



Activity 1.2: Understanding the Greenhouse Effect

Grades 5 – 6

Description: In Part 1: Modeling the Greenhouse Effect, students will complete a lab that demonstrates the greenhouse effect and will discuss the results of the lab.

In Part 2: Earth's Energy Balance, students will color in a diagram, answer opinion questions, and perform a skit to understand Earth's energy balance. Students will learn that most of the energy on Earth originates from the sun. They will also learn what happens to the energy once it reaches Earth's atmosphere. Students will be introduced to the concept of greenhouse gases. The activity will close with a discussion of natural vs. human-induced changes in greenhouse gas concentrations.

Total Time: Two to three 45-minute class periods

Materials:

Part 1

Per group

- Two thermometers
- Two cans
- Water
- Plastic bag
- Modeling the Greenhouse Effect lab worksheet
- Pens or pencils

Part 2

- Student handout
- Earth's Energy Balance Diagram
- Colored pencils
- "Character" cards
- 30 dry lima beans (using food is a nice analogy because it represents another form of energy)

Prior Knowledge

It is helpful for students to have covered the different types of energy and energy transformation, particularly light to heat, as this transformation is an important process in understanding how greenhouse gasses retain heat in the atmosphere.

National Science Education Standards

B.3.f The sun is a major source of energy for the changes on Earth's surface.

D.1.h The atmosphere is a mixture of nitrogen, oxygen, and trace gases that include water vapor.

AAAS Benchmarks

8C/H8 Sunlight is the ultimate source of most of the energy we use. The energy in fossil fuels such as oil and coal comes from energy that plants captured from the sun long ago.

4B/H4 Greenhouse gases in the atmosphere, such as carbon dioxide and water vapor, are transparent to much of the incoming sunlight but not to the infrared light from the warmed surface of the earth. When greenhouse gases increase, more thermal energy is trapped in the atmosphere and the temperature of the earth increases.

Guiding Questions

- What are greenhouse gasses?
- What are the effects of greenhouse gases in the atmosphere?
- Where does most of the energy on earth originate?
- What happens to the energy once it reaches earth?



- What is the greenhouse effect?

Assessment(s)

- Modeling the Greenhouse Effect lab worksheet
- Earth's Energy Balance Diagram handout
- Journal entry describing what happens to the energy that comes from the sun

Background Information: Climate and Earth's Energy Budget

Adapted from "Climate and the Earth's Energy Budget" by Rebecca Lindsey, January 14, 2009

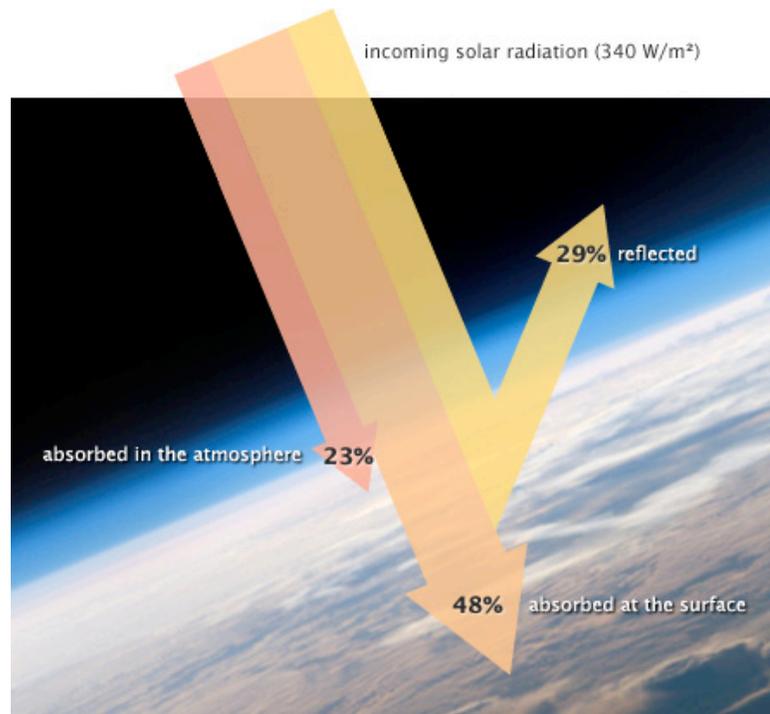
Full article can be found at: <http://earthobservatory.nasa.gov/Features/EnergyBalance/page1.php>

The Earth's climate is a solar-powered system. Globally, over the course of the year, the Earth system—land surfaces, oceans, and atmosphere—absorbs an average of about 240 watts of solar power per square meter (one watt is one joule of energy every second). The absorbed sunlight drives photosynthesis, fuels evaporation, melts snow and ice and warms the Earth system.

The sun doesn't heat the Earth evenly. Because the Earth is a sphere, the sun heats equatorial regions more than polar regions (the sun's light hits there more directly and so is more intense in those regions). The atmosphere and ocean work nonstop to even out solar heating imbalances through evaporation of surface water, convection, rainfall, winds, and ocean circulation. Together, atmosphere and ocean circulation are known as Earth's heat engine.

Earth's heat engine does more than simply move heat from one part of the surface to another; it also moves heat from the Earth's surface and lower atmosphere back to space. This flow of incoming and outgoing energy is Earth's energy budget. For Earth's temperature to be stable over long periods of time, incoming energy and outgoing energy have to be equal. In other words, the energy budget at the top of the atmosphere must balance. This state of balance is called radiative equilibrium.

About 29 percent of the solar energy that arrives at the top of the atmosphere is reflected back to space by clouds, atmospheric particles, or bright ground surfaces like sea ice and snow. This energy plays no role in Earth's climate system. About 23 percent of incoming solar energy is absorbed in the atmosphere by water vapor, dust and ozone, and 48 percent passes through the atmosphere and is absorbed by the surface. Thus, about 71 percent of the total





incoming solar energy is absorbed by the Earth system.

