Buses, Trees, and Carbon
1. Introduction

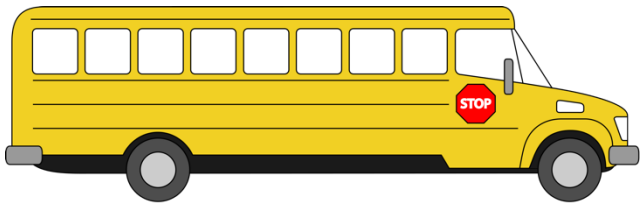
No science class can prepare your for all of the science-related problems you will encounter in the future. You will need to track down information, do investigations, and synthesize ideas on your own. In this activity, we will practice that kind of learning. You will be determining the carbon dioxide emissions from your school's bus fleet and will calculate how many trees it would take to completely offset these emissions. First, you will be introduced to the activities that will enable you to make this determination.

Background: There are roughly a half million school buses in the United States that are used to transport students to school. Each of these buses uses an average of about 1700 gallons of fuel per year, and that fuel is mostly converted into carbon dioxide and water when it is combusted.

The increasing amount of carbon dioxide in the atmosphere is a problem for the planet. Carbon dioxide is a greenhouse gas, meaning it prevents some of the sun's radiation from going back into space. The effect is a warmer planet. Because the amount of carbon dioxide in the atmosphere continues to rise each year, there is a growing interest in becoming **carbon neutral**. This means that actions are taken to remove the carbon dioxide from the atmosphere that was emitted as a result of human activity. Becoming carbon neutral is one way to reduce your **carbon footprint**, or the amount of carbon dioxide that is emitted as a result of your activity.

One option for becoming more carbon neutral is to plant trees. Trees take in or sequester carbon dioxide and water to produce glucose and oxygen during photosynthesis. While some of that glucose is converted back into carbon dioxide when trees undergo cellular respiration, trees also keep some carbon atoms and build them to their bodies. In other words, trees store carbon atoms as part of the molecules that comprise the wood and other solid materials of the tree. The more carbon atoms that are sequestered in trees and other plants, the lower the carbon dioxide levels in the atmosphere.

In this activity, you will determine how many trees you would have to plant per year to negate the carbon footprint of your school's bus fleet. In other words, you will determine how many trees it would take to completely sequester the carbon dioxide that is emitted from bus transportation at your school. You will also consider whether or not it would be better to ride the bus to school or ride in a car.



A. Overview: this activity consists of four parts:

a. **Introduction –** you will be introduced to the primary question and background information. You will work with individuals in your school to determine how much fuel your buses use in a given year and how much carbon dioxide is released from this amount of fuel.
b. **Media Evaluation –** you will utilize internet sources to determine how much carbon dioxide a tree can sequester and will critique your sources and the other sources for credibility.
c. **Local Information –** you will determine how much space is available for planting trees based on satellite map images. You will then calculate the amount of CO_2 sequestered in a log and in a live tree.
d. **Presentation of Conclusions –** you will determine how many trees it would take to offset the carbon dioxide emissions from your school's bus fleet and present your findings to the class.

B. Protocol: you will work in small groups to determine how much fuel the bus fleet of your school uses in a typical year. There are multiple ways you can obtain this information. One is to simply contact the department or company that your school uses for bus transportation. Another option is to contact your school or district's administration to determine if they have this information on hand (for example, in a budget report).

You should work with your instructor to determine the guidelines for obtaining this information (for example, you may need to ask for permission to use a classroom phone for this purpose). You can and should consider working with other groups to share information. For example, your class may decide to have different groups contact different people and share the information they collect with everyone if and when they obtain it. You may not get this information today. As long has you have this information by the time you complete the last portion of this project (Part 4), you will be ok.

C. Questions

1. How much fuel does your school's bus fleet use in a year? -OR- How many miles do all of the buses of your school travel in a year and what do these buses get for an average number of miles per gallon?

_____

2. How did you acquire this information? Briefly describe the person or source the provided you with the information needed to answer the question above.

