GREENHOUSE GASES UNIT

Adapted from the University of Northern Iowa's Energy Education Project

Overview: In this module, students are introduced to the different heat-trapping abilities of the major greenhouse gases. The students are challenged to build three-dimensional models illustrating this differing heat-trapping ability. In Activity 2, students keep an Energy Diary which includes a record of all the activities they engaged in, over a one-day period, requiring the use of electricity. They are then able to analyze this data to determine their total contribution to the CO_2 in Earth's atmosphere as a result of their use of electricity for that day. In the final activity, students discover the CO_2-absorbing ability of trees. Mathematics is used as a tool to help the students convince others to go out and plant a tree.

Objectives:

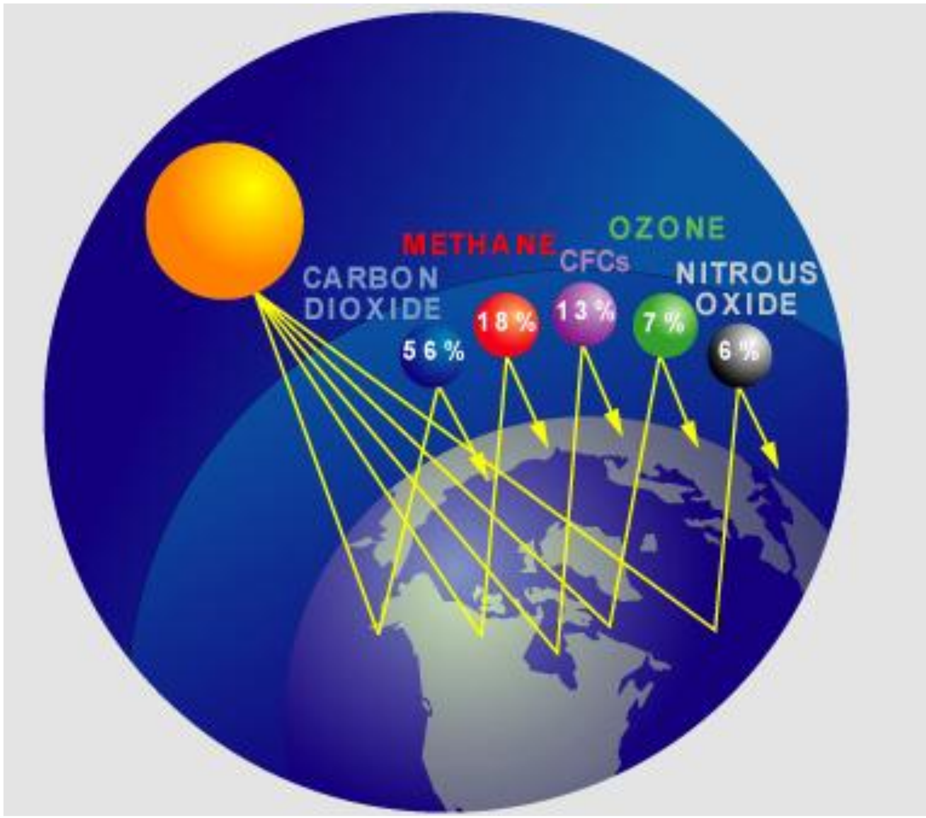
1. Students will design and construct three-dimensional models illustrating the heat-trapping abilities of the major greenhouse gases.
2. Students will be able to interpret data related to electrical appliances to determine the amount of CO_2 emission given off in the production of the electricity needed to operate the appliances.
3. Students will be able to identify ways in which their personal use of energy contributes to carbon dioxide emissions.
4. Students will be able to use mathematics to help them convince people of the importance of tree-planting to help combat high CO_2 levels in our atmosphere.

Subject: Mathematics

Suggested Grade Level: Can be modified for grades 5 – 10

Suggested Teaching Strategies: As students complete the science portion of this unit, they gain experience in testing for the presence of carbon dioxide. They learn the major sources of excess carbon dioxide in our atmosphere as well. At this point, students may develop (or may already have developed) the attitude that greenhouse gases are not related to them...they have to do with big cities and factories. The mathematics activities are designed to show students that this is not the case. Each person contributes to the high CO_2 levels in Earth's atmosphere, especially where high amounts of electricity are used and lots of driving is involved.