The Earth's temperature doesn't rise infinitely, however, because atoms and molecules on Earth do not just absorb sunlight, they also radiate back out heat energy. The amount of heat a surface radiates is proportional to the fourth power of its temperature (if the temperature doubles, radiated heat energy increases by 16 times!). This large increase in heat loss in response to a relatively smaller increase in temperature—referred to as radiative cooling—is the primary mechanism that prevents runaway heating on Earth.

The atmosphere and the surface of the Earth together absorb 71 percent of incoming solar radiation, so they must radiate that much energy back to space for the planet's average temperature to remain stable. However, the atmosphere and the surface absorb sunlight and radiate heat at different rates. The atmosphere absorbs 23 percent of incoming sunlight while the surface absorbs 48. The atmosphere radiates heat equivalent to 59 percent of incoming sunlight; the surface radiates only 12 percent. In other words, most solar heating happens at the surface, while most radiative cooling happens in the atmosphere. How does this reshuffling of energy between the surface and atmosphere happen?

Surface Energy Budget

To understand how the Earth's climate system balances the energy budget, we have to consider processes occurring at the three levels: 1) the surface of the Earth, where most solar heating takes place; 2) the edge of Earth's atmosphere, where sunlight enters the system; and 3) the atmosphere in between. At each level, the amount of incoming and outgoing energy, or net flux, must be equal.

Remember that about 29 percent of incoming sunlight is reflected back to space by bright particles in the atmosphere or bright ground surfaces, which leaves about 71 percent to be absorbed by the atmosphere (23 percent) and the land (48 percent). For the energy budget at Earth's surface to balance, processes on the ground must get rid of the 48 percent of incoming solar energy that the ocean and land surfaces absorb. Energy leaves the surface through three processes: evaporation, convection, and emission of thermal infrared energy.

About 25 percent of incoming solar energy leaves the surface through evaporation. Liquid water molecules absorb incoming solar energy and they change phase from liquid to gas. The heat energy that it took to evaporate the water is latent in the random motions of the water vapor molecules as they spread through the atmosphere. When the water vapor molecules condense back into rain, the latent heat is released to the surrounding atmosphere. Evaporation from tropical oceans and the subsequent release of latent heat are the primary drivers of the atmospheric heat engine.

An additional 5 percent of incoming solar energy leaves the surface through convection. Air in direct contact with the sun-warmed ground becomes warm and buoyant. In general, the atmosphere is warmer near the surface and colder at higher altitudes and, under these conditions, warm air rises, shuttling heat away from the surface.



Finally, a net of about 17 percent of incoming solar energy leaves the surface as thermal infrared energy (heat) radiated by atoms and molecules on the surface. This net upward flux results from two large but opposing fluxes: heat flowing upward from the surface to the atmosphere (117 percent) and heat flowing downward from the atmosphere to the ground (100 percent). (These competing fluxes are part of the greenhouse effect, described below).

The Atmosphere's Energy Budget

Just as the incoming and outgoing energy at the Earth's surface must balance, the flow of energy into the atmosphere must be balanced by an equal flow of energy out of the atmosphere and back to space. Satellite measurements indicate that the atmosphere radiates thermal infrared energy equivalent to 59 percent of the incoming solar energy. If the atmosphere is radiating this much, it must be absorbing that much. Where does that energy come from?

Clouds, aerosols, water vapor, and ozone directly absorb 23 percent of incoming solar energy. Evaporation and convection transfer 25 and 5 percent of incoming solar energy from the surface to the atmosphere. These three processes transfer the equivalent of 53 percent of the incoming solar energy to the atmosphere. The remaining fraction (about 5-6 percent) comes from the Earth's surface.

The Natural Greenhouse Effect

Just as the major atmospheric gases (oxygen and nitrogen) are transparent to incoming sunlight, they are also transparent to outgoing heat energy. However, water vapor, carbon dioxide, methane and other trace gases are "opaque" to many wavelengths of heat energy and so trap that heat in the atmosphere. Remember that the surface radiates the net equivalent of 17 percent of incoming solar energy as thermal infrared. However, the amount that directly escapes to space is only about 12 percent of incoming solar energy. The remaining fraction—a net 5-6 percent of incoming solar energy—is transferred to the atmosphere when greenhouse gas molecules absorb thermal infrared energy radiated by the surface.

When greenhouse gas molecules absorb thermal infrared energy, their temperature rises, and then they radiate an increased amount of heat in all directions. Heat radiated upward continues to encounter greenhouse gas molecules; those molecules absorb the heat, their temperature rises and the amount of heat they radiate increases. Heat radiated downward ultimately comes back into contact with the Earth's surface, where it is absorbed. The temperature of the surface becomes warmer than it would be if it were heated only by direct sunlight. This additional heating of the Earth's surface by the atmosphere is the natural greenhouse effect.

Effect on Surface Temperature

The natural greenhouse effect raises the Earth's surface temperature to about 15 degrees Celsius on average—more than 30 degrees warmer than it would be if it didn't have an atmosphere. The amount of heat radiated from the atmosphere back to the surface (sometimes called "back radiation") is equivalent to 100 percent of the incoming solar energy. The Earth's surface responds to the "extra" (on top of direct solar heating) energy by raising its temperature.



Why doesn't the natural greenhouse effect cause a runaway increase in surface temperature? Remember that the amount of energy a surface radiates always increases faster than its temperature rises—outgoing energy increases with the fourth power of temperature. As solar heating and “back radiation” from the atmosphere raise the surface temperature, the surface simultaneously releases an increasing amount of heat—equivalent to about 117 percent of incoming solar energy. The net upward heat flow, then, is equivalent to 17 percent of incoming sunlight (117 percent up minus 100 percent down).

Some of the heat escapes directly to space and the rest is transferred to higher and higher levels of the atmosphere, until the energy leaving the top of the atmosphere matches the amount of incoming solar energy. Because the maximum possible amount of incoming sunlight is fixed by the solar constant (which depends only on Earth's distance from the sun and very small variations during the solar cycle), the natural greenhouse effect does not cause a runaway increase in surface temperature on Earth.

