How saving energy keeps the Earth a "cool" place to live

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Overview: Use the study of and electromagnetic radiation and the composition of Earth's atmosphere to understand the greenhouse effect, and how energy conservation can reduce the greenhouse gas emissions.

Objectives: Introduce students to electromagnetic radiation, the composition of the Earth's atmosphere, and the greenhouse effect. Identify greenhouse gases released when fossil fuels are burned and how burning fossil fuels influences the concentration of greenhouse gases in the Earth's atmosphere.

Subjects: Physical Science, Environmental Science, Physics

Suggested Grade Level: 9-12

California Standards Addressed:

Physics: Waves

4. Waves have characteristic properties that do not depend on the type of wave. As a basis for understanding this concept:
    a. *Students know* waves carry energy from one place to another.
    e. *Students know* radio waves, light, and X-rays are different wavelength bands in the spectrum of electromagnetic waves whose speed in a vacuum is approximately 3×10^8 m/s (186,000 miles/second).

Earth Science: Energy in the Earth System

4. Energy enters the Earth system primarily as solar radiation and eventually escapes as heat. As a basis for understanding this concept:
    d. *Students know* the relative amount of incoming solar energy compared with Earth's internal energy and the energy used by society.
    e. *Students know* the fate of incoming solar radiation in terms of reflection, absorption, and photosynthesis.
    f. *Students know* the different atmospheric gases that absorb the Earth's thermal radiation and the mechanism and significance of the greenhouse effect.
    g. *Students know* the differing greenhouse conditions on Earth, Mars, and Venus; the origins of those conditions; and the climatic consequences of each.

Earth Science: Structure and Composition of the Atmosphere

8. Life has changed Earth's atmosphere, and changes in the atmosphere affect conditions for life. As a basis for understanding this concept:
    a. Students know the thermal structure and chemical composition of the atmosphere.

    c. Students know the location of the ozone layer in the upper atmosphere, its role in absorbing ultraviolet radiation, and the way in which this layer varies both naturally and in response to human activities.

Physics: Conservation of Energy and Momentum

2. The laws of conservation of energy and momentum provide a way to predict and describe the movement of objects.

Investigation & Experimentation

1. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other four strands, students should develop their own questions and perform investigations. Students will:
    l. Analyze situations and solve problems that require combining and applying concepts from more than one area of science.
    m. Investigate a science-based societal issue by researching the literature, analyzing data, and communicating the findings. Examples of issues include irradiation of food, cloning of animals by somatic cell nuclear transfer, choice of energy sources, and land and water use decisions in California.

Materials:

Hotplate or Infrared lamp
Flashlight
Currency Checker
Old x-ray film
Radio
Microwave
Flasks
1-hole stopper
Thermometer
Vinegar
Baking soda
Matches
Lab stove/burner

Procedure:

Anticipatory set: Teacher asks all in class to take a deep breath. What is in this air that you are breathing?

1. Why is conserving energy important?

In groups of 3, write down reasons why it is important to you to conserve energy.

1. [Conserving energy reduces air pollution.]
2. [Conserving energy reduces greenhouse gases.]
3. [Conserving energy reduces our heavy dependence on imported petroleum.]

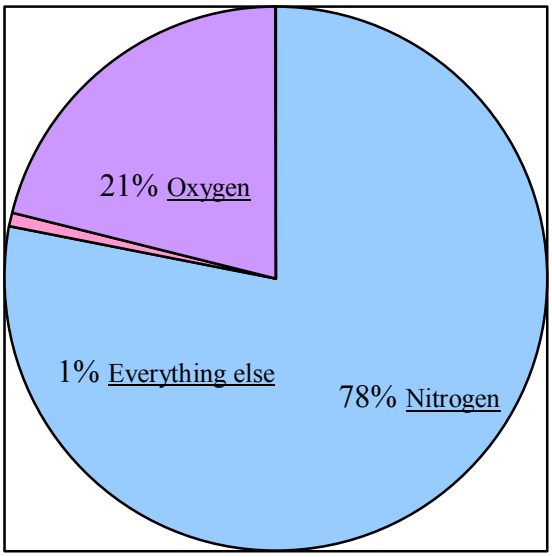
4. [Conserving energy helps us keep our natural resources for the next generation, helps us be wise stewards of the environment.]

