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Greenhouse Gases: The Chemistry Behind the Culprits

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Unit Rationale

This unit is intended for ninth grade Science students enrolled in a Physical Chemistry or Integrated Science course; however it can also be used in a Chemistry or Environmental Science course. I teach at a health sciences, business, and technology magnet high school in New Haven. Our students live in New Haven, as well as seventeen surrounding cities and towns including Branford, Wallingford, Ansonia, West Haven, and Hamden. This is a relatively small school with approximately 750 students, of which twenty-five percent are freshmen and over sixty percent of the ninth graders are female. A typical class consists of fifty-five percent African American, thirty-three percent Latino, seven percent Caucasian, and five percent Asian and Middle Eastern.

This unit is based on 82 minute block periods that meet every other day and is a part of a larger unit that on Global Interdependence and henceforth will be referred to as the "subunit". This is part of the Connecticut State Science Standards, Content Standard 9.8, in which students learn how the use of resources by human populations affects the quality of the environment. One of the state mandated expected performances (D22) for this standard is that students be able to explain how the accumulation of carbon dioxide in the atmosphere increases Earth's "greenhouse" effect and may cause climate changes. The larger unit will span an entire marking period, approximately 8 weeks.

Encouraging students to access their prior knowledge of other science topics and apply them to new content is highly desirable. Thus students need to be well aware of the basic biogeochemical cycles, specifically the carbon and water cycles and the layers of the Earth's atmosphere. They will also need to understand phase changes and the differences in the amount of heat energy in solids, liquids and gases. Students should also understand the periodic table and the types of bonds formed between atoms to make compounds. A basic understanding of fossil fuels and the resulting products of combustion of these products will also be helpful. This knowledge will be critical as students will need to identify what the various greenhouse gases are and how they are connected to these cycles. We will discuss what the greenhouse effect is, how it has changed over time, and who the 'culprits' or responsible compounds are that contribute it. Students will be able to relate the material in this subunit to their lives and see how everyday activities impact not only their community, but also the environment on a global scale.

Unit Objectives

By the end of this curriculum subunit students will be expected to be able to:

1. Identify and distinguish between the different layers of the Earth's atmosphere
2. Distinguish between climate and weather
3. Identify greenhouse gases and their sources, both natural and man-made.
4. Describe the properties of these gases that cause them to be categorized as "greenhouse gases".
5. Describe the effect of these gases on the Earth and its climate.

Unit Strategies

We will focus on four greenhouse gases: water vapor, methane (CH_4), fluorinated gases, and carbon dioxide (CO_2). We will explore the sources of each gas; review the history of their release to the atmosphere, and their global warming potential. We will discuss the impact that the greenhouse effect has on climate, as well as the concept of global warming. This will lead into the identification of the man-made sources and the alternatives that may be available to reduce those emissions.

The Earth's Atmosphere and Climate

The atmosphere of the Earth is made up of four principal layers; the troposphere, the stratosphere, the mesosphere, and the thermosphere, which are determined based on variations in temperature that occur vertically from the surface outward. The troposphere is the layer closest to the surface of the Earth. It is where most of the water vapor and suspended particles in the atmosphere collect and is the location where weather occurs. The average height of the troposphere is twelve kilometers and the temperature decreases as altitude increases at a rate of 6.5ºC per kilometer (13). The next layer is the stratosphere which is located between an altitude of twelve and fifty kilometers. Planes and weather balloons are present in this layer, as is the ozone layer that protects us from the harmful ultraviolet radiation in sunlight. The temperature in the stratosphere is constant between twelve and twenty kilometers; however above that the temperature increases as the altitude increases (13). The ozone layer is located in the upper stratosphere and its absorption of UV radiation results in warming temperatures in this region. The mesosphere extends from an altitude of fifty kilometers to eighty kilometers and the temperature decreases as the altitude increases (13). The thermosphere is the outermost layer that extends from an altitude of eighty kilometers into outer space and the temperature within this layer increases quickly as the altitude increases (13).