Climate Forcings and Global Warming

Any changes to the Earth's climate system that affect how much energy enters or leaves the system alters Earth's radiative equilibrium and can force temperatures to rise or fall. These destabilizing influences are called climate forcings. Natural climate forcings include changes in the Sun's brightness, Milankovitch cycles (small variations in the shape of Earth's orbit and its axis of rotation that occur over thousands of years) and large volcanic eruptions that inject light-reflecting particles as high as the stratosphere. Man-made forcings include particle pollution (aerosols), which absorb and reflect incoming sunlight; deforestation, which changes how the surface reflects and absorbs sunlight; and the rising concentration of atmospheric carbon dioxide and other greenhouse gases, which decrease heat radiated to space. A forcing can trigger feedbacks that intensify or weaken the original forcing. The loss of ice at the poles, which makes them less reflective and results in increased heat absorption, is an example of a feedback.

Increasing carbon dioxide forces the Earth's energy budget out of balance by absorbing heat radiated by the surface. It absorbs heat energy with wavelengths in a part of the energy spectrum that other gases, such as water vapor, do not. Although water vapor is a powerful absorber of many wavelengths of thermal infrared energy, it is almost transparent to others. The transparency at those wavelengths is like a window the atmosphere leaves open for radiative cooling of the Earth's surface.

Carbon dioxide is a very strong absorber of thermal infrared energy with wavelengths longer than those absorbed by water, which means that increasing concentrations of carbon dioxide partially “close” the atmospheric window. In other words, wavelengths of outgoing thermal infrared energy that our atmosphere's most abundant greenhouse gas—water vapor—would have let escape to space are instead absorbed by carbon dioxide.

The absorption of outgoing thermal infrared by carbon dioxide means that Earth still absorbs about 70 percent of the incoming solar energy, but an equivalent amount of heat is no longer leaving. The exact amount of the energy imbalance is very hard to measure, but it appears to be a



little over 0.8 watts per square meter. The imbalance is inferred from a combination of measurements, including satellite and ocean-based observations of sea level rise and warming.

When a forcing like increasing greenhouse gas concentrations bumps the energy budget out of balance, it doesn't change the global average surface temperature instantaneously. It may take years or even decades for the full impact of a forcing to be felt. This lag between when an imbalance occurs and when the impact on surface temperature becomes fully apparent is mostly because of the immense heat capacity of the oceans. The heat capacity of the oceans gives the climate a thermal inertia that can make surface warming or cooling more gradual, but it can't stop a change from occurring.

The changes we have seen in the climate so far are only part of the full response we can expect from the current energy imbalance, caused only by the greenhouse gases we have released so far. Global average surface temperature has risen between 0.6 and 0.9 degrees Celsius in the past century and it will likely rise at least 0.6 degrees in response to the existing energy imbalance.

As the surface temperature rises, the amount of heat the surface radiates will increase rapidly. If the concentration of greenhouse gases stabilizes, then Earth's climate will once again come into equilibrium, albeit with the "thermostat"—global average surface temperature—set at a higher temperature than it was before the Industrial Revolution.

However, as long as greenhouse gas concentrations continue to rise, the amount of absorbed solar energy will continue to exceed the amount of thermal infrared energy that can escape to space. The energy imbalance will continue to grow and surface temperatures will continue to rise.



Vocabulary

- **Earth's Atmosphere:** The layer of gases surrounding the Earth. The atmosphere protects life on Earth by absorbing infrared radiation emitted from Earth's surface. The light from the sun is transmitted through the atmosphere and warms the Earth. This warmth is absorbed by the Earth's atmosphere. Air is mainly composed of nitrogen, oxygen, and argon. These gases make up most of the atmosphere. Other gases are in the atmosphere in lower quantities. These include greenhouse gases like carbon dioxide and methane
- **Greenhouse Gas:** A gas in an atmosphere that lets in sunlight and traps heat energy. This process is the fundamental cause of the greenhouse effect. The primary greenhouse gases in the Earth's atmosphere are carbon dioxide, methane, water vapor, and nitrous oxide.
- **Greenhouse Effect:** The ability of gases in the atmosphere to absorb heat from the Earth is called the greenhouse effect.
- **Earth's Reflectivity:** The percentage of sunlight reflected by the Earth's surface features (water, ice, snow, plants) and atmosphere. Ice, especially with snow on top of it, has a high reflectivity. This means that most sunlight hitting the surface bounces back toward space. Water is much more absorbent and less reflective. So if there is a lot of water more solar radiation is absorbed by the ocean than when ice dominates. Clouds also play a significant role in the Earth's reflectivity as they reflect incoming sunlight back into space.
- **Earth's Albedo:** The percentage of solar energy reflected from the Earth back into space. It is a measure of the reflectivity of the earth's surface.
- **Luminosity:** The total amount of light energy given off of by an object (such as a light bulb or the sun).
- **Earth's Energy Absorption:** The amount of the sun's energy absorbed by the surface features of the Earth (plants, earth, water) and its atmosphere. The energy that is not absorbed is reflected back out into the atmosphere.
- **Solar Energy:** Energy from the sun. The sun emits energy in all wavelengths, peaking in the visible wavelengths. Energy from the Earth peaks in the infrared wavelengths.
- **Surface Features of the Earth:** Topography (land forms), bodies of water, and ground cover that cover the Earth's surface.
- **Earth's Energy Cycle/Earth's Energy Balance:** The Earth can be considered a physical system with an energy cycle that includes all incoming energy (primarily from the Sun) and all losses of outgoing energy (through reflectivity). Outgoing energy is a predominantly a combination of reflected solar energy and transmitted infrared energy. The planet is approximately in balance, so the amount of energy coming in is approximately equal to the amount going out. The Earth's energy balance is what keeps the Earth at its current temperature.



Part 1: Modeling the Greenhouse Effect

Description: Students will do a lab demonstration to learn about the greenhouse effect and then discuss the natural vs. human-induced changes in greenhouse gas concentrations.

Time: Approximately 30 minutes of active time. The lab needs to sit for at least 1 hour.

