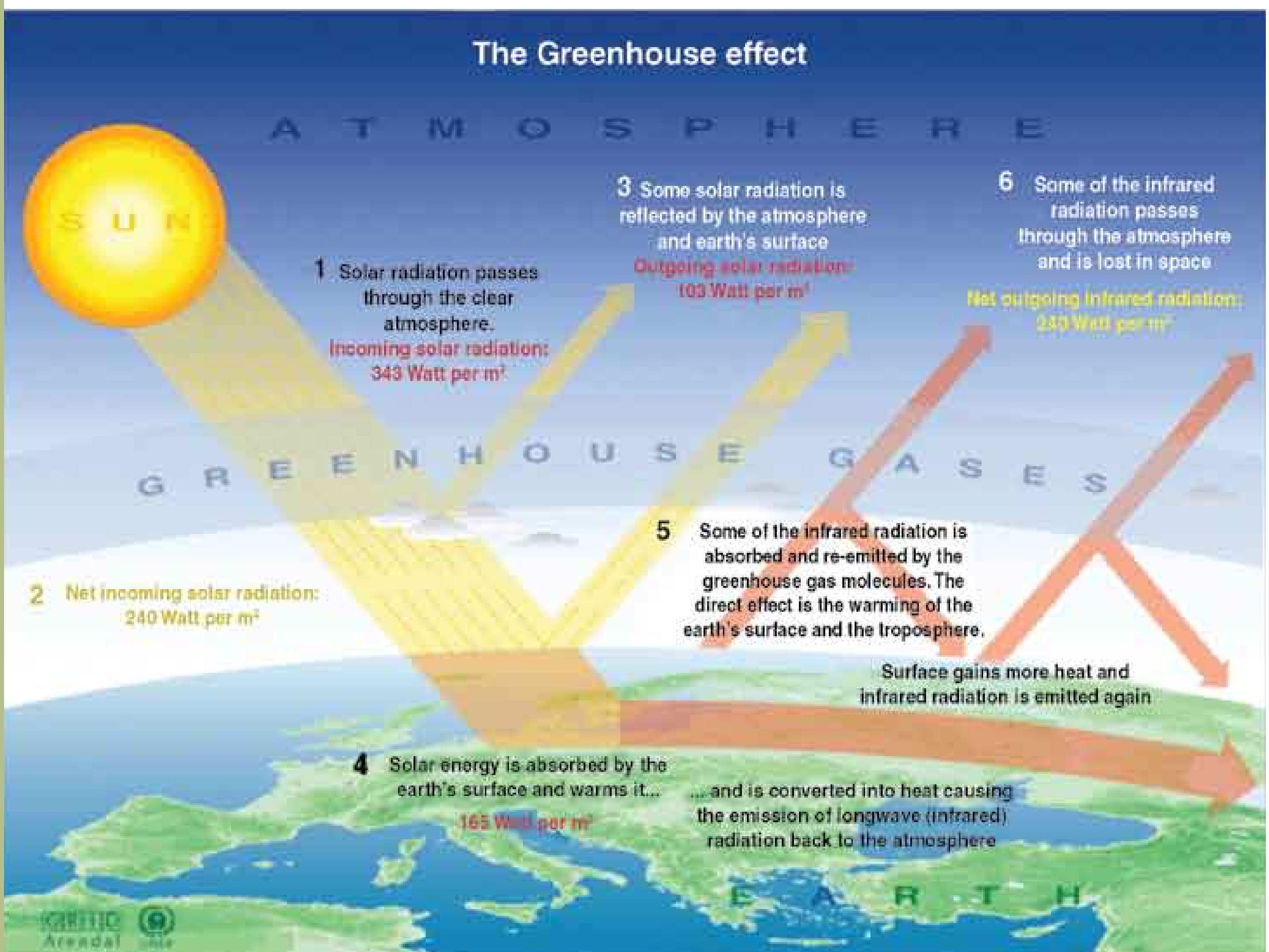
One heat-trapping gas that has a low GWP because its atmospheric residence time is only a few days is water vapor (H2O). Even though it has a low GWP, there is a lot of it in the atmosphere at any given time. Water vapor is the most common heat-trapping gas.

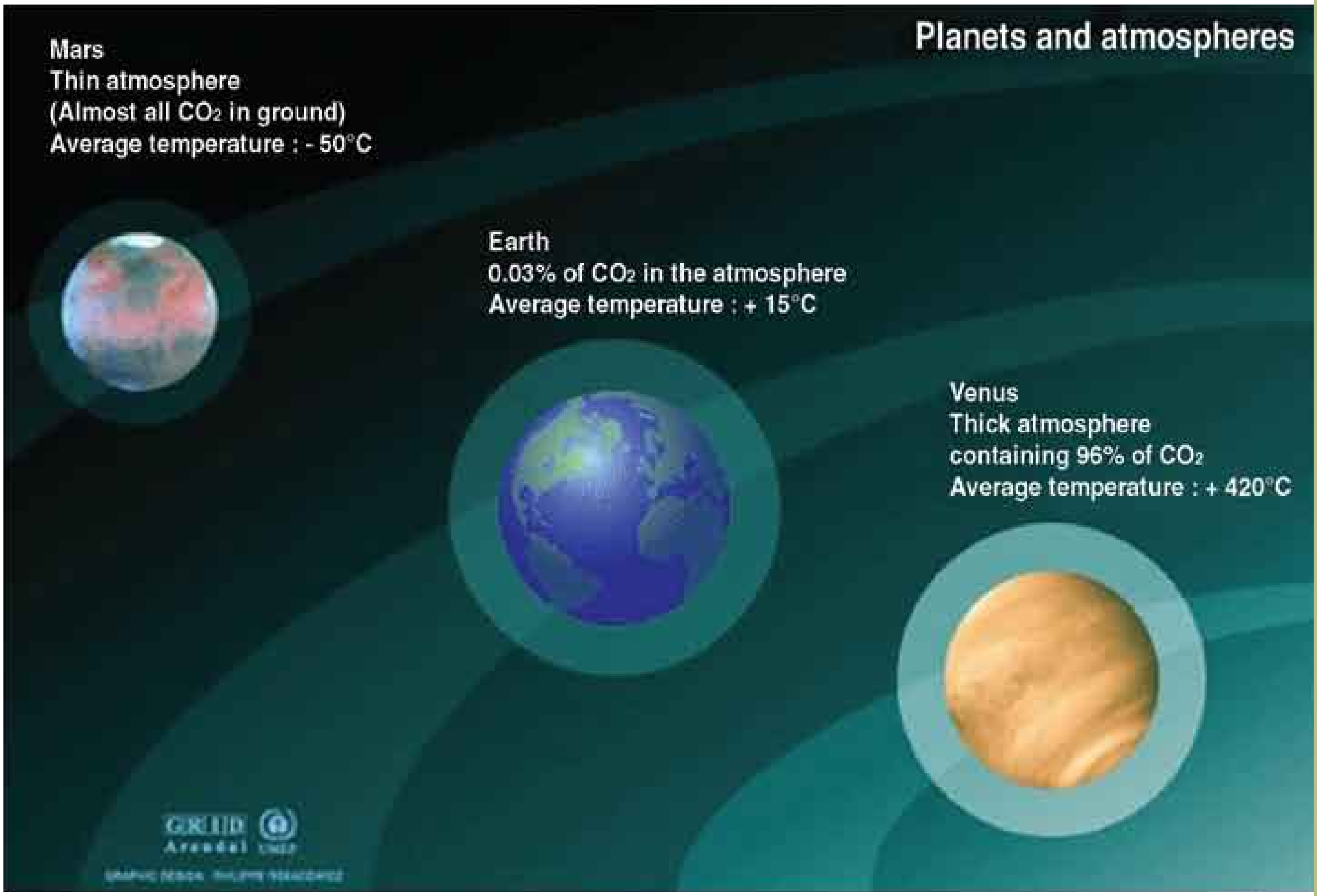
As we learn more about the greenhouse effect and global warming, we will be hearing a lot more about carbon dioxide and methane. Both of these gases have a big impact on how much heat is trapped in the lower atmosphere.

The concentration of gases in the atmosphere is measured in parts per million (ppm), parts per billion (ppb) or parts per trillion (ppt). For reference, concentrations of carbon dioxide are currently about 380 ppm and concentrations of methane are about 1,800 ppt.

Reading Number 3:
The greenhouse effect

Have you ever noticed that on a sunny day, the temperature is much higher inside of your car than it is outside when your car has been parked in the sun with the windows rolled up? Or have you ever gone inside of a greenhouse where plants are grown in the winter months and noticed that the temperature is much higher inside than it is outside? If you have, then you've experienced a greenhouse effect. The earth has a layer of gases that, although not a perfect analogy, act like the layer of glass on a greenhouse or in your car and trap heat that would otherwise be lost to space. The way it works is that energy, in the form of light and heat, comes from the sun. That energy is either reflected by the earth or absorbed and then re-radiated back towards space. When this out-going energy hits the layer of heat-trapping gases, some of it passes through back out into space, but some of it gets trapped and re-reflected back to earth. This keeps the temperature on Earth warmer than the temperature in space.





The atmosphere and this heat-trapping effect make life as we know it possible on earth. Without the heat-trapping gases in our atmosphere, temperatures on earth would average around 0 degrees F (-18 degrees C) and the surface of the earth would be frozen. Without an atmosphere, the temperatures on the earth would be more like they are on the moon. Because the moon doesn't have the atmosphere acting like a blanket, insulating the moon from the sun on the side that faces the sun and trapping heat on the dark side of the moon, temperatures vary dramatically between the side of the moon that faces the sun and the dark side of the moon. In fact on the side of the moon that faces the sun, the temperatures can reach 260 degrees F (water boils at 212 degrees F). On the dark side of the moon, it can get as cold as -280 degrees F.

On the earth there is a difference in temperature between the day and the night (this is called *diurnal variation*), but it is nowhere near the difference in temperatures experienced on the moon between the light side and the dark side. This is because of our atmosphere and our heat-trapping gases.

If a planet has a lot more heat-trapping gases, the temperature would be much hotter. For example, Venus has a much higher concentration of heat-trapping gases, and temperatures on the surface are above 350 degrees F (177 C). That is hot enough to melt lead!

Lesson Three:
Emissions of Heat-trapping Gases

Subjects

Science, Social Studies, Geography, Environmental Education, Language Arts

Estimated time

At least forty minutes

Grade Level

6-12

Objectives

- Students will be able to explain how increased atmospheric concentrations of heat-trapping gases warm the atmosphere.
- Students will be able to predict what will happen to global temperatures if atmospheric concentrations of heat-trapping gases increase.
- Students will be able to identify sources of heat-trapping emissions.
- Students will calculate their carbon footprint and identify ways they can reduce it.

Materials

Visual Aid displaying graphs for students. Handout Included, or you can contact WWF for electronic versions

Before You Begin

Several days before you plan to teach this lesson, ask students to record the following information about their home and family energy use:

- How do you heat your house: electric, natural gas or heating oil?
- On average, how many miles a week do you ride in or drive a car?
- What is the average gas mileage of the cars you drive or in which you ride?
- On average, how much does your family spend on electricity each month?
- On average, how much does your family spend on natural gas each month?
- On average, how much does your family spend on heating oil each month?
- What materials do your family currently recycle (glass, plastic, cardboard, aluminum and steel, newspaper)?

Lesson designed by Elizabeth K. Andre for the Will Steger Foundation.

Emissions of Heat-Trapping Gases

Procedure

1. Ask students to recall how the earth's atmosphere is structured, which atmospheric gases trap heat, and how global warming works. Answers should cover the following information:

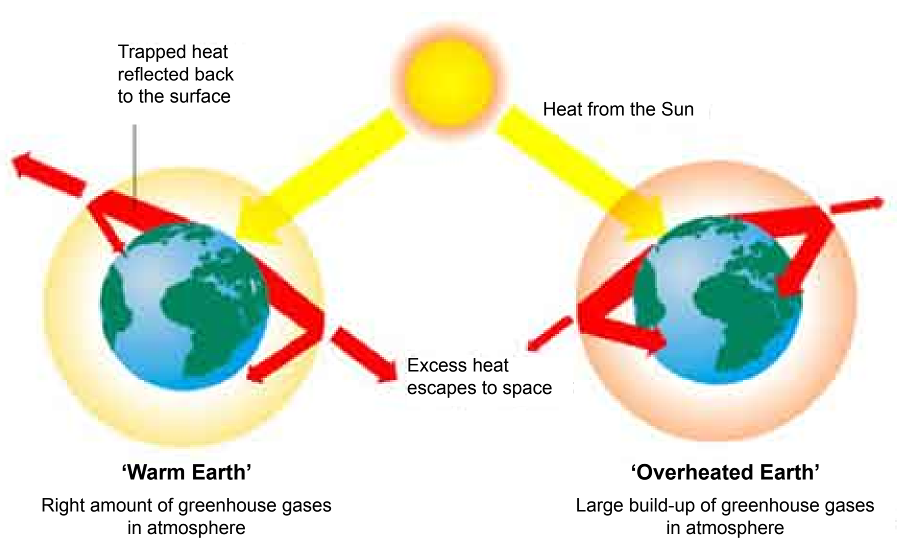
- When compared with the size of the earth, the atmosphere is a relatively thin layer of gases.
- Based on temperature, the atmosphere is divided into four layers: the troposphere, stratosphere, mesosphere and thermosphere.
- Heat-trapping gasses accumulate in the troposphere and include carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), water vapor (H_20), and chlorofluorocarbons (CFCs).
- The earth absorbs energy from the sun and then re-emits that energy back towards space. Some of that energy is absorbed by heat-trapping gasses and re-emitted back towards earth. This is what some scientists refer to as the greenhouse effect.
- Heat-trapping gasses make life as we know it possible on our planet. Without them, Earth would be a frozen wasteland with an average temperature of 0 degrees F (-18 degrees C). (5 min)

2. Ask students to predict, based on their understanding of the atmosphere and heat-trapping gases, what would happen with increasing levels of heat-trapping gases in the atmosphere. Students should be able to guess that more heat-trapping gases would hold more heat in the atmosphere and prevent it from radiating back into space. If they are having trouble guessing this, you could ask them what happens when they add more blankets to their bed.

(Note: Some students may have heard that global warming is "junk science" or that there is a big debate over whether or not it is really happening. You can let them know that there is no debate about whether or not increased levels of heat-trapping gases in the atmosphere will warm the planet. This is atmospheric physics. The only uncertainty lies in how much and how quickly the planet will warm.)

3. After students guess that increased levels of heat-trapping gasses will warm the planet, let them know that is correct. Show them the following visual and ask a student to summarize what is being illustrated. (Note: carbon dioxide (CO_2) is not the only heat-trapping gas.) (5 min)

Heat Escapes: The Enhanced Greenhouse Effect

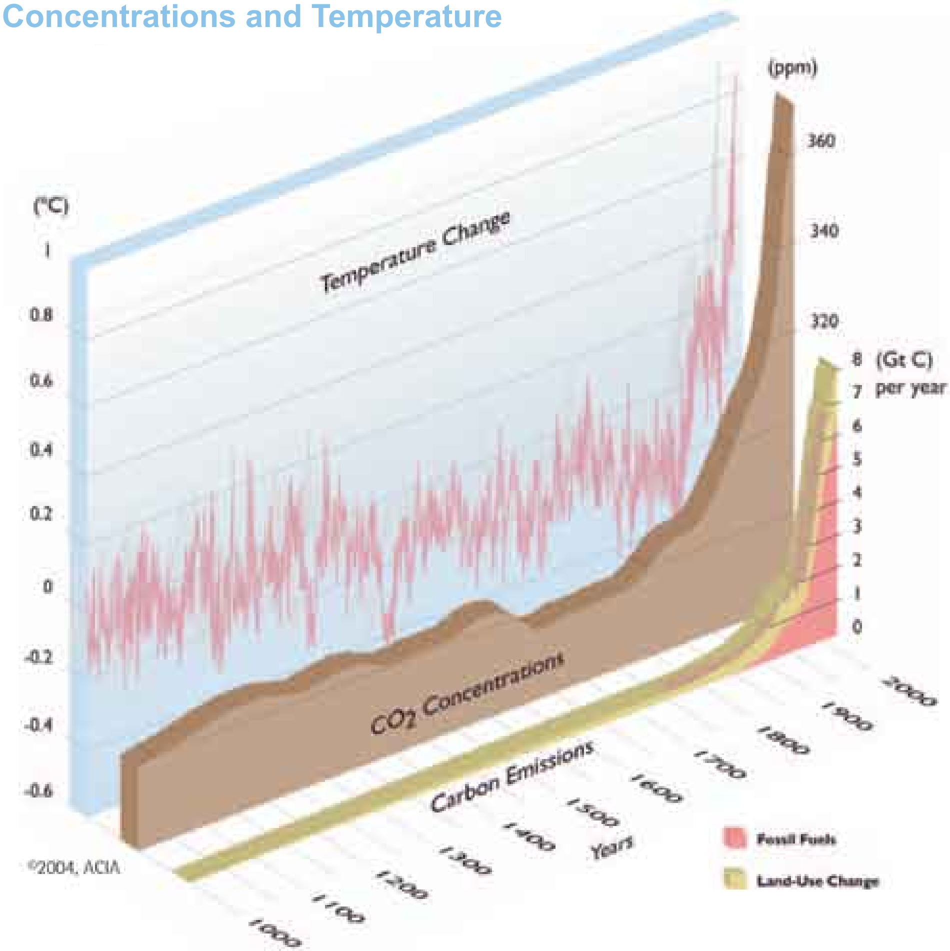


Source: http://www.thinkquest.org

4. Share with the students the following two graphs that show carbon dioxide (CO_2) levels and temperature change over the past 1,000 years and past 160,000 years (Source: Hassol, S. J., Correll, R., Prestrud, P., Weller, G., Anderson, P.A., Baldursson, S., et al. (2004).*Impacts of a Warming Arctic: Cambridge University Press, England).* Give the students several minutes to study the two graphs. Ask them to try to figure out on their own what the graphs are illustrating (you can let them know that *ppm* is an abbreviation for "parts per million" and *Gt C* is an abbreviation for "giga-tons of carbon"). (2 min)

5. Then ask the students to partner with the person sitting next to them. The pairs of students should discuss the graphs together and make sure that their partner understands what the graphs are representing. Let the students know that if they and their partner cannot understand the graph they can ask the pair sitting next to them. Let the students know that you are going to call on one student to explain the graphs to the class and that it is each person's responsibility to make sure that his or her partner understands the graphs. (2 min)

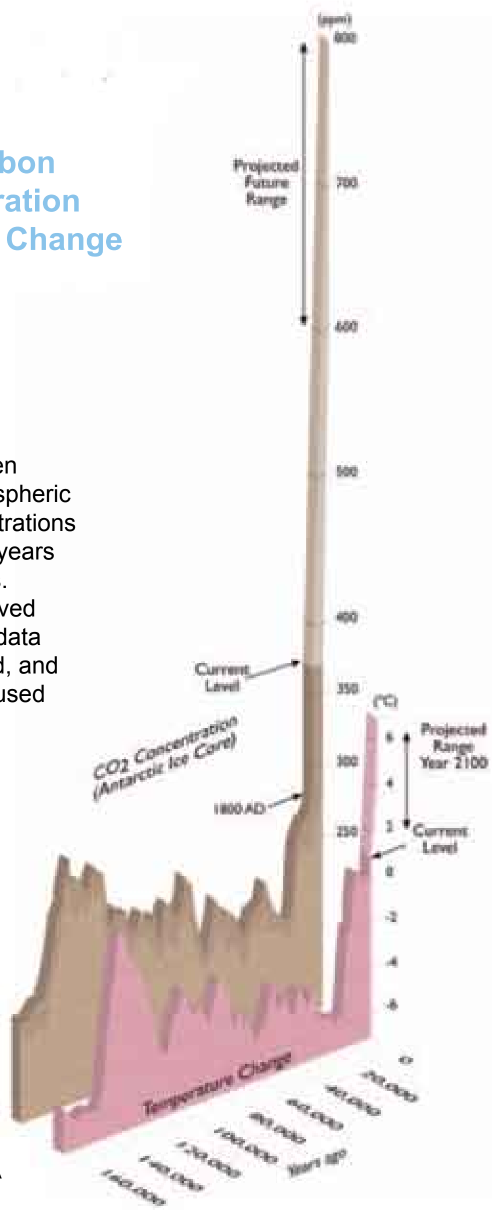
1000 Years of Changes in Carbon Emissions
CO_2 Concentrations and Temperature



This 1000-year record tracks the rise in carbon emissions due to human activities (fossil fuel burning and land clearing) and the subseqent increase in atmospheric carbon dioxide concentrations, and air temperatures. The earlier parts of this Northern Hemisphere temperature reconstruction are derived from historical data, tree rings, and corals, while the later parts were directly measured. Measurements of carbon dioxide (CO_2) in air bubbles trapped in ice cores form the earlier part of the CO_2 record; direct atmospheric measurements of CO_2 concentration began in 1957.

Atmospheric Carbon Dioxide Concentration and Temperature Change

This record illustrates the relationship between temperature and atmospheric carbon dioxide concentrations over the past 160,000 years and the next 100 years. Historical data are derived from ice cores, recent data were directly measured, and model projections are used for the next 100 years.



6. Ask a student to explain the graph to the class. Student responses should cover these points:

- As CO2 concentrations increase, global average temperature increases.
- CO2 concentrations are now higher than they have been at any time in the past 160,000 years.
- There is a range of projected future levels of both CO2 and temperature.
- Human-caused emissions of carbon come from both the burning of fossil fuels and from land-use changes such as deforestation and land-clearing.
- The majority of human-caused carbon emissions today comes from the burning of fossil fuels. (5 min)

  (Note: The reason there is a range of projections for both atmospheric CO2 concentrations and temperature is 1) to account for different scenarios of human response to a changing climate and 2) to account for uncertainty in climate models.)

7. Now that students understand that increased atmospheric concentrations of heat-trapping gases will warm the planet and what the sources are of human-caused emissions, they will calculate the amount of heat-trapping emissions for which they are directly responsible and learn ways they could reduce their emissions.

8. If students have access to the internet in class, ask them to enter the answers they researched about their home and family energy use into the U.S. Environmental Protection Agency's greenhouse gas calculator at http://www.epa.gov/climatechange/emissions/ind_calculator.html. (5 min)

> *(Note: If your students do not have internet access in class, make this a homework activity and give them several days advance notice to complete it. If you have internet access in class as a teacher, but the students do not have access in class, have one student volunteer to share his or her information on home and family energy use. Enter his or her information into the EPA calculator and share the process and results with the rest of the class. If there is no internet access in your class, you can still make rough calculations of personal carbon emissions by using the EPA's Global Warming Wheel Card that you can order from the National Service Center for Environmental Publications (NSCEP) at 1-800-490-9198 or download, print, and assemble in advance.)*

9. Give each student a list of twenty ways they can reduce their personal emissions of heat-trapping gases. The list is available for download at http://www.undoit.org/graphics/undoit_steps.pdf.

10. Have each student identify actions from the list that he or she could conceivably take. Each student should then calculate the total amount of heat-trapping emissions that he or she would save by taking these actions. (10 min)

11. Each student should then convert these numbers to more-easily conceptualized quantities at the U.S. Climate Technology Cooperation Gateway at http://www.usctcgateway.gov/tool/. This site is recognized by the U.S. Environmental Protection Agency. (5 min)

> *(Note: If there is no internet access in your classroom, consider visiting this site in advance and calculating some of your figures to share with the class. For example, you might decide to wash your clothes in cold or warm water instead of hot. This would amount to an annual savings of 350 pounds of carbon dioxide (CO_2). At the U.S. Climate Technology Cooperation Gateway site, you could convert this number to the more easily conceptualized 18 gallons of gasoline or the amount four tree saplings would take up in ten years of growing.)*

Homework: Each student writes his or her thoughts and ideas about heat-trapping emissions. Suggested topics for student writing could include: actions they will take to reduce heat-trapping emissions, why they chose those actions, their predictions of how much effort it will take to make these changes, factors that may inhibit them from taking some of the actions, factors they see keeping other people from taking action, etc.

WWF Extension Activity

Prior to starting this activity teachers should look up the population of the towns, cities, and states that the students reside in as well as the population of the United States and of the world.

Have each of the students write the total amount of heat-trapping emissions that he or she would save, from section 9, onto the blackboard. Next have them calculate the class average. While the students are doing their calculations write the population statistics on the board and ask the students to calculate the average savings if everyone in their town, city, state, country and world would take emissions reducing precautions like the ones they just researched. This calculation is as simple as multiplying the class average by the population statistics at the different scales (town, city, country, world). Finally, have the students enter the number into the calculator used in step 10 in order to more-easily conceptualize their results.

Discuss these results and what they think it means. A few sample questions to broaden the discussion are:

1. How many of you are going to try and implement some of the activities you researched?
2. What do you think it would take to convince others to try and implement emission-reducing activities?
3. Should the government play a role in illustrating to people how their every day actions can influence the environment? Do they already? If not, who?

Notes to the teacher:

- There is a large amount of misinformation in the general public about global warming. Students may have heard that humans are not causing global warming—that the earth goes through natural cycles of warming and cooling and that the warming that we've experienced over the last two-hundred years is caused by something other than human activity. Let your students know it is true that the earth does go through periods of warming as well as periods of cooling and has done this several times in the history of the planet. The intense and rapid warming that we have experienced over the past hundred years, however, can be explained only when human impacts are factored in. There is broad international scientific consensus that the majority of warming over the past several decades is caused by human activity.

- One of the most common misconceptions is that human-caused emissions of heat-trapping gases are insignificant because the majority of heat-trapping gas in the atmosphere is water vapor that is naturally occurring. It is true that on a sunny day water vapor is responsible for as much as 70% of the greenhouse effect, compared with 25% for carbon dioxide. The difference, however, is that water vapor stays in the atmosphere for only a short time (days) before it falls as precipitation. Heat-trapping emissions from human sources (burning fuels or deforestation), by contrast, can have a very long life in the atmosphere, so they keep accumulating. For example, the atmospheric lifetime of CO2 is estimated at 200 to 450 years (unless an individual CO2 molecule is taken up by plants or absorbed by the ocean) and the heat-trapping gas tetraflouromethane has an atmospheric lifetime of 50,000 years. Also, the more the atmosphere warms, the more water vapor it can hold, which in turn causes the atmosphere to warm more until it reaches equilibrium.

- Another common misconception is that because a warmer atmosphere can hold more water, more clouds will cool the planet enough to offset the warming from the increased concentrations of heat-trapping gases. It is true that clouds can have a regional cooling effect, but their long-term effect is an area of active research among scientists.

(Source: Albritton, D. L., Meira Fiho, L. G., Cubasch, U., Dai, X., Ding, Y., Griggs, D.J., et al. (2001). *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, England).

National Standards Alignment:

National Science Education Standards

Unifying Concepts and Processes (5-12): Systems, order, and organization; Evidence, models, and explanation; Change, constancy, and measurement

Earth and Space Science (5-12): Structure of the earth system; Energy in the earth system

Science in Personal and Social Perspectives (5-12):Populations, resources, and environments; Environmental quality; Natural and human induced hazards; Science and technology in local, national, and global challenges

Curriculum Standards for Social Studies

Strand 3: People, places, and environments

Strand 7: Production, distribution, and consumption

Strand 8: Science and technology

Strand 9: Global connections

National Geography Standards

Physical Systems: Standard 7: The physical processes that shape patterns on the Earth's surface.

Environment and Society: Standard 14: How human actions modify the physical environment.

Environmental Education (K-12)

Strand 1: Questioning and Analysis Skills: Designing investigations; Collecting information; Working with models and simulations; Developing explanations

Strand 2.1: Knowledge of Environmental Processes and Systems: The Earth as a Physical System; Processes that shape the earth; Energy

Strand 2.3: Knowledge of Environmental Processes and Systems: Humans and Their Societies; Change and conflict

Strand 2.4: Knowledge of Environmental Processes and Systems: Environment and Society; Human/environment interactions; Technology; Environmental issues

Strand 3: Skills for Understanding and Addressing Environmental Issues: Forming and evaluating personal views; Evaluating the need for citizen action; Planning and taking action; Evaluating the results of actions

Strand 4: Personal and Civic Responsibility: Accepting personal responsibility

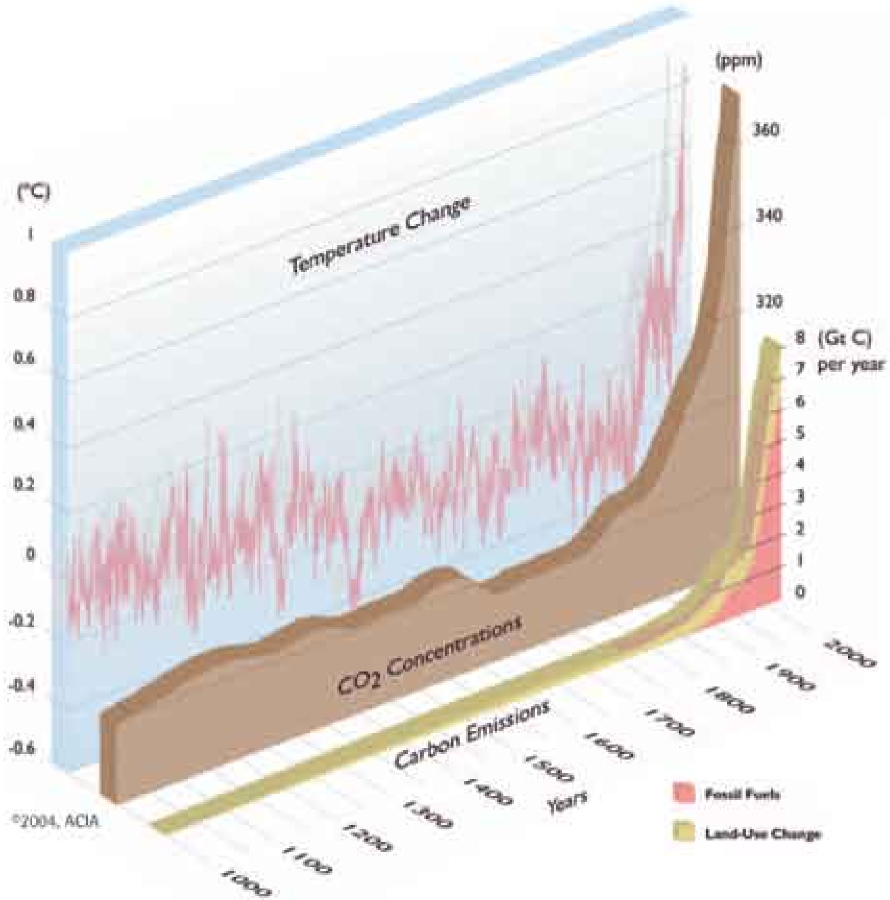
Language Arts

Standard 7: Students conduct research on issues and interests by generating ideas and questions, and by posing problems. They gather, evaluate, and synthesize data from a variety of sources (e.g. print and non-print texts, artifacts, people) to communicate their discoveries in ways that suit their purpose and audience.