Global warming describes a gradual increase in the average temperature of the Earth's surface and atmosphere which can lead to a change in climate (10). Climate must be differentiated from weather. Weather is the day-to-day, short-term condition of the atmosphere at a particular time, whereas climate is the long-term condition (14, 15). Climate describes the weather patterns of a particular region over many years and depends on the regions temperature and precipitation, which are directly related to the amount of solar energy received and retained by the Earth (14, 15). The climate of the Earth has varied over its billions of years in existence from long periods of warmth to the Ice Ages due to natural factors such as orbital changes, changes in the amount of solar energy, volcanic eruptions, and meteoritic events.

Solar energy within the troposphere is transferred by radiation, conduction, and convection. Of the solar energy that reaches the Earth's atmosphere, 20% is absorbed by clouds, dust and gases in the atmosphere, 50% is absorbed by the surface of the Earth, 5% is reflected back into space by the surface, and 25% is reflected back into space by clouds, dust and gases in the atmosphere (14). The 30% that is reflected back by clouds, dust, gases and the Earth's surface is called albedo. Some of solar energy absorbed by the Earth's surface is reradiated back into the atmosphere in the form of infrared radiation (IR), which has a long wavelength. The accumulation of certain gases in the atmosphere can block and trap the long-wavelength IR resulting in the buildup of heat in the atmosphere called the greenhouse effect. The high absorption rate of IR waves by these gases differentiates them from others in abundance in the atmosphere, such as nitrogen which is not a greenhouse gas.

The greenhouse effect is a natural phenomenon that is critical to providing the temperature conditions we need to survive. The Earth's average temperature is approximately 15ºC or 59ºF, but without greenhouse gases the surface would be about -18ºC or 0ºF (15). Thus, certain levels of greenhouse gases are important to maintaining life on Earth. However, certain human activities have intensified this effect resulting in an even warmer environment. Svante Arrhenius predicted back in 1896 that human activity as a result of the Industrial Revolution would eventually have an impact on global climate (10). There are several greenhouse gases; ozone, nitrous oxide, water vapor, methane, fluorinated gases, and carbon dioxide. In the interest of time, this subunit focuses on the latter four, which are the major greenhouse gases.

Water Vapor

Water is a polar compound made up of two hydrogen atoms bonded to an oxygen atom (H_2O) and conditions on Earth allow it exist to as a solid, liquid or gas. Venus, Mars, and Earth all started out with more than 95% carbon dioxide in their atmospheres, however the phase of water on those planets differ resulting in very different temperatures. Venus is really hot with temperatures of 477ºC, thus the water is all vaporized, whereas Mars is really cold with temperatures of -53ºC, thus the water is frozen (14). The presence of water on Earth as a liquid and gas is key to Earth's current conditions and plays a major role in both carbon sequestration as well as the greenhouse effect. Most of the carbon dioxide that was once abundant in the atmosphere is now sequestered in sediments and bedrock. The carbon dioxide in the atmosphere dissolved into the Earth's oceans, eventually precipitating out as calcium carbonate ($CaCO_3$), which formed the sediments and limestone that hold the majority of the carbon on Earth (14).

Water vapor is responsible for the precipitation that occurs in different climates as it changes to and from a liquid and ice due to condensation and freezing resulting in clouds, rain, hail, sleet, snow and fog (16). Water vapor is the most abundant and most overlooked greenhouse gas by the general public, contributing to between 36 and 66% of the greenhouse effect (12). It is a naturally occurring gas that is not significantly impacted by human activities. Of the three phases in which water exists, water vapor has the highest heat energy and the lowest density. As the temperature increases, it causes surface water to evaporate leading to an increase in the relative humidity. Relative humidity is the ratio of the amount of water vapor in the air to the maximum amount of water vapor that can exist at a specific temperature (14). This is because warmer air can hold more water than colder air due to its lower density. The more water vapor the air holds, the more heat energy that radiates from the Earth is held within the lower atmosphere (13). Venus underwent what is called a 'runaway greenhouse effect' where the rising temperatures of the atmosphere reached the boiling point of water causing water on the surface of the planet to evaporate. The ultraviolet rays from the sun caused H^{+} and O^{2-} ions in water to dissociate. The hydrogen gas that formed was able to escape from the atmosphere and the oxygen recombined and is bound up in rocks (19). This water vapor further contributed to the greenhouse effect and held more infrared heat in, resulting in even higher temperatures and further evaporation of water and eventual loss of all water.

