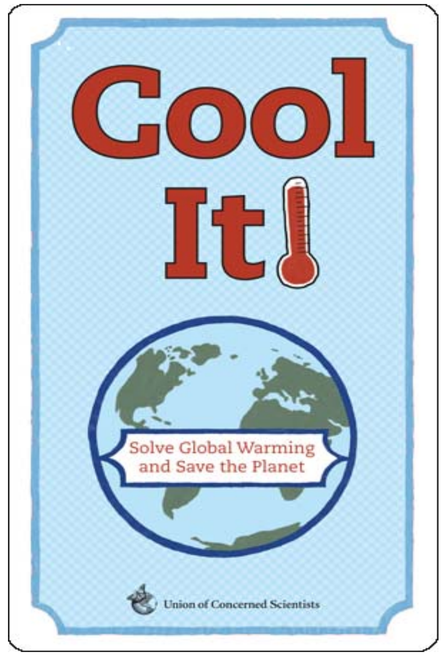
Union of Concerned Scientists
Citizens and Scientists for Environmental Solutions

Cool It! Teacher's Guide



Teacher Background Information

Global warming is well under way and will have wide-ranging consequences for our health and well-being. The primary cause of global warming is the burning of fossil fuels, including gasoline in cars and coal in power plants. Additionally, destroying tropical forests contributes about 15 percent of the heat-trapping emissions that cause global warming.

When too much carbon dioxide and certain other heat-trapping gases are released into the air, they act like a blanket, trapping heat in our atmosphere that would otherwise escape back into space. The excess heat changes the climate, which affects weather patterns globally and in the United States.

Currently, the United States and other countries are engaged in debate regarding what to do to reduce the heat-trapping emissions that cause global warming and to adapt to both the warming already under way and future warming as well.

How do we know that humans are the major cause of global warming?

Scientists have identified several lines of evidence demonstrating that human activity is the main driver of recent observed warming.

We know from ground, ocean, and satellite-based measurements that the global average temperature increased roughly 1 degree Fahrenheit (ºF) over the twentieth century. Scientists have eliminated natural factors such as volcanic activity, the sun's power, and the distance from Earth to the sun as causes of the observed temperature increase, because those factors did not change significantly enough over that time period. Carbon dioxide levels in the atmosphere, however, increased dramatically. Therefore, an increase in the levels of carbon dioxide (as well as other heat-trapping gases) largely explains the warming scientists have observed in the past several decades.

We know that the excess carbon dioxide in the atmosphere is from human activity because carbon dioxide from fossil fuel combustion and tropical deforestation tends to have fewer neutrons in its atoms than carbon dioxide processed through natural cycles. Measurements of different types of carbon dioxide in the atmosphere show an increase in "lighter" carbon dioxide molecules proportional to the amounts of fossil fuels that have been burned and tropical forests that have been destroyed over the last several centuries.

There are additional human "fingerprints" on global warming. The boundary between the lower atmosphere (troposphere) and the higher atmosphere (stratosphere) has shifted upward in recent decades. This boundary has likely changed because heat-trapping gases accumulate in the lower atmosphere, which expands as it heats up. This change would not occur if the sun were the sole climate driver, for instance, because solar changes would warm both atmospheric layers and certainly would not warm one while cooling the other.

How does carbon dioxide warm the earth?

Earth receives energy from the sun in a variety of wavelengths, some of which we see as sunlight and others that are invisible to the naked eye, such as shorter-wavelength ultraviolet radiation and longer-wavelength infrared radiation. As this energy passes through the atmosphere, some is reflected back into space by clouds and small particles such as sulfates; some is reflected by the earth's surface; and some is absorbed into the atmosphere by substances such as soot, stratospheric ozone, and water vapor. The remaining solar energy is absorbed by the earth itself, warming the planet's surface.

If all of the energy emitted from the earth's surface escaped into space, the planet would be too cold to sustain human life. Fortunately, some of this energy stays in the atmosphere and is sent back toward the earth by clouds, or is released when clouds condense to form rain or snow, or is absorbed by atmospheric gases composed of three or more atoms, such as water vapor (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4).