_____

_____

2. Preparation for Future: Media Evaluation

You will be determining the carbon dioxide emissions from your school's bus fleet and will calculate how many trees you would have to plant per year to completely offset these emissions. In this activity, you will use internet sources to determine how much carbon dioxide a tree can sequester.

A. Protocol: you will work in small groups and use internet search browsers to find credible information on how much carbon dioxide a tree can sequester and store per year. You will need this information to determine how many trees it would take to completely sequester the carbon dioxide emitted from combustion of fuel in your school's buses over the course of a year.

To begin, type the following phrase into a search engine (such as Google or Bing) exactly as you see it here:

tree carbon dioxide sequestration

Review the websites that are listed on the first page of search results. As a team, determine which of these websites provides information that is most useful for your needs and is credible and reliable.

Your instructor will have each group present which website they determined to be most useful, credible, and reliable and defend their choice using evidence. You may choose to use a different group's website after everyone has presented to complete this project, or you can decide to keep using the same website you originally chose.

B. Questions: answer each of the following prior to the whole-class discussion.

1. Of the search results, which site did you decide was most useful, credible and reliable?

   _____

2. Why did you choose this site? How do you know it is credible?

   _____

3. Is this site reliable? Do the data presented agree with other sources?

   _____

4. Will you use this site for your project or did you determine that another website was better? Explain your choice.

   _____

Questions: answer each of the following *after* the whole-class discussion.

5. How much carbon dioxide can be sequestered by a tree in a year? Use the information from your website to determine how to best answer this question. Be sure to include as many specifics as possible. For example, taller trees with a greater circumference should be able to sequester more CO_2 than a shorter tree with a smaller circumference.

6. Do different trees sequester different amounts of carbon dioxide? For example, does it matter if a tree is a deciduous or a coniferous tree? Use a search engine if needed.

   Yes No (circle one). Explain: _____

7. Which option would result in fewer carbon dioxide emissions – if more students rode the bus to school or if more students rode to school in cars. Use credible internet sites to determine the answer to this question and provide an explanation.

   It would be better if more students: *rode the bus were driven separately*
   (circle one)

   because _____

   Source*:* _____

3. Preparation for Future Learning: Local Information

You will be determining the carbon dioxide emissions from your school's bus fleet and will calculate how many trees you would have to plant per year to completely offset these emissions. In this activity you will collect local information to determine the carbon dioxide emissions from your school's bus fleet and determine how much space is available for trees.

A. Protocol: In these activities, you will determine the amount of space available for planting trees, and the amount of carbon dioxide sequestered by a given tree and/or a log. Your instructor may choose to do only some of these options.

B. Space Available for Trees: for this portion of the activity, you will need a computer, tablet, or a smart phone with internet access. First, use a search engine or online map program (such as Google Maps) to find a satellite image of your community surrounding your school. Next, estimate how much land is available for planting trees on your school's grounds and in the areas surrounding your school. You may want to keep the following considerations in mind:

- *Some open areas may need to remain open and free of trees to stay useful (e.g. a football field would not work if it was covered in trees).*
- *Some (if not most) of the land around your school's property is probably privately owned. The owners of this land would have to voluntarily plant more trees. They may not be willing to do this.*
- *Some of the largest open areas of land are used for agricultural purposes. Because the owner's income is dependent on agricultural use, these owners are not likely to be willing to convert large portions of it to forested land. Some farmers can receive small amounts of federal financial support for converting a part of their land into wildlife habitat through a program called the Conservation Reserve Program (CRP).*
- *Some open space is not suitable for trees or would only be suitable after extensive effort (e.g. an abandoned parking lot would not be feasible without major efforts to remove the asphalt and restore the soil).*

Complete the questions below. Be prepared to discuss as a class.

1. How much land is available for planting trees in the area around your school?

   Circle one: A lot A limited amount Hardly any at all

2. How does this affect the plan to neutralize carbon dioxide emissions from your school's buses by planting trees in your area?

C. Carbon Dioxide Sequestered in a Log: in this step, you will use a dry log provided by your instructor to see how much CO_2 it has sequestered. This log needs to be a completely dry and free of any other materials (like mold or fungi).