Methane

Approximately sixteen percent of global warming is due to methane (15). Methane consists of a carbon atom bonded to four hydrogen atoms (CH_4) and is a major component in natural gas, one of the three fossil fuels. Methane is released by natural sources such as wetlands, termites, and bacteria in the oceans. Humans contribute the majority of methane released to the atmosphere through fossil fuel production, livestock and manure management, wastewater treatment and landfills, accounting for 70% of methane released (15). The domestication and herding of animals and the introduction of the wetlands technique of rice growing over the last thousands of years has contributed significant amounts of methane to the atmosphere.

The abundance of methane in the Earth's atmosphere is greater now than it has been in the last 400,000 years, with concentrations 150% above those prior to the Industrial Revolution (10). Global warming potential (GWP) is the ability of a gas to trap heat and warm the atmosphere compared to that of carbon dioxide over a specific time period (10, 15). Methane has a GWP twenty-one times greater than that of carbon dioxide, which makes it a significant environmental hazard (10).

Fluorinated Gases

Chlorofluorocarbons (CFCs) are anthropogenic, or man-made, substances once used in foaming agents, pesticides, aerosols, fire extinguishers and coolants in refrigerators and air conditioners (10, 15). They contributed to the destruction of the ozone layer in polar regions which resulted in the phasing out of these compounds under the Montreal Protocol and Clear Air Act Amendments of 1990 (10).

Other fluorinated gases such as hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6) were introduced as substitutes for CFCs, but their stable molecular structures and resistance to chemical reactions in the atmosphere has resulted in these compounds being potent greenhouse gases. In addition to their use as substitutes for ozone depleting substances, they are also emitted from aluminum and magnesium production plants, electrical transmission stations and semiconductor manufacture facilities. Although they account for only two percent of the total greenhouse gas emissions, their GWP make them a larger threat. These fluorinated gases are 140 to 23,900 times more potent than carbon dioxide in trapping reradiated heat (10).

Carbon dioxide

Carbon dioxide consists of two oxygen atoms double bonded to a carbon atom (CO_2) and makes up 0.037 percent of the Earth's atmosphere (15). It is used to provide the fizz in soda and makes bread rise. It has a major role in the carbon cycle in which it is released and absorbed by natural processes. Plants and animals release carbon dioxide to the atmosphere as we respire. Plants can also take up a large quantity of carbon dioxide which they use during photosynthesis, resulting in the oxygen released to the atmosphere. Of the 50% of the solar energy that is absorbed by the Earth's surface, only 0.02% of it is used for photosynthesis. Other natural sources of carbon dioxide include volcanic eruptions, evaporation of ocean water, decaying organisms, and weathering of limestone rock.

The Earth's atmosphere was once a carbon dioxide rich environment similar to that of Venus and Mars, with surface temperatures of 290ºC (15). The atmosphere of Venus has a high carbon dioxide concentration, so much so that the energy of the sun is trapped creating very hot surface temperatures (15). Unlike Venus and Mars, the Earth has been subjected to drastic changes in its atmosphere and climate. Eighty percent of carbon dioxide once in the Earth's atmosphere is sequestered in limestone, but there is a substantial amount that is dissolved in the oceans (14). Evaporation of the oceans not only adds to the atmosphere carbon dioxide levels but also water vapor, resulting in an increase in two greenhouse gases. The following chemical equations show how carbon dioxide levels are affected by water and can lead to either carbon dioxide production or carbon sequestration depending on how high the dissolved carbon dioxide concentration is (14):

$$H_2O + CO_2 \rightarrow H_2CO_3 + Ca^{2+} \rightarrow CaCO_3$$

The carbon dioxide concentrations between the last ice age and the present have more than doubled, contributing to 60% of the greenhouse effect (4). The global concentrations of carbon dioxide have increased by 35% between the start of the Industrial Revolution in the 1700s and 2005 (10). These changes to the atmospheric concentrations of carbon dioxide are due to human activities including fossil fuel combustion, deforestation, and industrial production processes for the manufacture of lime, cement, steel, and other metals.