Long-wave radiation absorbed by these gases is in turn re-emitted in all directions, including back toward the earth, and some of this re-emitted energy is absorbed again by these gases and re-emitted. The net effect is that most of the outgoing radiation is kept within the atmosphere instead of escaping into space. Heat-trapping gases, in balanced proportions, act like a blanket surrounding the earth, keeping temperatures within a range that enables life to thrive on a planet with liquid water. Unfortunately, these gases—especially carbon dioxide—are accumulating in the atmosphere at increasing concentrations. As a result, the insulating blanket is getting too thick and overheating the earth because less energy (heat) is escaping into space.

What are some examples of how the climate is changing?

- Increase in global average surface temperature of about 1°F in the twentieth century
- Decrease in extent of snow cover and sea ice and retreat of mountain glaciers in the latter half of the twentieth century
- Rise in average global sea level and ocean water temperatures
- Likely increase in average precipitation over the middle and high latitudes of the Northern Hemisphere and over tropical land areas
- Increase in the frequency of extreme precipitation events in some regions of the world
- Thawing of permafrost
- Lengthening of the growing season in middle and high latitudes
- Plant and animal species moving toward the poles and up to higher elevations
- Decline of some plant and animal species
- Earlier flowering of trees
- Earlier emergence of insects
- Earlier egg-laying by birds

How do we know how much more the climate will change in the future?

Scientists have no way of knowing how much more carbon dioxide people will generate in the future. Therefore, they make estimates of how much Earth will warm based on different assumptions about the sorts of technology people will be using decades from now, the type of energy sources people will choose, and how the population will change. Lower-emissions scenarios estimate an additional warming of about 2ºF above today's levels. Higher-emissions scenarios show warming of more than 11.5ºF.

While there is uncertainty about how some aspects of the climate will react to higher levels of carbon dioxide and other heat-trapping gases and higher temperatures, it appears that most of the changes would further exacerbate warming. (For instance, in polar regions the melting of ice, which tends to reflect light back into space, uncovers dark-colored ground, which absorbs more heat.) Many scientists believe that scenarios and computer models underestimate the amount of global warming that higher carbon dioxide levels could cause.

Most of human civilization has been built on the relatively stable climate of the past several hundred (and even the past several thousand) years. Scientists, economists, and public health officials worry about the dangers of rapidly changing climate, including threats to coastal cities from rising sea levels, the spread of tropical diseases, and disruptions to agriculture.

Some people have cast doubt on the scientific consensus around climate change. How do you answer them?

The human causes and potential negative impacts of climate change are apparent worldwide and have been recognized by nearly every major national and international scientific body, including the National Academy of Sciences, the American Meteorological Society, the American Geophysical Union, and the Nobel Prize-winning Intergovernmental Panel on Climate Change (IPCC).

The IPCC's Fourth Assessment Report (2007) represents an unprecedented collaboration of more than 2,500 expert scientific reviewers, more than 800 contributing authors, and more than 450 lead authors from more than 130 countries. Most work cited in the IPCC report was previously published in peer-reviewed scholarly literature. One component of the IPCC report, on the physical-science basis of climate change, was written by 620 people and reviewed by more than 600 experts.

The United States Global Climate Research Project, a collaboration of 13 federal agencies, shares the view that human activity is driving global warming and that global warming threatens the United States and the rest of the world. Its 2009 report states, "Global warming is unequivocal and primarily human-induced. Global temperature has increased over the past fifty years. This observed increase is due primarily to human-induced emissions of heat-trapping gases."

However, a small but vocal group of politicians, media personalities, and industry interests regularly spread disinformation about climate-change science. These contrarian views are almost never found in the scientific literature. Most are found only on ideologically driven websites that exist far outside the bounds of effective scientific review and fact-checking. The resources listed below can help you address these arguments if they come up during class discussion or in discussions with parents.