Standard 8: Students use a variety of technological and informational resources (e.g. libraries, databases, networks, video) to gather and synthesize information and create and communicate knowledge.

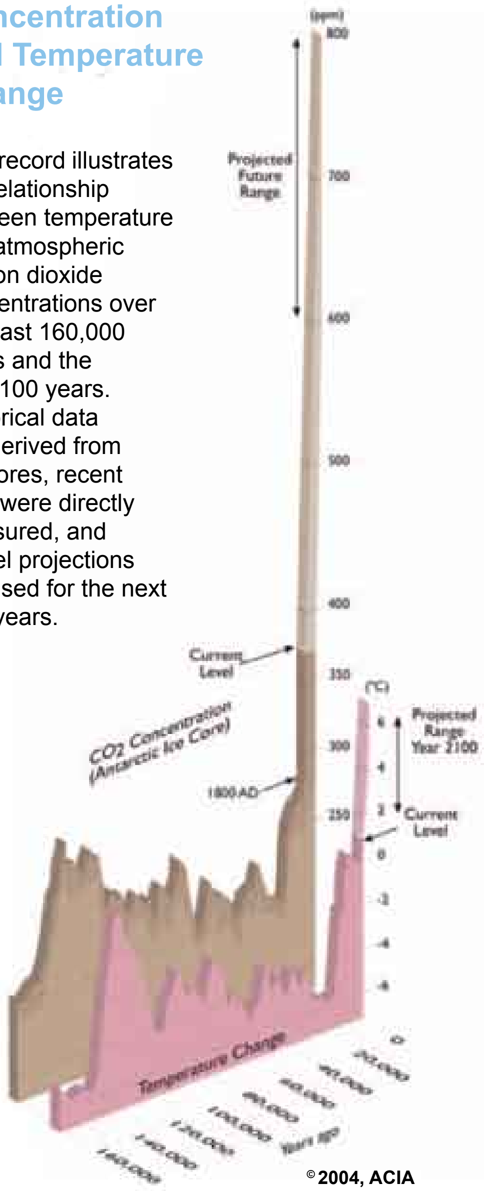
This 1000-year record tracks the rise in carbon emissions due to human activities (fossil fuel burning and land clearing) and the subseqent increase in atmospheric carbon dioxide concentrations, and air temperatures. The earlier parts of this Northern Hemisphere temperature reconstruction are derived from historical data, tree rings, and corals, while the later parts were directly measured. Measurements of carbon dioxide (CO_2) in air bubbles trapped in ice cores form the earlier part of the CO_2 record; direct atmospheric measurements of CO_2 concentration began in 1957.

1000 Years of Changes in Carbon Emissions CO_2 Concentrations and Temperature

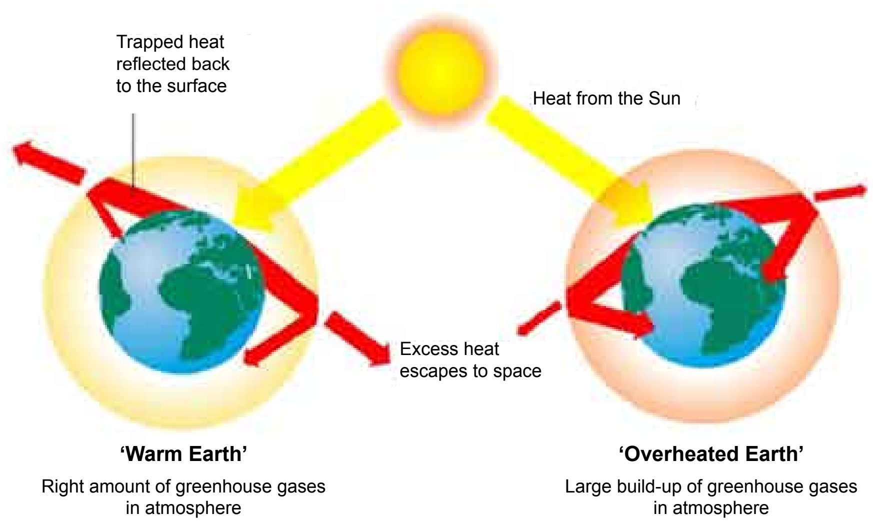


Atmospheric Carbon Dioxide Concentration and Temperature Change

This record illustrates the relationship between temperature and atmospheric carbon dioxide concentrations over the past 160,000 years and the next 100 years. Historical data are derived from ice cores, recent data were directly measured, and model projections are used for the next 100 years.



Heat Escapes: The Enhanced Greenhouse Effect



Source: http://www.thinkquest.org

Lesson Four:
Communities of Living Things

Subjects

Sciences, Social Studies, Geography, Environmental Education, Language arts, Theater

Estimated Time

One 45-minute class period

Grade Level

6-12

Objectives

- Students will be able to explain how changing weather patterns, a changing balance of competitors, and changes in the availability of food and shelter can increase uncertainty for communities of living things.
- Students will be able to give examples of these uncertainties and disruptions from the Arctic communities.
- Students will predict how continued warming may affect communities of living things with which they are familiar.

Materials

The following readings should be made available to the class:

- Reading 1: Polar Bears
- Reading 2: Ice-edge Dwellers
- Reading 3: Land-Dwellers
- Reading 4: Plant Communities
- Reading 5: Human Communities

(Note: All of these are provided for you in this curriculum, but can also be found at the following website free of charge: www.Globalwarming101.com.)

Lesson designed by Elizabeth K. Andre for the Will Steger Foundation.

Communities of Living Things

Procedure

Divide students into as many as five groups, depending on the number of students in the class. If there are not enough students to make five groups of at least two or three students, make fewer groups. Give each group one of the readings about impacts of global warming on communities of living things (use scrap paper to print these if possible). If you have fewer than five groups, consider giving more than one set of passages to a group.

- Reading 1: Polar Bears
- Reading 2: Ice-edge Dwellers
- Reading 3: Land-Dwellers
- Reading 4: Plant Communities
- Reading 5: Human Communities

  Reference: Hassol, S. J., Correll, R., Prestrud, P., Weller, G., Anderson, P.A., Baldursson, S., et al. (2004). *Impacts of a Warming Arctic,* Arctic Climate Impact Assessment. Cambridge University Press, England

Have students take turns reading aloud sections of their passage to the rest of their group. (5 min)

Next have each group discuss the impacts described in their passages and then plan a skit to illustrate these impacts. Skits should be a maximum of three minutes long. Groups will have very little time to plan their skits, so let them know in advance that skits do not need to be "polished." They should be impromptu, quickly moving and fun. (5 min)

The entire class should then reconvene and groups should take turns presenting their skit. After each group's skit, one member of the group should explain to the entire class the impact they were illustrating, including Arctic-specific examples from the passage. To allow for transition time between groups and to allow time for each group to explain the concepts in their skit, plan for five minutes for each group. (25 min)

Homework: Each student thinks of a way in which continued global warming could affect a community of living things with which he or she is familiar. Each student then writes up his or her ideas and submits them to the teacher. Students may also read the essays from other students and see how their ideas compare.

Notes to the teacher

- As the students are reading the passages to each other and planning and practicing their skits, circulate between the groups and listen to each group for a few moments to gauge the progress of the groups and to make certain that students are focusing their efforts on the task. Before dividing the students into groups, explain the entire activity to them and let them know how much time they will have for each section of the activity.
- Clearly set the expectation that skits should respect other members of the class and respect the living beings portrayed in the skits. Let students know that no inappropriate language, harassing, discriminatory content, or explicitly sexual or violent portrayals will be tolerated.
- Monitor the time closely to ensure that all groups have time to present their skit. Give groups a "two minute warning" and a "one minute warning."

National Standards Alignment

National Science Education Standards

Unifying Concepts and Processes Standards (K-12): Systems, order, and organization

Life Science Standards (5-12): Structure and function in living systems; Regulation and behavior; Populations and ecosystems; Diversity and adaptations of organisms; Biological evolution; Interdependence of organisms; Behavior of organisms

Science in Personal and Social Perspectives (5-12): Populations, resources, and environments; Population growth; Personal and community health; Natural Resources; Environmental quality; Natural and human induced hazards

Curriculum Standards for Social Studies

Strand 1: Culture

Strand 3: People, Places, and Environments

Strand 7: Production, Distribution, and Consumption

Strand 8: Science Technology and Society

Strand 9: Global Connections

National Geography Standards

Environment and Society: Standard 14: How human actions modify the physical environment

Environment and Society: Standard 15: How physical systems affect human systems

Environment and Society: Standard 16: The changes that occur in the meaning, use, distribution, and importance of resources.

Environmental Education Guidelines for Learning (K-12)

Strand 1: Questioning and Analysis Skills: Developing explanations

Strand 2.2: Knowledge of Environmental Processes - The Living Environment: Organisms, populations, and communities; Systems and connections

Strand 2.3: Knowledge of Environmental Processes – Humans and Their Societies: Culture; Political and economic systems; Global connections

Strand 2.4: Knowledge of Environmental Processes – Environment and Society: Human/environment interactions; Resources; Technology; Environmental issues

Strand 3.1: Skills for Understanding and Addressing Environmental Issues – Skills for Analyzing and Investigating Environmental Issues: Identifying and investigating issues; Sorting the consequences of issues

Standards for the Language Arts

Standard 4: Students adjust their use of spoken, written, and visual language (e.g. conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.

Standard 12: Students use spoken, written, and visual language to accomplish their own purposes (e.g. for learning, enjoyment, persuasion, and the exchange of information).

National Standards for Arts Education

Theater: Content Standard 2: Acting by assuming roles and interacting in improvisations

Theater: Content Standard 5: Researching by finding information to support classroom dramatizations

Reading One: Polar Bears

Impact: Difficulty getting food.

Polar bears hunt ice-dwelling seals. The polar bears walk quietly on the ice to the edge of a seal's breathing hole in the ice. The bear then waits for the seal to surface for air. This hunting technique takes much less energy for the bear than chasing a seal while swimming. If warmer conditions cause the ice to form later in the fall and break up earlier in the spring, become unstable, or retreat too far from shore, polar bears will have difficulty getting enough food. In fact, if the ice retreats too far from the shore, bears can drown trying to swim out to the ice.

If a female bear doesn't get enough food, she will have less fat stored to help her have cubs. Underweight females have fewer and smaller cubs that are less likely to survive. When the polar bear mother and cubs emerge from their den in the spring, it will have been between five and seven months since the mother has eaten. She will need to be successful hunting for her family to survive. She needs ice on which to hunt.

Impact: Loss of shelter.

In addition to making it more difficult for polar bears to get food, global warming can also directly cause bear deaths. For example increased number and strength of spring rainstorms can cause bear dens to collapse.

Impact: Barriers to travel.

Earlier break-up of sea ice can separate traditional den sites from feeding areas and young cubs would not be able to swim to the feeding areas.

Impact: Competition from newly arrived species.

As the climate warms, grizzly bears extend their range to the north. Grizzly bears are more aggressive than polar bears and can out-compete them. They can also interbreed with polar bears, thereby reducing the numbers of non-hybrid polar bears.

Impact: Increased pollution due to climate change.

Many of the air pollutants from the industrialized parts of the northern hemisphere reach the Arctic through the circulation of the atmosphere and the flow of water. Climate change is predicted to bring more precipitation (snow and rain) and higher river flows to the Arctic. This will bring more chemical contaminants. Plants and animals that are low on the food chain will absorb these pollutants and then seals will eat them and absorb those pollutants at higher concentrations. Polar bears, at the top of the food chain, will eat seals and absorb the pollutants at even higher concentrations. Pollution stored in polar bears can affect their health, especially when they are already weak from not getting enough food.

Polar Bear, Ursus maritimus, mother with cubs. Churchill area, Manitoba, Canada

Reading Two: Ice-edge Dwellers

Impact: Habitat disintegrating.

Ice-dependent seals like the ringed seal, ribbon seal and bearded seal give birth and nurse their pups on the ice. They make their lairs out of snow on top of the ice. If there is not enough snow cover, they will have difficulty rearing their young. If the ice breaks up too early, pups can be separated from their mothers and drown. The seals also use the ice to rest.

Observed sea ice September 1979 **Observed sea ice September 2003**

The two images above, constructed from satellite data, compare arctic sea ice concentrations in September of 1979 and 2003. September is the month in which sea ice is at its yearly minimum and 1979 marks the first year that data of this kind became available in meaningful form. The lowest concentration of sea ice on record was in September 2002.

Impact: Difficulty getting food.

Walrus depend on the sea ice to find food. The edge of the ice is an area rich in plant and animal life. The most productive areas are over the shallow water nearest to the coasts. Walrus can use the ice to rest and then dive down to the bottom to eat clams and other shellfish that grow there. When the ice edge retreats away from the shallow areas, there will be fewer clams nearby for the walrus to eat.

Some sea birds like ivory gulls and little auks also depend on the ice to find food. The ivory gull nests on rocky cliffs near the ocean and then flies to the nearby sea ice to fish through cracks in the ice and scavenge for food left on top. If the sea ice retreats too far from the coast the birds have difficulty getting enough food.

Atlantic walrus (Odobenus rosmarus rosmarus), Apalona Island, Franz Josef Land, Svalbard, Spitsbergen, Norway. Arctic archipelago

Impact: Competition from newly arrived species.

Inuit people report seeing new animals they have never seen before. These animals are expanding northward as the climate warms and now compete with native Arctic species for food and habitat.

© WWF-Canon / Wim Van Passel

Reindeer (Rangifer tarandus). Reindeer are herbivores and the most northern of all the deer. They are the only deer where both the females and males have antlers. They feed on lichens and grasses. Alkhornet , Franz Josef Land, Svalbard, Spitsbergen, Norway. Arctic archipelago

Reading Three: Land Dwellers

Impact: Difficulty getting to food.

Global warming has affected the winter temperature and precipitation in the Arctic. Precipitation that once fell as snow now increasingly falls as freezing rain. This freezing rain as well as increasingly-common freeze-thaw events (when the changing temperature rises above freezing and snow begins to melt and then falls below freezing and the water turns to ice), can cover plants in a layer of ice. Even if the plants can survive being covered in ice, animals have difficulty reaching the plants and can starve. Lemmings, musk ox and reindeer/caribou have all had large die-offs due to ice crusting making their food inaccessible.

Impact: Disintegration of shelter.

Even though snow may seem cold to you, it provides much-needed insulation for small animals like lemmings and voles, who live and find food in the space between the frozen ground and the snow. For them, the snow is a shelter from the cold winds and very cold air temperatures. Mild and wet winter weather can reduce the ability of the snow to provide insulation and can even make the under-snow spaces collapse. Some animals such as snowy owls, skuas, and ermines hunt lemmings and voles and almost nothing else. If numbers of lemmings and voles decline due to disintegration of their shelter, numbers of their predators will decline as well.

© WWF-Canon / Vladimir Filonov

Siberian weasel, Mustela sibirica, in the rocks. Lazovsky State Nature Reserve. Far East. Russian Federation

Reading Four: Plant Communities

Impact: Thawing permafrost destabilizes the soil.

The ice in the permafrost (permanently frozen ground) helps maintain the structure of the soil. When it melts, trees can start to fall over or sink-holes can develop which then seasonally fill with water and kill trees living there.

Impact: Thawing permafrost drains wetlands and ponds.

In some Arctic wetlands, ponds and lakes, the water is perched on top of a layer of permafrost. The permafrost acts like the countertop in your kitchen and the wetlands are like a sponge that is completely full of water sitting on top of the counter. If the permafrost melts, then the water can drain out of the wetlands and ponds just like the water would drip out the bottom of the sponge if there were no countertop. When wetlands and ponds drain, not only are the plants that live there affected, but also the fish and other animals that rely on the water.

Impact: Potential desertification.

Even though the total amount of precipitation is projected to increase in the Arctic, precipitation may come at times of the year when plants do not need it, or it may come in extreme events where most of it runs off to the rivers quickly. Also, as the temperatures get warmer, more water will evaporate and plants will transpire more water. Both processes acting together, known as evapotranspiration, send water back into the atmosphere. It is possible that in certain areas the increased precipitation may not be able to keep up with the increased evapotranspiration. If this happens, areas can dry out and become polar deserts.

Impact: Insect pests thrive with warmer temperatures.

When winters are long and very cold and when summers are short, as they traditionally have been in the Arctic, numbers of pests like the spruce bark beetle are kept in check. Spruce bark beetles can kill spruce trees. Warmer winters mean that more bark beetles survive each year. Also, the bark beetle usually needs two years to complete its life cycle. When the summers are unusually warm and long, however, bark beetle lifecycles can be accelerated and take only one year. This means that there will be many more beetles. Also, healthy spruce trees have natural defenses against bark beetle attacks. When the beetles try to bore into the tree to lay eggs, the tree can push pitch (sap) out against the beetle and keep her from being able to get into the tree far enough to lay eggs. When trees are stressed from drought and warmer than normal temperatures, however, they do not have enough pitch to fight the beetles.

Spruce forest killed by Bark beetle. National Park "Bavarian Forest", Germany.

Similarly, spruce bud worms, another pest that can kill spruce trees, lay more eggs when it is warmer. Also, warmer temperatures make spruce bud worms change the time of their reproduction. When this happens, the natural predators of the spruce bud worm are not available or ready to eat them, so bud worm numbers increase.

Impact: Competition from invading species.

As temperatures warm, plant species begin to shift their ranges northward, invading areas previously inhabited by Arctic species. Many of the adaptations that allow Arctic species to survive in such cold conditions also limit their ability to compete with invading species. For example, when the temperature gets above about 60 degrees F (16 degrees C), black and white spruce trees are not able to grow as well. If temperatures get too hot, the black and white spruce will not be able to grow at all.

Impact: Increased forest fires.

As climate warms and forests dry, forest fires increase. The average area of North American Boreal (northern) forests that burns each year has more than doubled since 1970.

Reading Five: Human Communities

Impact: Diminishing food supplies.

For thousands of years, groups of people (Native peoples of the Arctic, formerly known as Eskimos) have relied on hunting caribou to have enough food to survive through the cold seasons. Today the Inuit have access to food that is shipped into stores. For many Inuit families, however, store-bought food is too expensive to be their sole source of food. For this reason as well as for cultural reasons, Inuit rely on the caribou hunt for much of their food source. As numbers of caribou decline due to climate change-related impacts, the Inuit can face hardships.

The Inuit also hunt seals, walrus, polar bears, whales, moose, musk ox, ducks, geese, ptarmigan and fish. As the number and location of these animals are impacted by climate change, the Inuit will also face changes to their diet.

Impact: Decline in cultural resources.

In addition to using caribou for food, Inuit people also value caribou as an important part of their mythology, spirituality and cultural identity.

Impact: Inability to reach hunting grounds.

Climate-related changes can make it difficult for Inuit hunters to reach the places where they hunt. For example, unusually deep snow, late freeze-up and early break-up of river and sea ice can make travel treacherous or impossible.

Impact: Difficulty traveling and navigating.

Many Inuit villages are accessible only by dogsled, snowmobile, or sometimes on roads over permafrost (permanently frozen ground). As the snow and ice-free period of the year gets longer, travel by dogsled or snowmobile becomes difficult or even impossible. As the permafrost melts earlier and to a greater depth, the roads become impassable mud-pits. Also, some Inuit people use the prevailing wind direction to navigate over frozen tundra and sea ice. For many generations these winds have always blown in the same direction. As weather patterns change, the wind can change direction and Inuit may get lost trying to find important cultural sites.

Little church in the Inuit village of Ittoqqortoormiit (Scoresbysund), one of the most remote of Greenland's towns, Denmark

Impact: Erosion of coastal communities.

Warmer ocean water and air can melt the permafrost that stabilizes coastal land and shorelines. This, combined with rising sea levels and a reduction in the shore ice and sea ice that once buffered the wave action from storms, can make coastal buildings, pipelines and roads fall into the ocean and flood low-lying areas, contaminating them with salt.

Impact: Increased accessibility to ships.

As the sea ice diminishes, ocean that previously was locked in ice and therefore inaccessible to most ships can now be navigated. For example, in Pangnirtung, a remote Inuit village on the southern tip of Baffin Island in the Canadian Arctic, a cruise ship recently arrived and unloaded its passengers into a village that before was accessible only by air or dogsled.

Impact: Increased pollution due to climate change.

Many of the air pollutants from the industrialized parts of the northern hemisphere reach the Arctic through the circulation of the atmosphere and the flow of water. Climate change is predicted to bring more precipitation (snow and rain) and higher river flows to the Arctic. This will bring more chemical contaminants. Plants and animals that are low on the food chain will absorb these pollutants and then humans will eat them and absorb those pollutants at higher concentrations. Inuit women have such high levels of PCB pollutants in their breast milk that they are asked to not breast feed their babies.

Lesson Five: Climate Change and People

Subjects

Science, Social Studies, Geography, Environmental Education, Language Arts

Estimated Time

One 45-minute class period

Grade Level

9-12

Objectives

- Students, working in groups, will each read different articles about social impacts of climate change.
- Students will be responsible for explaining what they have learned to members of the other groups.
- Students will be able to explain the effect climate change will have on the economy and people.

Materials

The following readings should be made available to the class:

- Reading Number 1: "Warm Winters Upset Rhythms of Maple Sugar"
- Reading Number 2: "Climate Change Fight Can't Wait"
- Reading Number 3: "Scientists Say Millions Could Flee Rising Seas"
- Reading Number 4: "Scientists Detail Social, Economic Costs of Unbridled Climate Change"

Prerequisite Knowledge – Teacher

- Socially, climate change will affect economic factors, habitat for humans and animal species, reduced availability of natural resources such as water or petroleum, etc.
- Social impacts include the effects on humans beyond the immediate environmental change, i.e., depleted fisheries cause unemployment and force groups to look for alternative means of survival, sea level rise causes massive inland migration, homelessness, and unemployment, tropical temperatures moving north cause the spread of diseases in locations where they have not been a problem before.

Climate Change and People

Procedure

1. Divide students into groups of four and distribute one copy of each reading into each group. Instruct the students to each read one article and take notes so they are able to explain their article to the other group members. Have the students discuss their articles in their groups and to come up with the top-five ways they believe climate change will affect people all over the world.

2. Have the students present their top-five lists to the class and explain why they think these are the most important impacts climate change will have.

3. At the end of the presentations, ask the students which social impact seems to be the most pressing at this time, or the most alarming for the future. Ask them to consider the size of the population that will be effected. Remind them to consider the effects on employment, economy, real estate, and availability of resources including food, water, gas, oil, and other necessities. Ask them to try to think beyond the obvious to discover risks that they have not yet considered, i.e., what will happen to predatory animals in the Everglades if all of their habitat is lost? What then will happen if the Florida panthers try to migrate through the suburbs of Orlando?

   Ask the students to think about what other kinds of products will be threatened by climate change, as shown in the maple syrup article. Ask them to discuss the broader implications of this specific article. Discuss the importance of these articles in relation to the financial burdens and rising sea-level issues.

Extend

1. Instruct the students to search the Web or library for articles supporting or disputing their claims as to the area of climate change that will have the most devastating impacts. Students can search environmental journals online or in the library and find valuable resources through the *Google Scholar* Web search tool. Perhaps in their original groups of four, ask the students to create posters demonstrating the results of their research. Students should offer evidence to support their conclusions, and evidence to disputer alternative ideas, perhaps those favored by other groups in class. Posters can be posted in the school or classroom to allow student to browse at their convenience.

2. In relation to the maple syrup article, ask the students to make a grocery list identifying products that will no longer be easily available with a changing climate. If warmer climates move north, what agricultural products will be able to grow in the U.S? What products will we have to begin importing from Canada, Europe, or Asia? What will happen to southern crops such as sugarcane, cotton, oranges, and tropical fruits? Instruct the students to identify the most likely outcome for the items on their grocery list, i.e., some things might be no longer available and others will have higher prices due to import taxes. Then the students should identify products which will become more available due to climate change, i.e. tropical fruits in the south or soybeans in the north.

National Standards Alignment:

National Science Education Standards

Science in Personal and Social Perspectives, Content Standard (9-12): Environmental quality; Science and technology in local, national, and global changes

Curriculum Standards for Social Studies

Strand 2: Time, Continuity, and Change

Strand 3: People, Places, and Environments

Strand 8: Science, Technology, and Society

Strand 9: Global Connections

National Geography Standards

Standard 15: Environment and Society. How physical systems affect human systems.

Environmental Education Guidelines for Learning (K-12)

Strand 1: Questioning and Analysis Skills

Strand 2: Knowledge of Environmental Processes and Systems

Strand 2.1: The Earth as a Physical System

Strand 2.4: Environment and Society

Strand 3: Skills for Understanding and Addressing Environmental Issues

Strand 3.1: Skills for Analyzing and Investigating Environmental Issues

Standards for the English Language Arts

Standard 2: Students read a wide range of literature from many periods in many genres to build an understanding of the many dimensions (e.g., philosophical, ethical, aesthetic) of human experience.

Standard 4: Students adjust their use of spoken, written, and visual language (e.g., conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.

Standard 9: Students develop an understanding of and respect for diversity in language use, patterns, and dialects across cultures, ethnic groups, geographic regions, and social roles.

Standard 12: Students use spoken, written, and visual language to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information.

The New York Times
nytimes.com

March 3, 2007

WARMING TRENDS

Warm Winters Upset Rhythms of Maple Sugar

By PAM BELLUCK

MONTPELIER, Vt. — One might expect Burr Morse to have maple sugaring down to a science.

For more than 200 years, Mr. Morse's family has been culling sweet sap from maple trees, a passion that has manifested itself not only in jug upon jug of maple syrup, but also in maple-cured bacon, maple cream and maple soap, not to mention the display of a suggestively curved tree trunk Mr. Morse calls the Venus de Maple.

But lately nature seems to be playing havoc with Mr. Morse and other maple mavens.

Warmer-than-usual winters are throwing things out of kilter, causing confusion among maple syrup producers, called sugar makers, and stoking fears for the survival of New England's maple forests.

"We can't rely on tradition like we used to," said Mr. Morse, 58, who once routinely began the sugaring season by inserting taps into trees around Town Meeting Day, the first Tuesday in March, and collecting sap to boil into syrup up until about six weeks later. The maple's biological clock is set by the timing of cold weather.

For at least 10 years some farmers have been starting sooner. But last year Mr. Morse tapped his trees in February and still missed out on so much sap that instead of producing his usual 1,000 gallons of syrup, he made only 700.

"You might be tempted to say, well that's a bunch of baloney — global warming," said Mr. Morse, drilling his first tap holes this season in mid-February, as snow hugged the maples and Vermont braced for a record snowfall. "But the way I feel, we get too much warm. How many winters are we going to go with Decembers turning into short-sleeve weather, before the maple trees say, 'I don't like it here any more?'"

There is no way to know for certain, but scientists are increasingly persuaded that human-caused global warming is changing climate conditions that affect sugaring.

While some farmers and other Vermonters suggest the recent warm years could be just a cyclical hiccup of nature or the result of El Niño, many maple researchers now say it seems more like a long-term trend. Since 1971, according to National Oceanic and Atmospheric Administration data, winter temperatures in the Northeast have increased by 2.8 degrees.

"It appears to be a rather dire situation for the maple industry in the Northeast if conditions continue to go toward the predictions that have been made for global warming," said Tim Perkins, director of the Proctor Maple Research Center at the University of Vermont.

Dr. Perkins studied the records of maple syrup production over the last 40 years and found a fairly steady progression of the maple sugaring season moving earlier and earlier, and also getting shorter.

"We had this long list of factors we started with that could possibly explain it," Dr. Perkins said. "We have eliminated all of those various factors. We are at this point convinced that it is climatic influence."

Over the long haul, the industry in New England may face an even more profound challenge, the disappearance of sugar maples altogether as the climate zone they have evolved for moves across the Canadian border.

"One hundred to 200 years from now," Dr. Perkins said, "there may be very few maples here, mainly oak, hickory and pine. There are projections that say over about 110 years our climate will be similar to that of Virginia."

Dr. Perkins and Tom Vogelmann, chairman of the plant biology department at the University of Vermont, said that while new sap-tapping technology is helping sugar makers keep up syrup production, for now, at some point the season will become so short that large syrup producers will no longer get enough sap to make it worthwhile.

"It's within, well, probably my lifetime that you'll see this happen," Professor Vogelmann said. "How can you have the state of Vermont and not have maple syrup?"