The energy stored in fossil fuels is released when they are burned and this energy is used for transportation and electricity production. The burning of fossil fuels also releases the carbon sequestered in the fossil fuels in the form of carbon dioxide. Twenty-five percent of 32 billion tons of carbon dioxide released to the atmosphere globally in 2006 came from the United States (5). Although transportation is usually held responsible for the majority of carbon dioxide emissions in the US, energy use by office buildings and home actually produce 32% of the total carbon dioxide emissions in this country (5). Deforestation contributes to the release of carbon dioxide because the trees are either burned or slowly decompose over time, both of which result in emissions to the atmosphere.

Global Warming

Data collected by NASA and NOAA show an increase in the Earth's average surface temperature of 1.3ºF since 1900, most of which has occurred within the last fifteen years primarily the result of human activities(10). Increased carbon dioxide level can lead to 1.5-4.5ºC increases in global temperatures over the next 50 to 100 years (14). Models have predicted even greater increases in the average surface temperature by the end of the century, but it is not known just how much, how fast, or to what extent this will change the Earth's climate.

Scientists use a variety of techniques to study the Earth's changing temperatures. Satellites can provide some details as the climate changes occurring, however the data is limited to the last 20 to 30 years (9). Another method used is the instrumental temperature measurements which provides data back to the nineteenth century. Instrumental measurements include the use of thermometers to measure temperature, barometers to measure pressure, anemometers to measure wind speed and direction, and rain gauges to measure precipitation. Finally, scientists can also use paleoclimatic data which can provide climatic information from millions of years ago. "Paleo-" is a Greek root which means ancient. This technique involves the analysis of ice from thick ancient ice-caps such as Greenland and sediment cores from the deep, cold sea floor, tree rings, fossils, corals, and caves to evaluate the global temperature fluctuations that have taken place (9).

Some changes have already been observed including a reduction in glaciers, a rise in the sea level, changes in flora and fauna distribution, thawing of permafrost, and changes in growing seasons. There have been earlier breeding of birds and amphibians, flowering of plants, and migration of birds (15). The warmer waters near Antarctica has resulted in the thinning of the ice shelves, which would cause a rise in sea level if they melted due to the increase in the amount of grounded ice that would flow into the sea (6).

Some of the effects that scientists predict to occur due to rising temperatures are more frequent and longer heat waves, larger mosquito populations migrating to higher latitudes, increases in surface-level ozone concentrations, increases in the number of endangered or extinct species, drought and flooding, all of which can lead to public health issues. The loss of biodiversity due to extinction can lead to an increase in the number of parasites of both plants and animals infecting new hosts that are not evolved enough to fight them. Microorganisms native to tropical climates that may be dangerous to humans or animals could possible spread into more temperate zones as the temperatures continue to increase.

Drought occurs when the rain expected does not come despite increases in temperature. The hot, dry winds dry out the soil and erodes the plants, which can lead to famine and disease (14). The percentage of the Earth's surface impacted by drought has more than doubled since the 1970s according to studies conducted by the National Center for Atmospheric Research (4). Further increases can lead to habitat destruction, a rise in the number of wildfires and a starving or malnutrition increases. Flooding can not only result in increases in the number of people that drown, but also poses a water quality issue and results in the loss of land. In the US, the sewer systems in more than 700 cities overflow dirty water into clean water supplies contaminating the drinking water supply (2).

With global warming comes the potential for stronger hurricanes, which threatens many of the cities in similar levee situations as New Orleans (3). Mosquito populations could significantly multiply due to the warmer temperatures potentially resulting in a spike in the number of malaria, encephalitis, dengue, and other insect-borne infectious diseases (2).