Additional resources

If you have other questions about global warming, check out the briefings, updates, recommendations, analyses, guides, and links on this site. In addition, there are many other websites that answer frequently asked questions. We recommend the following:

Union of Concerned Scientists Global Warming FAQ
http://www.ucsusa.org/global_warming/science_and_impacts/science/global-warming-faq.html

Scientific Responses to Common Contrarian Claims about Climate Science (*New Scientist* magazine)
http://www.newscientist.com/article/dn11462-climate-change-a-guide-for-the-perplexed.html

National Oceanic and Atmospheric Administration FAQ
http://lwf.ncdc.noaa.gov/oa/climate/globalwarming.html

The U.S. Environmental Protection Agency
http://www.epa.gov/climatechange/science/index.html

The Carbon Dioxide Information Analysis Center (Oak Ridge National Laboratory)
http://cdiac.esd.ornl.gov/pns/faq.html

Findings of the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report
Working Group I: Climate Change Science
http://www.ucsusa.org/global_warming/science_and_impacts/science/findings-of-the-ipcc-fourth-2.html

Working Group II: Climate Change Impacts
http://www.ucsusa.org/global_warming/science_and_impacts/science/findings-of-the-ipcc-fourth.html

Working Group III: Climate Change Mitigation
http://www.ucsusa.org/global_warming/science_and_impacts/science/findings-of-the-ipcc-fourth-1.html

Lesson Plan

The following instructional sequence follows the 5E format used in many inquiry-based science lessons at all levels. Modify it to fit your own needs.

Engage

Asking students to explain a story related to global warming is a good way to interest them. It will also help the teacher find out how much students know about the mechanics of global warming before giving them any instruction.

The story can be modified to fit the students' grade level or the teacher's instructional time frame. This story could also be used for assessment at the end of the card game and instruction.

On a bright sunny day in July, Joe went with his mother to the mall. Joe's mother locked the car doors and rolled up all the windows tightly when she parked in the outside parking lot. Joe forgot that he had left some candy in the back seat, and he and his mother were in the mall for about an hour. When they returned, what do you think they felt as they opened the car doors? What do you think had happened to Joe's candy? What can Joe's mother do the next time she parks the car to prevent this from happening? Why will doing this work?

<u>Instructional strategy</u>

- Present the story (or your version of it) to the students and have them write answers individually first. Then assign them to small groups in which they share and, if possible, come to consensus about what their group will tell the rest of the class. Write their answers in a sharing format—on the board, overhead, or on an interactive blackboard. Do not give the students the correct answer at this point. Tell them that you are going to set up a model they can use to verify their answers and to see what else they can determine.

- Most students will probably be able to say that the inside of the car will be much hotter than the outside air, but most will not know why. There might be a few good suggestions from students about what to do to keep the car from getting too hot. The model that you set up in the next part of the lesson can explain why the car gets very hot inside and how to keep it from getting so hot. The model can also be used to explain the mechanics of global warming.

Background information

Most students should be familiar with the scenario of a closed car getting hot when parked in the sun. This effect can occur in any season but is especially noticeable in the summer. Most states have laws against leaving children or animals in cars parked in the sun in the summer. There have been stories in the news about people being arrested for this offense. You could use one of those articles in place of this story, omitting the explanation until the students have had time to do some investigating on their own.

What happens inside the car is comparable to the "greenhouse effect" on Earth—and to the way global warming occurs. Short-wavelength rays of light are able to pass into the car through the windshield and windows, just as sunlight passes through the glass of a greenhouse. When the rays strike the inside of the car, the seats, dashboard, and other parts absorb some of the energy, heat up, and then radiate heat into the car. However, the heat inside the car consists of longer-wavelength infrared rays, which cannot pass through glass, so heat builds up and the temperature inside the car rises. (See the diagram below of how this happens.)

Putting "sunglasses" (cardboard or reflective material sold just for this purpose) inside the windshield of the car will cut down on the amount of sunlight entering the car and cause less heating inside. Parking in the shade under a tree or inside a garage will also prevent heat from building up because not so much sunlight can enter the car. If the car must be parked in the sun, then all the windows should be left rolled down as far as is safe. This will let some of the heat escape, and the temperature will not increase nearly as much as if the windows were all rolled up.

Explore

Perform a demonstration (or, if there is enough time and ample materials, have the students conduct a hands-on investigation) to model why the car gets hot inside when parked in the sun and to show the mechanics behind the greenhouse effect and global warming.