1. First we need to determine the weight of the carbon atoms in the dry weight of the tree. Because trees are roughly 50% carbon (when dry), we simply have to multiply our dry weight by 0.5 to find the weight of carbon in the tree.

   Dry weight: _____ x 0.5 = _____ (kg of carbon)

2. Next we need to determine how much CO_2 was sequestered by the tree based on its carbon content. In other words, how much CO_2 did the tree take in and turn into tree? Because carbon is a little over a third of the weight of CO_2, we simply multiply our carbon weight by 3.67 to determine the weight of CO_2 sequestered.

Weight of carbon: _____ x 3.67 = _____kg CO_2 sequestered

3. A school bus emits an average of 17,237 kg (38,000 lbs.) of CO_2 per year. How many logs of this size would it take to sequester the average annual emissions of one school bus?

   _____

   Show your work!

D. Carbon Dioxide Sequestered by a Tree: in this step, you will go outside and determine how much carbon dioxide has been sequestered by a tree. You will need string, a measuring device, a partner, and a pen or pencil for this activity.

1. **Determine the diameter (width) of your tree's canopy**. Work with a partner. You will need a ball of string and a meter stick or measuring tape. One person (Partner A) should stand under the edge of the tree's canopy (the furthest point from the trunk that leaves are found) and hold the ball of string. The other person (Partner B) should unwind the string and walk past the tree trunk to the edge of the canopy directly across from the first person. Mark the edge of the canopy on the string and use a meter stick or measuring tape to measure the diameter of the canopy in meters. It may be easier to measure in centimeters and then divide by 100.

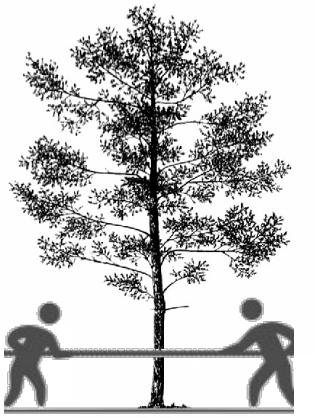


Image source: conifers.org

2. **What is the diameter (width) of your tree's canopy?** _____meters

3. **What is the radius of your tree's canopy?** To calculate the radius of the tree's canopy, divide the diameter in half.

   Diameter: _____ m ÷ 2 = _____ **m ← (Radius of tree's canopy)**

4. **What is the total area of your tree's canopy?** To calculate the total area of the tree's canopy, square the radius and multiple it by pi (3.14).

   Radius Squared = _____ m^2 (*e.g. if your radius was 2 m, this would be 2 x 2 = 4 m^2*)

   Squared Radius x 3.14 = _____ m^2 ← (**Total area of the tree's canopy)**

5. Next we need to determine how much CO_2 is absorbed by the tree per year. A typical tree will absorb 0.205 kg (0.5 lbs.) of CO2 per square meter of tree canopy. To determine how much CO2 that our tree will absorb per year, we have to multiply the total area of the tree's canopy that we calculated in the previous question by 0.205 kg.

   Total Area of the Canopy: _____ x 0.205 kg = _____

   This is the amount of CO_2 sequestered by this particular tree in a given year. ↑

6. A school bus emits an average of 17,237 kg (38,000 lbs.) of CO_2 per year. How many trees of this size would it take to sequester the average annual emissions of one school bus? If you are unsure how to set up this equation, ask for help.

   _____

   _____

   Show your work!

7. The Environmental Protection Agency (EPA) estimates a typical passenger vehicle emits about 4.7 metric tons (1000 kg) of carbon dioxide per year. That is 1300 kg of carbon moving from gasoline into the atmosphere per year[1]. Every gallon of gasoline burned creates about 8.9 kg of CO2.

   Does your tree sequester 1300 kg of carbon per year? *Yes No* (*circle one*)

   How many trees like yours would it take to sequester 1300 kg of carbon per year?

   _____

   _____

   Show your work!