Begin the unit by asking students what they know about global climate change and greenhouse gases. They will likely have lots of ideas to share, especially if they are working on the science section of this unit. There are about 30 different gases considered to be greenhouse gases. Each of these traps excess heat within the Earth's atmosphere. The main culprits of global warming are thought to be carbon dioxide (CO_2), chlorofluocarbons (CFC's), nitrous oxide (N_2O), and methane (CH_4). Each of these four gases is present in the atmosphere in differing amounts. To make matters even more complicated, each gas traps a different amount of heat and each gas stays active in the atmosphere for a different number of years. Both the amounts and the heat-trapping ability of the gases are taken into account in developing graphs like the one shown below.



Carbon Dioxide (CO_2): 56%
Methane (CH_4): 18%
Chlorofluorocarbons (CFCs): 13%
Ozone (O_3): 7%
Nitrous Oxide (NOx): 6%

This graph shows that CO_2 certainly may play a large role in global climate change. But you cannot tell anything about the amounts of CO_2 in our atmosphere, its heat-trapping ability, or how long it stays in the atmosphere from this graph. In the first activity, students will be given some of this information and will develop models to illustrate the relative heat-trapping ability of each of the four major greenhouse gases. Share this information with students by asking them which gas is present in the largest amount, according to the pie graph. They will, of course, say CO_2. However, this is not the case. It will be difficult for students to see that the graph does not mean "amounts of each gas," it means "amount of damage or warming" caused by each gas. Activity 1 will help clear up some of this confusion by having students illustrate the different heat-trapping abilities of each type of gas.

HEAT TRAPS

Objective: Students will design and construct models illustrating the heat-trapping abilities of the major greenhouse gases.

Subject: Math

Suggested Grade Level: 6 – 8

Materials: Graph paper, scissors, calculators, tape, markers, scratch paper

---

BACKGROUND

History tells us that the Earth has been through many temperature fluctuations – through ice ages and warm spells even though no humans were around to cause these changes. The amount of CO_2 not only changes from year to year, however, but from place to place and season to season, and people also feed into changing carbon dioxide in our atmosphere.

Increased CO_2 from fossil fuel burning along with reduced CO_2 removal from deforestation resulted in an increase in CO_2 levels in the atmosphere from about 314 parts per million in 1958 to about 348 in 1988. In 2008, CO_2 levels were at 387 parts per million (ppm), up almost 40% since the industrial revolution and the highest for at least the last 650,000 years. CO_2 accounts for 56% of global warming.

Methane (CH_4) is thought to be the 2nd most destructive greenhouse gas, 18% of global warming. It is produced by decomposing matter and in the digestive tracts of cattle, sheep, termites, and other organisms. Some methane escapes from industrial and other man-made sources.

Methane decays more rapidly in the atmosphere than does CO_2. A single CO_2 molecule may remain in the atmosphere for 250 years. It takes about 10 years for a molecule of methane to break down in the atmosphere. One CFC molecule may remain in the atmosphere for 75 years. A nitrous oxide molecule may remain in the atmosphere for 175 years. Even when these figures are taken into account, carbon dioxide is still considered to be the largest contributor to the greenhouse effect.

Chlorofluorocarbons (CFC's) are used in air conditioners and refrigerators, in the production of plastic foams, in various industrial processes, and in aerosol propellants. Use of CFC's in aerosol cans has been banned in the United States since 1978. Many other countries have banned the use of CFC's as well. They still make up 13% of global warming potential.

Ozone (O3) plays important roles in the atmospheric environment through radiative and chemical processes. It absorbs UV radiation in the stratosphere, making a temperature profile, and circulates the atmosphere with its absorbed energy. It also absorbs IR radiation, and is thus one of the greenhouse gases. It makes up 7% of global warming concerns.