What to expect to accomplish:

- Know which __gases__ make up the Earth's atmosphere.
- Know the Electromagnetic radiation (EMR) __spectrum__ and where IR and UV radiation compare to the other forms of EMR.
- Be able to explain the __Greenhouse__ effect: what causes it, how it can help and how it can hurt life on Earth.
- Write the chemical __equations__ and explain how acid rain/fog is formed and its damaging effects.

2. Understanding the Earth's Atmosphere

Composition of the Earth's atmosphere



What is in that remaining 1%?

- Water - (H2O) 1-4 %
- Argon - (Ar) 0.93% **inert**
- carbon dioxide - (CO2) 0.035%
- Neon - (Ne) 0.002% **inert**
- Methane, natural gas - (CH_4) 0.0002%
- Ozone - O_3

And other trace gases such as helium and xenon

Gases in the atmosphere

- 78% N_2 – Nitrogen
- 21% O_2 – Oxygen
- 1% - Other gases

Greenhouse Gases in the Atmosphere

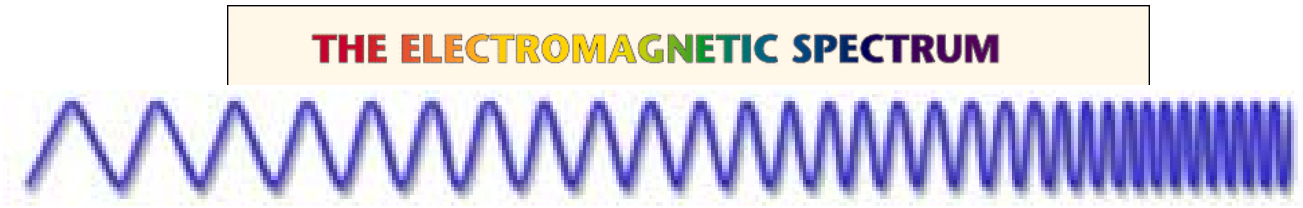
- CO_2, carbon dioxide
- CH_4, methane
- H_2O, water

What are Greenhouse gases?

Gases that trap radiated __heat___ from the Earth making the Earth __warmer___. Without Greenhouse gases, the Earth would be well below zero degrees every night and almost uninhabitable. With too high a concentration of Greenhouse gases, the Earth would become to warm. The planet __Venus__ is an example. Being closer to the Sun, it gets about twice the Sunlight. But because of high concentrations of the Greenhouse gas CO_2, it is about 900°F day and night on the surface of Venus!

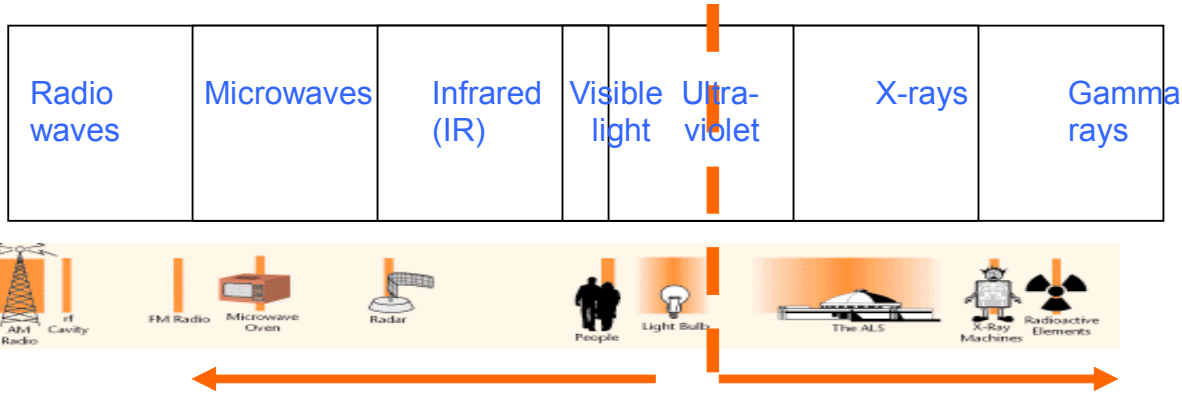
Teacher Demonstration: Turn on a hotplate. Then unplug it, hold it cautiously by the base, and aim the coils toward students. Students even 10 feet away will feel its radiated heat on their faces. This is an example of radiated heat, or infrared radiation (IR). IR is what Greenhouse gases trap and reflect back to Earth, keeping the Earth warmer.