NOTE: You may break up the lab activity across two days if you are not able to come back to the activity after an hour. Have students complete the pre-lab worksheet and prepare their greenhouse model on day 1. On day 2, put the student-prepared models in the sun (or under hot lamps) for at least an hour before the class period starts, so that when students arrive they can immediately begin taking measurements.

Materials:

Part 1

Per group

- Two thermometers
- Two empty soda cans
- 100 ml. water
- 1 large plastic zip-lock bag
- Modeling the Greenhouse Effect lab worksheet
- Pens or pencils

Procedure

1. Before students come into the classroom write the following discussion question on the board: *“Animals, people, and many of the things that we use in our daily lives such as automobiles and electricity make gases such as carbon dioxide. These gases form a blanket around Earth similar to plants inside a greenhouse or sitting in a car in the sun. How do you think this layer of “greenhouse gases” might affect Earth’s temperature?”*
2. Have a student read the introduction question aloud. Then have students brainstorm their answers and record their answers on the board. At this point you may choose to give students simple definitions of atmosphere and greenhouse gas or wait and introduce them in part 2 of this activity when they discuss the role of greenhouse gases in Earth’s energy balance.
 - **Earth’s Atmosphere:** The layer of gases surrounding Earth. The atmosphere protects life on Earth by absorbing light energy from the sun. It is the air that we breathe and is made up of a mixture of gases including oxygen and carbon dioxide.
 - **Greenhouse Gas:** A gas in an atmosphere that lets in sunlight and traps heat energy. This trapping of heat energy is called the greenhouse effect. Gases that trap energy are called greenhouse gases. Carbon dioxide is a greenhouse gas.
3. Explain that they are going to do an experiment that models this layer of “greenhouse gases” to see what effects it has on temperature.
4. Guide students through the worksheet before beginning the lab. Depending on the amount of time you have and the level of your students, you can either have students brainstorm how you might set up the experiment before handing out the worksheet or you can hand out the worksheet, read through it, and ask them to think about how the setup of the experiment models the role of greenhouse gases around Earth. Through discussion or



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explanation, students should understand that the cans of water represent the Earth and that the bag around one represents greenhouse gases (or the Earth's atmosphere).

5. Have students follow the directions on the lab sheets and place cans in a sunny spot. The cans will stay in the sunny spot for at least 1 hour. During this wait time you may begin part 2, Greenhouse Gases: human vs. natural causes.

If you have 45-minute class periods, set aside the cans and continue on to Part 2. At least an hour before the next class, place the cans in a sunny window or under a hot lamp, so the models have time to heat up and students can begin taking measurements when they arrive.

6. After 1 hour, have students take the final temperatures, record their data and answer the post-lab questions. You can collect the labs for a grade or go over the answers in class.
7. As you discuss the lab, key points to communicate are that
 - the bag represents the layer of greenhouse gases (including carbon dioxide and other gasses) surrounding the Earth;
 - greenhouse gases trap heat and keep the planet warm;
 - greenhouse gases are necessary for life on our planet to exist, otherwise the planet would freeze;
 - and adding more greenhouse gases to the planet is like making a thicker bag, trapping more heat and increasing the Earth's temperature.
8. Lab sheets should be placed in student portfolios.



Name: _____ Date: _____ Room: _____

Modeling the Greenhouse Effect

Introduction:

Animals and plants release gases such as carbon dioxide and oxygen into the atmosphere. These gases form a blanket around the Earth similar to putting a plastic bag around a can. How do you think this might affect Earth's temperature? Think about what happens when you wrap up in a blanket on a cold night.

Materials:

- 2 thermometers
- 1 plastic ziplock bag
- 2 empty soda cans
- 100 ml of water

Procedure:

Part 1

1. Fill each can with 50 ml of water.
2. Put a thermometer in each can and wait two minutes (make sure the thermometer is in the water). Record the temperature of the water in each can on your data table. This is the initial temperature.
3. Put the thermometers back into the cans.
4. Place one can and thermometer in a ziplock bag and seal the bag.
5. Put both cans next to each other in a sunny spot and leave them there for at least an hour. Your teacher will tell you when it is time to start Part 2 of the experiment.

Part 2

6. Record the temperature on the thermometer in each can on your data table. This is the final temperature.
7. Subtract the initial temperature from the final temperature to find the change in temperature. Record this in your data table.

Data table:

Can	Initial temperature (C)	Final temperature (C)	Change in temperature
With bag			
Without bag			



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Name: _____ Date: _____ Room: _____

Questions:

1. Was there a difference in final temperature between the can with the bag around it and the can with no bag? What do you think caused the difference?
2. What do you think would happen to the final temperature if you used a thicker bag, or two bags, around the can?
3. What does the bag represent? Explain.
4. Explain why the greenhouse effect is necessary for life on earth, but how it may be a problem if the concentration of greenhouse gases increases?



Part 2: Earth's Energy Balance

Description: Students color in a diagram, answer opinion questions, and perform a skit enacting energy movement through the atmosphere. Students will learn that the primary source of energy on Earth is the sun, and what happens to that energy once it reaches Earth's atmosphere. Students are introduced to the concept of greenhouse gases. The activity will close with a discussion of natural versus human-induced changes in greenhouse gas concentrations.