Experts say gradual warming has already contributed to a shift of syrup production to Canada, although other factors may be more responsible, including Canadian subsidies, improved technology, and a decline in New England family farms.

"In the '50s and '60s, 80 percent of world's maple syrup came from the U.S., and 20 percent came from Canada," said Barrett N. Rock, a professor of natural resources at the University of New Hampshire. "Today it's exactly the opposite. The climate that we used to have here in New England has moved north to the point where it's now in Quebec."

Maple trees are so iconic here that a good deal of tourism revolves around leaf peeping of the maples' fall tapestry, maple syrup festivals and visits to maple sugar bushes, the name for sugar maple orchards.

While there have always been some weather fluctuations, certain conditions are critical to syrup production. To make sap, trees require what Professor Rock called a "cold recharge period," several weeks of below-freezing temperatures that traditionally fell in December and January, followed by a span of very cold nights and warmer days.

Catching the first sap of the season is important because it "makes the best syrup," Dr. Perkins said. But tapping too early can cause a sugar maker to miss the back end of the season because eventually bacteria clog the holes in the trees and prevent more sap from emerging.

"It's a real conundrum the sugar producers face," Professor Rock said. "Do I tap early to catch the early sap flow or do I wait until the regular season,

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Bashkortostan (Bashkir Republic), European & Central Russia, Russian Federation. Mixed forest (pine, spruce, linden, maple, oak, birch) in the Zilmerdag range, Southern Ural Bashkortostan, Russia.

Autumn, Western North Carolina deciduous forest and countryside © Liza Schillo 2003

and maybe not get the highest quality syrup, but the tap flow remains open until the first buds on trees in April?"

In Vermont, which makes a third of the country's syrup, sugar makers are trying different approaches.

Rick Marsh, president of the Vermont Maple Sugar Makers' Association, has kept his production high by tapping his 8,000 maples in January and using a tap with a disposable tip designed to minimize bacteria growth and keep the holes open longer. Instead of having the tap spill the sap into buckets, Mr. Marsh, like many sugar makers, hooks the tap to a labyrinth of plastic tubes and uses a high-powered vacuum to suck out the sap through the tubes. "Farmers say, 'I can't afford to keep making these changes' " in technology, Mr. Marsh said. "I say you can't afford not to."

Still, Mr. Marsh, whose sugar bush in Jeffersonville is near a "Think Maple!" sign, said it was a "crapshoot" to decide when to tap. "Anybody plays poker, you're a sugar maker. If you don't get the right weather, it's like not getting the right cards. And if you misjudge the weather, it's like you misplayed your cards."

Tim Young in Waterville tapped his 10,000 maple trees in November. "The environment's changing, and I want to change with it," said Mr. Young, who made 1,800 gallons of syrup by January and has left the taps in hopes of catching a second sap run by April.

Not every sugar maker believes global warming is responsible or that the weather changes are part of a long-term trend. Don Harlow, 75, of Putney, said there were some warm years in the 1950s, and he blames El Niño for the current weather pattern.

Still, he said, "I think what we're experiencing is a tragic, disastrous change." He added that he tapped too late last year and made only 1,800 gallons of syrup, instead of his usual 2,500. This year, he said, "in the first week of January, heaven sakes, it was 60 degrees in Vermont."

Global warming is such a concern to Arthur Berndt, one of Vermont's largest sugar makers, that he became a plaintiff in a lawsuit filed by environmentalists and four cities against the Export-Import Bank and the Overseas Private Investment Corporation. The suit says the agencies contribute to carbon dioxide emissions by financing overseas fossil fuel projects like oil fields and pipelines, and seeks to compel them to abide by American restrictions.

December was so warm, Mr. Berndt said, "I was seeding my asparagus bed on Christmas day."

BBC NEWS

Climate change fight 'can't wait'

The world cannot afford to wait before tackling climate change, the UK prime minister has warned.

A report by economist Sir Nicholas Stern suggests that global warming could shrink the global economy by 20%.

But taking action now would cost just 1% of global gross domestic product, the 700-page study says.

Tony Blair said the Stern Review showed that scientific evidence of global warming was "overwhelming" and its consequences "disastrous".

International response

The review coincides with the release of new data by the United Nations showing an upward trend in emission of greenhouse gases - a development for which Sir Nicholas said that rich countries must shoulder most of the responsibility.

And Chancellor Gordon Brown promised the UK would lead the international response to tackle climate change.

The BBC's Nick Robinson said that, while the Stern Review did not recommend specific tax rises, upping the cost of flying - both people and goods - and driving was on the agenda of all three main political parties.

Environment Secretary David Miliband said the Queen's Speech would now feature a climate bill to establish an independent Carbon Committee to "work with government to reduce emissions over time and across the economy".

"We have the time and knowledge to act but only if we act internationally, strongly and urgently ."

Sir Nicholas Stern

The report says that without action, up to 200 million people could become refugees as their homes are hit by drought or flood.

"Whilst there is much more we need to understand - both in science and economics - we know enough now to be clear about the magnitude of the risks, the timescale for action and how to act effectively," Sir Nicholas said.

"That's why I'm optimistic - having done this review - that we have the time and knowledge to act. But only if we act internationally, strongly and urgently."

Mr. Blair said the consequences for the planet of inaction were "literally disastrous".

"This disaster is not set to happen in some science fiction future many years ahead, but in our lifetime," he said.

"Investment now will pay us back many times in the future, not just environmentally but economically as well."

"For every £1 invested now we can save £5, or possibly more, by acting now.

"We can't wait the five years it took to negotiate Kyoto - we simply don't have the time. We accept we have to go further (than Kyoto)."

Large risks

Sir Nicholas, a former chief economist of the World Bank, told BBC Radio 4's Today programme: "Unless it's international, we will not make the reductions on the scale which will be required."

He went on: "What we have shown is the magnitude of these risks is very large and has to be taken into account in the kind of investments the world makes today and the consumption patterns it has."

The Stern Review forecasts that 1% of global gross domestic product (GDP) must be spent on tackling climate change immediately.

It warns that if no action is taken:

- Floods from rising sea levels could displace up to 100 million people
- Melting glaciers could cause water shortages for 1 in 6 of the world's population
- Wildlife will be harmed; at worst up to 40% of species could become extinct
- Droughts may create tens or even hundreds of millions of "climate refugees"

Clear objectives

The study is the first major contribution to the global warming debate by an economist, rather than an environmental scientist.

Mr. Brown, who commissioned the report, has also recruited former US Vice-President Al Gore as an environment adviser.

> **"There is the greatest opportunity of all, the prize of securing and safeguarding the planet for our generations to come."**
>
> Gordon Brown

"In the 20th century our national economic ambitions were the twin objectives of achieving stable economic growth and full employment," Mr. Brown said.

"Now in the 21st century our new objectives are clear, they are threefold: growth, full employment and environmental care."

He said the green challenge was also an opportunity "for new markets, for new jobs, new technologies, new exports where companies, universities and social enterprises in Britain can lead the world".

"And then there is the greatest opportunity of all, the prize of securing and safeguarding the planet for our generations to come."

Mr Brown called for a long-term framework of a worldwide carbon market that would lead to "a low-carbon global economy". Among his plans are:

- Reducing European-wide emissions by 30% by 2020, and at least 60% by 2050
- By 2010, having 5% of all UK vehicles running on biofuels
- Creating an independent environmental authority to work with the government
- Establishing trade links with Brazil, Papua New Guinea and Costa Rica to ensure sustainable forestry
- Working with China on clean coal technologies

The review was welcomed by groups including the European Commission and business group the CBI.

"Provided we act with sufficient speed, we will not have to make a choice between averting climate change and promoting growth and investment," said CBI head Richard Lambert.

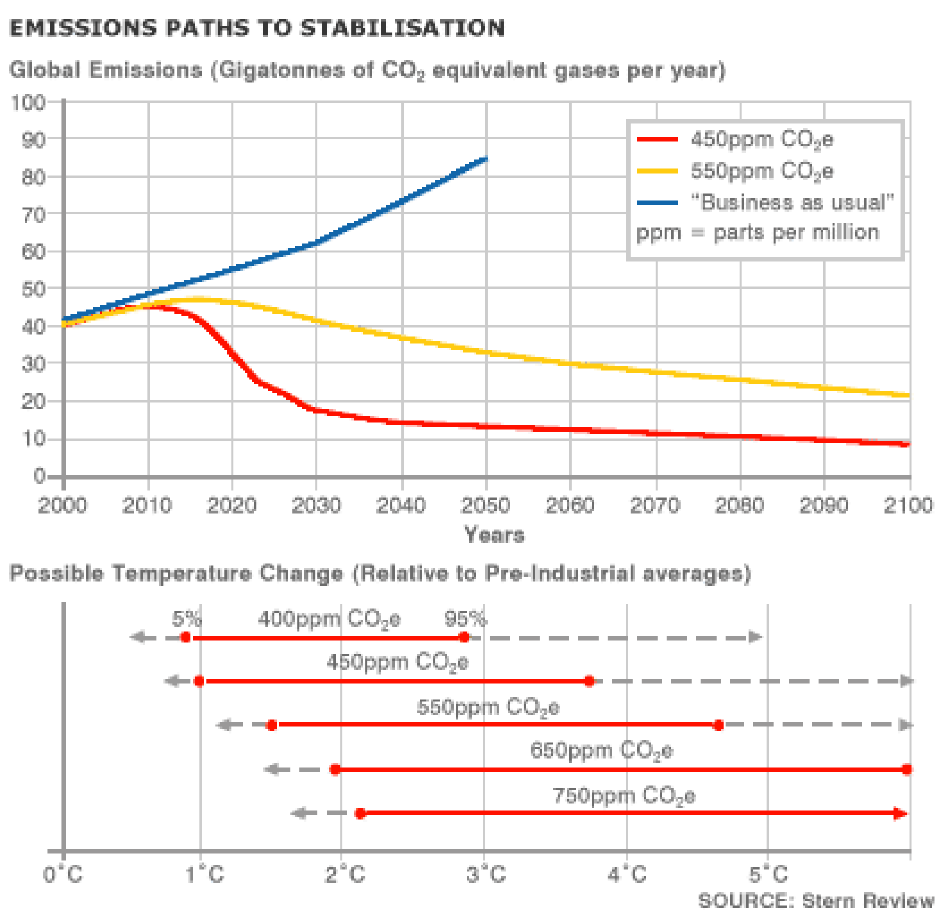
Pia Hansen, of the European Commission, said the report "clearly makes a case for action".

"Climate change is not a problem that Europe can afford to put into the 'too difficult' pile," she said.

"It is not an option to wait and see, and we must act now."

Story from BBC NEWS:
http://news.bbc.co.uk/go/pr/fr/-/2/hi/business/6096084.stm

Published: 2006/10/31 00:32:34 GMT



REUTERS

Scientists Say Millions Could Flee Rising Seas

November 10, 2006 — By Daniel Wallis, Reuters

NAIROBI — Nations must make plans to help tens of millions of "sea level refugees" if climate change continues to ravage the world's oceans, German researchers said on Thursday.

Waters are rising and warming, increasing the destructive power of storms, they said, and seas are becoming more acidic, threatening to throw entire food chains into chaos.

"In the long run, sea level rises are going to be the most severe impact of global warming on human society," said Professor Stefan Rahmstorf, presenting a report by German scientists at a major United Nations climate change meeting.

Warming could melt ice sheets and raise water levels, and the report said nations should already be considering making a "managed retreat" from the most endangered areas, including low-lying island states, parts of Bangladesh or even the U.S. state of Florida.

A report by international scientists who advise the U.N. has predicted a sea level rise of up to 88 cm between 1990 and 2100.

The situation was worsened, the German team said on Thursday, by the increasing frequency of extreme storms whipped up by warming sea surface temperatures -- meaning many would flee coastal areas hit by hurricanes.

Many of the world's biggest cities, from Tokyo to Buenos Aires, are by the coast. Some rich nations might be able to build ever higher dikes, such as in the Netherlands, but poor nations were destined to be swamped.

The low-lying Pacific island nation of Tuvalu has already agreed a deal for New Zealand to take about half its 10,000 people to work in agriculture if it becomes swamped by rising sea levels.

Hurricane Energy

Rahmstorf said their data did not conclusively prove warmer seas created more storms, but that there was a clear link between rising temperatures and hurricanes' power.

"Since 1980 we've seen a strong rise up to unprecedented levels of hurricane energy now in the Atlantic," he said.

Villager in Bajo village. Bajos or sea-gypsies, live almost exclusively by the exploitation of marine resources at a very low subsistence level. Sampela, Wakatobi Marine National Park Southeast Sulawesi, Indonesia

Some 189 nations are meeting in Kenya to explore options for a global deal to combat climate change, with most focusing on cutting the amount of carbon dioxide pumped into the air by industry and modern lifestyles.

The report's authors, the German Advisory Council on Global Change, said about a third of that CO2 was being absorbed by the world's oceans, making them more acidic.

If not checked, it said, that would have profound effects on marine organisms -- hindering everything from tiny shrimps to lobsters from forming their calcite shells -- with disastrous results for ocean food chains, and on human communities depending on sea life to survive.

Coral reefs that attract fish and protect coasts from storms and erosion are also threatened by acidity, and CO2 emissions meant they could all be dead by 2065, Rahmstorf said.

"Acidity is causing a major threat to coral reefs, on top of the bleaching effect that comes with warming," he said.

Reefs get bleached when warm water forces out tiny algae living in them, giving reefs nutrients and their vivid colours. Without algae, corals whiten and eventually die.

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Scientists Detail Social, Economic Costs of Unbridled Climate Change

by Catherine Komp

Oct. 17, 2006 – A pair of scientists at Tufts University have catalogued the social and economic effects of unabated global climate change.

In a study released last week by Tufts' Global Development and Environment Institute, researchers predict that upon reaching an increase of 2 degrees Celsius in the mean global surface temperature, "incalculable" social and environmental harms could be triggered, including more tropical diseases, decreased crop yields in the developing world and a "total loss of arctic ice and the extinction of many arctic species."

According to the Intergovernmental Panel on Climate Change, the best current estimate of the earth's increase in surface temperature is 0.6 degrees Celsius since the late Nineteenth Century.

Ackerman and Stanton, noting that all future temperature change predictions are estimates, state that if mean global temperatures rise by more than 2 degrees Celsius, the result could be widespread species extinctions, the collapse of the Amazon ecosystem, a major increase in sea levels and a shut-down of the ocean's circulation system.

The report also points to previously conducted research indicating that trillions of dollars in climate change damage could be averted by immediately reducing greenhouse gas emissions. In a 2005 study for the German Institute for Economic Research, economist Claudia Kemfert estimated that the repercussions from climate change could cost up to $20 trillion in the year 2100. Kemfert warned that even with climate protection policies to cap warming increases at 2 degrees Celsius, the costs would be about $8 trillion.

In another study, University of Cambridge researcher Chris Hope estimated in 2003 that average annual damages would be $26 trillion from 2000 through 2200 if no new climate change policies are enacted.

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Panthera onca Jaguar Brazil

The Tufts report also casts doubt on the supposed short-term benefits of global warming, like higher agricultural yields, decreased temperature-related deaths and increased enjoyment for people who live in cold climates. Researchers forecast that these benefits do not apply to all geographic areas, but that all areas will begin to experience the extreme effects of climate change after surface temperature rises by 2 degrees.

Lesson Six: Climate Change in My City

Subjects

Science, Social Studies, Geography, Technology, Environmental Education, Language Arts

Estimated Time

One 45-minute class period

Grade Level

9-12

Objectives

Students use an historical climate index to analyze climate change on local, regional, and global scales.

- Students describe how global temperature has changed over the last 100 years.
- Students explain why long-term temperature records vary from one location to the next.
- Students demonstrate how different spatial scales affect the record of long-term temperature trends.

Materials

- Computers with Internet access
- *Global Warming: Early Warning Signs* map available at http://www.climatehotmap.org/ by the Union of Concerned Scientists

Prerequisite Knowledge – Teacher

- Weather concerns the present and near-term future state of the atmosphere, whereas, climate accounts for all past weather events as well as the future (in the form of climate model predictions). See WWF Curriculum Glossary for further explanation.
- Scientists evaluate global warming by looking at trends in the global temperature, which is the average of the highs and lows measured at thousands of locations around the Earth. Observations collected over the last century suggest the average land-surface temperature has risen 0.45-0.6°C (0.8-1.0°F). The surface of the ocean has also warmed at a similar rate. Studies that combine land and sea measurements have generally estimated that global temperatures have warmed 0.3-0.6°C (0.5-1.0°F) in the last century.
- Regional and local temperature trends will be different from the global average—over the last century some areas have warmed while others have cooled.

Prerequisite Knowledge – Student

- Weather is the state of the atmosphere at a specific time and place, whereas, climate is the average weather over a long time period for a given place or region. Climate change is the long-term alteration in the average weather conditions for a particular location.
- Historical temperature and precipitation data are evaluated relative to a "normal," which is the average for a particular subperiod of time or the average of all the years of record.

Lesson designed by the Union of Concerned Scientists.

Climate Change in My City

Procedure

Engage

Have students think about the weather in their state over the last year. Ask them what stands out in their minds, e.g., warm winter, rainy spring, heavy snowfall, etc. Then ask them to make a judgment, based on their own observations, as to whether the previous season was warmer or colder than normal, and whether it was drier or wetter than normal. Ask them to consider what factors influence their responses, e.g., how much time they spend outside, how much their lifestyles depend on the weather, etc. Have each student record his/her observations on paper, then tally the results for the entire class.

Explore

Part 1: Comparing predictions to data

1. Have students compare their predictions to the actual data available from the National Climatic Data Center. This information can be found at http://www.ncdc.noaa.gov/oa/climate/research/monitoring.html. Click on the link for "State of the Climate," and select the "2007 Report" (or appropriate year). Scroll through this page to find links to monthly or seasonal reports. For example, click on "Climate of 2000: June - August in Historical Perspective" to find information on summer 2000 temperature and precipitation relative to historical averages. Click on "U.S. Regional/Statewide Analyses" to find information on a state-by-state basis. This page has color-coded maps showing which states were warmer/colder than normal and which states were wetter/drier than normal. Make sure students also note what data are being used to calculate the normal, e.g., 1961-1990 or entire record.

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Bayan Olgi at 1.600 m the center of the Kazakh Aimag. HQ of the Altai Tavn Bodg Special Protected Area. Flooded after heavy rains.

2. Ask students to write short essays comparing their predictions to the actual data. Ask them to comment on the reliability of human memory versus measurements taken with a thermometer or rain gauge.

Part 2: Comparing data on spatial scales

1. Students compare the seasonal climate data at different spatial scales. For the example given above, direct students to the "Climate of 2000: June - August in Historical Perspective." Then ask them to determine whether the average temperature was above/below normal for at least three different spatial scales: state or region, U.S national, and global. Repeat the analysis for precipitation. The U.S. information can be found under the heading "U.S. National Analysis," and the global information can be found under "Global Analysis." Prior to conducting the research, ask students to formulate hypotheses concerning whether or not they expect to find different results at the different scales.

2. Ask students to construct a chart that summarizes the information they collect. An example might look like this:

Time Period June-August 2000	Temp. (Above/ Below Normal?)	Basis For Normal	Precipitation (Above/ Below Normal)	Basis For Normal
Regional		1895-1999		1961-1990
Northeast	Below		Above	
South	Above		Below	
West	Above		Below	
National	Above	1895-1999	Below	1961-1990
Global	Above	1880-1999	Below	1961-1990

3. Students should analyze the data and draw conclusions related to their hypotheses.

Extended Procedure

4. Divide the class into small groups and assign each group a different region of the country or world. For presentation to the rest of the class, ask them to prepare a five-to-ten-minute news report that summarizes the climate for that region for a particular month, season, or year. The report should include temperature, precipitation, any unusual or extreme events, and how the climate for the chosen period compares to long-term averages. The NCDC Web site can be a primary resource for this exercise, as can other weather-related Web sites or newspapers and magazines.

Part 3: Regional climate tracking

Students use the Internet to determine changes in climate for their city or town (or one that is nearby) over the past 100 years. The "Common Sense Climate Index" is a measure of whether an area has experienced a temperature change that should be noticeable to most people who have lived at that location for a few decades.

NASA's Goddard Institute for Space Science maintains a Web site with clickable maps by which students can search for the Common Sense Index for U.S. and world cities. Go to http://data.giss.nasa.gov/csci/stations/. Scroll to the bottom of the page for the U.S. map. Major cities are shown as a guide, but students can click anywhere on the map to bring up the city or town closest to them. Clicking on the station name brings up the Climate Index and seasonal temperature curves for that station. Students should work individually or in pairs to answer these questions on a worksheet:

a. Describe the Climate Index curve for your city: What is the overall trend? Were there particular periods in the past when temperatures were increasing or decreasing?

b. Describe the seasonal curves for temperature in the same manner. How do the trends differ among the seasons?

c. Compare the curve for the town/city to the U.S. and global average curves ((http://data.giss.nasa.gov/csci/bargraphs/). How are they similar? How are they different? Suggest reasons for any differences.

d. A useful comparison curve is the Climate Index for Barrow, Alaska. This region has experienced significant warmth since the mid-1970s. Based on the Climate Index data for this city, is it likely that the climate change is noticeable to people living in this region?

Extend

Students use the *Global Warming: Early Warning Signs* map and other resources to evaluate how global climate change might impact the region where they live. Have students examine the *Global Warming* map to determine the kinds of impacts expected in a world with increasing global temperatures. From the nine categories listed, instruct students to consider which impacts are most relevant for their region of the country. Remind them to think about which impacts will greatly affect the physical needs of residents, environmental conditions, impacts to wildlife, economy, resident psychology, regional/national defense, food and water, and migration etc. Students can then explore the impacts for their region in detail at the U.S National Assessment Web site: http://www.usgcrp.gov/usgcrp/nacc/default.htm. In groups, have the students create a newspaper with stories and headlines that demonstrate the state of life in their region with the onset of these impacts. Instruct them to select an editor for each group and encourage creativity with editorials, news stories, cartoon graphics, weather and sports sections, etc. Instruct the students to provide references from their own reading and research.

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Rain storm clouds piling up over the Chobe river, which forms the natural border between Namibia and Botswana in the most eastern part of the Caprivi strip. Kasika Conservancy, East Caprivi, Namibia. February 2006

Suggested Resources

NCDC Extreme Weather and Climate Events http://www.ncdc.noaa.gov/oa/climate/severeweather/extremes.html
This Web site is a gateway to climatic data and reports on extreme weather events throughout the U.S. and the world.

National Weather Service Heat Stress Information http://lwf.ncdc.noaa.gov/oa/climate/research/heatstress
Describes the "heat index" and heat stress, and provides links to forecasts and further information about heat waves.

Karl, T.R., N. Nicholls, and J. Gregory, 1997. "The Coming Climate." *Scientific American,* 78-83. This article describes the climate changes projected to occur as Earth warms.

National Standards Alignment

National Science Education Standards

Unifying Concepts and Processes (K-12): Consistency, change, and measure

Science as Inquiry, Content Standard A (9-12): Abilities necessary to do scientific inquiry; Understandings about scientific inquiry

Earth and Space Science, Content Standard D (9-12): Energy in the Earth system; Science in Personal and Social Perspectives, Content Standard F (9-12): Environmental quality; Science and technology in local, national, and global changes

Curriculum Standards for Social Studies

Strand 3: People, Places, and Environments

Strand 8: Science, Technology, and Society

Strand 9: Global Connections

National Geography Standards

Standard 1: World in Spatial Terms. How to use maps and other geographic representations,
tools, and technologies to acquire, process, and report information from a spatial perspective.

Standard 4: Places and Regions. The physical and human characteristics of places.

Standard 15: Environment and Society. How physical systems affect human systems.

Standard 17: Uses of Geography. How to apply geography to interpret the past.

Standard 18: Uses of Geography. How to apply geography to interpret the present and plan for the future.

Drought/ Mangrove in parched land, French Guiana

Technology Foundation Standards

Standard 1: Basic Operations and Concepts. Students are proficient in the use of technology.

Standard 3: Technology Productivity Tools. Students use technology tools to enhance learning, increase productivity, and promote creativity.

Standard 5: Technology Research Tools. Students use technology to locate, evaluate, and collect information from a variety of sources.

Environmental Education Guidelines for Learning (K-12)

Strand 1: Questioning and Analysis Skills

Strand 1.1: The Earth as a Physical System

Strand 2: Knowledge of Environmental Processes and Systems

Strand 2.4: Environment and Society

Strand 3: Skills for Understanding and Addressing Environmental Issues

Strand 3.1: Skills for Analyzing and Investigating Environmental Issues

Standards for the English Arts

Standard 4: Students adjust their use of spoken, written, and visual language (e.g., conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.

Standard 8: Students use a variety of technological and informational resources (e.g., libraries. databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge.

Standard 12: Students use spoken, written, and visual language to accomplish their own purposes (e.g., for learning, enjoyment).

Lesson Seven:
Climate Change and Disease

Subjects

Science, Social Studies, Geography, Technology, Environmental Education, Language Arts

Estimated Time

One 45-minute class period

Grade Level

9-12

Objectives

Students research the relationship between hosts, parasites, and vectors for common vector-borne diseases (VBDs) and evaluate how climate change could affect the spread of disease.

- Students explain how VBDs are transmitted.
- Students describe how climate affects the life cycle of vectors.
- Students explore how social factors affect the occurrence and spread of disease.

Materials

- Computers with Internet access
- *Map of malaria distribution (see suggested resources)*
- *Global Warming: Early Warning Signs* map available at http://www.climatehotmap.org/ by the Union of Concerned Scientists

Lesson designed by the Union of Concerned Scientists.

Prerequisite Knowledge – Teacher

- Climate models project a global mean warming by 2100 in the range of 1- 3.5◦C. Increasing temperatures will be accompanied by changes in rainfall and humidity, including a likely increase in the frequency of heavy precipitation events. Some areas will become drier because higher temperatures also increase evaporation.
- A VBD is one in which the disease-causing microorganism is transmitted from an infected individual to another individual by an arthropod (e.g., mosquito, tick, etc.) or some other agent. Other animals, wild and domesticated, sometimes serve as intermediary hosts. Key VBDs of concern include malaria, Lyme disease, dengue fever, yellow fever, Hantavirus pulmonary syndrome, and several forms of encephalitis.
- Climate constrains the range of many VBDs. Vector-borne diseases are currently found mainly in tropical and subtropical countries and are relatively rare in temperate zones. Mosquitoes, for example, are limited to seasons and regions where temperatures stay above a certain minimum. Winter freezing kills many eggs, larvae, and adults. Climate also influences the availability of suitable habitat and food supply for vectors.
- Weather affects the timing and intensity of disease outbreaks. Within their temperature range of tolerance, mosquitoes will reproduce more quickly and bite more in warmer conditions. Warmer temperatures also allow the parasites within mosquitoes to mature more quickly, increasing the chances that the mosquito will transfer the infection. Floods can trigger outbreaks by creating breeding grounds for insects. Droughts can reduce the number of predators that would normally limit vector populations.
- Several modeling studies have predicted that increasing temperatures will lead to the spread of malaria and other diseases into previously unaffected areas. Climate change may also affect the severity of the disease at a given location. Due to the complexity of the relationships, the models do not account for all of the ways in which climate can affect the vector, human host, and parasite, and the interactions among them.
- Socioeconomic factors also affect the distribution of VBDs. A good public health infrastructure, including prompt treatment of cases to reduce the risk of spread of disease and mosquito-control measures, helps limit disease transmission in developed countries. For example, malaria once extended into the northern U.S. and Canada, but, by 1930, was confined to southern regions of the U.S. and, by 1970, had been eradicated. Additionally, international travel increases the likelihood of an outbreak in nonendemic areas (although weather also plays a role by making conditions suitable for the spread of the disease). And an increase in drug and pesticide resistance as a consequence of overuse makes control of VBDs more difficult. Land-use by humans can change the availability of habitat for vectors.

Prerequisite Knowledge – Student

- Students should understand the concept of an ecosystem, including the relationship between abiotic and biotic factors and how a food chain works.
- Students should know the physical/atmospheric measurements that are used to characterize a region’s climate.

Climate Change and Disease

Procedure

Engage

Have students look over maps of the present-day distribution of malaria to characterize the countries where malaria occurs. Specifically, they should consider the climate of the country, such as average annual temperatures, average nighttime (low) temperatures, and precipitation, and whether it is a developing or developed nation. [A world atlas with maps of global temperature and precipitation distribution is probably the easiest way to search for this information. General information on climate for individual countries can be found in the CIA's World Factbook at https://www.cia.gov/library/publications/the-world-factbook/index.html. Climate statistics for world cities can be found at http://www.weatherbase.com/.] Instruct students to write short essays comparing countries with malaria to those without malaria, suggesting possible reasons for the differences between the two groups.

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Brown plant hopper: vector of the Ragged stunt virus Plant Pathology Department, IRRI (International Rice Research Institute) Manila, Philippines

Explore

1. Write the names of different VBDs, along with the name of the vector, onto 3 x 5 index cards (see list of diseases on chart). Divide students into pairs and have each pair pull an index card out of a box. One student in the pair should research how the disease spreads from one human to another, and the other student should research the life cycle of the vector. Ask the students to create a poster or diorama that illustrates the relationships between the host, parasite, and vector, and how the disease can be transmitted from one human to another. The students should present their findings orally to the class.

2. Bring the class together as a group and ask them to use what they have learned from the oral presentations to brainstorm about how climate might influence the spread of the diseases discussed. Guide the discussion by having students consider three perspectives:

    a. How does climate impact the vector directly?

    b. How does climate impact the vector's (or intermediary host's) habitat?

    c. How does climate impact the parasite?