Nitrous oxide (N_2O) is produced by the breakdown of nitrogen fertilizers, livestock wastes, and by burning of various fuels. The mean growth rate of the global mean mixing ratio during the latest 10 years (1994 - 2004) was 0.8 ppb/year. This mixing ratio corresponds to 118% of the pre-industrial level. 6% of global warming.

PROCEDURE

The purpose of this activity is to illustrate the relative heat-trapping ability of each of the major greenhouse gases. This exercise will help students to better grasp the process of making models to scale.

Begin the activity by asking students to name the major greenhouse gases. If students have already completed the science portion of this module, they will likely know these gases. If they are unable to name the four major greenhouse gases, list them on the chalkboard. Behind each name, write the chemical formula. Ask students to imagine that these gases act like blankets, holding heat in the Earth's atmosphere. Each "gas blanket" has a different ability to trap heat. Their job, in this activity, is to help us better picture the amounts of heat each gas blanket can trap.

Students are likely to have difficulty comparing the heat trapping ability of each gas to a standard. In this case, the standard should be CO_2 since all other gases are compared to CO_2. Provide several examples to show students how this concept works. For example, ask students what they know about the average lifetime of a dog. Most kids will know that dogs live an average of about 14 years. By using a standard, we sometimes say things like, "that is equal to 72 years in dog years." Do not use the greenhouse gases to illustrate how comparisons to standards work. The challenge will be for them to figure this out for themselves.

Challenge students to find the most efficient way to make their models. For example, it would be very difficult and time-consuming to tape together 20 separate cubes to illustrate the heat-trapping ability of methane. However, students can easily cut out a sheet of graph paper that is 4 cubes tall, but goes the length of the paper. By simply creasing the paper in the right places and folding the creases, students can make 10 cubes that are connected in one piece.

Because this activity has the potential to use a great deal of graph paper, students have been informed on the student direction page, that they may have only three complete sheets of graph paper, but an unlimited (within reason) supply of scratch paper. This will necessitate that students come up with a way of figuring out what to do. They will likely think of making a template using their graph paper or simply measuring with a metric ruler. Resist the temptation of giving them hints to solve this dilemma. They will benefit more from the opportunity to problem solve!

Encourage students to plan their models. Once the CO_2 cube has been constructed, students should calculate the number of sheets of paper needed to illustrate the heat-trapping ability of CFC's.

SAMPLE ANSWERS TO SUMMING UP

1. Because CFC's have the ability to trap a great deal of heat, it is important that the level of CFC's in our environment be kept as low as possible.
2. Student answers will vary, depending on the size of the CO_2 cube used as their standard.

HOME COMMUNITY CONNECTIONS

- Ask students to check the labels of the spray cans in their homes. Is there any mention of CFC's on the label? What chemicals are used in place of CFC's?
- Challenge students to conduct air quality tests in various places around your community. Do this by attaching an index card to a stick. Cover the index card with a thin layer of petroleum jelly. Place the stick and card outside. Particles will stick to the jelly. Compare the amount of particulates (dirt, dust, and other solid particles) on the card for different sites and for the same sites on different days. Devise a mathematical way in which to rate the air quality at each test site, based on the contents of each test card.

EXTENSIONS

- Combine all the class models to build a cloud ceiling in your classroom. Add models of the sun, the sun's rays, and any other graphics to make the display interesting and informative.
- Ask students to make their models into mobiles. Devise a way to suspend pictures of the sources of each gas as part of the mobile. Display the completed mobiles around the classroom.

Heat Traps

Problem

- How can you build models to show how much heat is trapped by different types of greenhouse gases?