Time: Two class periods

Materials:

Part 2

- Desk lamp
- Student handout
- Earth's Energy Balance Diagram worksheet
- Colored pencils
- "Character" cards
- 30 dry lima beans (using food is a nice analogy because it represents another form of energy)

Procedure

Day 1 (*You may begin this discussion while waiting to begin Part 2 of the lab*)

1. Before beginning, put the desk lamp on your desk or in an easily accessible location.
2. Ask students what they know about energy. Take student answers and write them on the board. The depth and length of the discussion will depend on your students' background knowledge and whether you have already covered this content.
3. Turn on the desk lamp. Ask students what kind of energy is being used to turn on the lamp (electrical). Ask students what kind of energy the lamp is giving off (light), is that all? Have one or a few students come to the front of the class and hold their hand near the lamp. What do they feel? The lamp is also giving off heat energy. Explain that the electrical energy is being transformed to light energy through the light bulb and that the light energy is transformed to heat energy when it hits their hands.
4. Ask students how the example of the light is similar to the sun and Earth. The sun gives off light that warms Earth—if you stand in the sun, you can feel the warmth. Through this discussion, students should understand that light and heat are both different forms of energy and that light from the sun is transformed to heat energy when it reaches Earth's surface.
5. Have students breathe in and breathe out slowly and concentrate on how it feels to breathe. Ask students:
What were you breathing in? (oxygen, air)
What is the "air" made up of? (oxygen, CO₂, water vapor, nitrogen, other gases)

Air is mainly composed of nitrogen, oxygen, and argon, which together constitute the major gases of the atmosphere. We breathe in oxygen and breathe out CO₂. Plants take in CO₂ and produce oxygen. The remaining gases are often referred to as trace gases, among which are the greenhouse gases.



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Explain that the air, or atmosphere, is not only important because we breathe it, but that it supports life on Earth in other ways – by helping to maintain the temperature of the Earth.

Explain that the atmosphere is a layer of gases surrounding the Earth. The atmosphere protects life on Earth by absorbing ultraviolet solar radiation from the sun, warming the surface through heat retention (greenhouse effect), and reducing temperature extremes between day and night. To make it a little more concrete for the students, you may want to add that the gases act much like the glass on a greenhouse, trapping heat in—and ask students what happens to the interior of a car left out in the sun on a summer day?

This is a good stopping point to go back and complete Part 2 of the lab activity.

6. Next, students will work through the diagram. This can be done in several ways. You can pass out the handout, which will guide them through the diagram and have them work through the handout and diagram alone or in groups. Alternatively, you can lead the class and have the students work through the handout and diagram step by step. In either case, it is worthwhile to discuss the italicized questions. Below are the italicized questions with possible student answers/discussion points.
7. *Based on the name, what do you think is the effect of the greenhouse gases?*
Students may recognize that a greenhouse is hot or that a greenhouse is designed to protect plants. They may conclude that greenhouse gases keep the Earth warm or protect the Earth. If students have already completed part 2 of the lab, the results should inform their response.
8. *You have already colored arrow 2 orange. Why do you think arrow 6 is also colored orange?*
Arrow 2 and arrow 6 both represent energy that comes directly from the sun so both are orange.
9. *Why do you think arrow 6 is thinner than arrow 2?*
Arrow 6 is thinner than arrow 2 because some of the energy from the sun was lost into space after being reflected by the atmosphere or by clouds.
10. *Why do you think you colored the Earth's surface green?*
Earth's surface is green because the Earth is covered by plants (among other things). Plants are highlighted here because they use the sun's energy to grow.
11. *Explain how the energy from the sun that reaches Earth may be used on Earth?*
The energy is used for plants to grow. When animals eat plants, they get energy as well.

Day 2 (depending on time, all activities may be completed in one day)



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12. Select 6 students to “act out” Earth’s energy balance. Assign roles to the students using the cards below. One student each will play: the sun, cloud, Earth’s atmosphere/greenhouse gases, Earth’s surface, plants, and space.
13. Before performing the activity, you can hang the cards on yarn to make necklaces or simply have the students tape the cards to their shirts. You will “narrate” the scene as students act it out. Explain to the students that beans will represent energy.
14. Ask them why it makes sense that food is used to represent energy (the students may answer that they get energy from food, so it makes sense to have beans represent energy). Give 30 dry lima beans to the student playing the sun.
15. Read through the following narration and have the students act:
 - **Most of the energy on Earth originates from the sun. Some of the energy from the sun reaches Earth’s atmosphere. The sun will now give 30 beans to the Earth’s atmosphere.**
 - **Some of the energy is reflected off Earth’s atmosphere and goes out into space. The atmosphere will now give five beans to space, representing energy that is radiated out.**
 - **Some of the energy will pass through the atmosphere toward Earth. Some of that energy will hit the clouds, while the rest will continue to Earth’s surface. The atmosphere will now give five beans to the cloud, and the rest of the beans to the Earth’s surface.**
 - **The energy that hits the clouds may be reflected to space. The cloud will now give its five beans to space.**
 - **The energy that reached the Earth can be used on Earth, for instance, to make plants grow. Earth’s surface will give five beans to the plant. This energy can be used to make the plant grow. If an animal eats the plant, the energy will be transferred to the animal.**
 - **The energy that is not absorbed by plants or other parts of the Earth’s surface is radiated back toward the atmosphere. Earth will give its remaining beans back to the atmosphere.**
 - **Some of the energy that reaches the atmosphere passes through the atmosphere and ends up in space. The atmosphere will give seven beans to space.**
 - **The rest of the energy is stopped by the greenhouse gases and sent back to Earth. Now, the atmosphere will give its remaining energy back to Earth. This energy helps to heat up the Earth to a temperature that can sustain living things.**

[end of play – everyone takes a bow]



Ask the students: Where did all the energy originate? Where did most of the energy end up? Was this surprising to you?

16. After students have performed the skit once, you can have new students play the roles and have a student, or several students, narrate to see if the students can remember or reason through the steps.
17. After the students have completed color-coding the diagram and performing the skit, check for understanding. Have students look at the diagram. Ask them to write a paragraph in their journals explaining what happens to the energy that comes from the sun to the Earth. You may collect these journal entries to determine if students understand the concepts.



Name: _____ Date: _____ Class: _____

Earth's Energy Balance – Student Handout

Directions: You will color in the diagram “Earth’s energy balance” to learn about what happens to energy from the sun when it reaches the Earth. Follow each step below to color code your diagram. You will need colored pencils, crayons, or markers to complete this activity.

Answer the questions as you go.

1. Locate the number 1 on the diagram. Number 1 represents the sun. Most of the energy on earth originates from the sun. Color the sun yellow.
2. Locate the number 2 on the diagram. Number 2 represents the energy from the sun that comes toward Earth. Color the number 2 arrow orange.
3. Locate the number 3 in the diagram. Number 3 represents Earth’s atmosphere. The atmosphere is made of gases. Some of the gases in the Earth’s atmosphere are called greenhouse gases. Color Earth’s atmosphere purple.