Students should consider the role of climatic factors such as temperature, precipitation, presence of surface water, humidity, wind, soil moisture, and frequency of storms or droughts. Record ideas on an overhead at the front of the room, and provide a summary sheet for the students to use as reference.

3. Divide students into new groups of four to explore in more detail the impact of climate on vectors. Assign each group a specific vector: tick, rodent, mosquito, snail, bird. Ask the students to fill out a chart highlighting how projected climate changes due to an enhanced greenhouse effect might impact their vector. This can be done as an in-class group activity, with students drawing on the ideas and examples from the previous exercises. Alternatively, students could research the vector in more depth individually as a take-home assignment, then complete the chart as a group during the next class period. An example chart format is shown on the following page. Students can either

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Health scouts show how to use impregnated mosquito nets, Salapoumbé. The Jengi project provides support to health campaigns in the villages. AIDS and malaria are major causes of mortality in south east Cameroon.

read the *Global Warming: Early Warning Signs map* to learn about overall projected climate changes, or they can research climate changes for their region of the country by reading the U.S. National Assessment reports (http://www.usgcrp.gov/usgcrp/nacc/default.htm). Students may not be able to fill in all of the spaces in their charts for their vectors, but they should try to fill in as many as possible.

4. Have each student write a reflective essay in which they comment on the group's predictions of the potential effects of climate change on disease transmission. Questions to consider include: How easy/difficult was it to evaluate the impacts on the vector and vector habitat? How easy/difficult was it to evaluate the impacts on disease transmission? What, if anything, made the evaluation difficult? How accurate does the group think their predictions are? What additional information would the group like to have to complete the chart? If possible, the teacher should follow up this activity with a discussion on the use of models to predict the impact of climate change on disease. A color map showing model projections of changes in malaria distribution with a warming climate can be found in the Epstein (August 2000) Scientific American article.

http://www.sciam.com/article.cfm?colID=1&articleID=0008C7B2-E060-1C73-9B81809EC588EF21 .

Vector-Borne Diseases

Disease	Vector
Malaria	*Anopheles mosquito*
Yellow fever	mosquito
Dengue fever	*Aedes* mosquito
Schistosomiasis	water snails
West Nile virus	*Culex* mosquito
Leishmaniasis	Sand flies
Lyme disease	Tick
Plague	Flea/Rodent
Japanese encephalitis	*Culex* mosquito
African trypanosomiasis	Tsetse flies
Hantavirus pulmonary syndrome	Rodents
St. Louis encephalitis	*Culex* mosquito
Dracunculiasis	*Cyclops* (minute crustacean)
Onchocerciasis	blackflies

Extend

Students can examine a specific example of how weather affects disease by reading about the West Nile virus outbreak in New York City (see http://query.nytimes.com/gst/fullpage.html?sec=health&res=9B05E3DB103BF935A3575BC0A9649C8B63) or Hantavirus pulmonary syndrome in the U.S. Southwest. The sequence of extreme weather events that likely contributed to the outbreaks is described in the passage "Opportunists Like Sequential Extremes" from the Epstein (2000) article. Have the students read this passage and draw a timeline or flow diagram illustrating the sequence of events leading to the outbreak. An example for the West Nile virus outbreak is shown in the article. Then ask students to look at their diagrams and mark places where changes in human behavior (both individual and community level) could have helped curb the spread of the disease. As a final assignment, students redraw their first diagram incorporating the changes in human behavior and illustrate how those changes influenced the outcome.

Student Name________________________________ Group________________________

Climate Change	Direct Impact on Vector	Impact on Vector Habitat	Impact on Parasite	Potential Impact on Disease Transmission
More heat waves				
Change in flooding				
Change in drought frequency				
Heavier snowfalls				
Sea level rise				
Extreme weather				

Suggested Resources

Malaria Maps:

The Center for Disease Control's "Yellow Book," titled *Health Information for International Travel, 1999–2000*, can be downloaded free at http://www.cdc.gov/travel/reference.htm.

This resource includes a section on malaria and a map showing countries in which malaria is endemic. A separate listing at the front of the book shows disease risk for specific countries. A world map showing countries in which malaria is endemic can also be found at the Malaria Database, "Introduction" section.
http://www.wehi.edu.au/MalDB-www/intro.html

General Information on VBDs:

Division of Vector-Borne Infectious Diseases, Centers for Disease Control and Prevention.
http://www.cdc.gov/ncidod/dvbid/index.htm
This site provides fact sheets, images, and world maps showing the distribution of several types of VBDs. A good resource for student research.

Malaria Foundation International
http://www.malaria.org/
Provides basic information about malaria, including answers to frequently asked questions, a comprehensive glossary of terms, and links to other sites with information about malaria.

West Nile Virus Information
http://www.audubon.org/bird/wnv/
A site with strong background information and numerous links to more information about the West Nile virus outbreak in the U.S.

Vector Life Cycles:

The Life Cycle of the Mosquito
http://www.mosquitoes.org/LifeCycle.html

Mosquito Bytes
http://whyfiles.org/016skeeter/index.html

Climate Change and Human Health:

"Global Warming Could Increase U.S. Death Rate." Occupational and Environmental Medicine Online, 28 May 2007.
http://www.sciam.com/article.cfm?alias=global-warming-could-incr

Epstein, P.R., 1997. "Climate, Ecology, and Human Health." Consequences vol. 3 (2), Global Change Research Information Office.
http://www.gcrio.org/CONSEQUENCES/vol3no2/climhealth.html

The Physicians for Social Responsibility
http://www.psr.org/site/PageServer?pagename=Links_global_warming
Links to facts sheets and other resources on climate change and human health.

U.S. National Assessment Health Sector
http://ehis.niehs.nih.gov/topic/global/patz-full.html
Executive summary of the report from the health sector of the U.S. National Assessment. Includes a section on VBDs, as well as adaptation and prevention strategies.

Epstein, P.R. 1999. "Enhanced: Climate and Health." *Science vol.* 285 (5426), 347-348.
http://www.sciencemag.org/cgi/content/full/285/5426/347
This enhanced electronic version provides an extensive list of additional Web sites and literature on the topic.

World Health Organization – Climate and Health
http://www.who.int/globalchange/climate/en/
Web page providing information on the effects of climate on human health and links to WHO publications. The report, "Climate Change and Human Health: Impact and Adaptation," contains an informative section (Chapter 3) on the impacts of climate change on VBDs. It can be downloaded as a pdf file at
http://www.who.int/globalchange/publications/cchhbook/en/index.html.

National Standards Alignment:

National Science Education Standards

Unifying Concepts and Processes (K-12): Consistency, change, and measure

Science as Inquiry, Content Standard A (9-12): Abilities necessary to do scientific inquiry; Understandings about scientific inquiry

Life Science, Content Standard C (9-12): Interdependence of organisms; Matter, energy, and organization in living systems; Behavior of organisms

Earth and Space Science, Content Standard D (9-12): Energy in the Earth system

Science in Personal and Social Perspectives, Content Standard F (9-12): Personal and community health; Environmental quality; Science and technology in local, national, and global changes

Curriculum Standards for Social Studies

Strand 3: People, Places, and Environments

Strand 8: Science, Technology, and Society

Strand 9: Global Connections

National Geography Standards

Standard 1: World in Spatial Terms. How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective.

Standard 4: Places and Regions. The physical and human characteristics of places.

Standard 15: Environment and Society. How physical systems affect human systems.

Standard 18: Uses of Geography. How to apply geography to interpret the present and plan for the future.

Technology Foundation Standards

Standard 1: Basic Operations and Concepts. Students are proficient in the use of technology.

Standard 5: Technology Research Tools. Students use technology to locate, evaluate, and collect information from a variety of sources.

Environmental Education Guidelines for Learning (K-12)

Strand 1: Questioning and Analysis Skills

Strand 2: Knowledge of Environmental Processes and Systems

Strand 2.1: The Earth as a Physical System

Strand 2.2: The Living Environment

Strand 2.3: Environment and Society

Strand 3: Skills for Understanding and Addressing Environmental Issues

Strand 3.1: Skills for Analyzing and Investigating Environmental Issues

Strand 3.2: Decision-making and Citizenship Skills

Standards for the English Language Arts

Standard 4: Students adjust their use of spoken, written, and visual language (e.g., conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.

Standard 8: Students use a variety of technological and informational resources (e.g., libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge.

Standard 12: Students use spoken, written, and visual language to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information).

Lesson Eight:
Climate Change and Ecosystems

Subjects
Science, Geography, Environmental Education, Technology, Language Arts

Estimated Time
Six to nine class periods, including one suggested field trip

Time-Reduction Suggestions
- Part 1 could be researched individually before class
- The field trip is not mandatory, but makes an abstract idea more real for students
- Part 2, #3 could be assigned as homework

Grade Level
9-12

Objectives
Students research the interdependencies among plants and animals in an ecosystem and explore how climate change might affect those interdependencies and the ecosystem as a whole.

- Students explore the complexity of ecosystem interdependencies.
- Students explain how climate change could affect the components of an ecosystem.
- Students suggest ways to detect the impacts of climate change on ecosystems.

Materials
- Regional nature guides; biology or environmental science textbooks
- Computers with Internet access (desirable, but not necessary)
- *Global Warming: Early Warning Signs* map available at http://www.climatehotmap.org/ by the Union of Concerned Scientists

Lesson designed by the Union of Concerned Scientists.

Prerequisite Knowledge – Teacher

- The geographic ranges of plant and animal species are affected by climatic factors such as temperature, precipitation, soil moisture, humidity, and wind. A shift in the magnitude or variability of these factors in a given location due to global climate change will likely impact the organisms living there.
- Species sensitive to temperature may respond to a warmer climate by moving to cooler locations at higher latitudes or elevations. Examples of plant and animal range shifts can be found on the map Global Warming: Early Warning Signs.
- Factors other than climate may limit the extent to which organisms can shift their ranges.
- Physical barriers such as mountain ranges or extensive human settlement may prevent some species from shifting to more suitable habitats. In the case of isolated mountaintop species, there may be no new habitat at higher elevation to colonize. Even in cases where no barriers are present, other limiting factors, such as nutrient or food availability, soil type, and the presence of adequate breeding sites, may prevent a range shift. See the EPA's global warming Web site for a discussion of factors that could limit a range shift for North American forests at http://yosemite.epa.gov/oar/globalwarming.nsf/content/ImpactsForests.html
- In addition to the direct effects of temperature on organism physiology, projected climate changes under an enhanced greenhouse effect might change the availability of food, space, shelter, or water; upset the predator/prey balance of an ecosystem; increase susceptibility to pests/disease; change the frequency of natural hazards such as fires, droughts, and flooding. These effects might lead to local population declines or extinction for some species.

Prerequisite Knowledge – Student

- Students should understand the concept of an ecosystem, including the relationship between abiotic and biotic factors and how a food chain works.
- Students should know the physical/atmospheric measurements that are used to characterize a region's climate.

Cahaba river One of the wildest undammed rivers in the southeast Bibb County, Alabama United States Of America

Climate Change and Ecosystems

Procedure

Part 1: Class discussion on vegetation and animal species

Using their prior knowledge only, ask students to answer the question: In what ways does climate affect plants and animals? Ask them to consider how latitude and altitude determine what types of species live in a region. Have students look at a world map of vegetation and evaluate how climate influences the distribution of plants. Ask students to identify the ways in which temperature affects the life cycle of animals (e.g., migration, hibernation, breeding).

Develop a list of climatic effects on plants and animals from student answers that can be used as a reference guide for student research.

Part 2: Regional ecosystems

1. Have students use their knowledge of their part of the country to name the ecosystems found in nearby natural areas (such as lakes, wetlands, fields, forests, rivers, or seashore). Have the class vote on one ecosystem to study in more detail. If time and resources allow, the teacher should pick an ecosystem that students can visit in one or two field trips to collect data.

2. Ask students to research, as a class, the basic components of the ecosystem they have chosen. Students should look for organisms in each category of producers, herbivores, omnivores, carnivores, and decomposers. Nature guides, library books, and the Internet could all be sources of information for this exercise. The Web sites of State Departments of Conservation or the local Audubon Society would be good resources. If possible, take students on a field trip to collect data on the types of plants and animals found in the ecosystem. Students or the teacher can design a species observation sheet, and guidebooks can be used to assist with identifications in the field. Supplement the field observations with Internet or library research, especially for the larger mammals or nocturnal animals. A good online field guide can be found at eNature.com – see Suggested Resources.

3. After the class has finished their research, have each student create a web (using drawings or pictures, for example) of the basic components of the ecosystem showing interrelationships. The web should include physical factors such as the sun, atmosphere, water, soil, and nutrients. At this point, students can begin to develop hypotheses concerning how climate change might affect the ecosystem. Ask each student to read the text on "Plant and Animal Range Shifts" from the *Global Warming: Early Warning Signs* map to learn how climate change affects organisms. Then have each student prepare a report to be presented orally to the class on how climate change could affect one of the plants or animals in the regional ecosystem. Give students some example questions to help them focus their research (see the example handout, "Guidelines for Students"). Students can also use the information generated by the class in the Part 1 activity above. Teachers should use the regional reports of the U.S. National Assessment at http://www.usgcrp.gov/usgcrp/nacc/default.htm to find the projected climate changes for their region of the country. The table of climate changes in the example "Guidelines for Students" can then be modified to fit the regional projections.

4. Each student should present his/her research findings in the form of a hypothesis concerning how the projected climate changes might affect their organism, and the reasoning behind the hypothesis. Explain that each student will be expected to write a summary essay reflecting how the ecosystem as a whole might be different if the projected climate changes occur (see #5). Hence, each student will be responsible for understanding the material presented by other members of the class.

5. As a final exercise, have each student prepare a description of the ecosystem as it is today, using his/her web for illustration, and a description of what they think the ecosystem might look like in 2100 if the projected climate changes occur, using a new web for illustration.

Extended Procedure

1. Ask students to make a list of the measurements that could be taken to try to detect the beginning signs of climate change in the ecosystem. Ask them to

Rhododendron and ancient, old growth Hemlocks in the Joyce Kilmer Memorial Forest. © Liza Schillo consider physical, biological, and chemical measurement possibilities. This exercise could be done as a class activity, or it could be included in the writing assignment in #5 from above.

2. Have students research the possible effects of climate change on an ecosystem significantly different from the one they have just studied. Depending on your school location, this might be a coastal system, coral reef, desert, or mountainous area. If possible, pick an area in a country other than the United States (e.g., Great Barrier Reef, Canadian Arctic). The **World Wildlife Fund** Web site is a good source for information on climate change impacts in internationally protected areas. Ask students to compare and contrast the impacts in each of the two systems they have studied.

Suggested Resources

EPA Global Warming Impacts http://yosemite.epa.gov/oar/globalwarming.nsf/content/Impacts.html
A good starting point for student research on climate change impacts on ecosystems. Reports are available by ecosystem type (coastal zone, forests, wetlands, etc.), by animal type (birds, fisheries), and by state.

EPA Plant and Animal Impacts Bibliography
http://yosemite.epa.gov/oar/globalwarming.nsf/uniqueKeyLookup/SHSU5BNJWW/$file/Bibliography.pdf?OpenElement
For in-depth research, this site offers an extensive listing of scientific articles about the impacts of climate change on wildlife.

World Wildlife Fund Climate Change Campaign
http://www.panda.org/about_wwf/what_we_do/climate_change/solutions/where_we_work/index.cfm
This site is an overview of WWF's goals for reducing climate change and a gateway to online reports on the WWF projects against climate change worldwide, as well as key effects and potential solutions of climate change in each world region.

eNature Online Field Guides
http://www.enature.com
A user-friendly site where students can see pictures and read about plant and animal species found in different habitats of North America (scroll down to the "Habitat Guides" section). Teachers can also create a classroom species list.

Global Climate Change Online Resources
http://www.aaas.org/climate/
A comprehensive listing of online resources about global climate change, arranged by topics such as events, recent news, the science, and what you can do.

The Intergovernmental Panel on Climate Change (IPCC)
Approximately every five years, IPCC releases an assessment of the state of climate change science. The latest assessment, Climate Change 2007, is available online in four parts; the synthesized report is due for completion soon. Each part includes an executive summary.

- The Physical Science Basis section: http://ipcc-wg1.ucar.edu/wg1/wg1-report.html
- The Impacts, Adaptation, and Vulnerability section (outline form): [link unavailable]
- The Mitigation of Climate Change section (pre-copy-edit version): http://www.mnp.nl/ipcc/pages_media/AR4-chapters.html
- Union of Concerned Scientists (UCS). The UCS Web site contains many resources for teaching climate change. Below are links to several of these.
- Confronting Climate Change in the Gulf Coast Region http://www.ucsusa.org/gulf/
- Confronting Climate Change in California http://www.ucsusa.org/global_warming/science/confronting-climate-change-in-california.html
- The Science of Climate Change http://www.ucsusa.org/global_warming/science/
- Global Warming: Frequently Asked Questions http://www.ucsusa.org/global_warming/science/global-warming-faq.html
- Common Sense on Climate Change: Practical Solutions to Global Warming http://www.ucsusa.org/assets/documents/global_warming/ClimateSolns.pdf

National Standards Alignment:

National Science Education Standards

Unifying Concepts and Processes (K-12): Consistency, change, and measure

Science as Inquiry, Content Standard A (9-12): Abilities necessary to do scientific inquiry; Understandings about scientific inquiry

Life Science, Content Standard C (9-12): Interdependence of organisms; Matter, energy, and organization in living systems; Behavior of organisms

Earth and Space Science, Content Standard D (9-12): Energy in the Earth system

Science in Personal and Social Perspectives, Content Standard F (9-12): Environmental quality; Science and technology in local, national, and global changes

Social Studies

Strand 3: People, Places, and Environments

Strand 8: Science, Technology, and Society

Strand 9: Global Connections

Geography

Standard 4: Places and Regions. The physical and human characteristics of places.

Standard 8: Physical Systems. The characteristic and spatial distribution of ecosystems on the Earth's surface.

Technology

Standard 1: Basic Operations and Concepts. Students are proficient in the use of technology.

Standard 5: Technology Research Tools. Students use technology to locate, evaluate, and collect information from a variety of sources.

Environmental Education

Strand 1: Questioning and Analysis Skills

Strand 2: Knowledge of Environmental Processes and Systems

Strand 2.1: The Earth as a Physical System

Strand 2.2: The Living Environment

Strand 2.3: Environment and Society

Strand 3: Skills for Understanding and Addressing Environmental Issues

Strand 3.3: Skills for Analyzing and Investigating Environmental Issues

Strand 3.4: Decision-making and Citizenship Skills

Language Arts

Standard 4: Students adjust their use of spoken, written, and visual language (e.g., conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.

Standard 8: Students use a variety of technological and informational resources (e.g., libraries. databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge.

Standard 12: Students use spoken, written, and visual language to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information.)

Swallowtail butterfly on a tiger lily. © Liza Schillo

Student Activity Sheet: CLIMATE CHANGE AND ECOSYSTEMS

The state Department of Natural Resources has asked your class to evaluate how climate change due to an enhanced greenhouse effect might impact an ecosystem in your state. In a previous activity, your class identified the major components of the ecosystem you have chosen to study.

Because the organisms in the ecosystem function in a complex web of interdependencies, your class will need more information to evaluate how climate change would affect the system as a whole. Your task as a member of the climate-impacts evaluation team is to describe in detail how the projected climate changes could impact one species in the ecosystem. You will present your findings to the class and use this information, and that of your teammates, to construct “before” and “after” pictures of the ecosystem, using both text and illustrations. In your research, try to consider all of the ways in which climate could impact your species, both directly and indirectly.

The questions below will help you get started, but you may be able to identify other important relationships between your species and climate. Be creative!

My species is ______________________________________.

Its place in the food chain is (circle one): producer, herbivore, carnivore, omnivore, decomposer.

Illustrate the function of this species in the ecosystem by sketching interrelationships with other organisms:

Climate can affect a species directly by constraining organisms to areas within their temperature tolerances, or indirectly by affecting food supply, availability of shelter, or other factors necessary for survival. To determine how climate change might affect a particular species, scientists must first try to understand all of the ways in which present climate influences that species. Research the life cycle, habits, and physiological needs of your species to identify the ways in which climate affects it today. Use the following questions as a guide to get started. List other questions you think are important in the space provided.

Life Cycle: What are the life stages of the species? When do changes from one stage to another take place? How is the species affected by the seasons? How does the species reproduce? When and how often does it breed?

Food: What are the nutritional needs of the species? What are its preferred foods? What are other food sources? What do the young eat? Is the food supply influenced by the seasons?

Shelter: Where does the species live in the ecosystem? Does it share this space with other species? What kind of shelter does it need for breeding/raising its young?

Predators/Disease: What species, if any, depend on this species for food (or parasitic/symbiotic relationships)? What diseases or pests affect this species? What conditions make the species susceptible to disease?

Competitors: What species compete with this species for food, shelter, or other needs? What, if anything, maintains a balance among these competitors?

Other Important Factors:

Evaluating Climate Change Impacts:

Now that you have learned more about your species' life habits and needs, it's time to consider how global climate change might play a role in its future. Some scientific studies have suggested that climate change could change the distribution of species in an area because warmer temperatures would cause some species to shift their geographic ranges to cooler areas, either to higher latitudes or to higher elevations on mountain slopes. Other studies indicate that in areas where species are unable to move to accommodate changing climate conditions, for example, in places where their movement is blocked by large cities, population numbers could decline or local populations could become extinct. In fact, the impact of climate change on a species is likely to be complex because its survival is linked to many factors. You have identified some of the factors that are important to the survival of your species. Now look at the list of projected climate changes and evaluate how each of these changes might impact the species you studied.

Use a table to characterize the impact as "little or no impact," "moderate impact," or "significant impact."

Name____ Group_____________________

Climate Change	Impact: (Little or None; Moderate; or Significant)	Nature of Impact: (i.e., range shift north, earlier egg-laying, fewer breeding sites)
Higher temps./ More heat waves		1. 2. 3.
More heavy downpours		1. 2. 3.
Change in drought frequency/ severity		1. 2. 3.
Heavier snowfalls		1. 2. 3.
Change in flooding frequency/ severity		1. 2. 3.
Change in fire frequency/ severity		1. 2. 3.
Sea level rise		1. 2. 3.
Polar warming		1. 2. 3.

Lesson Nine: The Forecaster

Subjects

Mathematics, Science, Social Studies, Geography, Environmental Education, Language Arts

Estimated Time

One class period for graphing and prediction activity; entire semester for follow-up

Time-Reduction Suggestion

Rather than keeping track of weather-report accuracy in class, it could be monitored individually as a homework assignment to be turned in and presented at the end of the semester.

Grade Level

9-12

Objectives

- Students use critical reading skills and Internet research to gather facts about weather and climate changes.
- Students hypothesize about how and why weather patterns and climate may be changing and check their hypotheses over a period of time.
- Students participate in class discussions about whether climate change is affecting the weather in their area.

Materials

- Internet or a copy of the *Farmers' Almanac*
- Graphing paper

The Forecaster

Procedure

1. Instruct the students to create a graph or chart that compares the local weather from 10, 20, 50, and 100 years ago. A resource for this information is the *Farmers' Almanac*, available at http://www.almanac.com/weathercenter/. Have the students document precipitation, average temperatures, and number of damaging storms (tornadoes, hurricanes, floods, etc.), or anything else relevant to your region. Also ask the students to try to find phenological data (blooming dates for plants, storm seasons, ice freeze and thaw dates) for the area 10, 20, 50, and 100 years ago. Using the graphs and charts, have students draw conclusions about whether or not the weather and climate in your region is changing or has stayed the same over the past century.

2. Based on the historical data and trends, have the class (perhaps in pairs) make a long-term weather forecast for the region. Ask the students to then compare their forecast to what experts are forecasting. What are the main similarities or differences? Does looking at the forecast of the experts change any student's opinion about their forecast? Discuss the reasons why they forecasted the weather the way they did. Do they believe the experts may be wrong about anything?

3. As a class, keep track of the weather for the following months and go back and assess the accuracy of the forecast at the end of the season, semester, or year. Also discuss the trends of any phenological data they found, and ask the students to deliberate over whether there is sufficient information to say that any changes in regional phenological trends are being caused by climate change.

Notes to the teacher:

- With regard to temperature, the science community refers to measurements in Celsius. However, the majority of youth in the U.S. are more familiar with Fahrenheit. We would suggest charting the temperatures in Celsius and Fahrenheit, so that students will become more familiar with the conversion. Simply charting in Celsius would make it more difficult for students to understand the meaning of the number, i.e., how 30°C feels.

Water-spout (an extraordinary and dangerous meteor, consisting of a large mass of water, collected into a sort of column by the force of a whirlwind, and moved with rapidity along the surface of the sea), above the Adriatic Sea. A sailing boat gives the scale of the water-spout.

Web resources for phenological data:

USA National Phenology Network: http://www.uwm.edu/Dept/Geography/npn/

Links to Phenological-related Web Sites: http://sws-wis.com/lifecycles/links.html

Web resources for climate predictions:

National Weather Service Climate Prediction Center: http://www.cpc.noaa.gov/

Experimental Climate Prediction Center: http://ecpc.ucsd.edu/

The International Research Institute for Climate and Society: http://portal.iri.columbia.edu/portal/server.pt

National Centers for Environmental Prediction: http://www.ncep.noaa.gov/

National Standards Alignment:

Principal and Standards for School Mathematics

Data Analysis and Probability (9-12):

Strand 1: Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer; understand the differences among various kinds of studies and which types of inferences can legitimately be drawn from each; know the characteristics of well-designed studies, including the role of randomization in surveys and experiments; understand the meaning of measurement data and categorical data, of univariate and bivariate data, and of the term variable; understand histograms, parallel box plots, and scatter plots and use them to display data; compute basic statistics and understand the distinction between a statistic and a parameter.

National Science Education Standards

Unifying Concepts and Processes (K-12): Consistency, change, and measure

Science as Inquiry, Content Standard A (9-12): Abilities necessary to do scientific inquiry; Understandings about scientific inquiry

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Fog in the Appalachian Mountains

Curriculum Standards for Social Studies

Strand 3: People, Places, and Environments

Strand 9: Global Connections

National Geography Standards

Standard 1: World in Spatial Terms. How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective.

Standard 4: Places and Regions. The physical and human characteristics of places.

Standard 15: Environment and Society. How physical systems affect human systems.

Standard 18: Uses of Geography. How to apply geography to interpret the present and plan for the future.

Environmental Education Guidelines for Learning (K-12)

Strand 1: Questioning and Analysis Skills: Organizing information; Working with models and simulations; Developing explanations

Strand 2: Knowledge of Environmental Processes and Systems: Processes that shape the Earth; Energy

Strand 2.2: The Living Environment: Systems and Connections

Standards for the Language Arts

Standard 4: Students adjust their use of spoken, written, and visual language (e.g., conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.

Standard 12: Students use spoken, written, and visual language to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information).

Working with Others

Standard 4: Displays effective interpersonal communication skills.

Lesson Ten:
Car Quest

Subjects

Science, Technology, Environmental Education, Economics

Estimated time

Four class sessions and time for web research

Time-Reduction Suggestions

Web research can be omitted, or time can be reduced by making it an in-class activity by using a teacher developed vehicle fleet or student developed dream fleet.

Grade level

9-12

Objectives

Assess the environmental impacts of a fleet of cars and then research and prepare a report about greener transportation choices.

Materials

- Copies of the "Vehicle Fleet Environmental Impact Summary"
- "Web Quest Group Tasks"
- Computers with Internet access

Background

According to many scientists who study the effects of consumer actions on the environment, no purchase we make has a bigger effect than our choice of car. After all, our choices about which car we drive can mean the difference of thousands of pounds of carbon dioxide released into the atmosphere, a significant amount of airborne pollutants, and the amount of strain we place on nonrenewable resources.

Unfortunately, there are no cars available today that are perfectly clean. Although we might be able to walk, bike, or use public transportation to get around, most of us rely on cars for at least some of our transportation needs. And many people simply enjoy driving. Regardless of whether they're old enough to drive, most of your students are probably thinking about the kinds of cars they'd like to have—weighing different factors such as speed, looks, cost, comfort, and safety. But how many of your students also weigh environmental factors when they think about their dream cars?

How many are even aware of the effects that different kinds of cars can have on the environment?

In this activity, your students will determine the environmental effects of cars—real cars in a parking lot, a fleet consisting of all of their dream cars, or a fleet of your choosing. They'll compute how many tons of heat-trapping gases are produced each year, how much it costs to fuel the cars, and so on. Then they'll research and prepare reports on "greener" transportation alternatives.

Before You Begin

Familiarize yourself with the Web sites recommended for student research (see Step 4 and the "Web Quest Group Task"). Decide what fleet of cars you'd like students to evaluate—the cars parked outside in the parking lot, a fleet of the students' own dream cars, or a fleet of your own creation (see "Choosing the Fleet" below). Make enough copies of the "Vehicle Fleet Environmental Impact Summary" chart for each pair of students and create a large version that can be filled in by the entire class (see Step 5 under "What to Do"). Make one copy of the "Web Quest Group Tasks" cards and cut out each of the cards so that you can distribute one task topic to each of four student groups.

Choosing the Fleet

This activity is written to evaluate the fleet of cars in your school or institution's parking lot. But you should feel free to adapt it so that students evaluate their dream car fleet or a fleet you've made up. If you have students evaluate their dream car fleet, you may not see as much variety in the cars they evaluate, and it will be less of a hands-on experience, but they may be more interested in their research. If the students evaluate a fleet you've come up with, they'll have less of a hands-on experience, but you'll be able to be very clear and specific about years, models, and so on—considerations that may not be obvious when students look at cars firsthand.