Materials

- 3 sheets of graph paper
- Scissors
- Tape
- Markers
- Calculator
- Scratch paper

Let's Investigate

What does eating fast food have to do with sunburns and skin cancer? Every time you pick up a hamburger in a plastic foam container, you are increasing your chances of impacting global warming, getting a severe sunburn and, possibly, skin cancer. As the plastic packaging slowly breaks down, the plastic gives off chlorofluorocarbons (CFC's). CFC's are chemicals that trap excess heat in the Earth's atmosphere. One CFC molecule is capable of trapping 10,000 times more heat than one molecule of carbon dioxide. CFC's cause further damage by attacking the ozone layer. Each chlorine atom in a CFC molecule can attack and destroy 100,000 ozone molecules. Our fast-food society is just one thing that is upsetting the atmospheric balance that has protected the Earth for millions of years.

What about the other greenhouse gases? Do they all trap the same amount of heat? Definitely not. Below is a table showing the relative amount of heat trapped by the different greenhouse gases, compared to carbon dioxide's heat trapping ability.

Greenhouse Gas Heat Trapping Ability Compared to CO_2
Carbon Dioxide (CO_2) – 1
Methane (CH_4) – 20-30
Nitrous Oxide (N_2O) – 180
Chlorofluorocarbons (CFCs) – 10,000

Your job in this investigation is to build cubes that will show the different heat-trapping abilities of the major greenhouse gases. All the greenhouse gases listed in the table above are compared to the heat trapping ability of carbon dioxide. This means you can represent CO_2 by one square cube. If a particular gas, GAS X, is known to trap three times the amount of heat as CO_2, you would build a model for GAS X that is the size of three CO_2 cubes.

Using the graph paper provided by your teacher, prepare cube-shaped models that show the amount of heat trapped by each of the different greenhouse gases, compared to carbon dioxide. You do have one extra challenge; you may have only three sheets of graph paper for your models. You may, however, use scratch paper for your models. Begin by building your CO_2 cube. Once that is done, determine the number of sheets of paper needed to show the heat-trapping ability of a CFC molecule. If it requires too much paper, scale down your CO_2 cube.

Once your models have been completed, add some color to the models. Make certain that each model is clearly labeled. Devise some interesting way to display your models.

Summing Up

1. Based on the amount of heat trapped by the different greenhouse gases, which gas would you conclude is most important to keep at low levels in our atmosphere? Explain your choice.

2. How many sheets of graph paper would be needed to show how much heat is trapped by a gas that traps 25,000 times as much heat as does CO_2?

DEAR DIARY…

Objective: Students will identify ways in which their personal use of energy contributes to carbon dioxide emissions.

Subject: Math

Suggested Grade Level: 9 – 10

Materials: Calculators, table to figure CO_2 emissions (Appendix)

BACKGROUND

Carbon dioxide is considered to be the largest contributor to the greenhouse gases. How much coal does it take to turn on each light bulb in your home? And, how much of the carbon dioxide in our atmosphere can we blame on that one light bulb at your house? More than half of the electricity produced in this country comes from utility plants powered by coal. Coal burning is our largest source of carbon dioxide, the major greenhouse gas.

To figure out how electricity use contributes to the greenhouse effect that many scientists believe is already warming our planet; it helps to understand how energy use is calculated. Electric companies bill for the number of kilowatts. One kilowatt is equal to 1,000 watts. If a 100 watt light bulb is left on for 10 hours, one kilowatt hour (KWH) of electricity is used. Suppose a 100-watt bulb, serving as an outside night light, is left on for eight hours a night, 365 days a year. This bulb consumes 292 KWH of electricity a year ((365 x 8 x 100)/1,000 = 292 KWH). By knowing the watt rating of a particular appliance and the amount of time the appliance is used for, it is possible to estimate the amount of carbon dioxide emitted in the process of producing the electricity needed to "power" the appliance. Of course this assumes that all of the electricity in your area is produced by coal-burning power plants. The calculation also necessitates averaging the CO_2 emissions based on the different grades of coal that are burned throughout the United States. Obviously, students will be getting an estimate, rather than an exact answer.

PROCEDURE

In this activity, students become familiar with one of the major sources of carbon dioxide: the production of electricity. They identify ways in which they might decrease their contribution to the carbon dioxide in our atmosphere by decreasing their use of electricity.