Based on the name, what do you think the greenhouse gases do to the planet? (Think about the lab you did earlier in this activity. What happened to the temperature of the water in the can in the bag?)

4. Locate the number 4 on the diagram. Some of the energy that reaches Earth’s atmosphere is radiated into space without reaching Earth. Arrow number 4 represents the energy that was radiated into space. Color this arrow red.
5. Some of the energy from the sun passes through the atmosphere. However, some of this energy is reflected to space when it hits clouds in the sky. Locate the number 5 on the diagram. Arrow number 5 represents the energy that is radiated into space from the clouds. Color this arrow blue.
6. Some of the energy from the sun passes through the Earth’s atmosphere and the clouds and reaches the Earth’s surface. Locate number 6 on the diagram. Arrow number 6 represents the energy from the sun that reaches the Earth’s surface. Color arrow number 6 orange.

You have already colored arrow 2 orange. Why do you think arrow 6 is also colored orange?



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Name: _____ Date: _____ Class: _____

(6 continued) Why do you think arrow 6 is thinner than arrow 2?

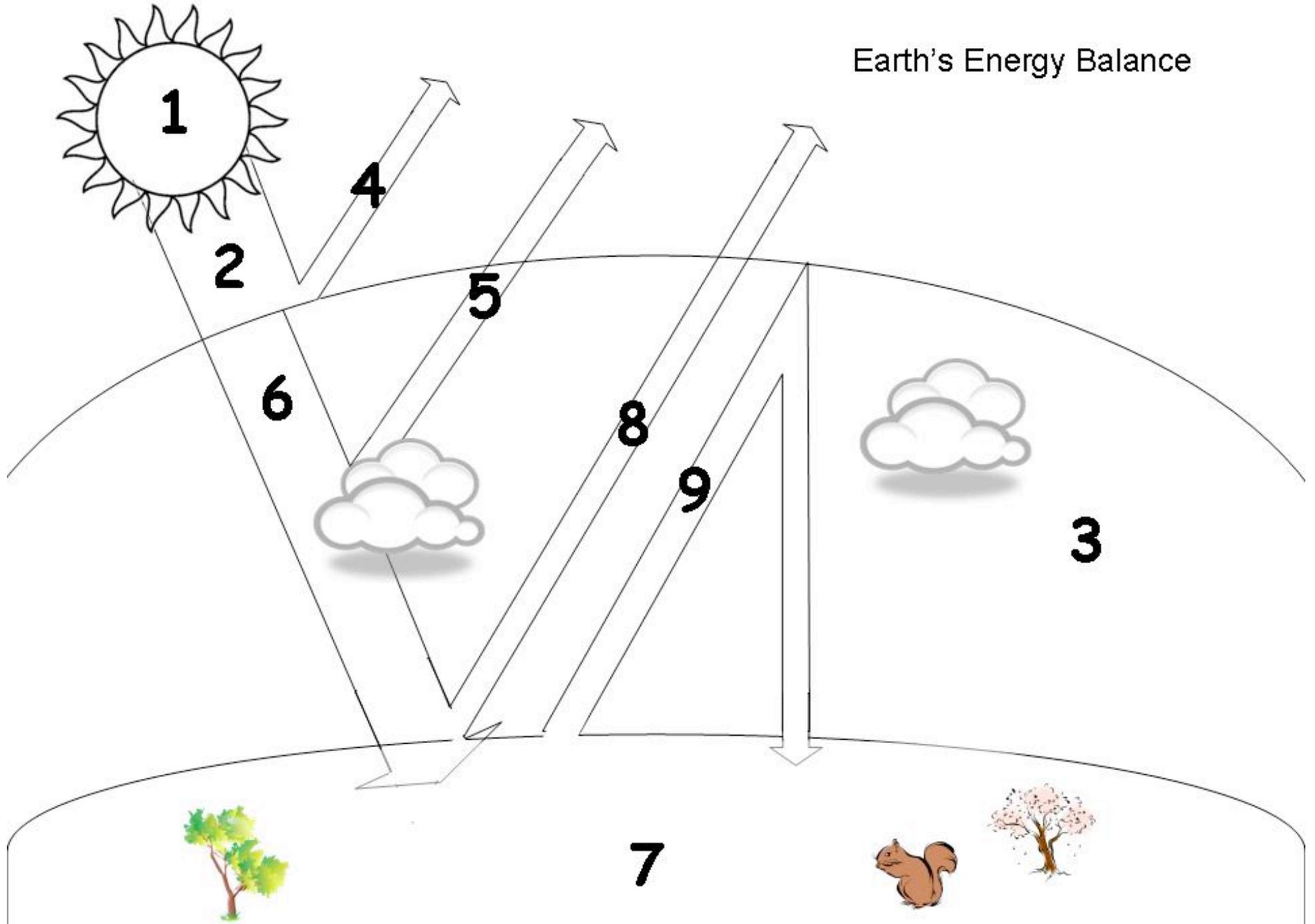
7. Locate number 7 on the diagram. Number 7 represents the Earth's surface. Color the Earth's surface green. Some of the energy that reaches the Earth's surface is used by organisms on Earth.

Why do you think you colored the Earth's surface green?

Explain how the energy that reaches Earth may be used on Earth?

8. The energy that is not absorbed on Earth is radiated back toward space. Locate number 8 on the diagram. Number 8 represents the energy that is radiated away from Earth and goes into space. Color arrow number 8 brown.
9. Some of the energy that is not absorbed by the Earth is radiated back to space but does not reach space. Instead, the greenhouse gases radiate the energy back toward Earth! Locate number 9 on the diagram. The number 9 arrow represents energy that is re-radiated back to Earth. This additional energy helps keep Earth at a temperature that is appropriate for living things. Color the arrow of number 9 pink.