Materials:

- At least three large transparent containers (beakers, pint- or quart-sized food jars with lids, or the bottom halves of two-liter plastic soda bottles) for each group that is making a model. All the containers should be of the same type.
- Lids for the containers (clear plastic wrap secured tightly with a rubber band will work for the beakers and soda bottle bottoms; it's a good idea to tape the cut edge of the plastic bottles so the plastic wrap doesn't break)
- A location in direct sunlight or near a lamp
- Alcohol thermometers that will fit inside the containers (plastic- or metal-backed thermometers work well)

Ask students what a model is and ask them to give some everyday examples. (Most will know that a model is a small version of an actual object and will likely name some toys.) Then ask them to name some scientific models (such as a globe or a solar-system model) and to explain how they are helpful to scientists. Explain that models are useful when objects, processes, or events are too dangerous, too fast, too far away, or too large to be observed firsthand.

Have students brainstorm about how the class could make a model of a car to try to figure out why the temperature inside rises and how that can be prevented. (Students should be able to suggest the sun or another heat source, a clear material for the windshield/windows, and something to represent the inside of the car.) Whatever you use in your demonstration, be sure to explain how the parts of your setup correspond to the various parts of the car scenario.

Build the demonstration around the various answers students gave after hearing the story about the car parked in the sun. For example, set up at least three identical glass or plastic containers: one tightly sealed to represent the car with all the windows rolled up, another without a top to represent the windows rolled down, and the third with paper partially wrapped around it to show a car with "sunglasses" over the windshield. If there are enough containers, use one for each suggestion given by the students. Have students predict what will happen to the temperature in each container and how the results will compare to one another. Ask them to give supporting reasons for making each prediction.

This is also a good place to reinforce inquiry skills by discussing the need to make a "fair" comparison of all the models by keeping everything the same except the factor that is being tested.

This demonstration works well outside in the direct sun or in your classroom if you have direct sun exposure. If necessary, it can also be done with a lamp placed very close to the containers, in which case you can use only two containers and have them receive approximately the same amount of light from the lamp.

You can place some fabric or crumbled construction paper inside the containers to represent the inside and seats of the car. (Soil can be used if you want to model the floor of a greenhouse or the earth.)

The thermometers should measure the temperature of the air only, so the bulbs should not touch the container. It is also best to place the thermometers with their backs to the light to prevent direct heating of the alcohol bulbs. If you use glass thermometers without backing, it might be necessary to tape them to a backing to shield their bulbs.

Before doing this with students, try the setup and test the results to make sure it works, to find out how long it takes to get a result, and to determine the amount of temperature change you can expect. In most cases you should be able to see a difference in temperature in about 15–20 minutes, which means there is enough time to conduct this demonstration in a single 45-minute class period if necessary. The closed and sealed container should show a greater increase in temperature than the containers that are open or shaded.

Explain

Have the students draw and label the setup used in the demonstration, then write down the results for each container and explain why each container behaved as it did. Ask them which part of the model represents each part of the car. Revisit the parked-car story and ask students if what they just learned from the model can help them better figure out why the temperature in the car increased when it was parked in the sun—and what could be done to prevent that from happening in the future.

Share the students' drawings and explanations and exhibit the teacher's labeled drawing for the students to see and copy onto their drawings. Ask students to self-assess their drawings, noting what, if anything, they left out. Lead them to see that the sides of the container are like the glass in the car windshield and windows, that the light is like the sun, and that the inside of the container is like the inside of the car.

Review the definition of a model. Ask students what part of the model in the demonstration would be like Earth's atmosphere (the clear container), what part would be like the earth (the fabric or crumpled paper), and what would be like the blanket of extra carbon dioxide and other heat-trapping gases (the lid on the container). Ask students how the model in the demonstration, although not perfect, can help show how too much carbon dioxide in the atmosphere causes global warming. Help them see that the sides of the container are like the atmosphere through which the sunlight passes, the inside of the container is like Earth's surface, and the top of the container is like the heat-trapping gases. (Refer to the diagram below.)

At this point, with more advanced students or with higher grade levels, you can introduce the electromagnetic spectrum as well as heat and energy transfer.

Elaborate

Have students apply what they have learned in the model to what happens in the real world by playing *Cool It!*.

Instructional strategy
Refer to the rules and tips for playing the game.

Background information
See the introductory information at the start of the teacher's guide.