Potential Solutions for Global Warming

Using more energy efficient appliances and vehicles are ways of reducing the amount of fossil fuels that we need. Utility companies now offer reduced rates for consumers that use high energy consuming appliances such as dishwashers, washing machines, and air conditioners during off peak hours. Walking, riding a bike, or carpooling are currently endorsed by many companies as a means of reducing the emissions due to transportation.

Energy sources such as wind turbines, solar cells, hydrogen fuel cells, nuclear power, hydroelectricity, and geothermal power are promising alternatives to conventional methods of producing the energy we need to run our lives. Solar cells absorb the sun's energy which can be reradiated as thermal energy to heat the house, heat water, or converted into electrical energy (13). However traditional methods of providing heat and electricity are still needed at night and during periods of frequent cloudy days. Wind turbines use the kinetic energy of the wind to rotate turbines which can produce electricity (13). Wind farms, which are large areas of land with many wind turbines, are currently in use in the United States, primarily California. Hydrogen fuel cells chemically reacts hydrogen and oxygen to generate electricity (13). The end product of this nonpolluting alternative simply water.

Nuclear fission is currently being used as a means of producing approximately twenty percent of the electrical energy in the United States (13). Fission occurs when an atom of uranium is struck with a neutron, which causes it to split into two new smaller elements and two or three additional neutrons. These newly created neutrons are used to start a chain reaction with other atoms of uranium generating a tremendous amount of energy. The drawback of this method is the radioactive waste that is generated by the fission of uranium which isolated and stored so that is does not harm humans or the environment. Nuclear fusion is a process in which the nuclei of two isotopes of hydrogen are combined to produce helium, neutrons and energy (13). Fusion occurs natural inside the sun and stars and requires extremely hot temperatures. Fusion also can produce massive amounts of energy; however it is still in the research stages as scientists try to work on some of the challenges that exist with this method. The biggest challenge they face is trying to contain plasma such as that of a small star in a chamber that can withstand temperatures similar to that of the sun.

Hydroelectricity uses the kinetic energy in flowing water to turn turbine, generating electricity. Some hydroelectric plants can use the natural flow of river; however some require the construction of dams. Although it does not generate any pollution the construction of the dams can significantly impact the natural habitat of many aquatic animals. Geothermal power uses the heat within the Earth to generate electricity. Water is pumped deep into the ground where the thermal energy of the Earth turns it to steam, which is used to drive electric generators (13). Geothermal power plants are typically constructed near volcanoes; however it is not a widely available alternative. Hybrid vehicles and those powered by biofuels are becoming more common in the automobile industry. Even 'green' office buildings are being constructed in order to reduce the amount of emissions of greenhouse gases to the atmosphere. These alternative methods of producing energy are currently in use; however they are not widespread enough to replace the use of fossil fuels.

Unit Activities

Activity 1: Greenhouse Effect Pre-Instruction Essay

At the beginning of the unit, students will be asked to write an essay as to their thoughts on the greenhouse effect and whether they feel it is a real threat or media hype. They will be asked to revisit this position paper at the end of this subunit.

Activity 2: Greenhouse Gas Emission Graphs

Science regularly integrates the other core content areas: History, English, and Mathematics. Students will need to utilize their math skills to construct and interpret graphs of the release of several greenhouse gases and relate it to the changes in temperature experienced on Earth. This will require inter-department collaboration between the Science and Business teachers, who teach ninth graders to use Microsoft Office products. Students will be provided data from the US Inventory of Greenhouse Gas Emissions (16). Emissions data from 1990 - 2005 for three of the greenhouse gases covered in this subunit (fluorinated gases, methane, and carbon dioxide) and their various sources are provided. The students will be asked to construct one of the following two choices of graphs:

1. Students can choose one gas and construct a graph comparing the emission levels from various sources of that gas.
2. Students can construct a graph of the total emissions for all three gases and compare the emission levels between the different types.