Car Quest

Procedure

1. Discuss "dream cars"

Ask the students if they've ever thought about what kind of car they'd most like to own. What cars do they have in mind? Has anyone considered a lifestyle without a car? What factors have influenced their choices? Has anybody considered environmental factors when selecting a dream car? Why or why not?

(If students don't have any ideas, you might give them a few minutes to browse some major carmakers' Web sites. Also, if any students in your group hope never to own a car, suggest that they might someday need to rent a car for a special trip or other purpose. Those students can also browse the Web briefly for ideas about the kind of car they'd want in the short term.)

Explain to the students that this activity will enable them to learn more about the environmental effects of the cars that people drive.

2. Organize the group for a fleet survey

Tell the students that they'll be going outside and taking an inventory of the cars parked in the lot. Divide the students into teams of two, and give each team a copy of the "Vehicle Fleet Environmental Impact Summary." Explain that you'll be assigning each team a different section of the lot, and they'll record the make (for example, Honda), model (for example, Accord), type (sedan, SUV, small pick-up, sports car, and so on), and, if possible, year of the vehicles in their section. In other words, they'll be filling in only the first three columns of their chart for now, keeping a tally in column one of the total number of vehicles of each type they find (see "Sample Vehicle Fleet Environmental Impact Summary"). Later they'll be researching the information for the final columns.

Note: If the students can't tell the year of a vehicle by looking at it, they should either make an estimate or put the current year.

Before you head outside, review some basic parking lot safety tips. Tell the students to be attentive to the movement of cars in and out of spaces and to assume that drivers probably don't see them unless the drivers indicate otherwise. Explain that most drivers won't expect to find students walking in and around the cars. You may want to assign two students the task of warning people going out to their cars and the parking area that there are students carrying out research in the lot.

3. Begin the fleet survey

Head outside and gather your group around as you assign their study areas. Divide the parking lot into as many equal areas as needed so that each team of two students is responsible for surveying approximately the same number of cars. Then have students fill in the first three columns of their chart.

4. Investigate the fleet's environmental effects

Once back in the classroom, have the students use the Internet to investigate the environmental effects of the vehicles in their parking lot and complete the data in the remaining columns of their chart. Tell the students that as they visit the Web sites that have this data, they may need more information about the vehicles in their area than they actually know. Tell them that if they don't know whether the car they saw was an automatic or manual transmission, they should use data for an automatic; if they don't know what type of engine it had, they should use the smallest size (usually V-4 or V-6).

Environmental information (particularly regarding mileage, annual fuel costs, and greenhouse gas emissions) for most cars can be found at the Department of Energy's Web site on fuel economy (www.fueleconomy.gov). Greenhouse gases emitted are listed in tons per year, assuming that the average car is driven 15,000 miles per year. (You might explain to them that, while the Department of Energy Web site uses the term "greenhouse gas," they may also see them referred to as "heat-trapping gas" in other publications.) Airborne pollutants are listed with a rating system and may have several scores, so students should determine an approximate average.

Safety information is available from the National Highway Traffic Safety Administration's "Buying a Safer Car" Web site (www.safercar.gov). This information assigns stars in various categories, so students should determine an approximate average for their vehicles.

5. Interpret the fleet data

After each team has completed its “Vehicle Fleet Environmental Impact Summary,” have the teams pool their data onto a single large chart. Invite the first team to enter its data, using tally marks instead of numerals in Column 1. Then, as other teams add their data, they can simply add another tally mark beside any vehicle that they also researched. Once all the data have been recorded, have the students determine the total number of cars and overall averages for each column. Ask the students to review the chart and share any observations or interpretations they have made. If the students don’t address them on their own, you might ask the following questions:

- Which cars have the highest and lowest safety ratings?
- Are the more fuel-efficient cars any more or less safe than the cars with less fuel efficiency?
- How important do you think the car's safety rating is in weighing the pros and cons of different car choices? Would different individuals be likely to value safety differently? (Encourage the students to think about different user groups such as parents, people who use their car for long commutes, and so on.)
- Which types of vehicles have the greatest environmental effects?
- What are some of the trade-offs a buyer has to weigh when deciding which car to buy (for example, fuel cost, safety, and emissions)?
- Does this kind of research help consumers make more informed decisions? Do the students think that in the future they'll do this much research to find out about a car they intend to buy? Other products?
- Did this research affect anyone's thoughts about their dream cars? How? Encourage the students to calculate the environmental impacts of their dream cars. Do they seem like good or bad choices from an environmental standpoint?

The students might note that few consumers have the time to thoroughly research each purchase they make. But by knowing where to look for information and gathering as much data as possible, consumers can make better and more informed decisions. For products as expensive and with as large an environmental effect as a car, it's important to gather as much information as possible before making a decision.

You may also want to have students run through some calculations to compare the environmental effects of different fleets. For example, have the students calculate the total annual amount of greenhouse gas emissions and consumption of nonrenewable fuel for the entire parking lot fleet, assuming each parking lot vehicle drove 15,000 miles per year. Does this number seem high?

Is it hard to visualize? Now have them make the same calculation assuming an entire fleet of very fuel-efficient cars, and again for an entire fleet of their dream cars. How do the numbers compare? Do the students start to see how the collective effects of our car choices can really add up?

6. Conduct Web quests

Now that the students have sharpened their skills as car shoppers, tell them that they’ll have a chance to investigate some of the options they might have for purchasing “cleaner” cars when they’re ready to hit the dealers’ lots. And, if the students are given hand-me-down cars and don’t get the chance to shop for one, they’ll learn about some ways that they can improve that car’s fuel efficiency. Finally, for those students who are more interested in other modes of transportation, they’ll get the chance to investigate what other ways of getting around are available in your community.

Divide the students into four groups and have each group conduct a Web quest to answer a different question. (You can either let the students divide themselves according to the topics that most interest them, or you can randomly assign students to groups.)

Each group will focus on one of the following topics:

Hybrid Cars: What are hybrid cars? How do they work? Why are they so fuel efficient? Are they available for purchase in your community?

Alternative Fuels: What are “alternative” fuels? What materials are used as alternative fuels?

Increasing Fuel Efficiency: How can people increase the fuel efficiency of the cars they already own? How much savings (in tons of greenhouse gases emitted as well as in dollars) could one person get from making these changes?

Non-Car Transportation: What are some of the non-car transportation options in your community? Do they use less fuel per person than cars?

Give each group the appropriate sheet from the "Web Quest Group Tasks" pages. Students can either write answers to their guiding questions, create a poster that contains both written answers to their questions and visual aids such as pictures and diagrams, or prepare a PowerPoint presentation that summarizes their results. If some of the groups choose to develop a PowerPoint, the presentation should include four or five slides that address the guiding questions. No matter which format the groups choose, they should all cite the Websites or other resources that they consulted.

7. Discuss findings

After each group has presented its findings, discuss the pros and cons of that particular approach to reducing greenhouse gas and other pollutant emissions. How effective is it? How expensive is it? How feasible is it? Does it seem like a reasonable option for most people?

In conclusion, ask students to recall their dream car. Has this activity changed their priorities with regard to cars and other transportation options? Do they think they'll consider a car's environmental impact if they go car shopping? Will they think about making other choices to get around? If so, in what kinds of situations will they choose other options? Will some students try not to own a car in the future? Why or why not?

Writing Idea

In many parts of the country, people concerned about highway safety and the health of the planet use strong words to condemn the drivers of traditional sport utility vehicles (SUVs) and other big cars that have low fuel-efficiency. In turn, many SUV owners use strong words about the freedom to choose the kind of car they want. Have the students research and write a brief essay stating their own opinions about this controversial topic. With which side do they sympathize? How do they think we should balance out individual and public considerations when it comes to the cars we drive?

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The Ivory Park EcoCity, just outside Johannesburg, has created an EcoVillage, funded by the SA Department of Environmental Affairs and Tourism's Poverty Relief Programme, and partnered by WWF's Beddington Zero Energy Development project. The SA Government's Poverty Relief Programmes stipulate that at least 60% of all costs should go towards salaries, and that at least 60% of those hired should be women. There is an organic vegetable nursery; a bicycle refurbishment centre (many of the bicycles are from England's Royal Mail and from Ireland); a zero energy community centre, a kindergarten and a spiritual corner. The EcoVillage is meant as a showcase of how eco-friendly living is also community friendly. All buildings are constructed for maximum energy-efficiency, using recycled materials wherever possible. Energy-efficient heating and cooking methods are also showcased here. Republic of South Africa

Assessment

Remind the students that, at the start of the lesson, they had to think of their dream car. Have them write down that type of car. Below this, have them answer the following questions:

(1) Would you still want this type of car? Why or why not? (2) What are the environmental benefits

or problems with your dream car? (3) What might be a different car that would give you the same benefits of your dream car but would be a better choice environmentally? How do you know?

Unsatisfactory— One or more elements from the assignment are missing. The student fails to incorporate evidence from the class activities to support his or her position. Arguments are not presented logically or rationally.

Satisfactory— The student is able to logically present why he or she would or would not want the same vehicle now. Using information from class, benefits or problems with the student's dream car are identified. A rational alternative is presented and supported with solid argumentation.

Excellent— The student presents convincing arguments why he or she would or would not want the same vehicle. Benefits or problems are backed up with data and sources that were identified and used in the class. The student's rationale reveals critical reflection.

Extension

- Develop and carry out a plan to help educate the drivers of the parking lot vehicles about reducing the environmental effects of their cars.
- Research the availability of "green" cars (including hybrids) at car dealerships in your community. How many green cars have been purchased since the cars have become available? When, if at all, do dealers expect to have those cars available in the future if they don't have them now?
- While most forms of public transportation are more efficient than having each passenger drive a car, many buses and other public transportation vehicles are responsible for large amounts of pollution and fuel use. But more environmentally friendly mass transportation alternatives are available, and growing numbers of cities are beginning to turn to "clean" buses, light rail, and other greener options in public transportation. Challenge students to compare the environmental effects of the use of school buses to carpooling in personal vehicles. Also have students research the next generation of public transportation options.
- Research how the construction of roads threatens biodiversity in different parts of the world.

Web resources:

The Department of Energy provides information on gas mileage, greenhouse gas emissions, air pollution ratings, and safety information for new and used cars and trucks: www.fueleconomy.gov.

The National Highway Traffic Safety Administration's "Buying a Safer Car" supplies consumers with safety information, including frontal and side crash test results, to aid them in their vehicle purchase decisions: www.safercar.gov.

Consumer Reports provides expert advice and information that guides consumers to the best new and used vehicles on the market: www.consumerreports.org.

The Environmental Defense Fund provides several links that aid car buyers in finding the greenest car that suits their needs, looking at information on miles per gallon and air pollution emissions: www.environmentaldefense.org/article.cfm?contentID=5578.

The National 4-H Council's *Going Places, Making Choices* is a curriculum produced for high school students, focusing on the history of transportation, natural resources, land use and energy use, climate change, and community action: www.fourhcouncil.edu/enviro_gpmc.aspx.

The Public Transportation Partnership for Tomorrow provides information on who uses public transportation, who provides it, and what the benefits of public transportation are. It also reports on various transportation issues and links to local public transportation information by state: www.publictransportation.org.

The American Public Transportation Association provides statistics and online documents about energy consumption, environmental benefits, history, and various other public transportation related issues: www.apta.com.

National Standards Alignment:

National Science Education Standards

Unifying Concepts and Processes (K-12): Consistency, change, and measure

Science as Inquiry, Content Standard (9-12): Abilities necessary to do scientific inquiry; Understandings about scientific inquiry

Science in Personal and Social Perspective Content Standard (9-12): Environmental quality; Science and technology in local, national, and global changes

Technology Foundation Standards

Standard 3: Technology Productivity Tools. Students use technology tools to enhance learning, increase productivity, and promote creativity.

Environmental Education Guidelines for Learning (K-12)

Strand 1: Questioning and Analysis Skills

Strand 3: Skills for Understanding and Addressing Environmental Issues

Strand 3.1: Skills for Analyzing and Investigating Environmental Issues

Standards for Economics

Standard 2: Marginal Cost/Benefit

Standard 7: Markets-Price and Quantity Determination

Standard 9: Role of Competition

Standard 13: Role of Resources in determining Income

Standard 16: Role of Government

Standard 17: Using Cost/Benefit Analysis to Evaluate Government Programs

Vehicle Fleet Environmental Impact Summary

Number of Cars in Lot (Tally)	Make, Model, Year	Type	Miles per Gallon City and Hwy.	Average Safety Rating	Greenhouse Gases in Tons per Year	EPA Airborne Pollutants Score	Annual Fuel Cost
Total		Average:	/				

Sample Vehicle Fleet Environmental Impact Summary

# of Cars in Lot	Make/ Model/ Year	Type	mpg City/ Hwy	Average Safety Rating	Green-house Gases in Tons/Year	EPA Airborne Pollutants Score	Annual Fuel Cost
|||	2003 Honda Accord	sedan	24/33	5	6.9	6	$1028
||	2002 Nissan Xterra	SUV	19/24	4	9.1	4	$1371
|	2004 Toyota Prius (hybrid)	sedan	60/51	5	3.5	9	$524
|||	2004 Ford Explorer	SUV	15/20	5	11.4	7	$1693
Total 9	--	Averages:	29.5/32	4.75	7.7	6.5	$1154

Web Quest Group Tasks

Hybrid Cars

What's all the hype about hybrids? It's your job to find out. Search the Web to answer to the following questions.

What is a hybrid car?

How does it work?

Why are hybrids more fuel-efficient than conventional cars?

What are some types of hybrid cars that are available today? What are some that are still in the planning stages?

Are any hybrid models available for purchase in your community? Why or Why not?

Here are some tips that might help you on your quest:

- "How Stuff Works" provides an overview of hybrid cars. www.howstuffworks.com/hybrid-car.htm
- The U.S. government is also getting on board with hybrids. The Office of Transportation Technologies has a Web site on hybrids (also called hybrid electric vehicles, or HEVs). www.eere.energy.gov/cleancities/hev
- Honda (automobiles.honda.com) and Toyota (www.toyota.com) are the two major automakers that currently have hybrid cars for sale in the United States. In addition, Ford (www.ford.com), General Motors (www.gm.com), and others are developing hybrids, some of which are hitting markets now or in the near future.

Alternative Fuels

You may listen to alternative music, but do you use alternative fuels? What are they, anyway?

Your group is going to find out by taking on a Web quest to answer these questions:

What are alternative fuels?

What are some materials being used in alternative fuels?

What are the benefits of alternative fuels?

What are some of the barriers to using alternative fuels?

How do alternative fuels affect the U.S. economy?

Here are some tips that might help you on your quest:

- The government is taking a lot of interest in alternative fuels, and has a Web site focused on this new technology. www.eere.energy.gov/afdc
- The Environmental Protection Agency (the government division that helps create and enforce environmental regulations) has collected information about alternative fuels. www.epa.gov/otaq/consumer/fuels/altfuels/altfuels.htm
- The Rocky Mountain Institute studies energy issues and educates the public about the best ways to conserve energy. The web site includes information about alternative fuels, and a link to their transportation section which hosts downloadable book *Natural Capitalism.* www.rmi.org/sitepages/pid123.php
- The Union of Concerned Scientists provides information on biodiesel and natural gas. www.ucsusa.org/clean_vehicles/fuel_economy

Web Quest Group Tasks

Improving Fuel Efficiency

There are a lot of advanced technologies available that are making new cars more fuel-efficient.

But what if you can't afford a new car? Can you teach an old dog new tricks? Go on a Web quest to answer these questions:

What things can people do to increase the fuel efficiency of the cars they already own?

Would it be expensive to make the changes? How much savings (in greenhouse gas emissions and in dollars) could one person get from making those changes?

Does the U.S. government have national standards for vehicle fuel efficiency?

How would improving fuel efficiency affect the U.S. economy?

Here are some things that might help you on your quest:

- The U.S. government provides information about how to improve a car's fuel efficiency. www.fueleconomy.gov/feg/factors.shtml and www.fueleconomy.gov/feg/why.shtml
- More tips on improving fuel efficiency can be found at www.whatprice.co.uk/tips/fuel-efficiency.html

Alternatives to Cars

So, what if you'd rather just say "no thanks" to cars? Or what if you live in a place where it's easier not to drive? In this Web quest, you'll find out more about other ways of getting around and how to use those other transportation options in your community. Look online for answers to these questions:

Besides cars, what are some other ways of getting around where you live?

Which of those alternatives require no gasoline? Which require less gasoline per person than a car?

Do any of your alternatives require more gasoline per person?

What are the pros and cons of using other modes of transportation in your community?

How would alternatives affect the U.S. economy?

Here are some tips that might help you on your quest:

- City governments around the Monterey Bay, California, area provide information for local residents about alternatives to using cars. www.commutealternatives.info
- The city of Victoria in British Columbia, Canada, has information on how it is working to limit the use of cars in the city with a program called Transportation Demand Management, or TDM. www.vtpi.org/tdm
- Drivers.com provides information on drivers and driving, as well as information for people who want to get out from behind the wheel. www.drivers.com/topic/54
- Visit your city, town, or region's official Web site, a local chamber of commerce Web site, or other town sites for information about transportation options in your community.

Lesson Eleven: Energy Watch

Subjects
Science, Social Studies, Technology, Environmental Education

Estimated Time
One to two class periods plus out of class time

Time-Reduction Suggestion
Discussion can be limited to not utilize an entire class period.

Grade Level
9-12

Objectives
- Students will learn how to read and measure their home's energy consumption.
- Students will compare their household's average weekly consumption to the average residential consumption of their own state as well as others across the country.
- Using Internet research and prior knowledge students will develop a plan to reduce their home's weekly consumption of energy.
- Students will write a brief report or class presentation outlining the steps they took to reduce their home's consumption of energy and how well it worked.

Materials
- *Estimating Your Yearly Energy Use* worksheet
- Computer with Internet access

Prerequisite Knowledge – Teacher and Students
- An understanding that most things that rely upon energy are using energy that has been produced from greenhouse-gas-emitting fossil fuels.

Background
It can be difficult to see how one's daily actions, such as taking a shower or making tea, has an effect on the world as whole. This lesson aims to make that connection by illustrating how simple household activities, like turning on a light, rely upon energy produced from greenhouse-gas-emitting fossil fuels. There are also many ways to reduce individual or household's use of electricity. This lesson teaches students that reducing electricity use does not mean spending large amounts of money or giving up favorite household items.

Windturbines and flock of geese during a full moon night. Wind energy is well developed in the Netherlands.

Energy Watch

Procedure

Part 1: Making the connection

1. Ask your class if they think making lunch, taking a shower, or doing homework at night contributes to climate change. Once the connection is made that using energy contributes to climate change because it is produced by fossil fuels, ask them to name other things they do in their homes that rely upon the production of electricity.

2. Demonstrate to the students how to read their electric meter. Please see the following Web site for guidance: http://www.jea.com/customer/meter.asp. Explain that the device, if read correctly, can tell you how much electricity your house is using in a given period of time.

3. For homework have the class record the number that is on their homes' electric meters. One week later, have them go back to the meter and record the number they see now. By subtracting the first reading from the second each member of the class will know how much energy their household used that week.

4. Ask them if they think their weekly electricity consumption is above or below the average home. Instruct them to explain their answers.

5. Next have students work on the *Estimating Your Yearly Energy Use* worksheet. This worksheet will have them calculate their average yearly energy consumption using the data they collected and compare it to the average household's energy use in their state and others throughout the country.

Part 2: Reducing your footprint

1. Now have each student (or groups) write up a plan on how they can reduce their household's energy consumption. These should be things they can actually do in one week and will not cost their families any money. Additionally, make sure the class is focusing on solutions that will show up on their electric meters (walking to school or work will not affect the meter).

   a. Ideas can include: Making sure to turn off all the lights in rooms they are not using, unplugging appliances that are not being used, making sure to always turn off the computer when not using it, wash clothing in warm or cold water instead of hot, air drying their clothes instead of using a dryer, wear seasonally appropriate clothing in the house to reduce the amount of air conditioning or heating they use and naturally ventilate when appropriate, close the blinds on their windows during the hottest part of the day and when not at home to reduce the need for air conditioning.

b. Footprint Web resources:

American Council for an Energy-Efficient Economy Consumer Guide for Energy Savings: Condensed Online Version: http://www.aceee.org/consumerguide/

Energy Information Administration Residential Energy Maps, Year 2000, East South Central Division: http://www.eia.doe.gov/emeu/reps/recmap/rec_esc.html

Ten Ways to Reduce Your Energy Use, TheRenewablePlanet.com: http://www.therenewableplanet.com/green/reduceenergy/

Power Scorecard: Reduce Your Energy Consumption: http://powerscorecard.org/reduce_energy.cfm

Twenty Simple Tips for Lowering Your Home's Carbon Footprint, Kyero.com: http://www.kyero.com/articles/lower-your-carbon-footprint.php

2. Have the students take another reading of their homes' electric meter, making sure to record it. Then have them implement their plans to reduce the amount of electricity their homes are using. One week from the day they took their last reading have them come back and take another reading.
3. Have each student either write a short essay or give a quick speech to the class outlining how their plan worked and how difficult it was for them to reduce their use of electricity.

Extend

Have the students try to reduce their home energy usage over a month or semester-long period.

National Standards Alignment:

National Science Education Standards

Unifying Concepts and Processes (K-12): Consistency, change, and measure

Science as Inquiry, Content Standard (9-12): Abilities necessary to do scientific inquiry; Understandings about scientific inquiry

Science in Personal and Social Perspective Content Standard (9-12): Environmental quality; Science and technology in local, national, and global changes

Curriculum Standards for Social Studies

Strand 3: People, Places, and Environments

Strand 8: Science, Technology, and Society

Technology Foundation Standards

Standard 1: Basic Operations and Concepts. Students are proficient in the use of technology.

Standard 3: Technology Productivity Tools. Students use technology tools to enhance learning, increase productivity, and promote creativity.

Environmental Education Guidelines for Learning (K-12)

Strand 1: Questioning and Analysis Skills

Strand 3: Skills for Understanding and Addressing Environmental Issues

Strand 3.1: Skills for Analyzing and Investigating Environmental Issues

Estimating Your Yearly Energy Use

Record your family's weekly electricity consumption here: ______________ kWH

Hypothesis

Do you think this is above, below, or about the same as the average household's consumption in your state? Why?

Do you think this is above, below, or about the same as the average household's consumption in the country? Why?

Putting your household to the test

Using data from the National Energy Information Administration (EIA) we are going to see how efficient your family's home is in comparison to your state and the rest of the country. However the EIA only displays its data for the whole year and in BTUs. As a result we will need to do some minor calculations. Follow the steps below.

Step 1: Multiply your home's weekly consumption of energy by the number of weeks in a year and record that number below.

Step 2: To convert your data from kWH to BTU try doing the calculation below. Then check it with the online calculator provided below. (Hint 1 BTU = .00029 kWH) Calculator can be found here: www.eia.doe.gov/kids/energyfacts/science/energy_calculator.html

Step 3: Use the link below to check the maps provided by the EIA to see how efficient your family's home is in comparison to your state and the rest of the country. Each lightning bolt on the map represents 10 million BTU, so 4 symbols would represent 40 million BTU, which would be the value of average electricity consumption per household per year. All data are rounded to the nearest whole-number multiple of 10 million. http://www.eia.doe.gov/emeu/reps/recmap/rec_contents.html

Results

What did you find? Were you above or below your state's average?

What about other the other states? How did the average household energy consumption in your state compare to those in other states? What about your own household's use versus residents in other states?

Can you identify any reasons that residents in other states might use more or less energy than your state?

Do you think these calculations are 100% accurate? Did we make any assumptions that may be influencing your results?

Lesson Twelve: Write On!

Subjects
English Language Arts, Social Studies, Civics

Estimate Time
One 45-minute class period

Grade Level
9-12

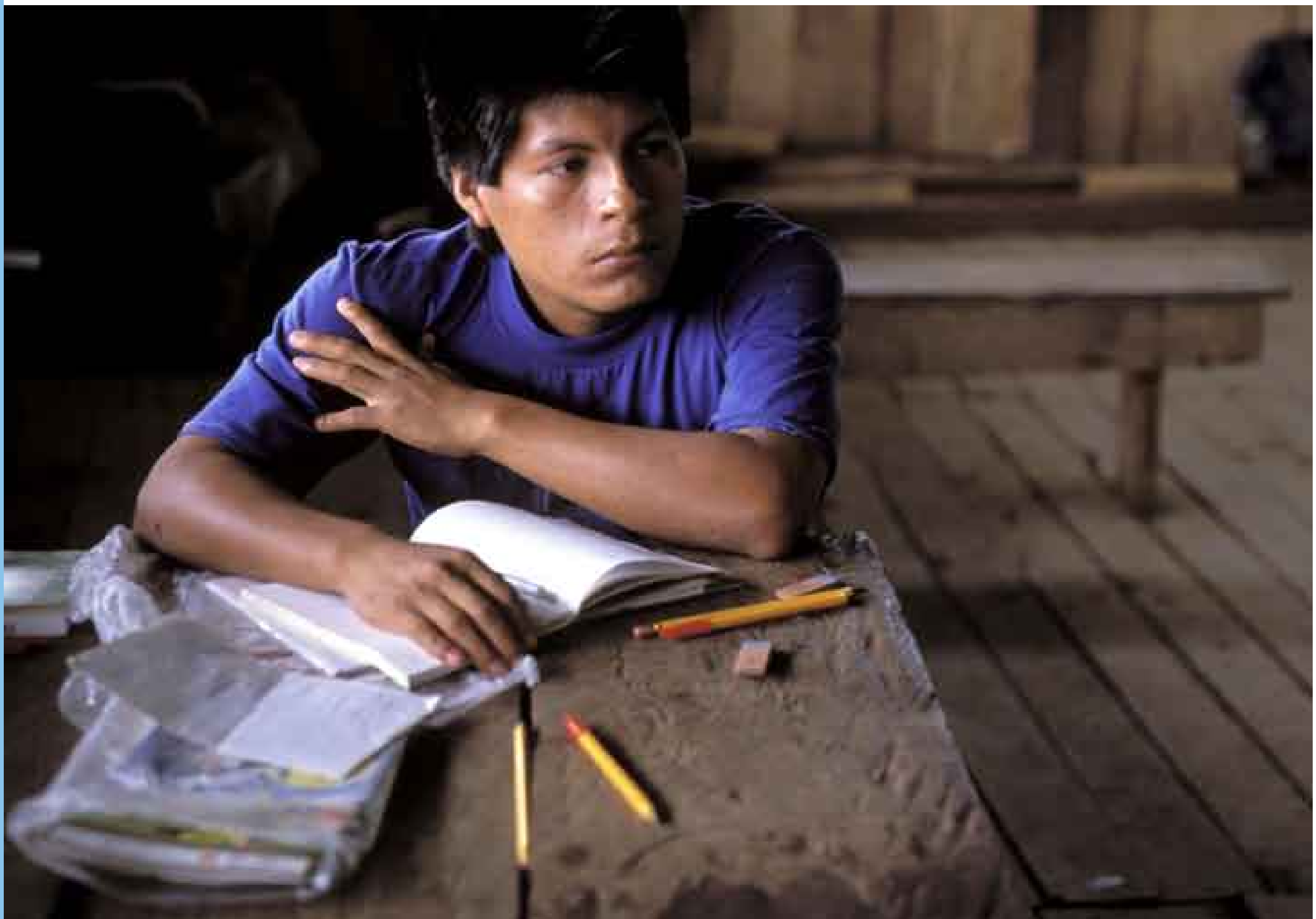
Overview
- Students write a letter to an editor of a newspaper or to a politician that will reflect their knowledge and articulate their views and concerns about climate change.
- This activity will help empower students and give them a voice on climate change and their concerns for their future and the future of their community.

Objectives
- Create a vision of a future with clean energy sources, low greenhouse gases and no climate change
- Discuss ways to take action, including writing letters to decision makers
- Write and send letters to politicians or media

Materials
- Student handout on letter-writing (provided)

Prerequisite Knowledge – Teacher and Students
- Familiarity with the basic science of climate change, potential impacts, and solutions.
- Knowledge of formal letter writing style, grammar, and using logic to create arguments.

Background
Students often feel overwhelmed and powerless in the face of environmental problems. This activity uses an awareness of climate change and its impacts to encourage students to take positive action to overcome that sense of helplessness by taking action to make an impact. It is based on the premise that the first step toward creating a better world is to envision a preferable future.



Twenty young (or very young) teachers or yet to be teachers follow a one month long course to enhance their knowledge, organized by UTEPA. This course brings professors from the city. They are going to go back to their own communities to teach the children how to read and write in spanish, basic history, biology and mathematics. Baboso, Awa Reserve. Awa Ethnic Forest Territory, Ecuador

Write On!

Procedure

1. Ask students to brainstorm their concerns about climate change and record these concerns on the board, or hold a class discussion on the political impacts on climate change, the current status of legislation, and what they believe needs to be done for the future.

2. Ask students, either working in groups, or as an entire class, to express their vision of a future where human impact on climate is no longer an issue. This vision should include the types of energy we would use, how we would care for the environment, how we would conserve and so on. They may suggest some of the following: a world where we are using cleaner renewable sources of energy, driving less polluting electric vehicles, idling is no longer practiced, reducing consumption of materials which are non-recyclable or non-reusable, and everything comes in less packaging, etc. The students' ideas can be recorded on the board as a brainstorming activity or visually as an art or mixed-media exercise (combining words and pictures).

3. To bridge the gap between the students' visualization of an ideal future and what needs to be done to create this vision, it is necessary to take action. Students need to know that being passive will not bring about the future that that they desire. Ask the students what actions can be done to ameliorate the problem, and try to encourage realistic responses while emphasizing a proactive approach.