8. If the tree that is sequestering the CO2 from our bus is cut down and burned, what happens to the CO2 that it absorbed?

   _____

[1] *This assumes the average gasoline vehicle today has a fuel economy of about 21.6 miles per gallon and drives around 11,400 miles per year.*

4. Preparation for Future Learning: Presentations of Conclusions

You will be determining the carbon dioxide emissions from your school's bus fleet and will calculate how many trees you would have to plant per year to completely offset these emissions. In this activity you will use the internet information that you have collected and the local information about your school's bus fleet to make and present a final determination.

Protocol: Our goal was to have carbon-neutral bus transportation for the school. The only way to get the CO_2 emitted from bus transportation back from the atmosphere is to sequester it through photosynthesis in plants. You will work in your assigned groups to determine how many trees you would have to plant per year to offset the carbon dioxide that is emitted as a result of the fuel combusted by your school's buses.

First, you will need to determine how much carbon dioxide is emitted based on how much fuel is used by all of the buses in a single year. According to the EPA, about 10 kg (22.4 lbs.) of CO2 are produced from burning a single gallon of diesel fuel, while a gallon of biodiesel (B20) results in the emission of about 8 kg (17.9 lbs.).

Next you will have to determine how much carbon dioxide is sequestered by a tree per year. You should use the credible information you found during your web search on the second day or the amount you calculated on the third day, depending on which you think is more credible (you may want to discuss this first as a class).

Once you know how much carbon dioxide is emitted from your school's bus transportation and how much carbon dioxide can be sequestered by a tree over the course of its life, you can do a simple math problem to determine how many trees you would need to plant per year. That equation would be:

[kg of CO_2 emitted by buses] ÷ [kg of CO_2 sequestered by a tree] = # of trees

Show your work in the space below. Be ready to present your findings to the class.

A. Questions

1. How many trees would your school need to plant per year to re-sequester and sequester the carbon dioxide emissions from your school's buses?

   We would need _____trees per year to re-sequester the CO2 from our buses.

2. Does it seem feasible to have this many trees on your school's grounds? Explain.

   _____

   _____

   _____

3. School buses transport roughly 26 million students per year. On average, school buses get an average of 7 miles of transportation for every gallon of diesel fuel. The average privately-owned vehicle gets 20.8 MPG. Would it be better for students to be driven to school (or drive themselves) than for them to take a bus?

   Keep in mind that the average school bus transports 36 students. When students are driven to school, the average privately-owned vehicle transports 1.5 students over a 10-mile roundtrip between home and school. This information is summarized in the table below. Which would be more efficient, transporting students by bus or by a privately-owned vehicle?

	Bus	Car
Average Number of Students Transported	36	1.5
Average Miles Per Gallon by Vehicle	7	20.8
Gal of Fuel Used Per Bus/car Per School Year	1714.00	86.50
Average Gal of Fuel Used Per Student Per Year	47.6	57.7

Data taken from http://www.americanschoolbuscouncil.org/issues/environmental-benefits

   It would be more efficient to transport students by _____.

4. In 2014, the US emitted a total of 5.4 *trillion* kg (12 *trillion* lbs.) of CO_2[2] from energy production and use. Based on your data, how many trees would have to be planted *each year* to offset these emissions?

   _____

   _____

   Show your work!

[2] 5406 million metric tons. Source: U.S. Energy-Related Carbon Dioxide Emissions, 2014 http://www.eia.gov/environment/emissions/carbon/

By now it might seem evident that in most cases we do not have enough open space to plant a sufficient number of trees to absorb all of the CO_2 from student transportation, let alone from the rest of human activity. However, there are other ways in which a person's carbon footprint can be reduced besides planting trees. The table below has estimations of the extent to which the CO_2 emissions from your lifestyle could be reduced from simple lifestyle changes.