Regardless of which graph they choose to construct, they will have to write an essay discussing the greenhouse gas(es), the sources, and the trends they observe in the graph. They will also be provided a graph of the average annual global temperature change and the atmosphere carbon dioxide concentration over the geological time scale of the last 150,000 years. They will be asked to discuss the spike in carbon dioxide levels that occurred in the 1800's and what they believe happened around that time to cause the increase. The desired responses are related to the Industrial Revolution, specifically the increased number of factories and the invention of the automobile. Additionally, one of the Science, Technology, and Society (STS) curriculum-embedded performance tasks on the Connecticut Academic Performance Test (CAPT) requires students to be able to utilize Microsoft Excel to create graphs illustrating the energy uses in Connecticut.

Activity 3: Greenhouse Effect Mini-Lab

Students will conduct a mini-experiment to track the effect of a greenhouse on temperature. It is desired that they infer that the effect of greenhouse conditions is similar to that of greenhouse gases in the atmosphere. They will also need to utilize their manual graphing skills and discuss the differences they observe.

Materials:

For each group of two or three students

1 Two thermometers
2 Clear plastic rectangular storage box (~ 6 quart size shoe box)
3 Stopwatch
4 Graph paper

Procedure:

1. Set both thermometers outside in the sun and allow them to come to a stable temperature.
2. Record the initial temperature.
3. Place one thermometer in the plastic storage box so that the temperature can be read clearly through the box.
4. Keep the remaining thermometer next to the storage box.
5. Start the stopwatch and begin measuring the temperature readings on both thermometers at two minute intervals for fifteen to twenty minutes.

6. Plot the change in temperature over time for both thermometers on the same graph.

Discussion Questions:

1. At what point in time did the temperature inside of the storage box change dramatically compared to that outside of the box?
2. Why do you think this occurred?
3. How is the storage box similar to the Earth's atmosphere?

Activity 4: Carbon Dioxide Measurement Lab

Students will conduct a series of greenhouse gas experiments that require students to detect carbon dioxide production and utilize acid/base chemistry to quantify the amount of carbon dioxide produced. Prior to this subunit students will have learned about acids, bases, pH, and the use of indicators to classify substances. They will also have to compare and contrast the carbon dioxide levels from various sources and discuss alternative energy sources. The NASA Explores program has developed a laboratory experiment entitled "Detection of Carbon Dioxide" in which students determine the amount of carbon dioxide emitted from various natural and anthropogenic sources. The materials, teacher's notes, and procedure are listed below (17).

Materials:

For each group of two or four students

- Five vials or test tubes
- Graduated cylinder
- Funnel straw
- Marble-size piece of modeling clay
- Four different colored balloons
- Four twist-ties
- 100- or 250-mL Erlenmeyer flask
- Dropper bottle of bromothymol blue indicator solution
- Dropper bottle of dilute household ammonia (1 part ammonia to 50 parts distilled water)
- 100 mL vinegar
- 5 mL baking soda

- Safety goggles

Notes:

The air solution in vial A will not turn yellow. The level of CO_2 in air is too low to affect bromothymol blue.

Procedure

1. Add 15 mL of water and 10 drops of bromothymol blue indicator solution to each vial or test tube. Label the vials A, B, C, D, and Control.
2. Fill each balloon as follows until it has a 7.5 diameter.
§ Sample A (Air) -- Use a tire pump to inflate the balloon to the required diameter. Twist the rubberneck of the balloon and fasten it shut with a twist tie. The tie should be at least 1 cm from the opening of the balloon. Record the color of the balloon used for this sample.
§ Sample B (Human Exhalation) -- Have one team member blow up a balloon to the required diameter. Twist and tie the balloon, and record the balloon color.
§ Sample C (Automobile Exhaust) -- Your teacher will supply you with this balloon. Record the color of the balloon.
§ Sample D (Nearly pure CO_2) -- Put 100 mL of vinegar in the flask. Using a funnel, add 5 mL of baking soda. Let the mixture bubble for 3 seconds to drive the air out, and then slip the balloon over the neck of the bottle. Inflate the balloon to the proper diameter. Twist and tie the balloon, and record the color.
3. Soften the clay, and wrap it around one end of the straw to make a small airtight collar that will fit into the neck of a balloon. The collar should look like a cone with the straw in its middle, and should be large enough to plug the neck of the balloon.
4. Pick up Balloon A. Keeping the tie on it; slip the balloon's neck over the clay collar. Hold it against the collar to make an airtight seal. Place the other end of the straw into the vial of water and bromothymol blue labeled A. Have another partner remove the tie on the balloon, and slowly untwist the balloon. Keeping the neck of the balloon pinched to control the flow of gas, gently squeeze the balloon so the gas slowly bubbles into the solution.
5. Repeat the same procedure with the other balloons and their respective vials. In some cases,