Possible answers could include: walking to school, letter writing to local and federal politicians, letter writing to newspaper editors, educating the community about climate change issues by holding a community meeting, school presentation or event, starting a newsletter, starting a poster campaign, inviting the local official to the school or classroom, conserving energy, joining a national or local youth group that is doing something about climate change, starting a recycling program, etc.

4. Ask students to take a first step by writing letters to encourage action on climate change. Explain that letter writing is a powerful tool for making change and that politicians feel that one letter represents the opinions of more than just the person writing it. Many politicians are interested in what students have to say, especially those who are undecided on the issue. Passionate and well-written letters from students can also be published in newspapers across the country.

5. Ask students to draft the outline of a letter to a local or national newspaper, to local governmental officials, or to local or national elected officials. Ask them to find the addresses online, and to give reasons why they chose to write to that person or newspaper.

6. Provide students with key points on writing effective and powerful letters. Distribute the handout on writing powerful letters. The return address for any letters sent should identify the student as sender, in care of the teacher, and the school's postal address.

7. Optional: Divide students into groups of three and ask them to read their letters one at a time. Other students should provide the "reader" with one positive comment about what they liked about his/her letter, and one suggestion to make the letter more powerful. Students make changes to letters based on the feedback received.

8. When the teacher believes the letters are adequate for delivery, instruct the students to mail the letters, but to keep a copy to turn into the teacher. Instruct the students that if they receive a response to their letter, they should bring the responses to class to present to the teacher. Instruct the students sending letters to newspapers to watch the newspapers for several weeks to see if their letter is printed in the "letter to the editor" section. Printed letters should also be brought to class to present to the teacher.

Notes to the teacher:

- An eco-friendly alternative would be to have all of the letters submitted electronically. This is possible for all major newspapers, federal officials, and most locally elected officials.
- Inform students that they should only send letters to elected officials in their own district or region, i.e., students in Montgomery, Alabama should not send letters to the governor of Louisiana.
- Students should not be graded based on the receipt of a reply or a printed letter, but instead by the level of effort the students put into writing their letters. The success of the letter should be judged by the use of logical arguments, understanding of science, proper grammar and writing style, effective personal arguments, and the ability for the letter to engage the reader.
- Replies and printed letters should be displayed in the school or classroom in order to show the students that their concerns receive attention from people with authority, and that they can have an impact in the world.

National Standards Alignment

Standards for the English Language Arts

Standard 4: Students adjust their use of spoken, written, and visual language (e.g., conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.

Standard 5: Students employ a wide range of strategies as they write and use different writing-process elements appropriately to communicate with different audiences for a variety of purposes.

Standard 7: Students conduct research on issues and interests by generating ideas and questions, and by posing problems.

Standard 8: Students use a variety of technological and informational resources (e.g., libraries. databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge.

Standard 11: Students participate as knowledgeable, reflective, creative, and critical members of a variety of literacy communities.

Standard 12: Students use spoken, written, and visual language to accomplish their own purposes (e.g., for learning, enjoyment).

Curriculum Standards for Social Studies

Strand 3: People, Places, and Environments

Strand 8: Science, Technology, and Society

Strand 9: Global Connections

Standards for Civics

Standard 5: Roles of the Citizen

Villager planting mangrove tree for future "tongog" production. Panay, Aklan, Philippines © WWF-Canon / Jürgen FREUND

Key Points for Writing Powerful Letters

Key points to consider when writing a letter to a politician:

- Keep your tone polite.
- Keep the letter short (maximum 600 to 800 words).
- State your case clearly. Deal with one topic and have one major message.
- If a student or the class is aware of anything positive that the politician has done regarding climate change, state it. For example, if the politician supports the Kyoto accord, acknowledge that.
- If a student is planning to criticize, encourage them to start with positive comments first.
- Express your concerns and support them with comments from others in your community.
- Put the main point at the beginning and progressively less important details toward the end.
- Make sure the letter is concise, grammatically correct, and has no spelling mistakes. Have someone edit the letter.

Key points to consider when writing a Letter to the Editor:

(Note: consider presenting a well-written sample letter from the editorial page for students to use as a guideline.)

- Deal with one topic and have one major message.
- Use a straightforward, factual approach.
- Do not make the letter too long -Newspapers generally don't print letters longer than 250 words.
- Put the main point at the beginning and progressively less important details toward the end.
- Make sure the letter is concise, grammatically correct, and has no spelling mistakes.
- Have someone edit the letter – everyone who reads the newspaper will see this letter, so make sure it is clear and easy to understand.
- Back up your opinions with evidence.

Letters should include a return address with the student's name, care of the teacher, and the school's address.

Lesson Thirteen: The Stabilization Wedges Game

Subject

Science

Estimated Time

Two-Three class periods

In the first period, the Stabilization Triangle and the concept of wedges are discussed and the technologies introduced. Students can further research the technologies as homework. In the second period, students play the game and present their results. Depending on the number of groups in the class, an additional period may be needed for the presentation of results. Assessment and application questions are included and may be assigned as homework after the game has been played, or discussed as a group as part of an additional class period/assignment.

Grade Level

9-12

Objectives

- The core purpose of this game is to convey the scale of effort needed to address the carbon and climate situation and the necessity of developing a portfolio of options.
- By the end of the exercise, students should understand the magnitude of human-sourced carbon emissions and feel comfortable comparing the effectiveness, benefits, and drawbacks of a variety of carbon-cutting strategies.
- The students should appreciate that **there is no easy or "right" solution to the carbon** and **climate problem.**

Materials

- 1 copy of Instructions and Wedge Table **per student (print single-sided to allow use of gameboard pieces!)**
- 1 Wedge Worksheet and 1 Gameboard with multi-colored wedge pieces **per group**, plus scissors for cutting out game pieces and glue sticks or tape to secure pieces to Gameboard
- Optional - overhead transparencies, posters, or other materials for group presentations

Background

Students will learn about the technologies currently available that can substantially cut carbon emissions, develop critical reasoning skills as they create their own portfolio of strategies to cut emissions, and verbally communicate the rationale for their selections. Working in teams, students will develop the skills to negotiate a solution that is both physically plausible and politically acceptable, and defend their solution to a larger group.

Lessons designed by Roberta Hotinski for The Carbon Mitigation Initiative.

Procedure

I. Introduction (40 minutes)

a. **Motivation.** Review the urgency of the carbon and climate problem and potential ways it may impact the students' futures.

b. **Present the Concepts**. Introduce the ideas of the Stabilization Triangle and its seven "wedges".

c. **Introduce the Technologies.** Briefly describe the 15 wedge strategies identified by CMI, then have students familiarize themselves with the strategies as homework. Participants are free to critique any of the wedge strategies that CMI has identified, and teams should feel free to use strategies not on our list.

d. **Form Teams.** Teams of 3 to 6 players are best, and it is particularly helpful to have each student be an appointed "expert" in a few of the technologies to promote good discussions. You may want to identify a recorder and reporter in each group.

e. **Explain the Rules.** See instructions in **Student Game Materials** at back of packet

II. Playing the Game (40 minutes)

a. **Filling in the Stabilization Triangle**. Teammates should work together to build a team stabilization triangle using 7 color-coded wedges labeled with specific strategies. Many strategies can be used more than once.

b. **Wedge Worksheet.** Each team should fill in one **stabilization wedge worksheet** to make sure players haven't violated the constraints of the game, to tally costs, and to predict judges' ratings of their solution. NOTE: Costs are for guidance only – they are not meant to be used to produce a numerical score that wins or loses the game!

c. **Reviewing the Triangle.** Each team should review the strengths and weaknesses of its strategies in preparation for reporting and defending its solutions to the class.

III. Reports (depending on the number of groups this may require an additional class period)

a. Representatives from each team will defend their solutions to the class in a 5-minute report. The presentation can be a simple verbal discussion by the group or a reporter designated by the group. If additional time is available, the presentations could include visual aids, such as a poster, PowerPoint presentation, etc.

b. Students should address not only the technical viability of their wedges, but also the economic, social, environmental and political implications of implementing their chosen strategies on a massive scale.

IV. Judging

In CMI workshops, the teams' triangles have been judged by experts from various global stakeholder groups, such as an environmental advocacy organization, the auto industry, a developing country, or the U.S. Judging ensures that economic and political impacts are considered and emphasizes the need for consensus among a broad coalition of stakeholders. For a classroom, judges can be recruited from local government, colleges, businesses, and non-profit organizations, or a teacher/facilitator can probe each team about the viability of its strategies.

V. Closure/Assessment of Student Learning

In addition to addressing the game and lessons learned, discussion questions are provided below that give opportunity to develop and assess the students' understanding of the wedges concept and its applications.

1) Given physical challenges and risks, how many wedges do you think each wedge strategy can each realistically provide?

2) In choosing wedge strategies, it's important to avoid double counting – removing the same emissions with two different strategies. For example, there are 6 strategies for cutting emissions from electricity, but we project only 5 wedges worth of carbon produced from the electric sector 50 years from now. Can you think of reasons, other than the adoption of alternative or nuclear energy, that emissions from electricity would be lower or higher than we predict? Examples: increased use of carbon-intensive coal versus natural gas (higher), slower population growth (lower), substitution of electricity for fuel, as via plug-in electric cars (higher).

3) Industrialized countries and developing countries now each contribute about half the world's emissions, although the poorer countries have about 85% of the world's population. (The U.S. alone emits one fourth of the world's CO_2.) If we agree to freeze global emissions at current levels, that means if **emissions in one region of the world go up as a result of economic/industrial development, then emissions must be cut elsewhere**. Should the richer countries reduce their emissions 50 years from now so that extra carbon emissions can be available to developing countries? If so, by how much?

4) Nuclear energy is already providing one-half wedge of emissions savings – what do you think the future of these plants should be?

5) Automobile emissions are a popular target for greenhouse gas cuts. What percent of greenhouse gases do you think come from the world's passenger vehicles? (answer: about 18%)

Resources & Feedback

More stabilization wedge resources, including background articles and slides, and a form for feedback are available at http://www.princeton.edu/~cmi/resources/stabwedge.htm.

National Standards Alignment:

National Science Education Standards

Unifying Concepts and Processes (K-12): Systems, Order and Organization

Science as Inquiry, Content Standard (9-12): Abilities necessary to do scientific inquiry; Understandings about scientific inquiry

Science in Personal and Social Perspectives, Content Standard (9-12): Natural and Human Induced Hazards; Environmental Quality

Stabilization Wedges: A Concept & Game

The **Carbon Mitigation Initiative** is a joint project of Princeton University, BP, and Ford Motor Company to find solutions to the greenhouse gas problem. To emphasize the need for early action, Co-Directors Robert Socolow and Stephen Pacala created the concept of stabilization wedges – 25 billion ton "wedges" that need to be cut out of predicted future carbon emissions in the next 50 years to avoid a doubling of atmospheric carbon dioxide over pre-industrial levels.

The following pages contain:

- An introduction to the carbon and climate problem and the stabilization wedge concept (pp. 1-3)
- Descriptions of currently available mitigation tools that have the capacity to reduce future emissions by at least one wedge (pp. 4-8)
- Materials and instructions for carrying out the "Stabilization Wedges Game," an activity that drives home the scale of the carbon mitigation challenge and the tradeoffs involved in planning climate policy (pp. 9-16)

You can download a free up-to-date copy of this guide and view additional resources at our wedge website:

http://www.princeton.edu/~cmi/resources/stabwedge.htm

We hope to revise these materials with your input! If you have questions or feedback, please contact Dr. Roberta Hotinski, Consultant to CMI, at **hotinski@hotmail.com**.

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The Carbon and Climate Problem

Evidence continues to accumulate that carbon dioxide, or CO_2, from fossil fuel burning is causing dangerous interference in the climate. Including 2006, six of the seven warmest years on record have occurred since 2001 and the ten warmest years have occurred since 1995. Tropical glaciers with ice thousands and tens of thousands years old are disappearing, offering graphic rebuttal to claims that the recent warming is part of a natural cycle. Models predict that, without action to curb the growth of greenhouse gases in the atmosphere, we risk triggering catastrophe -- cessation of the dominant pattern of ocean circulation, loss of the West Antarctic ice sheet, or a several-fold increase in category-five hurricanes.

CO_2 and some other gases in the atmosphere change the climate by letting sunlight pass through the atmosphere and warm the planet, but hindering the escape of heat to outer space (a phenomenon popularly known as "the greenhouse effect"). By burning fossil fuels, which are composed mainly of hydrogen and carbon, we add CO_2 to the atmosphere.

The Earth's atmosphere currently contains about **800 billion tons** of carbon as CO_2, and combustion of fossil fuels currently adds about **7 billion tons of carbon** every year. If we think of the atmosphere as a bathtub, these carbon emissions are like water coming out of the tap to fill the tub (Figure 1). The ocean and land biosphere act as two drains for this bathtub – carbon can be taken out of the atmosphere by being dissolved in the surface ocean or being taken up by growing forests. However, these two "drains" only take out about half the carbon we emit to the atmosphere every year. The remainder accumulates in the atmosphere – currently at a rate of roughly 4 billion tons per year – so the level of carbon in the tub is rising.

The fossil fuel tap was "opened" with the Industrial Revolution.   In pre-industrial times, the atmosphere contained only about 600 billion tons of carbon, 200 billion tons less than today (Figure 2). As an illustration of the importance of CO_2 to the Earth's climate, ice core records show that past atmospheric carbon changes of a similar order have meant the difference between Ice Ages and the warmer conditions of the past 10,000 years.

Observations indicate that the carbon already added to the atmosphere has raised the global average temperature by around 1° Fahrenheit since the 19th century, and almost every year the fossil fuel tap is opened wider. An average of many forecasts predicts that we'll be adding **14 billion tons** of carbon per year to the "bathtub" in 50 years, twice today's rate, unless action is taken to control carbon emissions. If we follow this path, the amount of carbon in the atmosphere will reach 1200 billion tons -- **double its pre-industrial value** – well before the end of this century, **and will continue to increase** into the future. As a result, the Earth's temperature is expected to rise at a rate unprecedented in the last 10,000 years. **How can we get off this path?**

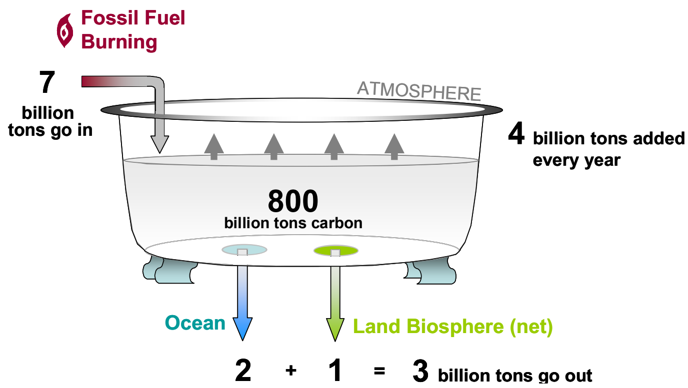


Figure 1. *The atmosphere as a bathtub, with current annual inputs and outputs of carbon. The level in the tub is rising by about 4 billion tons per year.*

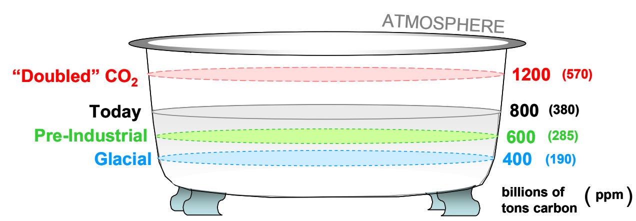


Figure 2. *Past, present, and potential future levels of carbon in the atmosphere in two units. 2.1 billions of tons of carbon = 1 part per million (ppm).*

An Introduction to Stabilization Wedges

The "stabilization wedges" concept is a simple tool for conveying the emissions cuts that can be made to avoid dramatic climate change.

We consider two futures - **allowing emissions to double versus keeping emissions at current levels** for the next 50 years (Figure 3). The emissions-doubling path (black dotted line) falls in the middle of the field of most estimates of future carbon emissions. The climb approxi-mately extends the climb for the past 50 years, during which the world's economy grew much faster than its car-bon emissions. Emissions could be higher or lower in 50 years, but this path is a reasonable reference scenario.

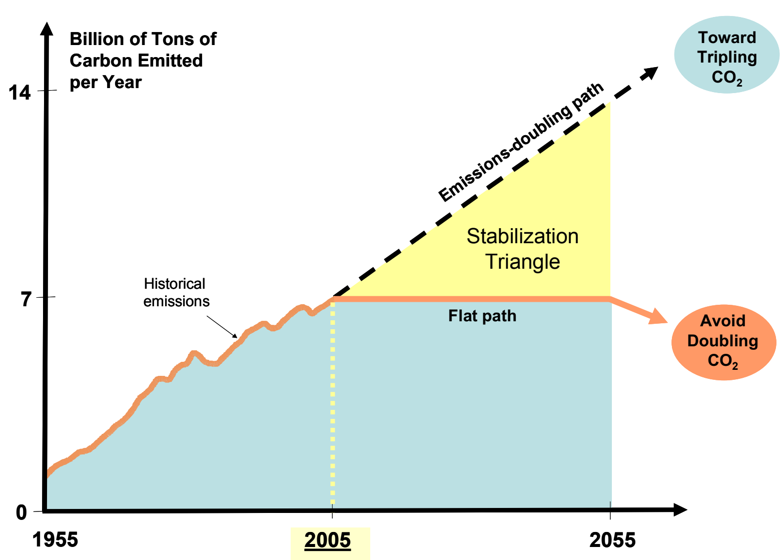


Figure 3. *Two possible emissions scenarios define the "stabilization triangle."*

The emissions-doubling path is predicted to lead to significant global warming by the end of this century. This warming is expected be accompanied by decreased crop yields, increased threats to human health, and more frequent extreme weather events. The planet could also face rising sea-level from melting of the West Antarctic Ice Sheet and Greenland glaciers and destabilization of the ocean's thermohaline circulation that helps redistribute the planet's heat and warm Western Europe.

In contrast, we can prevent a doubling of CO_2 if we can keep emissions flat for the next 50 years, then work to reduce emissions in the second half of the century (Figure 3, orange line). This path is predicted to keep atmospheric carbon under 1200 billion tons (which corresponds to about 570 parts per million (ppm)), allowing us to skirt the worst predicted consequences of climate change.

Keeping emissions flat will require cutting projected carbon output by about 7 billion tons per year by 2055, keeping a total of ~175 billion tons of carbon from entering the atmosphere (see yellow triangle in Figure 3). This carbon savings is what we call the **"stabilization triangle."**

The conventional wisdom has been that only revolutionary new technologies like nuclear fusion could enable such large emissions cuts. There is no reason, however, why one tool should have to solve the whole problem. CMI set out to quantify the impact that could be made by **a portfolio of existing technologies** deployed on a massive scale.

To make the problem more tractable, we divided the stabilization triangle into **seven "wedges."** (Figure 4) A wedge represents a carbon-cutting strategy that has the potential to grow from zero today to avoiding 1 billion tons of carbon emissions per year by 2055, or one-seventh of the stabilization triangle. The wedges can represent ways of either making energy with no or reduced carbon emissions (like nuclear or wind-produced electricity), or storing carbon dioxide to prevent it from building up as rapidly in the atmosphere (either through underground storage or biostorage).

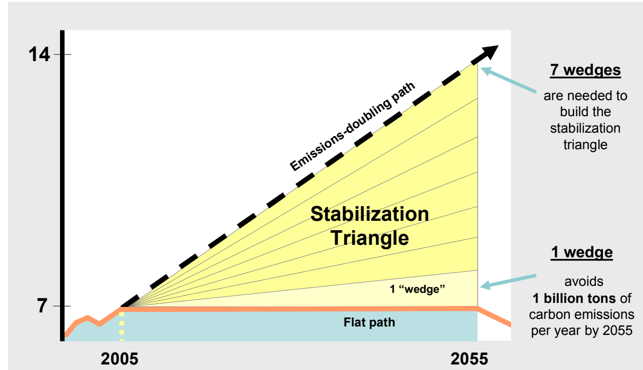


***Figure 4.** The seven "wedges" of the stabilization triangle.*

Keeping emissions flat will require the world's societies to "fill in" the seven wedges of the stabilization triangle. In CMI's analysis, **at least 15 strategies are available <u>now</u>** that, with scaling up, could each take care of at least one wedge of emissions reduction. No one strategy can take care of the whole triangle -- new strategies will be needed to address both fuel and electricity needs, and some wedge strategies compete with others to replace emissions from the same source -- but there is already a more than adequate portfolio of tools available to control carbon emissions for the next 50 years.

Wedge Strategies Currently Available

The following pages contain descriptions of 15 strategies already available that could be scaled up over the next 50 years to reduce global carbon emissions by 1 billion tons per year, or **one wedge.** They are grouped into four major color-coded categories:

Efficiency & Conservation

- Increased transport efficiency
- Reducing miles traveled
- Increased heating efficiency
- Increased efficiency of electricity production

Fossil-Fuel-Based Strategies

- Fuel switching (coal to gas)
- Fossil-based electricity with carbon capture & storage (CCS)
- Coal synfuels with CCS
- Fossil-based hydrogen fuel with CCS

Nuclear Energy

- Nuclear electricity

Renewables and Biostorage

- Wind-generated electricity
- Solar electricity
- Wind-generated hydrogen fuel
- Biofuels
- Forest storage
- Soil storage

Each strategy can be applied to one or more sectors, indicated by the following symbols:

= Electricity Production, = Heating and Direct Fuel Use, = Transportation, = Biostorage

Increased Efficiency & Conservation

1. Transport Efficiency

A typical 30 miles-per-gallon (30 mpg) car driving 10,000 miles per year emits a ton of carbon into the air annually. Today there are about 600 million cars in the world, and it's predicted that there will be about 2 billion passenger vehicles on the road in 50 years. **A wedge of emissions savings would be achieved if the fuel efficiency of all the cars projected for 2055 were doubled from 30 mpg to 60 mpg**. Efficiency improvements could come from using hybrid and diesel engine technologies, as well as making vehicles out of strong but lighter materials.

Cutting carbon emissions from trucks and planes by making these engines more efficient can also help with this wedge. Aviation is the fastest growing component of transportation.

2. Transport Conservation

A wedge would be achieved if the number of miles traveled by the world's cars were cut in half. Such a reduction in driving could be achieved if urban planning leads to more use of mass transit and if telecommuting becomes a good substitute for face-to-face communication.

3. Building Efficiency

Today carbon emissions arise about equally from providing electricity, transportation, and heat for industry and buildings. The largest potential savings in the buildings sector are in space heating and cooling, water heating, lighting, and electric appliances.

It's been projected that the buildings sector as a whole has the technological and economic potential to cut emissions in half. **Cutting emissions by 25% in all new and existing residential and commercial buildings would achieve a wedge worth of emissions reduction.** Carbon savings from space and water heating will come from both end-use efficiency strategies, like wall and roof insulation, and renewable energy strategies, like solar water heating and passive solar design.

4. Efficiency in Electricity Production

Today's coal-burning power plants produce about one-fourth of the world's carbon emissions, so increases in efficiency at these plants offer an important opportunity to reduce emissions. **Producing the world's current coal-based electricity with doubled efficiency would save a wedge worth of carbon emissions.**

More efficient conversion results at the plant level from better turbines, from using high-temperature fuel cells, and from combining fuel cells and turbines. At the system level, more efficient conversion results from more even distribution of electricity demand, from cogeneration (the co-production of electricity and useful heat), and from polygeneration (the co-production of chemicals and electricity).

Due to large contributions by hydropower and nuclear energy, the electricity sector already gets about 35% of its energy from non-carbon sources. Wedges can only come from the remaining 65%.

Suggested Link: **2007 IPCC Mitigation Report, pre-copy edit version**
http://www.mnp.nl/ipcc/pages_media/AR4-chapters.html

Carbon Capture & Storage (CCS)

If the CO_2 emissions from fossil fuels can be captured and stored, rather than vented to the atmosphere, then coal, oil, and natural gas could continue to be used to meet world energy demands without harmful climate consequences. The most economical way to pursue this is to capture CO_2 at large electricity or fuels plants, then store it underground. This strategy, called carbon capture and storage, or **CCS**, is already being tested in pilot projects around the world.

5. CCS Electricity

Today's coal-burning power plants produce about one fourth of the world's carbon emissions and are large point-sources of CO2 to the atmosphere. **A wedge would be achieved by applying CCS to 800 large (1 billion watt) baseload coal power plants or 1600 large baseload natural gas power plants in 50 years. As with all CCS strategies, to provide low-carbon energy the captured CO2 would need to be stored for centuries.**

There are currently 3 pilot storage projects in the world, which each store about 1 million tons of carbon underground per year. Storing a wedge worth of emissions will require 3,500 times the capacity of one of these projects.

6. CCS Hydrogen

Hydrogen is a desirable fuel for a low-carbon society because when it's burned the only emission product is water vapor. Because fossil fuels are composed mainly of carbon and hydrogen they are potential sources of hydrogen fuel, but to have a climate benefit the excess carbon must be captured and stored.

Pure hydrogen is now produced mainly in two industries: ammonia fertilizer production and petroleum refining. Today these hydrogen production plants generate about 100 million tons of capturable carbon. Now this CO2 is vented, but only small changes would be needed to implement carbon capture. **The scale of hydrogen production today is only ten times smaller than the scale of a wedge of carbon capture.**

Distributing hydrogen fuel, however, requires building a hydrogen infrastructure connecting large plants with smaller-scale users.

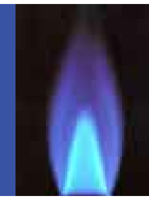
7. CCS Synfuels

In 50 years a significant fraction of the fuels used in vehicles and buildings may not come from conventional oil, but from coal. When coal is heated and combined with steam and air or oxygen, carbon monoxide and hydrogen are released and can be processed to make a liquid fuel called a "synfuel."

Coal-based synfuels result in nearly twice the carbon emissions of petroleum-derived fuels, since large amounts of excess carbon are released during the conversion of coal into liquid fuel. The world's largest synfuels facility, located in South Africa, is the largest point source of atmospheric CO2 emissions in the world. **A wedge is an activity that, over 50 years, can capture the CO2 emissions from 180 such coal-to-synfuels facilities.**

Suggested link: **U.S. National Energy Technology Laboratory: Sequestration FAQ's**
http://www.netl.doe.gov/technologies/carbon_seq/faqs.html

Fuel Switching



8. Fuel-Switching for Electricity

Because of the lower carbon content of natural gas and higher efficiencies of natural gas plants, producing electricity with natural gas results in only about half the emissions of coal. **A wedge would require 1,400 large (1 billion watt) natural gas plants displacing similar coal-electric plants.**

This wedge would require generating approximately four times the Year 2000 global production of electricity from natural gas. In 2055, 1 billion tons of carbon per year would be emitted from natural gas power plants instead of 2 billion tons per year from coal-based power plants.

Materials flows equivalent to one billion tons of carbon per year are huge: a wedge of flowing natural gas is equivalent to 50 large liquefied natural gas (LNG) tankers docking and discharging every day. Current LNG shipments world-wide are about one-tenth as large.

Suggested link: **U.S. Environmental Protection Agency: Electricity from Natural Gas**
http://www.epa.gov/cleanenergy/natgas.htm

Nuclear Energy

9. Nuclear Electricity

Nuclear fission currently provides about 17% of the world's electricity, and produces no CO_2. **Adding new nuclear electric plants to triple the world's current nuclear capacity would cut emissions by one wedge if coal plants were displaced.**

In the 1960s, when nuclear power's promise as a substitute for coal was most highly regarded, a global installed nuclear capacity of about 2000 billion watts was projected for the year 2000. The world now has about one-sixth of that envisioned capacity. If the remainder were to be built over the next 50 years to displace coal-based electricity, roughly two wedges could be achieved.

In contrast, phasing out the worlds' current capacity of nuclear power would require adding an additional half wedge of emissions cuts to keep emissions at today's levels.

Suggested link: **Climate Change 2001: Mitigation, "Nuclear Power"**
http://www.grida.no/climate/ipcc_tar/wg3/128.htm

Renewable Energy & Biostorage

10. Wind Electricity

Wind currently produces less than 1% of total global electricity, but wind electricity is growing at a rate of about 30% per year. **To gain a wedge of emissions savings from wind displacing coal-based electricity, current wind capacity would need to be scaled up by a factor of 30.**

Based on current turbine spacing on wind farms, a wedge of wind power would require a combined area roughly the size of Germany. However, land from which wind is harvested can be used for many other purposes, notably for crops or pasture.

11. Solar Electricity

Photovoltaic (PV) cells convert sunlight to electricity, providing a source of CO2-free and renewable energy. The land demand for solar is less than with other renewables, but **installing a wedge worth of PV would still require arrays with an area of two million hectares, or 20,000 km^2.** The arrays could be located on either dedicated land or on multiple-use surfaces such as the roofs and walls of buildings. The combined area of the arrays would cover an area the size of the U.S. state of New Jersey, or about 12 times the size of the London metropolitan area.

Since PV currently provides less than a tenth of one percent of global electricity, achieving a wedge of emissions reduction would require increasing the deployment of PV by a factor of 700 in 50 years, or installing PV at 60 times the current rate for 50 years.

A current drawback for PV electricity is its price, which is declining but is still 2-5 times higher than fossil-fuel-based electricity. Also, PV can not be collected at night and, like wind, is an intermittent energy source.

12. Wind Hydrogen

Hydrogen is a desirable fuel for a low-carbon society because when it's burned the only emission product is water vapor. To make hydrogen fuel from wind energy, electricity generated by wind turbines is used in electrolysis, a process that liberates hydrogen from water. **Wind hydrogen displacing vehicle fuel is only about half as efficient at reducing carbon emissions as wind electricity displacing coal electricity, and 4 million (rather than 2 million) windmills would be needed for one wedge of emissions reduction.** That increase would require scaling up current wind capacity by about 80 times, requiring a land area roughly the size of France.