Sustainable Behavioral Choices to Offset School Bus Emissions	Equiv. kg CO_2 (per year)	% of Avg Bus Emissions per Student	% of Avg American's Emissions (per year)
Biking/Walking to school 1 day a week for a year (average)	-64.0	20%	0.32%
Biking/Walking to school every day for a year (average)	-319.3	100%	1.60%
Using cold water to wash clothes and a low-flow showerhead for a year	-148.3	46%	0.74%
Eliminating beef from your diet for one year	-489.9	153%	2.45%
Eliminating red meat from your diet for one year	-747.1	234%	3.74%
Practicing a "Meatless Monday" diet every week for a year	-111.1	35%	0.56%
Adopting a vegetarian diet (diet still includes eggs & dairy) for a year	-865.9	271%	4.34%
Reducing portions to USDA-recommended serving sizes of meat, poultry, & eggs	-369.2	116%	1.85%
Avoiding air travel for one year (assuming average US flyer miles)	-89.8	28%	0.45%
Avoiding a transatlantic flight for a given year	-758.9	238%	3.80%
Using a fan instead of an AC window unit (per resident; summer nights only)	-511.7	160%	2.56%
Using a fan instead of central AC (per resident; summer nights only)	-506.2	159%	2.54%
Using a clothesline instead of a dryer for 6 months (per resident)	-106.6	33%	0.53%
Observing posted speed limits for one year (for average driving statistics)	-327.5	103%	1.64%
Choosing a 10% Renewable Energy Utility Option (per resident)	-226.3	71%	1.13%
Switching a home's energy to carbon-neutral energy (per resident)	-226.3	709%	11.34%
75% reduction of "Standby Power" used by appliances for 1 year (per resident)	-127.5	40%	0.64%
Reducing your daily shower time by 5 minuntes	-372.4	117%	1.87%
Switching one 75-watt incandescent bulb for a CFL (bulb's lifetime)	-369.2	116%	1.85%
Only using a hand dryer at school restroom (4x/day, weekdays)	-19.1	6%	0.09%
Switching to LED Christmas lights instead of traditional lights (per resident)	-83.0	26%	0.42%
Choosing no-rush shipping for a year of online purchases (for twenty-1 lb. Packages)	-384.2	120%	1.92%
Setting a thermostat 2 degrees warmer in summer and 2 degrees cooler in winter (per resident)	-348.8	109%	1.75%
Properly insulating a water heater & reducing the max temp < 120 deg. (per resident)	-323.0	101%	1.62%
Limiting daily television time to 2 hours (vs. avg of 6 hours/day) for one year	-53.5	17%	0.27%

5. Using the table on the previous page, choose up to 6 activities that you personally could adopt in order to reduce your lifestyle's CO_2 emissions by 318 kg (700 lbs.) or more. (318 kg of CO_2 is what the average student creates per year when they ride the bus to school and will serve as the baseline for this activity). Keep in mind that you can only choose activities that could apply to your own lifestyle. For example, if it is unlikely that your family will switch to a source of energy for your home that is completely carbon-neutral within the next year, you cannot choose that item as an option. You can also only choose activities that are not currently a part of your lifestyle (the goal is to reduce your lifestyle by an *additional* 318 kg). Choose options until you reach 318 kg or more.

Option 1: _____

Kilograms of CO_2 reduced: _____ % of Average American's Emissions: _____

Option 2: _____

Kilograms of CO_2 reduced: _____ % of Average American's Emissions: _____

Option 3: _____

Kilograms of CO_2 reduced: _____ % of Average American's Emissions: _____

Option 4: _____

Kilograms of CO_2 reduced: _____ % of Average American's Emissions: _____

Option 5: _____

Kilograms of CO_2 reduced: _____ % of Average American's Emissions: _____

Option 6: _____

Kilograms of CO_2 reduced: _____ % of Average American's Emissions: _____

6. If we wanted to *completely* negate the amount of CO2 produced by an average American lifestyle, how many kilograms of CO2 would we have to eliminate?

_____

_____

Show your work! Note that the table shows bus emissions are 1.6% of an average American's emissions. How can you use math to turn 1.6% into 100%?

DOE Bioenergy Research Centers

WWW.GLBRC.ORG/EDUCATION
EDUCATION@GLBRC.WISC.EDU

U.S. DEPARTMENT OF ENERGY