Earth's Energy Balance





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Earth's atmosphere and greenhouse gases



<http://climate.nasa.gov/imagesVideo/earthWallpaper/index.cfm>



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Clouds



http://commons.wikimedia.org/wiki/Cloud#mediaviewer/File:Sc_2.jpg



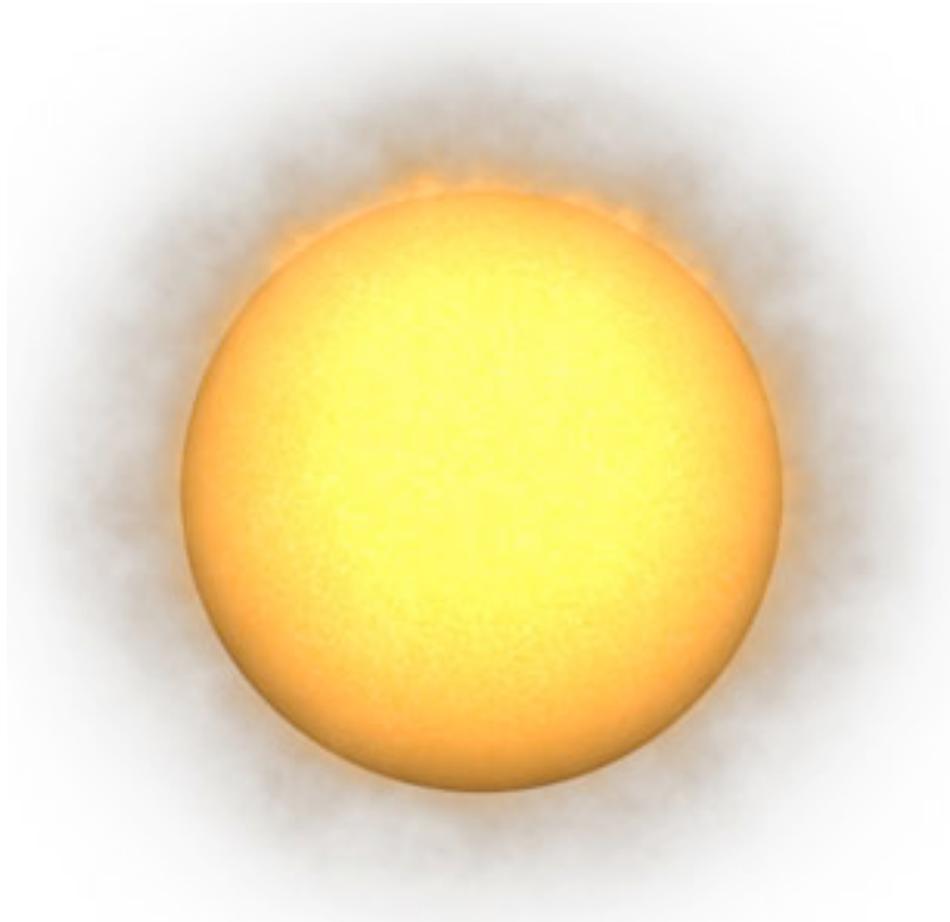
CHICAGO BOTANIC GARDEN

Earth's Surface



<http://climate.nasa.gov/imagesVideo/earthWallpaper/index.cfm>

Sun

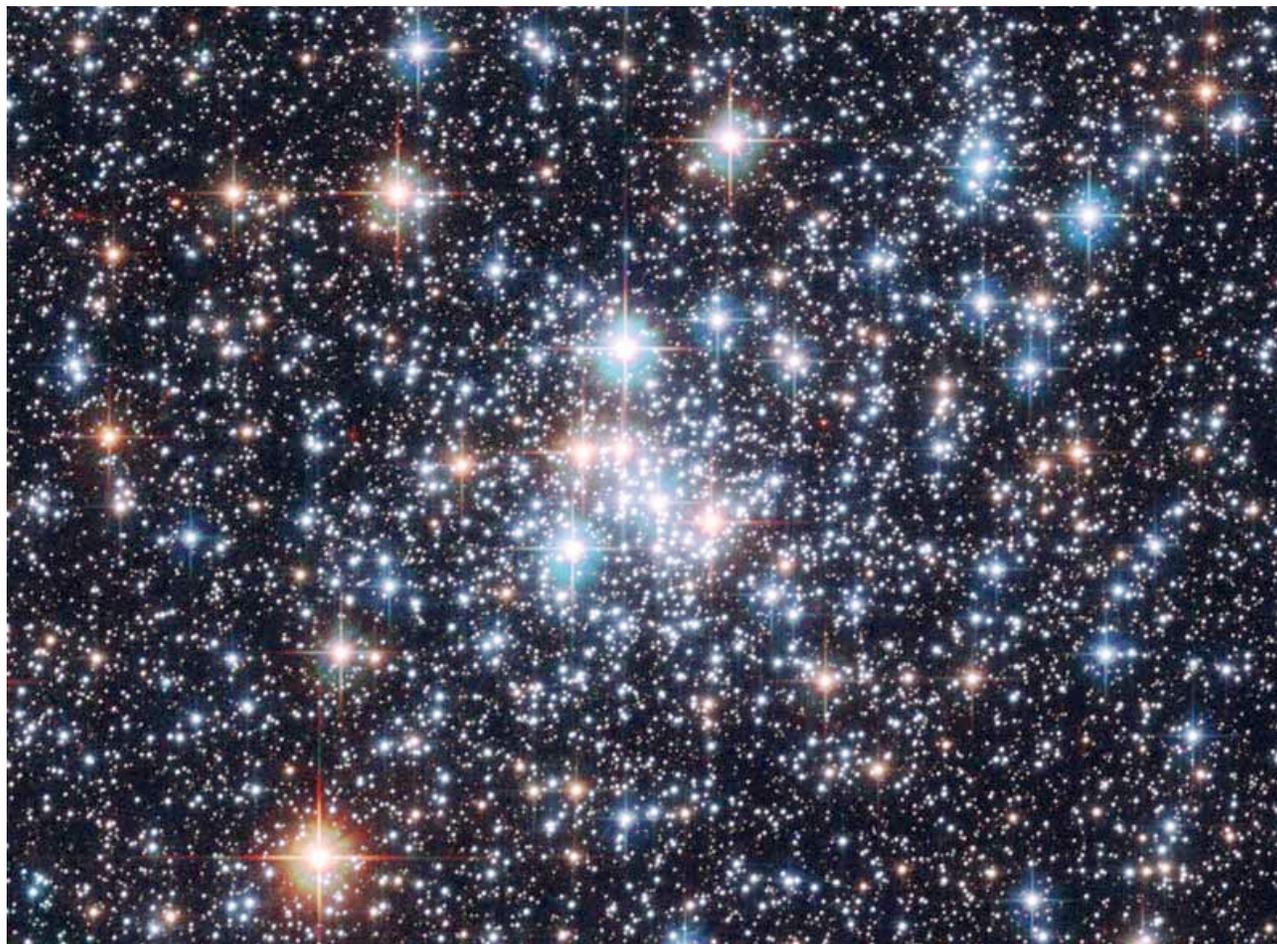


<http://sciencedude.ocreger.com/2012/01/31/nasa-warming-driven-by-humans-not-Sun/167369/>



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Space



<http://hubblesite.org/gallery/album/star/pr2006017c/>



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Plants



Chicago Botanic Garden



TEACHER ANSWER KEY

Modeling the Greenhouse Effect

Introduction:

Animals and plants release gases such as carbon dioxide and oxygen into the atmosphere. These gases form a blanket around Earth similar to putting a plastic bag around a can. How do you think this might affect Earth's temperature? Think about what happens when you wrap up in a blanket on a cold night.

Materials:

- 2 thermometers
- 1 plastic zip-lock bag
- 2 empty soda cans
- 100 ml of water

Procedure:

Part 1

8. Fill each can with 50 ml of water.
9. Put a thermometer in each can and wait two minutes (make sure the thermometer is in the water). Record the temperature of the water in each can on your data table. This is the initial temperature.
10. Put the thermometers back into the cans.
11. Place one can and thermometer in a zip-lock bag and seal the bag.
12. Put both cans next to each other in a sunny spot and leave them there for at least an hour. Your teacher will tell you when it is time to start Part 2 of the experiment

Part 2

13. Record the temperature on the thermometer in each can on your data table. This is the final temperature.
14. Subtract the initial temperature from the final temperature to find the change in temperature. Record this in your data table.

Data table:

Can	Initial temperature (C)	Final temperature (C)	Change in temperature
With bag			
Without bag			



TEACHER ANSWER KEY

Earth's Energy Balance – Student Handout

Directions: You will color in the diagram “Earth’s energy balance” to learn about what happens to energy from the sun when it reaches Earth. Follow each step below to color code your diagram. You will need colored pencils, crayons, or markers to complete this activity.

Answer the questions as you go.

1. Locate the number 1 on the diagram. Number 1 represents the sun. Most of the energy on Earth originates from the sun. Color the sun yellow.
2. Locate the number 2 on the diagram. Number 2 represents the energy from the sun that comes toward the Earth. Color the number 2 arrow orange.
3. Locate the number 3 in the diagram. Number 3 represents Earth’s atmosphere. The atmosphere is made of gases. Some of the gases in the Earth’s atmosphere are called greenhouse gases. Color the Earth’s atmosphere purple.