Unlike hydrogen produced from fossil fuels with CCS, wind hydrogen could be produced at small scales where it is needed. Wind hydrogen thus would require less investment in infrastructure for fuel distribution to homes and vehicles.

Renewables & Biostorage (cont'd)

13. Biofuels

Because plants take up carbon dioxide from the atmosphere, combustion of "biofuels" made from plants like corn and sugar cane simply returns borrowed carbon to the atmosphere. Thus burning biofuels for transportation and heating will not raise the atmosphere's net CO2 concentration.

The land constraints for biofuels, however, are more severe than for wind and solar electricity - just one wedge worth of carbon-neutral biofuels would require 1/6th of the world's cropland and an area roughly the size of India. Bioengineering to increase the efficiency of plant photosynthesis and use of crop residues could reduce that land demand, but large-scale production of plant-based biofuels will always be a land-intensive proposition.

Ethanol programs in the U.S. and Brazil currently produce over 35 billion liters of biofuel per year from corn and sugarcane, respectively. **One wedge of biofuels savings would require increasing today's ethanol production by about 30 times, and making it sustainable.**

14. Forest Storage

Land plants and soils contain large amounts of carbon. Today, there is a net *removal* of carbon from the atmosphere by these "natural sinks," in spite of deliberate deforestation by people that *adds* between 1 and 2 billion tons of carbon to the atmosphere. Evidently, the carbon in forests is increasing elsewhere on the planet.

Land plant biomass can be increased by both reducing deforestation and planting new forests. **Halting global deforestation in 50 years would provide one wedge of emissions savings.** To achieve a wedge through forest planting alone, new forests would have to be established over an area the size of the contiguous United States.

15. Soil Storage

Conversion of natural vegetation to cropland reduces soil carbon content by one-half to one-third. However, soil carbon loss can be reversed by agricultural practices that build up the carbon in soils, such as reducing the period of bare fallow, planting cover crops, and reducing aeration of the soil (such as by no till, ridge till, or chisel plow planting). **A wedge of emissions savings could be achieved by applying carbon management strategies to all of the world's existing agricultural soils.**

Suggested links:

U.S. DOE, Energy Efficiency & Renewable Energy
http://www.eere.energy.gov/

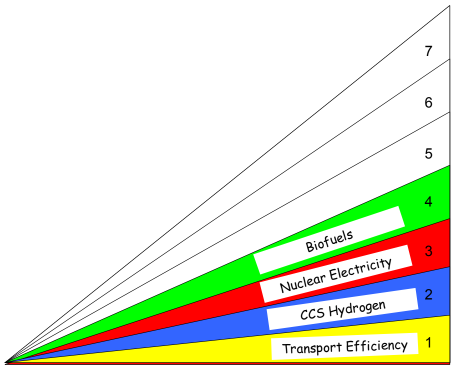
Climate Change 2001: Mitigation, "Land Use, Land-Use Change, and Carbon Cycling in Terrestrial Ecosystems"
http://www.grida.no/climate/ipcc_tar/wg3/158.htm

Student Game Instructions & Materials

The goal of this game is to construct a stabilization triangle using seven wedge strategies, with only a few constraints to guide you. From the 15 potential strategies, choose 7 wedges that your team considers the best global solutions. Keep costs and impacts in mind.

1) **Find the Wedge Gameboard** in the back of this packet and cut apart the red, green, yellow, and blue wedge pieces supplied (if not already done for you).

2) **Read the information** on each of the 15 strategies in the **Wedge Table** below. Costs ($, $$, $$$) are indicated on a relative basis, and are intended only to provide guidance, not a numerical score.



3) Each team should **choose one wedge strategy at a time** to fill the 7 spots on the wedge gameboard (see illustration of gameboard with 4 wedges filled in at left – this is only an example!).

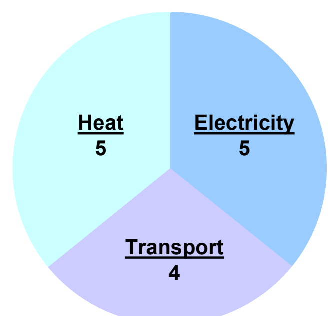
4) **The four colors of the wedge pieces indicate the major category** (fossil fuel-based (blue), efficiency and conservation (yellow), nuclear (red), and renewables and biostorage (green)). Choose a red, yellow, blue, or green wedge for your strategy, then **label the wedge to indicate the specific strategy** (examples shown in illustration at left).

5) **Most strategies may be used more than once**, **but not all cuts can come from one energy sector.**

Of the 14 billion tons of carbon emitted in the 2055 baseline scenario, we assume electricity production accounts for 5 wedges, transportation fuels accounts for 4 wedges, and direct fuel use for heat and other purposes accounts for 5 wedges <u>(see pie chart right).</u>

<u>Because biostorage takes carbon from all sources out of the atmosphere, biostorage wedges do not count toward an energy sector.</u>

Carbon Emissions by Sector



Need <u>7</u> wedges – not all wedges can come from one energy sector!

6) **Cost and impacts must be considered.** Each wedge should be viewed in terms of both technical and political viability.

7) For each of the 7 strategies chosen, each team should **fill out one line in the Wedge Worksheet**. After all 7 wedges have been chosen, tally total cuts from each energy sector (Electricity, Transport, and Heat) and costs. Use the scoring table to predict how different interest groups would rate your wedge on a scale from 1 to 5.

8) Each team should **give a 5-minute oral report** on the reasoning behind its triangle. The report should justify your choice of wedges to the judge(s) and to the other teams. **Note: There is no "right" answer** – the team that makes the best case wins, not necessarily the team with the cheapest or least challenging solution

Stabilization Wedges – 15 Ways to Cut Carbon

= Electricity Production, = Heating and Direct Fuel Use, = Transportation, = Biostorage

Strategy	Sector	Description	1 wedge could come from...	Cost	Challenges
1. Efficiency – Transport		Increase automobile fuel efficiency (2 billion cars projected in 2050)	**… doubling the efficiency of all world's cars from 30 to 60 mpg**	$	Car size & power
2. Conservation - Transport		Reduce miles traveled by passenger and/or freight vehicles	**… cutting miles traveled by all passenger vehicles in half**	$	Increased public transport, urban design
3. Efficiency -Buildings		Increase insulation, furnace and lighting efficiency	**… using best available technology in all new and existing buildings**	$	House size, consumer demand for appliances
4. Efficiency –Electricity		Increase efficiency of power generation	**… raising plant efficiency from 40% to 60%**	$	Increased plant costs
5. CCS Electricity		CO_2 from fossil fuel power plants captured, then stored underground (700 large coal plants or 1400 natural gas plants)	**… injecting a volume of CO2 every year equal to the volume of oil extracted**	$$	Possibility of CO_2 leakage
6. CCS Hydrogen		Hydrogen fuel from fossil sources with CCS displaces hydrocarbon fuels	**… producing hydrogen at 10 times the current rate**	$$$	New infrastructure needed, hydrogen safety issues
7. CCS Synfuels		Capture and store CO_2 emitted during synfuels production from coal	**… using CCS at 180 large synfuels plants**	$$	Emissions still only break even with gasoline
8. Fuel Switching – Electricity		Replacing coal-burning electric plants with natural gas plants (1400 1 GW coal plants)	**… using an amount of natural gas equal to that used for all purposes today**	$	Natural gas availability
9. Nuclear Electricity		Displace coal-burning electric plants with nuclear plants (2 x current capacity)	**… ~3 times the effort France put into expanding nuclear power in the 1980's, sustained for 50 years**	$$	Weapons proliferation, nuclear waste, local opposition
10. Wind Electricity		Wind displaces coal-based electricity (30 x current capacity)	**… using area equal to ~3% of U.S. land area for wind farms**	$$	Not In My Back Yard (NIMBY)
11. Solar Electricity		Solar PV displaces coal-based electricity (700 x current capacity)	**.. using the equivalent of a 100 x 200 km PV array**	$$$	PV cell materials
12. Wind Hydrogen		Produce hydrogen with wind electricity	**… powering half the world's cars predicted for 2050 with hydrogen**	$$	NIMBY, Hydrogen infrastructure, safety
13. Biofuels		Biomass fuels from plantations replace petroleum fuels	**… scaling up world ethanol production by a factor of 30**	$$	Biodiversity, competing land use
14. Forest Storage		Carbon stored in new forests	**… halting deforestation in 50 years**	$	Biodiversity, competing land use
15. Soil Storage		Farming techiques increase carbon retention or storage in soils	**… using conservation tillage on all the world's agricultural soils**	$	Reversed if land is deep-plowed later

For more information, go to the Carbon Mitigation Initiative website at http://www.princeton.edu/~cmi

Wedge Worksheet

1. Record your strategies to reduce total fossil fuel emissions by 7 wedges by 2055

(1 "wedge" = 1 billion tons carbon per year)

- You may use a strategy more than once
- Use only whole numbers of wedges
- You may use a maximum of
  - 5 electricity wedges (E)
  - 4 transportation wedges(T)
  - 5 heat or direct fuel use wedges (H)

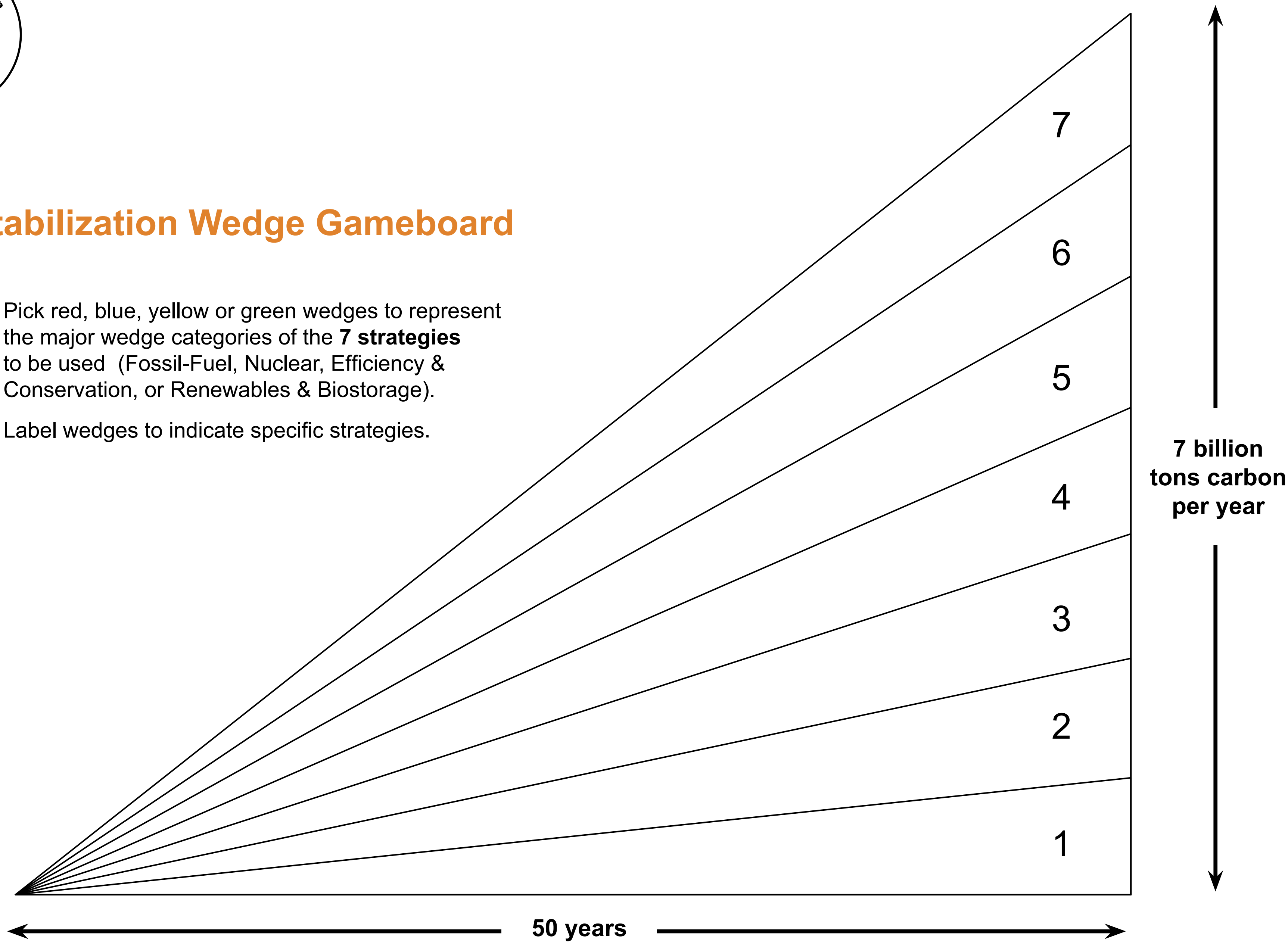
Wedge #	Strategy	Sector E,T,H, or B	Cost $	Challenges
1				
2				
3				
4				
5				
6				
7				
	TOTALS	E=_____ (5 max) T=_____ (4 max) H=_____ (5 max) B=_____	_____	

2. Guess the score each stakeholder group would give your team's triangle on a scale of 1 to 5 (5 = best).

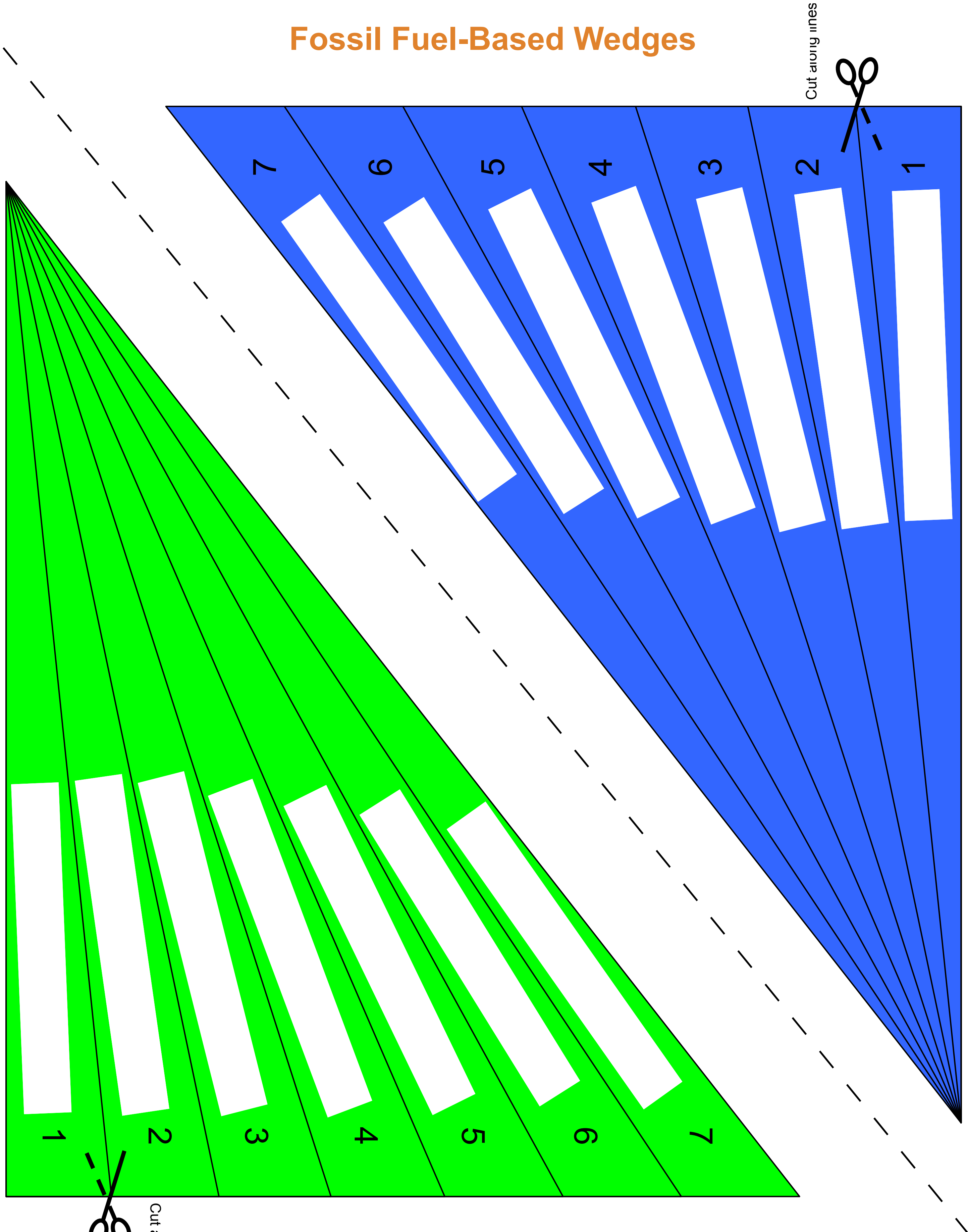
Judge:	Taxpayers/ Consumers	Energy Companies	Environmental Groups	Manufacturers	Industrialized country governments	Developing country governments
Score:						

Stabilization Wedge Gameboard

1. Pick red, blue, yellow or green wedges to represent the major wedge categories of the **7 strategies** to be used (Fossil-Fuel, Nuclear, Efficiency & Conservation, or Renewables & Biostorage).
2. Label wedges to indicate specific strategies.

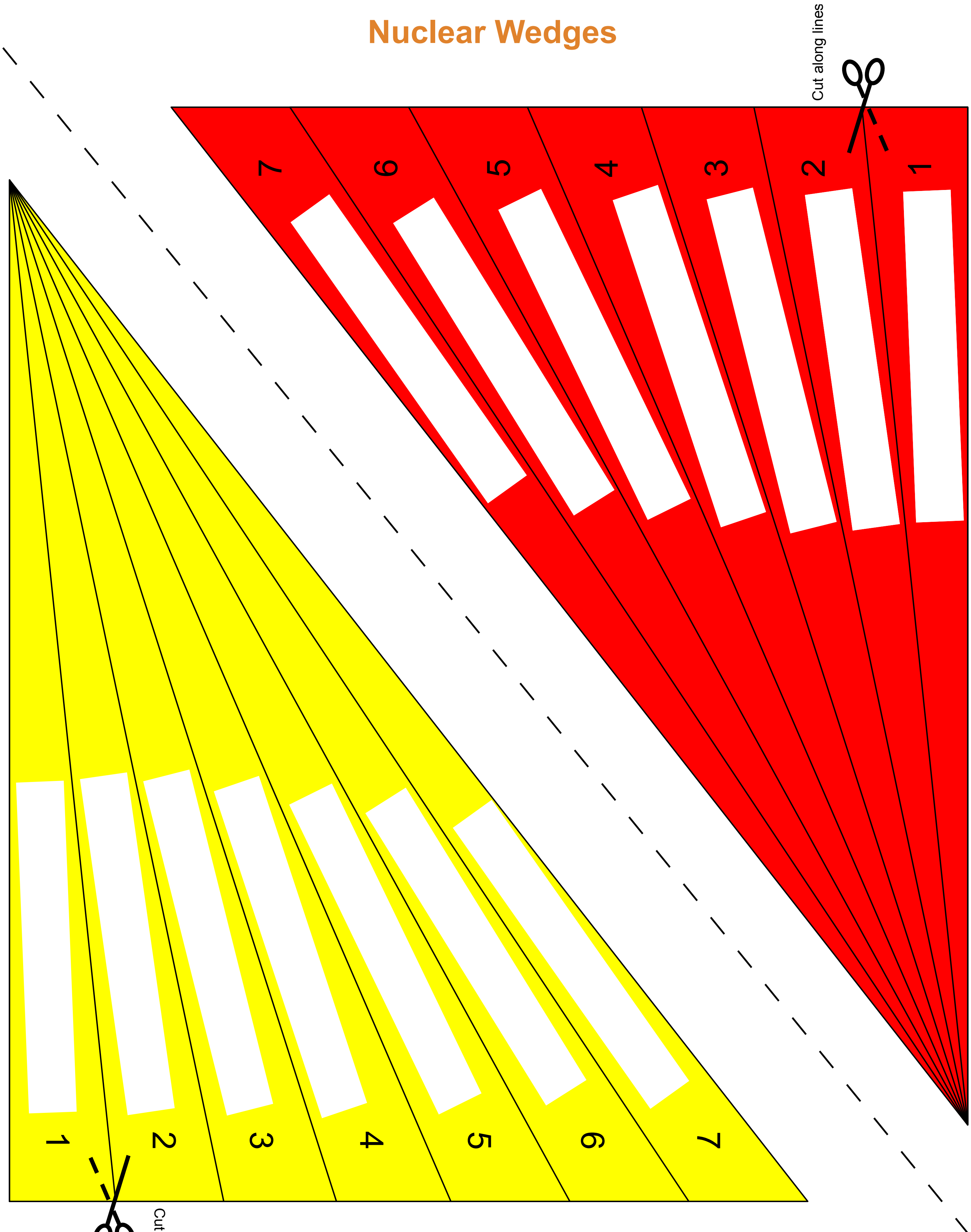


Fossil Fuel-Based Wedges



Renewables & Biostorage Wedges

Nuclear Wedges



Efficiency & Conservation Wedges

Lesson Fourteen:
The Great Climate Change Debate

Subjects

Science, Social Studies, Geography, Technology, Environmental Education, Language Arts, Civics

Estimated Time

Two 45-minute class periods

Grade Level

9-12

Overview

- This lesson focuses on the international debate over how to address climate change, possible political strategies, and scientific solutions to the problem.

Objectives

- Students gather information about climate change and the political and scientific strategies to address it.
- Students participate in an organized debate regarding the ways to address climate change on both a regional and global scale.
- Students learn about climate change, its possible long-term effects, and what ideas the scientific and political communities have been debating.

Materials

- Internet access: Medium-speed (28,000 BPS via modem) or High-speed (greater than 1 MBPS via network). Some example Internet sights are provided
- Books, magazines, or journal articles focused on climate change

Solar thermal electric panels at the EU research centre, Almeria, Andalucia. Spain

The Great Climate Change Debate

Procedure

Have students begin this activity by instructing them to search the Internet (start with the links provided) to gather information regarding possible solutions to climate change. After they have gathered enough information, ask them to read over the materials they have found and begin to gather further information on the solution(s) they think are most worth pursuing. As they are collecting their materials and before choosing their positions, have them consider the questions below:

- Will there be one successful action for climate change or will there be a need for multiple actions?
- Should we focus on how to adapt to the effects that we already see and know we will experience in the future?
- Will the solution be political, scientific, or both?
- Can science and policy work together on this issue? Are there examples of this in the past?
- Will the best actions be at the global, regional, or local levels?
- What role do students play in finding a solution to climate change?

The groups gather to participate in a debate about their positions. As participants offer their views, they should support their positions with evidence drawn from their research. Positions and evidence should be scrutinized by the group according to scientific and political merits, weight of evidence, and influences by outside parties.

Extend

As the discussion continues, students should write down all the solutions that are proposed. At an appropriate ending point, break the students up into three groups. The first two groups will represent the United States House of Representatives and the Senate while the third group will be the United Nations. If time permits have the students research their groups using the internet. Things they should consider should be who they represent (states, one country, or a global community) and what their group's responsibilities are. Finally have the groups attempt to vote on what the best strategies are for combating global warming. Let the students know that they can decide on multiple solutions. Each group should have a spokesperson, Speaker, who can summarize the reasons why the group voted the way they did to the rest of the class.

If time allows, then the House of Representatives and Senate should attempt to conform the results from their voting ballots to one agreement. When successful, the same should be done with the results from these U.S. branches with the United Nations.

House of Representatives Official Website: http://www.house.gov/house/Tying_it_all.shtml

United States Senate Official Website: http://www.senate.gov/

United Nations Official Website: http://www.un.org/aboutun

Web Resources

Global and U.S. Policy Links

United Nations Summary the Kyoto Protocol: http://unfccc.int/kyoto_protocol/background/items/2879.php

BBC Online coverage of the Kyoto Protocol: http://news.bbc.co.uk/2/hi/science/nature/4269921.stm

Official site of the Regional Greenhouse Gas Initiative (REGGI): http://www.rggi.org/about.htm

Article by the Pew Center on Climate Change about Congressional Action: http://www.pewclimate.org/what_s_being_done/in_the_congress/

Debate on how the U.S. should handle climate policy between John Kerry and Newt Gingrich: http://www.cnn.com/2007/POLITICS/04/10/gingrich.kerry/index.html

Official U.S. EPA National Goal to Reduce Climate Change: http://www.epa.gov/climatechange/policy/intensitygoal.html

NASA list of Global Warming and Climate Change Policy links: http://gcmd.nasa.gov/Resources/pointers/glob_warm.html

Citywide initiatives to combat climate change

Rocky Mountain News Report on Mayor of Denver's "Climate Action Plan": http://www.rockymountainnews.com/drmn/local/article/0,1299,DRMN_15_5580343,00.html

Cities Take Lead on Environment as Debate Drags at Federal Level: http://www.washingtonpost.com/wp-dyn/content/article/2007/06/08/AR2007060802779.html

New York Mayor Plans All-Hybrid Taxi Fleet: http://www.nytimes.com/2007/05/23/nyregion/23taxi.html?ex=1337659200&en=f4db51714fa1c796&ei=5124&partner=permalink&exprod=permalink

Businesses

http://www.worldwildlife.org/climate/projects/climatesavers/companies.cfm

Clean Energy Links

U.S. EPA clean energy links: http://www.epa.gov/solar/addinfo.htm

Natural Resource Defense Council's list of green energy and technology links: http://www.nrdc.org/reference/topics/energy.asp

National Standards Alignment

National Science Education Standards

Unifying Concepts and Processes (K-12): Consistency, change, and measure

Science as Inquiry, Content Standard A (9-12): Abilities necessary to do scientific inquiry; Understandings about scientific inquiry

Science in Personal and Social Perspectives, Content Standard F (9-12): Environmental quality; Science and technology in local, national, and global changes

Curriculum Standards for Social Studies

Strand 2: Time, Continuity, and Change

Strand 3: People, Places, and Environments

Strand 8: Science, Technology, and Society

Strand 9: Global Connections

National Geography Standards

Standard 15: Environment and Society. How physical systems affect human systems.

Technology Foundation Standards

Standard 3: Technology Productivity Tools. Students use technology tools to enhance learning, increase productivity, and promote creativity.

Alberto Granja spearheads a WWF project to recycle used oil from ships. He has so far collected 150,000 gallons that would otherwise have been cast overboard.

Environmental Education Guidelines for Learning (K-12)

Strand 1: Questioning and Analysis Skills

Strand 2: Knowledge of Environmental Processes and Systems

Strand 2.1: The Earth as a Physical System

Strand 2.4: Environment and Society

Strand 3: Skills for Understanding and Addressing Environmental Issues

Strand 3.1: Skills for Analyzing and Investigating Environmental Issues

Standards for the English Language Arts

Standard 2: Students read a wide range of literature from many periods in many genres to build an understanding of the many dimensions (e.g., philosophical, ethical, aesthetic) of human experience.

Standard 4: Students adjust their use of spoken, written, and visual language (e.g., conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.

Standard 5: Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences for a variety of purposes.

Standard 11: Students participate as knowledgeable, reflective, creative, and critical members of a variety of literacy communities.

Standard 12: Students use spoken, written, and visual language to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information.)

Standards for Civics

Standard 1: Civic Life, Politics, and Government

Standard 2: Foundations of the Political System

Standard 3: Principles of Democracy

Standard 4: Other Nations and World Affairs

Standard 5: Roles of the Citizen

Lesson Fifteen:
Climate Witness Oral History Project

Subjects

Science, Social Studies, Geography, Technology, Environmental Education, Language Arts

Estimated Time

Two to three 50-minute class periods

Time-Reduction Suggestions

Part 2 can be an out-of-class assignment, condensing the activity to two class periods; just ask students to bring three copies of their story to class.

- Classroom presentations of stories can be eliminated, moving the discussion to the end of Part 2, reducing the lesson to two class periods.
- Part 1 can be eliminated if similar lessons are conducted to replace it, such as *Climate Change in My City* or *The Forecaster*.

Teacher Note

This activity can be completed independent of other activities in this packet, or it can be done as a follow-up to an activity on regional effects of climate change. If desired, some of the tasks from other activities could be incorporated into this activity.

Grade Level

9-12

Overview

Students interview older residents in the community about climate changes during their lifetimes and compare the results to a climate change index that is based on historical temperature measurements.

Objectives

- Students explore the factors that determine human perceptions of weather and climate.
- Students use interviews to develop a nonfiction story on effects of climate change in their region.
- Students examine the historical record of climate change in their area.
- Students discuss the implications of human perceptions of local climate change on global climate change policy.
- Students use active listening and speaking strategies for classroom presentations.
- Students use creative writing skills to develop a story.
- Students work with a group or partner to critique, edit, and analyze each other's stories.
- Students will publish work on a website.

Materials

- Computers with Internet access
- WWF Guide to writing a Climate Witness Story and Interview Form (included)
- WWF Consent Form: Parent and Interviewee (included)
- Sample Interview Questions (included)

Background:

Changes in temperature, precipitation, and extreme weather all affect ecosystems, which affect the people dependent on those natural resources for food production and sustainable development. In recent decades, western science has documented many observed changes in climate and the associated impacts. Climate Witness seeks to extend such assessments of climate change to include observations from local people directly affected by global and local climate change.

Climate Witness is WWF's initiative to document the experiences from people who are witnessing the impacts of climate change on their local environment. By demonstrating that climate change is already affecting the lives of a growing number of people today, we will bring a real-life perspective to what many view as a somewhat ambiguous and distant threat, which will help us to promote effective solutions to climate change.