Evaluate

1. Check to see what your students have learned by having them complete the crossword puzzle below, which contains some of the key concepts from the card game.

2. Using any of the sector cards in *Cool It!*, jumble the order of the key information given. Give students a set of words/phrases and then use arrows to show the pathway that leads to global warming or to a solution. For example, give them the following set of words/phrases:

- carbon dioxide is released
- traps heat in the atmosphere
- trees are cut or burned
- carbon and oxygen combine
- the earth get warmer
- when
- which
- and
- making

They should be able to unscramble the order to say:

> When trees are cut or burned, carbon and oxygen combine and carbon dioxide is released, which traps heat in the atmosphere, making the earth get warmer.

More advanced students could be asked to select a card and draw the pathway on their own.

3. Have each student list at least three things that people could do to prevent an increase in heat-trapping gases and why these steps would work to decrease heat-trapping gases. Have the students then select one thing they think they can personally do and how they think they can achieve it.

Extend

1. Locate books, newspaper articles, websites, simulations, video clips, and other sources on global warming and have students research and share their findings about some of the topics featured in the cards of the game.

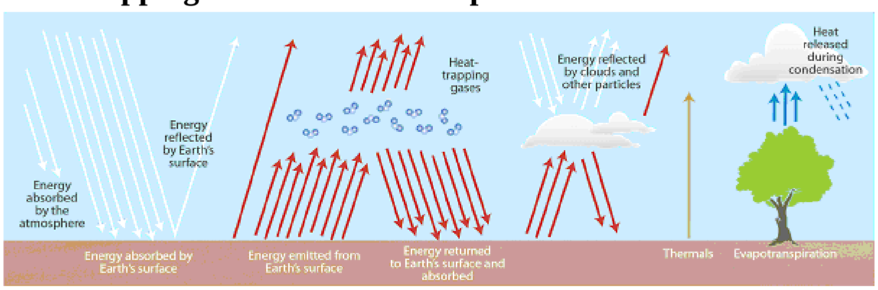
2. You could also arrange role playing, debates, or mock community meetings in which students examine the advantages and consequences of technological advances and their role in causing or curbing global warming. Have students assume the roles of all stakeholders involved in or affected by the changes. Articles and online resources can help with setting up student forums and debates, which can be especially effective if based on a real issue in the school or community. For example, students could debate the pros and cons of:

- Wind turbine farms
- Biofuels
- Building new coal-fired power plants
- Limiting urban sprawl
- Banning the burning of rainforests and the clearing of forest lands
- Building more nuclear power plants

3. Examine compact fluorescent light bulbs (CFLs) and incandescent (filament) light bulbs and compare their costs and energy use.

4. Explore the spectrum of sunlight using a chart of wavelengths. Compare the energy/wavelengths of ultraviolet sunlight with the infrared energy given off by the inside of the car (or Earth's surface) when it is warmed. Students should be able to see that ultraviolet rays are shorter than infrared rays and to infer that the shorter the wavelength of light, the more energy it has. Have students identify the ultraviolet energy (among the incoming solar rays) and infrared energy (most of the re-radiated energy) in their drawings of the car scenario. Wavelengths and energy can then be related to everyday events such as getting a sunburn from extended exposure to ultraviolet rays either in natural sunlight or in a tanning booth, as well as why restaurants use heat lamps to keep food warm.

Heat-trapping Gases in the Atmosphere



The molecules depicted in the diagram above represent heat-trapping gases such as water vapor, carbon dioxide, methane, and nitrous oxide. The numbers of incoming and outgoing arrows are proportional to the balance between incoming and outgoing energy. Data source: IPCC 2007. Figure: Union of Concerned Scientists.

National Science Education Standards for Grades 5–8

Physical Science

The sun is the major source of energy for changes on Earth's surface. The sun loses energy by emitting light. A tiny fraction of that light reaches the earth, transferring energy from the sun to the earth. The sun's energy arrives as light with a range of wavelengths, consisting of visible light, infrared, and ultraviolet radiation.

Earth and Space Science

The atmosphere is a mixture of nitrogen, oxygen, and trace gases, which include water vapor. The atmosphere has different properties at different elevations.