the bromothymol blue solution will change color, from blue to yellow, indicating the presence of carbonic acid formed from CO_2.
6. Analyze each of the samples by titrating them with drops of diluted ammonia. Ammonia neutralizes the carbonic acid. The bromothymol blue will return to a blue color when all the acid has reacted. Add drops of ammonia to each of the samples that turned yellow, carefully counting the number of drops needed until they are about the same color as your control. Record the results.

Discussion Questions

1. Which samples had the most and the least carbon dioxide?
2. Why didn't the air sample turn yellow?
3. Why is automobile exhaust a concern?
4. How could a city reduce the amount of CO_2 emissions?
5. What alternative power sources could be used with cars?
6. Why might it be difficult for the public to start using an alternative source?
Why should we be concerned about global warming?

Activity 5: "An Inconvenient Truth"

Towards the end of the subunit students will be shown "An Inconvenient Truth". This should take approximately one 82-minute class period. Students will answer the following questions about the movie (18).

1. What are the layers of the atmosphere?
2. Which layer plays a role in global warming?

3. What percent of solar energy is reradiated back?
4. Which wavelength of light is trapped in the atmosphere by greenhouse gases?
5. How can trapping infrared radiation by the earth's atmosphere be a **GOOD** thing?
6. How can trapping infrared radiation by the earth's atmosphere be a **BAD** thing?
7. Sketch the general trend of the "CO2 Level" versus time between 1958 and 2000 on the graph paper provided.
8. Discuss the relationships you observe in the graph created above.
9. During what time period did the levels of CO2 increase the most?
10. What branch of science involves the study of ice and sediment cores?
11. How much has the sea level risen over the last 100 years?
12. What would be the result of the melting of the ice sheets in Western Antarctica?
13. What are some natural sources of carbon dioxide?
14. How much do they contribute to atmospheric carbon dioxide emissions?
15. Which countries produce the most carbon dioxide emissions?
16. What percentage of the global population do the populations of those countries make up?
17. What is the Kyoto Protocol and why is it important?
18. Why didn't the United States sign the Kyoto Protocol?

Activity 6: Greenhouse Effect Post-Instruction Essay

Finally, students will be asked to re-examine the essay they wrote at the beginning of the subunit. They will need to utilize the Internet to locate documentation to support their position on whether or not the greenhouse effect is a true danger. For this activity to be most effective, students should have a working knowledge of how to evaluate the reliability and credibility of websites. A CAPT-STS curriculum-embedded task that will provide the students with these skills should have been completed in a previous marking period.

Conclusion

In conclusion, this subunit should provide students with an in-depth understanding of what the greenhouse effect is, its causes and lead to a discussion of potential solutions, including fuel cells, solar energy, water energy, and wind energy. Students will continue to build upon their graphing, interpretation, researching and persuasive writing skills, all of which will aid them in their other courses, as well as CAPT. The exposure to the content early on will help the students better understand the role of energy in our world.

Unit District Standards

Grade 9-10 Core Scientific Inquiry, Literacy, and Numeracy

Scientific literacy includes the ability to read, write, discuss and present coherent ideas about science.

Scientific literacy includes the ability to search for and assess the relevance and credibility of scientific information found in various print and electronic media.

Scientific numeracy includes the ability to use mathematical operations and procedures to calculate, analyze and present scientific data and ideas.