The problem of climate change is urgently upon us. Putting a human face on climate change and disseminating information about the impacts of climate change on people's lives is an important part of informing the public. Documenting local observations will help raise the level of personal and political concern about climate change in order for action to be taken to keep the planet below a 2°C increase in global mean temperature as compared to preindustrial times.

Climate Witness Oral History Project

Procedure

Part 1: Regional Effects

1. After your class completes lessons regarding the science of climate change (*Our Unique Atmosphere* and/or *Emissions of Heat-trapping Gases)*, lead a class discussion on the effects of climate change on their area. Ask the class to characterize the climate of their region. They should consider such factors as the average temperature and precipitation, the magnitude of the temperature change from one season to another, the seasonal distribution of precipitation, the nature of the air masses that affect the climate, proximity to the ocean, large mountain ranges, or large lakes, etc. Then ask the students if they have noticed any changes in their normal weather patterns and what this means for the future of agriculture, recreation, and habitation in the region.

2. Ask the students to interview an older relative or neighbor in the region about the changes in climate they have witnessed over the year. Hand out the WWF Guide to Writing a Climate Witness Story and Interview Form, the Consent Form, and the Sample Interview Questions handout. Ask the students to find a person who will consent to the assignment, and have him/her (the interviewee) fill out both the forms. You, as the teacher, will sign as the WWF liaison on the consent form. Ask him/her to use the Sample Interview Questions to develop a story. If you would like to add or change any questions, please feel free to adapt them. Then, he/she should go over the Interview Form with the volunteer, and ask him/her to explain his/her responses that are not apparent to the student based on the interview just conducted. Give the students a suitable amount of time to create a Climate Witness Story with a 1.5 page limit typed.

Part 2: Climate Witness Stories

1. When the class reconvenes with their stories, divide the class into groups of three. Ask the students to read each other's stories and offer

Piaroa indians in a dug out canoe descending a river. The Piaroa Tribe lives in the Amazon rain forest of Venezuela

© Liza Schillo, 2007

Wild Crocus next to a street in Washington, DC

comments based on the writing guidelines, grammar, focus, appropriateness to regional changes, and writing. After the students have offered their comments, ask them to edit their own stories as appropriate.

Part 3: Optional - Classroom Presentations

1. Ask the students to present their stories to the class, either by reading or offering a summary. Offer time for discussion after the information is presented.

- Did anyone say anything that surprised others? Were all the stories similar?
- What does the material presented demonstrate about the student's knowledge of his/her regional environment? Are there scientific predictions not discussed in the stories? Is there anything people do not understand or believe about the regional effects of climate change?
- Was there a clear opinion on change in climate or did answers differ from one resident to another? If they differed, were there any clear patterns relating the answers to the length of time the resident lived in the area, lifestyle, occupation, or other factors?
- Finally, how does perception of climate change affect a person's position on climate change policy? For example, people who believe there has been a noticeable change in local climate might be more interested in supporting efforts to curtail greenhouse gas emissions.

2. Ask the students to review the interview form, and have them decide if they consent to publish their stories on a WWF Web page for others to read and benefit from their observations. Explain that the stories will be listed with their names and region and the names of their interviewees, but without contact information. Their stories can be removed from the Web site any time at their discretion.

3. Ask the students to submit their stories electronically on the WWF Climate Portal Web site. Encourage your students to read the stories of others posted on the Web site from different regions. For extra credit, have students write a short summary of another student's story and analyze based on climate data in the region over the years, found by Internet research.

4. Please collect consent forms and send to:

Kate Graves, Climate Change Team
World Wildlife Fund
1250 24th St., NW
Washington, DC 20037

National Standards Alignment

National Science Education Standards

Unifying Concepts and Processes (K-12): Consistency, change, and measure

Science as Inquiry, Content Standard (9-12): Abilities necessary to do scientific inquiry; Understandings about scientific inquiry

Science in Personal and Social Perspectives, Content Standard (9-12): Environmental quality; Science and technology in local, national, and global changes

Curriculum Standards for Social Studies

Strand 2: Time, Continuity, and Change

Strand 3: People, Places, and Environments

Strand 8: Science, Technology, and Society

Strand 9: Global Connections

National Geography Standards

Standard 4: Places and Regions. The physical and human characteristics of places.

Standard 6: Places and Regions. How culture and experience influence people's perceptions of places and regions.

Standard 15: Environment and Society. How physical systems affect human systems.

Standard 18: Uses of Geography. How to apply geography to interpret the present and plan for the future.

Technology Foundation Standards

Standard 1: Basic Operations and Concepts. Students are proficient in the use of technology.

Standard 3: Technology Productivity Tools. Students use technology tools to enhance learning, increase productivity, and promote creativity.

Standard 4: Technology Communications Tools (for extension activities). Students use telecommunications to collaborate, publish, and interact with peers, experts, and other audiences.

Environmental Education Guidelines for Learning (K-12)

Strand 1: Questioning and Analysis Skills

Strand 2: Knowledge of Environmental Processes and Systems

Strand 2.1: The Earth as a Physical System

Strand 2.4: Environment and Society

Strand 3: Skills for Understanding and Addressing Environmental Issues

Strand 3.1: Skills for Analyzing and Investigating Environmental Issues

Standards for the English Language Arts

Standard 2: Students read a wide range of literature from many periods in many genres to build an understanding of the many dimensions (e.g., philosophical, ethical, aesthetic) of human experience.

Standard 4: Students adjust their use of spoken, written, and visual language (e.g., conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.

Standard 5: Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences for a variety of purposes.

Standard 6: Students apply knowledge of language structure, language conventions (e.g., spelling and punctuation), media techniques, figurative language, and genre to create, critique, and discuss print and nonprint texts.

Standard 9: Students develop an understanding of and respect for diversity in language use, patterns, and dialects across cultures, ethnic groups, geographic regions, and social roles.

Standard 11: Students participate as knowledgeable, reflective, creative, and critical members of a variety of literacy communities.

Standard 12: Students use spoken, written, and visual language to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information.

WWF CLIMATE WITNESS FORM

Climate Witness gathers hundreds of stories from people around the world who can see real climate change. Have you seen things changing over time? Let us know!

Instructions

- *Please fill in your personal information in Section 1*
- *Please tick the boxes for climate changes or consequences in Section 2, 3, 4 or 5. You may not have observations for every section, but we ask you to tick* ***at least one box from Section 2 or 3****.*
- *Only tick boxes where you have personally observed an impact or consequence, not assumptions*
- *Write your witness story in your own words. Please use the guides to writing in Sections 6 and 7 of this form, they will make it task easier, and make it consistent with other stories.*
- Attach your story to the form and send to: **WWF International,** Climate Witness Program, GPO Box 528, SYDNEY NSW 2001. or Fax: +61 (0)2 9281 1060.

1.YOUR PERSONAL INFORMATION

Your full name

Village or Town

Your Postal Address

State/County/Province

Country

Telephone

Email

Date of Birth

Age last birthday

Profession

Location of Observations

Length of time of observations

☐ Are you in principle available to answer questions from journalists?

☐ Are you prepared to travel to your capital for Climate Witness event if the costs were reimbursed?

☐ Are you prepared to travel internationally for Climate Witness event if the costs were reimbursed?

☐ Are you interested in receiving notices about similar climate witness stories from around the world?

☐ Are you interested in receiving notices about other climate witness stories from your county?

☐ Are you interesting in receiving WWF's climate witness newsletter once every 2 months?

2. YOUR CLIMATE OBSERVATIONS

Instructions *Please tick the* changes *you have witnessed directly in your area:*

Changes in Temperature	***Increase***	***Decrease***
Number of hot days	☐	☐
Number of cold days	☐	☐
Sea water temperature	☐	☐

Changes in extreme weather		
Heat waves	☐	☐
Tropical/extreme storms	☐	☐
New storm types	☐	☐
Hurricanes	☐	☐

Changes in precipitation	***Increase***	***Decrease***
Rainfall	☐	☐
Snowfall	☐	☐

Changes in ocean and wind currents		
Altered currents/upwellings	☐	☐
Tropical cyclones	☐	☐
Driving rain		
Extreme hail	☐	☐
Monsoon	☐	☐

3. CONSEQUENCES OF CHANGES

Instructions *Please tick the* consequences *of any climate changes you have witnessed directly in your area:*

Marine or freshwater systems

Coral Reefs ☐
- *Bleaching* ☐
- *Algae or seaweed growth* ☐

Marine ☐
- *Abundance of plankton* ☐
- *Open sea seasonal patterns* ☐
- *Open sea geographical patterns* ☐
- *Rocky shore & intertidal communities* ☐
- *Kelp forests and seaweed* ☐
- *Invasive species, bacteria, micro-organisms* ☐
- *Fish populations, recruitment* ☐
- *Sea birds and marine animals* ☐
- *Marine biodiversity* ☐

Changes in marine fisheries ☐

Changes in lakes ☐
- *Productivity or abundance of species* ☐
- *Community composition* ☐
- *Algal community composition* ☐
- *Fish migration* ☐
- *Annual and seasonal cycles* ☐
- *Changes in rivers* ☐
- *Species abundance, distribution & migration* ☐

Coastal processes and zones

Changes to coastal wetlands ☐

Changes in storm surges, flood heights and ☐

Coast land loss, damage or sea-level rise ☐

Human health

Heat and cold health effects ☐

Vector-bourne, rodent bourne diseases ☐
- *Tick Vectors* ☐
- *Lyme disease* ☐
- *Malaria* ☐
- *Dengue fever* ☐
- *West Nile virus* ☐
- *Leptospirosis* ☐
- *Hantavirus pulmonary syndrome* ☐
- *Schistosomes/ Bilharzia* ☐

Emerging food and water-bourne disease ☐
- *Salmonellosis* ☐

Pollen-and dust –related ☐

Health effects from wind, storm and floods ☐

Health effects from drought, or famine ☐

Food/water safety ☐

Air quality and disease ☐

Ultra violet radiation and health ☐

Terrestrial Systems

Terrestrial Systems	Deserts	Grassland & Savannahs	Forests & Woodlands	Tundra & Arctic	Mountains
Changes in seasonal patterns	☐	☐	☐	☐	☐
Changes in species distribution and abundances	☐	☐	☐	☐	☐
Changes in species form and reproduction	☐	☐	☐	☐	☐
Species community changes	☐	☐	☐	☐	☐
Species evolutionary process	☐	☐	☐	☐	☐
Wildfire/bushfire	☐	☐	☐	☐	☐

Freshwater Systems

Freshwater Systems	River	Lake	Groundwater	Snowmelt draining	Temperature	Chemistry
Changes in surface of groundwater systems	☐	☐	☐	☐		
Floods	☐	☐				
Droughts	☐	☐				
Physical and chemical aspects of rivers	☐				☐	☐

Glaciers, ice or permafrost

Glaciers, ice or permafrost	*Increase*	*Decrease*
Mountain glaciers	☐	☐
Ice caps/sheets/shelves	☐	☐
Snow cover	☐	☐
Frozen ground	☐	☐
Sea ice	☐	☐
Ocean freshening or circulation	☐	☐
Lake and river ice	☐	☐

Agriculture and Forestry

Agriculture and Forestry	*Crop & livestock*	*Forestry*
Changes in seasonal patterns	☐	☐
Changes in management practices	☐	☐
Changes to yield (*please specify*)	☐	☐
Pests and diseases (*please specify*)	☐	
Livestock	☐	

4. IMPACTS TO INDUSTRY SECTORS

Instructions *Please tick if you have witnessed any* effects to industry *in your area*

A Agriculture, forestry and fishing

- 01 Crop and animal production, hunting and related
  - 011 Growing of perennial crops ☐
  - 012 Growing of non-perennial crops ☐
  - 013 Plant propagation ☐
  - 014 Animal production ☐
  - 015 Mixed farming ☐
  - 016 Support activities for agriculture ☐
  - 017 Hunting, trapping and related activities ☐
- 02 Forestry and Logging
  - 021 Silviculture and other forestry ☐
  - 022 Logging ☐
  - 023 Gathering of non-forest products ☐
  - 024 Support services to forestry ☐
- 03 Fishing and aquaculture ☐

B Mining and quarrying ☐

C Manufacturing ☐

D Electricity, steam, gas & air-conditioning ☐

E Water supply, sewerage, waste management ☐

F Construction ☐

G Wholesale and retail trade, repair of motorbikes & cars ☐

H Transportation & storage ☐

I Accommodation and food service activities ☐

J Information and communication ☐

K Financial and insurance activities ☐

L Real estate activities ☐

M Professional, scientific & technical activities ☐

N Administrative support service activities, tourism ☐

O Public administration and defense ☐

P Education ☐

Q Human health and social work activities ☐

R Arts, entertainment and recreation, including sport ☐

S Other service activities ☐

T Activities of households as employers ☐

U Activities of extraterrestrial organizations and bodies ☐

5. PERSONAL IMPACTS

Instructions *Please tick if you have experienced any* personal effects *due to climate changes*

Livelihood ☐

Personal Property ☐

Business profits ☐

Occupational health and safety ☐

Insurance premiums ☐

Social issues ☐

Security ☐

Safety ☐

Other (*please specify*) ☐

____

6. GUIDE TO WRITING YOUR CLIMATE WITNESS STORY

What do we do with your story?

- We publish your story on the website to share it with people all around the world.
- We will also gather all the stories and pass them on to our climate scientists.
- The information in your stories will create a large database of observations adding to our knowledge of climate change.

WWF is interested in:

- How fast the climate is changing
- What the effects will be to fragile ecosystems and communities
- Your views on addressing the problem of climate change

General tips on writing

- We can only accept stories in English at this stage of the program.
- **Be specific.** It is better to say "the rainy season starts in September now, instead of October" rather than "it rains earlier than it used to".
- **Try not to use jargon words.** "Jargon" means words or phrases that are only known by people in your profession or location.
- **Keep the sentences simple and clear.** Remember that readers may not speak English as a first language.

7. CONTENT OF YOUR STORY

Please use this guide to write your climate witness story.

1. **Start with a paragraph about yourself.** The story should start with your name, town or city, state or province and country. Please include your profession or recreation.

   "My name is Giuseppe Miranti. I am 26 years old and I live in Piacenza, a province in the North of Italy. As the owner of a bio-agricultural company – Aziende Agricole Miranti – I produce fruit and vegetables and do organic cereal and livestock farming. I'm also a bee-keeper." – Guiseppe Miranti, Italy

2. **Tell us how long you have lived or worked in the area.** The length of time observing changes is an important part of climate science.

   I am 62 years old and have lived in Kunduchi for 42 years. - Rajabu Mohammed Soselo, Tanzania

   I've been working in the fields since the age of 18 - José Luis Oliveros Zafra, Spain

   Our family has lived here in Togoru for as long as anyone can remember – Kini Dunn, Fiji.

3. **Tell us how you observe or experience climate.** If some of the information comes from other people, then mention that in the story too.

   I have kept records of when apple trees blossom. – Johnothan Banks, Australia

   By working with the women in my community I have heard many stories about changes in our local environment in the past 20-30 years - Nelly Damaris Chepkoskei, Kenya

4. **Tell us the changes you are witnessing.** This section should just be about what is happening in your local area. It might be changes in the seasons, the rainfall, the tides, or something else. It is important to describe only the changes – keep them separate to your description of what the changes mean for your community (see next point).

   Many of the people in my village have experienced the ice fields melting that used to last all summer, and there is no more old ice left here. – Vladilen Kavry, Russia

5. **Tell us the *consequence* of the climate changes.** "Consequences" could be problems for wildlife or farm animals, damage to crops, to buildings near the sea, or to people. If they affect you personally, your neighbours or your livelihood, please explain how in this part of the story.

   The bears depend on sea ice to get to their prey, mostly seals and without sea ice their hunting ground is shrinking. The polar bears cause problems because they come looking for food in the village and often attack the sled dogs. – Vladilen Kavry, Russia

6. **Tell us what solutions you want to see from local or national leaders, or what you plan to do locally.** Climate witness stories can draw attention to the urgency of the problem and the need.

   [Climate change] needs to become a greater priority for everyone - politicians, business and people like you and me. Please listen to me and WWF and take action to ensure that CO_2 emissions are cut across Europe. - Cassian Garbett, England.

WWF Climate Witness Programme Consent Form

I, …………………………………… of ……………………………………………….……………………
……………………………………………………………………..… on this date………………………
hereby give consent to WWF International to use my Climate Witness testimonial and photos attached to this form for any purposes they see fit in raising awareness of the dangerous effects of climate change around the world and promoting effective solutions to the climate problem.

I realize that any form of active participation in the Climate Witness programme is voluntary. I also realize that I may be called upon to present my story in person for a range of media opportunities at some point in the future or for as long as the Climate Witness Programme is active. This may require me to travel either locally or to international events and where ever possible WWF agrees that my travel costs will be covered.

I am aware that I am not to use the WWF or Climate Witness Programme logos in any instance without the consent of the WWF liaison person who has been appointed to me. I have noted the specific solutions to climate change which my national WWF office is promoting and I broadly agree with these. If I would like to promote other solutions to climate change publicly I will only do so after consulting with my Climate Witness person.

I have been informed that all my personal information and contact details will remain confidential at all times unless the use of them is authorized by me and the WWF liaison person appointed to me as a way of maintaining privacy.

I understand that the testimonial prepared and associated photos will be approved and chosen by me/us before anything is used in any format for publication.

This consent form has be signed by Climate Witness

Name ………………………………………………………………..

Signature ……………………………………………………………

Date …………………………………………………………………

And witnessed by WWF Liaison Person

Name ………………………………………………………………..

Signature ……………………………………………………………

Date …………………………………………………………………

Sample Interview Questions

1. How long have you lived in the area?

2. What is your occupation? Has your occupation changed?

3. How much time do you spend outdoors now? Did you spend more/less time outdoors in the past?

4. How much would you say your life today is affected by climate? *Significantly/Somewhat/Not at all*

5. How much was your life in the past affected by climate? *Significantly/Somewhat/Not at all*

6. How often do you follow weather forecasts?

7. Overall, would you say that climate has changed significantly during your lifetime? If so, how has it changed?

8. How would you respond to the following statements?

Compared to the past, today's summer temperatures are
Much hotter somewhat hotter same somewhat cooler much cooler not sure

Compared to the past, today's winter temperatures are
Much colder somewhat colder same somewhat warmer much warmer not sure

Compared to the past, the number of unusually hot days now is
Much more somewhat more same somewhat fewer fewer not sure

Compared to the past, the number of unusually cold days now is
Much more somewhat more same somewhat fewer fewer not sure

Compared to the past, our climate today is
Much wetter somewhat wetter same somewhat drier much drier not sure

Compared to the past, the first frost now occurs
Much earlier somewhat earlier same time somewhat later much later not sure

Compared to the past, bird migration in the spring now occurs
Much earlier somewhat earlier same time somewhat later much later not sure

Compared to the past, ice breakup in spring now occurs
Much earlier somewhat earlier same time somewhat later much later not sure

We have more heavy downpours now than in the past
Strongly agree Agree Disagree Strongly disagree not sure

We have more droughts now than in the past
Strongly agree Agree Disagree Strongly disagree not sure

We have more snow now compared to the past
Strongly agree Agree Disagree Strongly disagree not sure

9. What do you believe to be the consequences of these changes?
   What will happen in your area if theses changes continue?

10. What are the options to prevent further changes?

11. What role do you believe the government should play with this problem? Local? Federal?

12. What will you do in your own community?

Permission Form for Participants in WWF's "Climate Witness Oral History Project"

Thank you for submitting your work to WWF's Climate Witness Oral History Project. By choosing to submit your work -- which could be text, a photograph, or any other work of authorship – you represent that your submission is your original work and that you have the right to submit it as part of this project. You give WWF permission, perpetually and throughout the world, without compensation or credit, to publish, copy, distribute, display, or otherwise use your work for non-commercial purposes, and to give others permission to use it for non-commercial purposes. You also give WWF permission to edit or modify your submission, and to use your name, likeness, and city and state in connection with it and with this project. While these rights do not obligate WWF to use your submission, we do thank you very much for your participation.

All who submit their work for inclusion in the project must sign.

Agreed:

Signature: ____________________ Print Name: ____________________

Address: ____________________ Telephone No.: ____________________

____________________ Date: ____________________

If the above individual is not yet 18 years old, the following statement must be signed:

I am the parent/legal guardian of the above-named child/minor and as such am fully authorized to enter into this agreement on his/her behalf.

.

Child's name: ____________________ Printed Name: ____________________

Parent's signature: ____________________ Telephone No.: ____________________

Address: ____________________ Date: ____________________

****Please return to Teacher****

Additional Resources

These are links to different Web sites that often have climate change updates. These should provide a great starting point for a variety of the research activities throughout the curriculum.

National Public Radio

http://www.npr.org/templates/story/story.php?storyId=9657621&ps=bb6

National Geographic

http://green.nationalgeographic.com/environment/global-warming/gw-impacts-interactive.html

The New York Times' Climate Change Section

http://topics.nytimes.com/top/news/science/topics/globalwarming/index.html

BBC News- Science and Nature

http://news.bbc.co.uk/2/hi/science/nature/default.stm

Chicago Tribune's special report on Antarctica and climate change

http://www.chicagotribune.com/news/nationworld/chi-antarcticamain-html,1,567386.htmlstory?coll=chi_news_specials_util&ctrack=2&cset=true

The Guardian's Special Report on Climate Change

http://www.guardian.co.uk/climatechange/0,12374,782494,00.html

Washington Post's Special Report on Climate Change

http://www.washingtonpost.com/wp-srv/nation/interactives/climate/index.html

Climate Change News Digest

(An internet news portal that provides updated links to the latest news on climate change)
http://www.climatechangenews.org/

Time Magazine

http://www.time.com/time/specials/2007/environment/

NewScientist.com

http://environment.newscientist.com/channel/earth/climate-change/

The Weather Channel

http://climate.weather.com/blog/

World Wildlife Fund

http://www.panda.org/about_wwf/what_we_do/climate_change/news/blog/index.cfm

Woods Hole Oceanographic Institute

http://www.whoi.edu

Climate Wire- by UNEP

http://www.climatewire.org/

Kilowatt Ours Website

www.KilowattOurs.org

Glossary of Terms

Adaptation: the process of changes in a living organism or in cultural systems that aid in adjustment to the conditions of the environment, facilitating the ability to inhabit and exploit a particular environment.

Airborne pollutant: a contaminant that is carried through the air.

Alternative fuel: a fuel used in vehicles that comes from a source other than petroleum, such as ethanol made from corn and biodiesel made from vegetable oil.

Atmosphere: The gaseous envelope surrounding a celestial body, comprised of the troposphere, mesosphere, stratosphere, and thermosphere.

Biodiversity: the variety of life on Earth, reflected in the variety of ecosystems and species, their processes and interactions, and the genetic variation within and among species.

Biotic factors: The living components of the environment, such as plants, animals and fungi, that affect ecological functions. The physical and chemical non-living factors in an environment are termed abiotic.

British Thermal Unit: One BTU is equivalent to the amount of heat required to raise the temperature of 1 pound of water by 1 degree Fahrenheit.

Carbon footprint: A representation of the effect human activities have on the climate in terms of the total amount of greenhouse gases produced (measured in units of carbon dioxide). *Substitute*: Ecological footprint

Climate: The average course or condition of the weather at a place usually over a period of years as exhibited by temperature, wind velocity, and precipitation; the prevailing set of conditions.

Climate change: The changing of Earth's temperature and weather patterns due to the release of greenhouse gases, especially carbon dioxide from the burning of fossil fuels. The gases accumulate in the atmosphere and act like a blanket, trapping heat. This results in a wide range of climate shifts, including simple warming of the planet's average temperature, as well as regions becoming wetter, dryer, and stormier.

Compact fluorescent light bulb (CFL): An alternative to incandescent light bulbs, which lose 90% of their energy to heat, CFLs use 1/5 to ¼ of the energy and last up to ten times longer.

Conservation: a careful preservation and protection of something; planned management of a natural resource to prevent exploitation, destruction, or neglect.

Desertification: The progressive destruction or degradation of existing vegetative cover to form desert. This can occur due to overgrazing, deforestation, drought, and the burning of extensive areas. Once formed, deserts can only support a sparse range of vegetation. Climatic effects associated with this phenomenon include increased albedo, reduced atmospheric humidity, and greater atmospheric dust (aerosol) loading.

Ecological footprint**:** a calculation that estimates the area of the Earth's productive land and water required to supply the resources than an individual or group demands, as well as to absorb the wastes that the individual or group produces. *Substitute*: carbon footprint

Ecosystem: A community of plants, animals and microorganisms, along with their environment, that function together as a unit. An ecosystem can be as large as a rain forest or as small as a rotting log.

Efficiency: The more ecologically aware use of energy in order to reduce economic costs and environmental impacts. Using less energy/electricity to perform the same function.

Emissions: substances discharged into the air (as by a smokestack or an automobile engine).

Energy star: A program of the US Government that certifies and labels products that are energy efficient.

EPA: The US Environmental Protection Agency; sets and enforces the standards on national pollution control.

Ethanol: Can be produced chemically from ethylene or biologically from the fermentation of various sugars from carbohydrates found in agricultural crops and cellulosic residues from crops or wood. Used in the United States as a gasoline octane enhancer and oxygenate, it increases octane 2.5 to 3.0 numbers at 10% concentration. Ethanol also can be used in higher concentration in alternative-fuel vehicles optimized for its use.

Fossil Fuels: fuels formed millions of years ago from decayed organisms. Oil, coal, and natural gas are all fossil fuels; nonrenewable energy.

Geographic range: The area bounded by the location of outlying populations of a species; the location of the smallest area within an imaginary boundary line that encloses all populations of a species.

Global warming: The increase in Earth's temperature caused by emissions of carbon dioxide and other gases that blanket the planet and trap heat within the atmosphere.

Greenhouse gas: see *heat-trapping gas.*

Greenhouse effect: The process that raises the temperature of air in lower levels of the atmosphere because of heat trapped at higher levels by "greenhouse gases" such as carbon dioxide, methane, and ozone.

Gross Domestic Product (GDP): Total value of a country's output, income or expenditure produced within the country's physical borders.

Habitat: the area where an animal, plant, microorganism, or other life form lives and finds the nutrients, water, sunlight, shelter, living space, and other essentials it needs to survive. Habitat loss, which includes the destruction, degradation, and fragmentation of habitats, is the primary cause of biodiversity loss.

Heat index: An index that combines air temperature and humidity to give an apparent temperature (eg. how hot it "feels").

Heat-trapping gas: any of several dozen gases in the earth's atmosphere that absorb infrared radiation. The two major heat-trapping gases are water vapor and carbon dioxide; others include methane, chlorofluorocarbons, and nitrogen oxides.

Hybrid-electric vehicle (HEV): A vehicle with a dual power system, usually a conventional internal combustion engine that runs on gasoline and an electric motor powered by batteries. Hybrid-electric vehicles are more fuel efficient and emit fewer pollutants than conventional vehicles.

Interdependence: The concept that everything in nature is connected to each other, and cannot survive without the help of other plants, animals and abiotic factors (such as sun, soil, water and air) around it.

Intergovernmental Panel on Climate Change (IPCC): The; established in 1988 by the World Meteorological Organization and the United Nations Environment Program (UNEP), the IPCC is the authoritative international body charged with studying climate change. The IPCC surveys the worldwide technical and scientific literature on climate change and publishes assessment reports. Its widely quoted 1995 report found that “the balance of evidence suggests that there is a discernible human influence on global climate.”

Kilowatt Hours (kWH): the basic unit of electric energy equal to 1 kilowatt or 1,000 watts of power used for one hour. The amount of power the customer uses is measured in kilowatt hours (kWh). A 100-Watt light bulb operated for 10 hours uses 1 kWh.

Mitigation: The elimination, reduction or control of the adverse environmental effects of a project, and includes restitution for any damage to the environment caused by such effects through replacement, restoration, compensation or any other means; actions and programs that reduce the risks and impacts associated with natural hazards such as climate change.

Natural resource: any aspect of the environment that species depend on for their survival. People depend on natural resources such as land, soil, energy, and fresh water.

Non-renewable energy: energy obtained from sources that are exhaustible, such as oil, coal, and natural gas.

Overconsumption: the use of resources at a rate that exceeds the ability of natural processes to replace them.

Phenology: The study of the relationship between climate and the timing of periodic natural phenomena such as migration of birds, bud bursting, or flowering of plants.

Renewable energy: energy obtained from sources that are essentially inexhaustible. Renewable sources of energy include wind and the sun.

Sequestration: The uptake and storage of carbon. For example, trees and plants absorb carbon dioxide, release the oxygen and store the carbon in above ground organic matter or in the soil. In the context of climate change response strategies, sequestration usually refers to the process of increasing the storage of carbon, for example reforestation, increasing the carbon content of the soil, or removal of carbon dioxide from flue gases for storage below ground or in the deep ocean.

Sustainability: The extraction of resources at a rate not exceeding nature’s capacity to replenish them; meeting present human needs for resources without damaging the ability of the ecosystem to provide for future needs of people and other species.

Thermohaline: In oceanography, the circulation path determined by temperature and salt– downwellings due to surface-water density created by low temperature and high salinity. Because dense water tends to eventually sink through less dense underlying layers, it contributes a vertical aspect to ocean currents.

Vector: A carrier of an infectious agent; capable of transmitting infection from one host to another.

Weather: The specific condition of the atmosphere at a particular place and time. It is measured in terms of such things as wind, temperature, humidity, atmospheric pressure, cloudiness, and precipitation. In most places, weather can change from hour-to-hour, day-to-day, and season-to-season. Climate is the average of weather over time and space.

Notes

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