3. Understanding Solar Radiation (light from the Sun)



_High__ Frequency
_short__ Wavelength
_High__ Energy

Frequency __Low_____
Wavelength __Long ____
Energy __Low___



Not _harmful___ to living things. ___harmful ____ to living things.

Teacher Demonstration:
Bring in examples of various forms of Electromagnetic radiation:

- An electrical hotplate or Infrared lamp
- Flashlight for visible light.
- Currency checker for ultraviolet.
- Microwave oven.
- Old x-ray film
- Radio

4. Understanding how Greenhouse gases make the Earth warmer

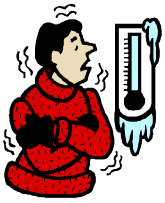
Preparation: Inquiry lesson style, students come up with three possibilities for what light can do when it strikes something. Shine a powerful flashlight (e.g., MAG light) through air (**transmission**), on different surfaces: water (**transmission**), dark counter or black paper (**absorption**), shiny surface (**reflection**). Shine on a student's hand and ask if the student feels his hand getting warmer. Most of the light is doing what? (**absorbed**). Shine through a student's fingers, and see the red glow come through the fingers; some light is being **transmitted**. Some is also being **reflected**, so you see the light reflected off of the fingers. In no light were reflected off the hand, it would appear black.

When light strikes any object or substance, three things can happen:

1. It can be _transmitted__.
2. It can be _reflected____.
3. It can be _absorbed____.

About 35% of the incoming solar radiation (Sun's energy) is **reflected** back into space by clouds, 15% is **absorbed** by the atmosphere. The remaining 50% is **transmitted** through the air to the Earth's surface, where it is **absorbed**.

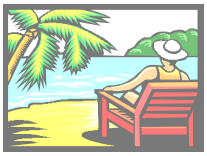
- When sunlight strikes nitrogen & oxygen in the atmosphere, most of it is transmitted.
- When sunlight strikes cloud cover, most of it is __reflected __ back out into space.
- When sunlight strikes lakes and oceans, most of it is transmitted down.
- When sunlight strikes greenhouse gases, most of it is transmitted down to the Earth's surface.
- When sunlight strikes the earth (dirt or plants), most of it is _absorbed __.
- The sunlight and UV radiation that the Earth absorbs changes to __heat__. As the earth heats, it radiates this energy back out into space as _infrared radiation_.



On its way back out into space, when IR strikes nitrogen and oxygen, most of it is _transmitted. This means the energy is lost to space, and the Earth __cools__. On its way back out into space, if IR strikes **greenhouse gases**, most of it is __absorbed__. It is **radiated** back to Earth, making it so that the Earth keeps that energy, keeping the Earth warmer. If there were no CO_2, methane, or other greenhouse gases in the Earth's atmosphere, the Earth's average temperature would be about __- 4°_ °F (-20°C). With the Earth's current levels of greenhouse gases in the atmosphere, the Earth's average temperature over its surface is about 59°F (15°C). Ahhhhhh! But, what would happen if the concentration of greenhouse gases in the Earth's atmosphere increased…?

[Get audience responses.]

Understanding check:



1. What are the two most common gases in the Earth's atmosphere?

2. Name as many greenhouse gases that you can.

3. [True / False] Even though there is hardly any CO_2 in the Earth's atmosphere, it has a powerful affect in causing the greenhouse effect.

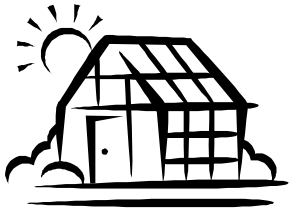
4. Complete the electromagnetic spectrum table (all the forms of light).

Radio	Microwave	IR		visible UV	X-ravs	Gamma ravs

_ low energy _ high energy
_ low freq. _ high freq.

5. In the above table, label the "low energy" and "high energy".
6. In the above table, label the "low frequency" and "high frequency" end.
7. What does IR stand for? __ Infrared (radiation) _____
8. When visible light strikes the nitrogen and oxygen in the atmosphere, most of it is [absorbed / transmitted / reflected].
9. When visible light coming from the Sun strikes CO_2 or any greenhouse gas in the atmosphere, most of it is [absorbed / transmitted / reflected].
10. What happens to the EMR energy that the mountains, land and plant cover absorb from the Sun? What type of energy is it changed into? _heat____.
11. When IR radiated from Earth back toward space strikes CO_2 or any greenhouse gas, most of it is [absorbed / transmitted / reflected].
12. When IR coming from inside a greenhouse strikes the glass of its roof, most of it is [absorbed / transmitted / reflected].