This activity helps to show students their possible impact on global warming. Most people believe that air pollution is a problem caused by factories and cars. This makes them feel they can do nothing to help alleviate air pollution problems. However, this is not the case. The largest contributor to excess carbon dioxide in the atmosphere is from the burning of fossil fuels. We burn fossil fuels directly in our cars. But our largest contribution to excess carbon dioxide in the atmosphere is from our use of electricity. Every time we use electricity, we are contributing to the greenhouse gases.

The directions for this activity are most easily delivered to students orally. Because of this, no student page is provided for this activity. Begin the activity by presenting students with this challenge:

Your Energy Diary Challenge: How much CO_2 do you put into the environment each day by your use of electricity?

- Keep a record of each time you use electricity in your home for one day. Use the chart provided in the Appendix or use your own.
- Record the name of the appliance and the amount of time you use it for.
- Write down the watt rating listed on the device.
- Be sure to consider those appliances that are left on, even when you are not using them, like the refrigerator.
- If the dishwasher is used or a load of family laundry is done, note this in your energy diary.
- Follow your teacher's directions for how to calculate the amount of CO_2 emitted in producing the electricity required to run the device.
- Determine the total amount of CO_2 emission caused by your use of electricity for that one day.

Students can calculate the approximate amount of carbon dioxide added to the atmosphere each time they use electricity in their home. All they need to know is the watt rating of the appliance and the amount of time they use the electricity. Students may need assistance in calculating the amounts of CO_2 emissions in cases where they use an appliance for only a portion of an hour. You may want to provide several examples of how students can determine the total CO_2 emissions, for example, when an appliance is used for only 5 minutes.

As students are keeping their energy diary for one day, they may list using some appliances that are not listed in the table. This can still be figured into their daily electricity use. Ask them to read the watt rating off the appliance. Use the table in Appendix B to illustrate how the conversion to pounds of CO_2 can be accomplished. The example (see the sample diary data table) of the electric range can be used to show students how to convert watt numbers to pounds of CO_2.

SUMMING UP QUESTIONS

1. Which four items on your list consumed the most electricity?
2. Which four items consumed the least electricity?
3. If you had to choose 3 items to "go without" for 2 weeks in order to help reduce CO_2 emissions, which items would you choose? Explain why you choose each item. How much CO_2 did you save over the 2 week period? (Show how you determined this.)

HOME COMMUNITY CONNECTIONS

1. Ask each student to draw up an Energy Diet Plan for their home. Get each member of your family to commit to making at least one change aimed at saving electricity. Be sure to let them decide what

they would like to cut back on. Ask them to specify the length of time each person would be involved. In the end, determine the amount of CO_2 emission saved by your family diet.

2. Roughly twenty pounds of CO_2 are emitted into the atmosphere for every one gallon of gasoline burned in your family car, truck, or van. Figure out your CO_2 contribution to the atmosphere from driving or being driven for a typical day. How much CO_2 has been emitted from your car in the past year? Since the car was made?

3. Obtain the monthly utility bills for the gas and electricity used in your home or apartment for one year. If the whole year's bills are not available, try to get a March or October bill and multiply the values by 12. (Using a summer or winter bill will result in a total that is either too large or too small.) Calculate the number of therms or kilowatt hours your family used in one year. Assuming the electricity is produced solely from burning coal, calculate the number of pounds of carbon dioxide your family produced by their consumption of electricity in the course of one year.

4. Energy experts say that the carbon dioxide released per family during the production of the things we buy and the services we use, is about equal to the amount of carbon dioxide produced by our direct use of energy. (Your answer to the above problem.) What, then, is the total amount of carbon dioxide produced by your family during the year?

5. If your family's car(s) were more efficient and got 5 more miles per gallon, how many pounds of carbon dioxide would be prevented from going into the air each year? There are about 180,000,000 cars, buses and trucks on the roads in the United States. How many pounds of carbon dioxide pollution would be saved each year if they all improved their vehicle efficiency by 5 miles per gallon?