Science and Technology

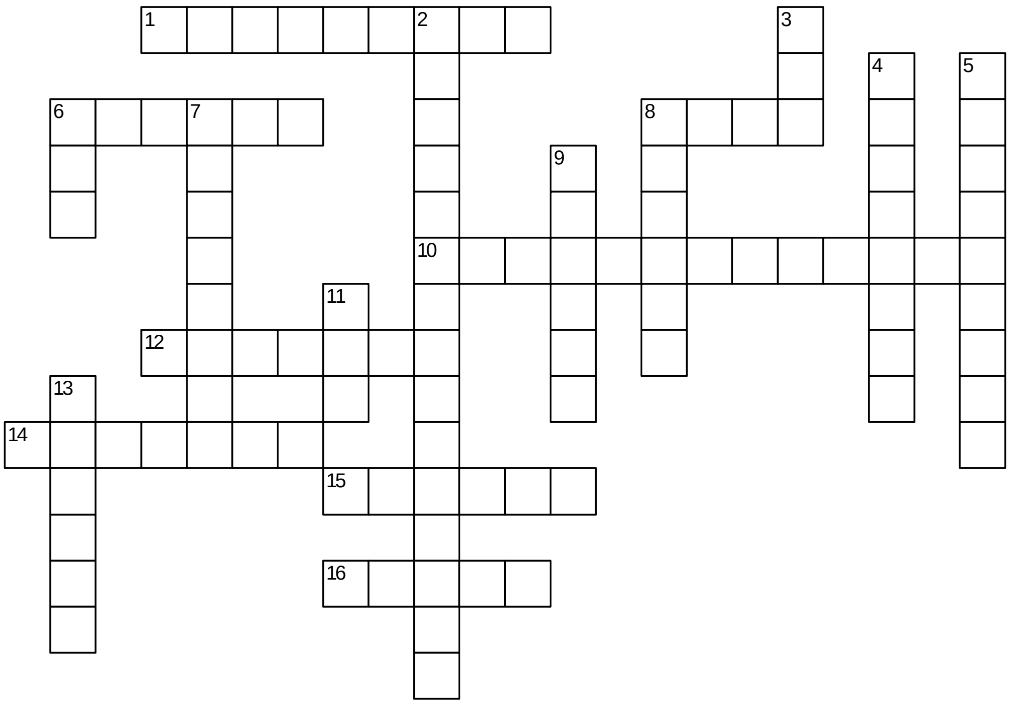
Technological solutions have intended benefits and unintended consequences. Some consequences can be predicted, others cannot.

Science in Personal and Social Perspectives

Scientists and engineers work in many different settings, including colleges and universities, businesses and industries, specific research institutions, and government agencies.

Source: National Research Council (NRC). *National Science Education Standards*. Washington, DC: National Academies Press, 1996.

Global Warming Crossword Puzzle



Across

1 One way to prevent tropical forests from being destroyed is to make them ____ land, like our national parks.
6 Carbon dioxide is made of carbon and ____.
8 Most energy used for electricity comes from burning ____.
10 The main gas that traps heat, making Earth warmer, is ____.
12 _________ is made from wood chips, grass, and other plant materials; it can be used in cars and is cleaner than gasoline.
14 Spinning ____ inside wind turbines create electricity.
15 Oil is liquid ____ left over from plant and animal materials that decayed millions of years ago.
16 Old buildings ____ a lot of electricity by letting heated air escape in the winter and cooled air escape in the summer.

Down

2 Cutting down trees in ____ can release a lot of carbon dioxide into the atmosphere.
3 Spiral-shaped light bulbs, commonly known as ________, use 75 percent less electricity than incandescent (filament) light bulbs.
4 Wind _______ create clean electricity to power homes and businesses.
5 Unlike hybrid cars, electric cars run only on ____.
6 Gasoline comes from ____.
7 Burning ____ in cars produces carbon dioxide.
8 Heat-trapping carbon dioxide can make the earth become warmer and lead to climate ______.
9 A car that uses both a gasoline engine and an electric motor is called a ____.
11 Solar cells capture light from the ____ and turn it into electricity.
13 When carbon dioxide and other gases trap heat, they cause the earth to get ____.

(Solution on next page)

Solution to Global Warming Crossword Puzzle