Grade 9 Core Science Strand I: Energy Transformations

Content Standard 9.3 - Various sources of energy are used by humans and each has advantages and disadvantages.

Expected Performance D8 - Describe the availability, current uses and environmental concerns related to the use of fossil fuels.

Expected Performance D9 - Describe the availability, current uses and environmental concerns related to the use of hydrogen fuel cells, wind and solar energy to produce electricity.

Grade 9 Core Science Strand III: Global Interdependence

Content Standard 9.7 - Elements on Earth move among reservoirs in the solid earth, oceans, atmosphere and organisms as post of biogeochemical cycles.

Expected Performance D18 - Explain how chemical and physical processes drive carbon to cycle through the major Earth reservoirs.

Content Standard 9.8 - The use of resources by human populations affects the quality of the environment.

Expected Performance D22 - Explain how the accumulation of carbon dioxide in the atmosphere increases Earth's greenhouse effect and may cause climate changes.

Notes

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Teacher Resources

Textbooks

Abbott, P.L. Natural Disasters. McGraw-Hill. pp 242-271. 2004. - Chapter on climate change provides details on each of greenhouse gases and history of the atmospheres on Earth, Venus and Mars.

Wysession. Frank. Yancopoulos. Physical Science: Concepts in Action. Prentice Hall. pp 745-784. 2004. - This is the current textbook used in the ninth grade Physical Chemistry course at my school. The chapter on the Earth's atmosphere provides background information on climate, weather, and the fate of solar energy.

Websites

http://www.unitedstreaming.com - This United Streaming site provides a variety of video clips and teacher resources on this and many science topics.

http://epa.gov.climatechange/basicinfo.html. - This US EPA site provides great detail on greenhouse gases and their effect on climate.

http://epa.gov/climatechange/emissions/downloads/2007GHGFastFacts.pdf. - This US EPA site provides the greenhouse gas emissions data between 1990 and 2005 needed for the graphing exercise (activity 2).

http://media.nasaexplores.com/lessons/02-011/9-12_2.pdf. - This website provided the materials and procedure for the carbon dioxide lab (activity 4) as well as several activities developed by the NASA Explores program.

Student Resources

Textbooks

Wysession. Frank. Yancopoulos. Physical Science: Concepts in Action. Prentice Hall. pp 745-784. 2004. - This is the current textbook used in the ninth grade Physical Chemistry course at my school. The chapter on the Earth's atmosphere provides background information on climate, weather, and the fate of solar energy.

Websites

http://www.ncdc.noaa.gov/paleo/globalwarming/howdo.html. - This is the National Climatic Data Center's website on paleoclimatology and its use in assessing global warming.

http://www.epa.gov/climatechange/kids/ - This is a US EPA website for children that explains global warming and climate change. It provides a vocabulary list and animations for the greenhouse effect and global warming.

http://www.timeforkids.com/TFK/specials/articles/0,6709,1113542,00.html - This is a TIME magazine website for kids that provides science articles and interviews on global warming.

Materials List for Classroom Use

Lab experiment materials for activity 3:

- Two thermometers
- Clear plastic rectangular storage box (~ 6 quart size shoe box)
- Stopwatch
- Graph paper

Lab experiment materials for activity 4:

1 Five vials or test tubes
2 Graduated cylinder
3 Funnel straw
4 Marble-size piece of modeling clay
5 Four different colored balloons
6 Four twist-ties
7 100- or 250-mL Erlenmeyer flask
8 Dropper bottle of bromothymol blue indicator solution
9 Dropper bottle of dilute household ammonia (1 part ammonia to 50 parts distilled water)
10 100 mL vinegar
11 5 mL baking soda
12 Safety goggles

Movie: "An Inconvenient Truth" (2006)

Projector: The teacher will need a projector to show various video clips related to the content and to show the movie "An Inconvenient Truth".

Graph paper: Used to sketch carbon dioxide trend shown in the movie "An Inconvenient Truth".

Computers: Students will need access to computers in order to construct graphs and research for the various activities in the subunit.