EXTENSIONS

1. Analyze your daily energy diary. In what ways could you save energy? Go on an energy diet for one day. Calculate the CO_2 savings you would get from your diet. How much emission would you save if you "dieted" for one week? For one year?

2. Make a list of other actions that your family could take to reduce carbon dioxide emissions. Estimate how much less carbon dioxide would be produced if all 11,400,000 households in the U.S. followed your suggestions.

Pounds of CO_2 Emitted by Producing Electricity for the Operation of Various Appliances

1 KWH will emit approximately 1.34 lbs of CO_2 (averaging the United States' total CO2 released per kWh in electricity generation). Find the Watt rating of the appliance and divide it by 1000 to find Kilowatts.

1. Multiply the kW by the time frame of use of the appliance. (1 hour = 1, 30 minutes = 0.5, 15 minutes = 0.25, etc.)
2. Multiply that answer by 1.34 to get pounds of CO_2 emitted in that appliance time frame.

EXAMPLE:
appliance: *electric range*
power rating: *12,500 Watts/1000 = 12.500 kW*
time used: *1 hour*
pounds of CO_2 emitted: *(12.500 kW)(1 hr)(1.34 lbs CO_2/kWh) = 16.75 lbs CO_2*

Sample Chart for Data Collection

Appliance	Watt Rating (B)	Time Used (C)	B x C	÷1000	x 1.34

SLOWING THE GREENHOUSE EFFECT

Adapted from the University of Northern Iowa's Energy Education Project

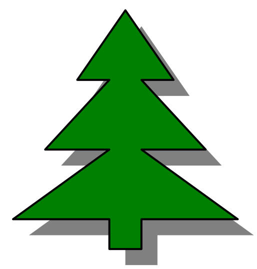
Objective: Students will determine how trees can help slow the greenhouse effect.

Subject: Math

Suggested Grade Level: 6 – 9

Materials: Calculators

BACKGROUND



Shade trees reduce cooling costs in the summer, but don't block out the sun's warming rays in the winter. They also absorb carbon dioxide and prevent it from going to the atmosphere. The process of absorbing CO_2 and releasing oxygen is part of photosynthesis.

PROCEDURE

The 13-48 pound range stated for the amount of CO_2 absorbed per trees presents an interesting challenge for students. While you may choose simply to use the average of this range, it would be more beneficial for students to set up their own criteria for how to use the numbers. For example, students may want to measure the circumference of the tree trunk one meter above the ground as their standard. They could take a trip around the school ground to see the variation that exists and then set up a scale by which they assign a number from 13 to 48 to different circumferences. You might challenge students to locate the widest and the smallest tree trunks in town and to bring that measure to school. Students may wish to estimate the height of the trees. For example, if the tree is one story or less in height, they might want to assign a number close to 13 to its CO_2 absorbing ability. This makes for interesting discussion the student's part, while requiring them to think about scales. It is important, however, that a class consensus be reached. If each student uses a different scale, it will not be possible to compare and pool results.

As students are deciding on which areas to sample, you may want to list several small parks, the school yard, and other key areas in your community. Ask students to volunteer to survey these areas. This would insure a broad sampling of a variety of areas. It would be best if each student chooses different areas to survey.

If there are very few trees in your area, you could take a class field trip to collect data. Alternatively, you could design an imaginary park and make calculations based on that park. Finally, you could skip straight to extension #2 and help get some trees planted in the area.

A sample data table for this activity is contained in the Appendix. Discuss with the class the types of data needed, then go over the data table with sample data from two students. Notice how the calculations are included as part of the data table. Review this with students before they begin collecting data.

Once all the data has been collected and the calculations completed, ask each person to display their findings on a class poster or on the chalkboard. This would allow students to determine total CO_2 absorption by all the trees surveyed by their classmates. Once a grand total has been achieved, students will really get the flavor that the trees in their town do make a difference on helping reduce greenhouse gases.

This would be a good point to introduce some of the extensions. Getting students involved in a plant-a-tree campaign would benefit both the students and their community.