Score: __ / 12



Greenhouse effect experiment

Instructions:

- Set up a high intensity lamp (100 to 250 W) equidistant from each flask. Place a one-hole stopper in each flask with a thermometer or temperature probe in the hole. Start the experiment by turning the lamp on (t = 0 sec) and then noting the temperatures every minute.
- The "air only" flask is just a thermometer for comparison. It should not change much.
- The "air in flask" should heat up some, because the glass itself functions like a Greenhouse gas.
- Before hand, place $\frac{1}{4}$ tsp. water in the "water vapor" flask and let it evaporate.
- "Methane" is less dense than air. You can capture it in an inverted flask held above your stove with a stopper in hand.
- "CO_2" is denser than air. Make it in a larger beaker by adding vinegar to baking soda, and pouring it into the flask.
- Verify that the flask is indeed filled with invisible CO_2 by inserting a lit match. It will go out. You can prepare this ahead of time, but it is more impressive to do it in front of students, one you have your technique down.

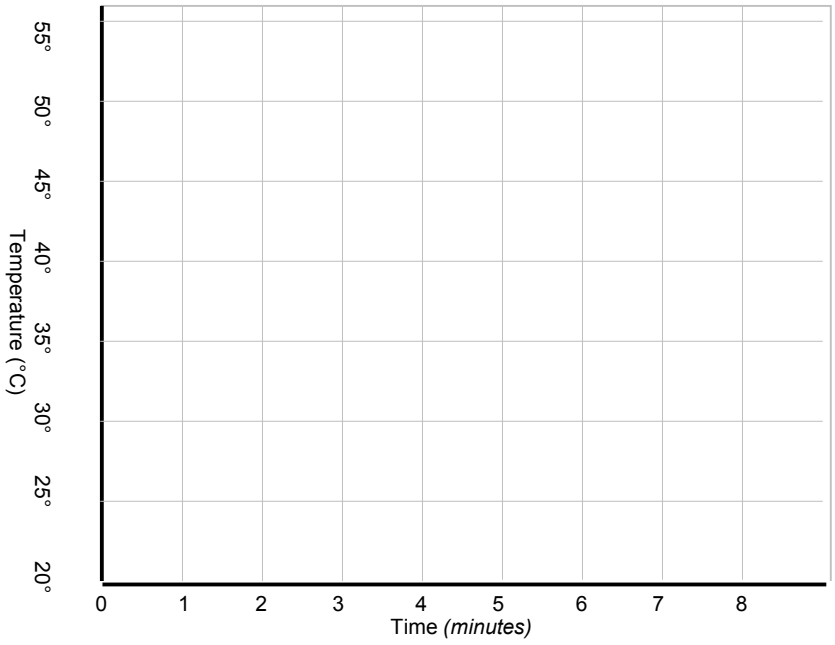
Concepts:

Describe what would happen if you were to sit in your car with the windows rolled up in the parking lot on a sunny summer day? _____

Greenhouse affect – When carbon dioxide, methane, and water vapor _____ infrared wavelengths coming from the ground, trapping solar energy and _____ the temperature.

Heating greenhouse gases; measuring **temperature** over **time**

time *(min.)*		air only	air in flask (control)	H_2O vapor in flask	CH_4 methane in flask	CO_2 in flask
0						
1						
2						
3						
4						
5						
6						
7						
8						



Conclusions:

How Carbon Dioxide is formed

All plant mass, animal tissue (including YOU), and fossil fuels have carbon that originally was originally pulled from carbon dioxide in the Earth's atmosphere, through photosynthesis. Plants breathe in carbon dioxide, and use the carbon to build plant tissue, and breathe out oxygen.

Photosynthesis: Carbon Dioxide ($CO2$) → Carbon (C) + Oxygen ($O2$)

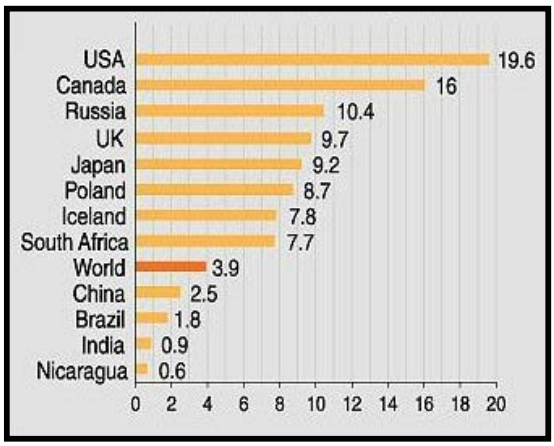
All fossil fuels (coal, gasoline, diesel, kerosene, wood, methane or natural gas, etc.) are based on carbon -containing molecules. Any time a fossil fuel is burned, the reaction goes like this:

Carbon Compounds (C) + Oxygen ($O2$) → Carbon Dioxide ($CO2$)

This reaction is also true when these things rot or decay on the ground or in the air. The black smoke you see in fires is unburned carbon that goes up as dust.

By burning now fossil fuels that were made thousands to millions of years ago, we are returning CO_2 to the atmosphere at a rate greater than ever before. On Earth we now know that the levels of CO_2 in the atmosphere are _increasing_.

Annual Carbon Dioxide emissions per nation (tons)



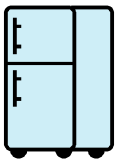
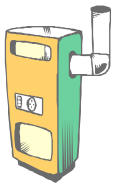
Pollutants in the air

From burning gasoline, diesel, fuel oil, coal, plastics, paper, wood and any carbon containing compounds

Pollutant	Effects	Demo
Carbon monoxide and carbon dioxide (CO and CO_2)	Increased average temperatures, better plant growth, mild acid rain $CO_2 + H_2O \rightarrow$ _H_2CO_3_ (Carbonic acid)	In a glass of water with a pH meter or some universal indicator solution in the glass, take a breath and blow bubbles for 1 min. The pH will go <7.0 (acidic) from the carbonic acid you just made.
Particulate matter (dust) and unburned carbon	__Lung__ problems, hazy skies. Incomplete burning results in _particulates___or dust	Burn small quantity of paint thinner in a dish. Shine a laser pointer above it. The beam you see is caused by unburned carbon, which is a pollutant.
Sulfur dioxide and sulfur trioxide (SO_2 and SO_3)	Acid rain, acid snow, acid fog $SO_3 + H_2O \rightarrow$ ___ H_2SO_4_ (Sulfuric acid) Kills fish in lakes, leaches nutrients out of soils, kills trees, damages brick, limestone and concrete. What happens to the limestone? _It is consumed/destroyed_	Place dilute sulfuric acid on limestone. The bubbles forming are CO_2 gas.
"NO_X" or nitrogen oxides (NO_2 and other NO_x compounds)	Acid rain, production of ozone Kills fish in lakes, leaches nutrients out of soils, kills trees, damages brick, limestone and concrete. $2H_2O + O_2 + 2NO_2 \rightarrow$ 4HNO_3___ (nitric acid) What happens to the water when the NO_x smoke bubbles through it? _It turns acid_. pH = ___	[This demo is hazardous and should only be done by trained Chemistry teachers.] Place several drops of concentrated nitric acid on <1982 Cu penny in a stoppered and vented 250 ml flask. Place the other end of the vent tubing into a 500 ml grad. cylinder filled with water. The water will turn acidic from the toxic NO_x Keep the vapors away from students.
Ozone : An unstable $O^-O{=}O$ molecule (O_3) which reacts with living plant and animal tissue.	Eye irritation, reduces lung functioning, inhibits plant growth.	Tesla coil spark s produces ozone.

How much carbon do these appliances produce per year?




TV (4 hrs/day)	VCR left on	AC	Refriger-ator	Furnace	Electric space heater	100W porch light left on	Printer left on

A key is not prepared for this exercise. You are invited to look up typical carbon production based on wattage on line.

Solutions – What you can do to help

1. Reduce energy consumption
   - leave VCR's off
   - turn computer printers off
   - unplug TV's that are infrequently used
   - setting heater at 68°F winter days, 60°F winter nights
   - setting AC to 78°F in summer days, OFF in evenings and at night and opening windows
   - plant deciduous trees on sun-facing walls

2. Use alternate sources of energy and renewable sources (solar, wind, hydroelectric and ethanol)

3. Use energy efficient appliances. Appliances with the California Energy Star symbol use much less electricity and can actually pay for themselves in savings over several years time. This is especially true for furnaces, AC's and refrigerators!

4. Using your vehicles wisely
   - perform required smog checks
   - make use of carpooling
   - buy cars that have high gasoline mileage ratings (> 30 MPG)
   - combine trips, driving smartly