Based on the name, what do you think the greenhouse gases do to the planet? (Think about the lab you did earlier in this activity. What happened to the temperature of the water in the can in the bag?)

Greenhouses let in light energy from the sun, but trap heat energy, making things warm. Based on the name, the greenhouse effect would mean that it warms the Earth or keeps it from getting cold. Based on our experiment with the water in the can, the greenhouse effect will warm the Earth.

4. Locate the number 4 on the diagram. Some of the energy that reaches Earth’s atmosphere is radiated into space without reaching Earth. Arrow number 4 represents the energy that was radiated into space. Color this arrow red.
5. Some of the energy from the sun passes through the atmosphere. However, some of this energy is reflected to space when it hits clouds in the sky. Locate the number 5 on the diagram. Arrow number 5 represents the energy that is radiated into space from the clouds. Color this arrow blue.
6. Some of the energy from the sun passes through Earth’s atmosphere and the clouds and reaches Earth’s surface. Locate number 6 on the diagram. Arrow number 6 represents the energy from the sun that reaches Earth’s surface. Color arrow number 6 orange.

You have already colored arrow 2 orange. Why do you think arrow 6 is also colored orange?

Both arrows represent direct sunlight that isn’t reflected back away from the Earth.



Name: _____ Date: _____ Class: _____

(6 Continued) Why do you think arrow 6 is thinner than arrow 2?

Arrow 6 is thinner than arrow two because it represents less energy. Some of the energy represented by arrow 2 is reflected back into space by the atmosphere, so that energy is not part of arrow 6.

7. Locate number 7 on the diagram. Number 7 represents the Earth's surface. Color the Earth's surface green. Some of the energy that reaches the Earth's surface is used by organisms on earth.

Why do you think you colored the Earth's surface green?

Green represents the plants that use the sun's energy for photosynthesis (to create their food and grow) and other living things on Earth that depend on the sun's energy.

Explain how the energy that reaches Earth may be used on Earth?

Energy that reaches the Earth is used by plants for photosynthesis. It is used to make food, it heats the atmosphere to keep us warm, and we use solar panels to use sunlight for power.

8. The energy that is not absorbed on Earth is radiated back toward space. Locate number 8 on the diagram. Number 8 represents the energy that is radiated away from Earth and goes into space. Color arrow number 8 brown.
9. Some of the energy that is not absorbed by Earth is radiated back to space but does not reach space. Instead, the greenhouse gases radiate the energy back toward Earth! Locate number 9 on the diagram. The number 9 arrow represents energy that is re-radiated back to Earth. This additional energy helps keep the Earth at a temperature that is appropriate for living things. Color the arrow of number 9 pink.