SAMPLE ANSWERS TO SUMMING UP

1. Some of the reasons students might list include; trees are different sizes due to their age, different trees have different leaf sizes, and each type of tree processes nutrients at a specific rate.

2. Information would be needed on the average number of pounds of CO_2 absorbed by a tree in the rainforest. This might require information on the average tree size in the rainforest. Information would also be needed on the average number of trees in an average acre of rainforest.

HOME/COMMUNITY CONNECTION

1. Challenge the class to draw a street plan of the downtown area of your city.

2. On the map, mark the places where trees are currently growing.

3. Draw up a plan designed to increase the number of trees in the downtown area. You may want to make Plan A, Plan B and Plan C, each proposing a larger number of trees for the area. As part of the plan, include information on the CO_2 absorbing ability of the proposed trees.

4. Mark the locations of the new trees on your map. Be sure to consider the importance of shade on buildings in deciding where to place the trees. (Shade helps reduce the cooling costs of buildings.)

EXTENSIONS

1. Challenge the class to determine the CO_2 absorbing ability of a larger area within your community. For example, how much CO_2 is absorbed by trees in the downtown area of your community?

2. Start a Plant-a-Tree Campaign within your community. As part of the campaign do the following:
    a. Design an advertising campaign aimed at getting people to plant more trees.
    b. Present your campaign in the form of a poster, brochure, newspaper, or other creative form.
    c. Emphasize and communicate the CO_2-absorbing abilities of trees.
    d. Design colorful graphs, charts, and other graphics to help illustrate the CO_2 absorbing abilities of trees.
    e. Be creative!

Slowing the Greenhouse Effect

Problem

How much carbon dioxide is removed from the atmosphere by the trees around your home?

Materials

- Calculator

Let's Investigate

A healthy, growing tree absorbs between 13 and 48 pounds of carbon dioxide per year. At the 13 pound rate, one acre of trees absorbs 2.6 tons of CO_2 per year. At this same rate, every ton of new wood removes 1.47 tons of CO_2 from the air and releases 1.07 tons of oxygen.

You can see that trees play a very important role in removing CO_2 from the atmosphere. To put this on a more personal level, let's look at the effect on CO_2 levels of trees in your area.

How much CO_2 do you think is absorbed by each of the following:

- The trees on the school grounds?
- The trees around your home?
- The trees in a local green space or park?

In order to answer these questions, you think you will need some information. Make a list of the information you will need to answer these questions.

You were told that growing trees absorb between 13 and 48 pounds of carbon dioxide each year. But which number do you use; 13 lb, 48 lb, or neither? As a class, set up a scale that will allow you to use both 13 and 48, as well as numbers between these values. After you have arrived at a group decision, write your scale below.

Identify three different areas from which you will collect tree data. They need not be the same as those listed in the question above. Collect your data as a homework assignment. Use the data table below to record your data. Be sure to label the rows and columns to describe the data you are recording. Also use the spaces in the data table to calculate the amount of CO_2 absorbed by the trees at each site. Use the scale your class has set up for determining the amount of CO_2 absorbed by each tree. Be sure you label your calculations clearly.

Summing Up

1. The rate of CO_2 absorption by each tree is at between 13 and 48 pounds per year. What are some reasons explaining why this figure is not the same for all trees?
2. Rainforests are being destroyed at a rate of over 50 acres per minute. What information would you need to know to be able to determine the amount of CO_2 absorption that is lost each minute as these acres are cleared of trees?

Sample Data Table for Two Students

Location	Number of Trees	Circumference of Tree	Pounds of CO2 Absorbed by the tree *
Alex's Yard	2	120 cm	18 lbs/tree x 2 trees = 36 lbs CO2
	3	60 cm	15 lbs/tree x 3 tress = 45 lbs CO2
Total for Alex's Yard……………………………………………………………81 lbs CO2			
Ellie's Yard	5	60 cm	15 lbs/tree x 5 trees = 75 lbs CO2
	1	160 cm	36 lbs/tree x 1 tree = 36 CO2
Total for Ellie's Yard…………………………………………………………111 lbs CO2			