Unit 3: Transportation

Unit Objectives

At the end of this unit the students will be able to:

- Understand that different modes of transportation and different transportation fuels have varied impacts on the climate.
- Describe how daily (transportation) choices of individuals, taken together, affect global resource cycles, ecosystems and natural resource supplies.
- State a clear proposal in support of a position.
- Listen critically and respond appropriately.
- Understand strategies for reducing transportation related greenhouse gas emissions.
- Identify how technological advances have changed our use of energy. (**Science Standard**)
- Collect, organize and display sufficient data to support analysis. (**Science Standard**)
- Clarify key aspects of an event, issue, or problem through inquiry and research. (**Social Studies Standard**)
- Examine the various characteristics, causes, and effects of an event, issue, or problem. (**Social Studies Standard**)
- Examine a controversial event, issue, or problem from more than one perspective. (**Social Studies Standard**)

Unit Background

Lesson 3A
Transportation Fuels Debate Game (60-80 minutes)

Lesson 3B
Lowering our Transportation Emissions (60 minutes)

Unit 3 Quiz
15 minutes

Unit 3 Appendix

Unit Background

In the last unit we looked at practical ways of reducing our home and school energy use. By reducing electricity use we can reduce the greenhouse gas (GHG) pollution we emit. Now we are going to shift our reduction focus to the fastest growing sector of GHG emissions: transportation.

According to the US Environmental Protection Agency (EPA), the transportation sector made up 29 percent of the nation's GHG emissions in 2006. Emissions are increasing more rapidly in this sector than in any other, and account for nearly half of the net increase in total US emissions since 1990. Transportation is the greatest end-use source of the most prevalent greenhouse gas, CO_2. These figures do not account for emissions associated with the lifecycle processes of fuel extraction and refining, vehicle manufacturing, and road construction and maintenance – all of which result in significant GHG pollution.

Individual transportation emissions can be significantly reduced through a number of strategies. These include:

- The use of alternative modes of transportation like walking, biking, carpooling and public transportation whenever possible.
- Avoiding unnecessary trips and practicing "trip chaining," or combining trips, to decrease the number of miles driven.
- Keeping up with vehicle maintenance. Well-maintained vehicles achieve greater mileage, with an average improvement of four percent and as much as 40 percent for major repairs. Properly inflating tires improves vehicle efficiency by an average of 3.3 percent.
- Leaving heavy items at home. Miles per gallon decreases by two percent for every extra 100 pounds. A loaded roof rack decreases efficiency by five percent.
- Smart driving:
  - Avoiding aggressive driving (rapid acceleration and braking as well as speeding), which can lower highway mileage by 33 percent and in-town mileage by five percent. Cruise control can help maintain constant speeds and usually saves gas.
  - Idling for more than thirty seconds uses more gas than turning off the car and restarting it. Although many drivers idle to warm up their vehicle, the best thing for modern vehicles is to drive off slowly to warm up the catalytic converter and other moving parts.
- When driving is necessary and when vehicle options are available, using the least emissions-intensive vehicle available. This might be a vehicle that achieves high mileage per gallon like a hybrid; an all electric vehicle; or one that can substitute biofuels like non-food crop based ethanol or biodiesel for gasoline and diesel respectively. Biofuels are discussed in more detail in the introduction to lesson 3A on transportation fuels.
- Considering mode of travel (bus, train, airplane, passenger vehicle) for long-distance and vacation travel. A new report on greenhouse gas emissions and long distance travel from the Union of Concerned Scientists has some surprises about the efficiency of airplanes and car travel, amongst other interesting information. Check out the report at: *http://www.ucsusa.org/assets/documents/clean_vehicles/greentravel_slick_opt_web.pdf*
- Finally, supporting policies and programs that build and maintain the infrastructure for these modes of transportation can lead to substantial collective emission reductions.

If you are a resident of Lane County, Oregon contact CLI at ***climlead@uoregon.edu*** for Lesson S5, Getting to School Efficiently. This lesson highlights some of the transportation resources available to Lane County residents.

Sources:

US Environmental Protection Agency, "Transportation and Climate," http://www.epa.gov/oms/climate/ Retrieved 22 September, 2009.

US Department of Energy, fueleconomy.gov http://www.fueleconomy.gov/feg/drive.shtml Retrieved 22 September, 2009.

Lesson 3A—Transportation Fuels Debate Game

(Adapted from the "Transportation Fuels Debate Game" developed by The National Energy Education and Development Project; *www.need.org)*

Objectives

- Students will become familiar with the different types of fuels available for transportation, and the advantages and disadvantages of each.

Suggested Timeframe

(60-80 minutes)

- 10 minutes—Introduce the unit
- 10 minutes—Introduce the game
- 20-30 minutes—Game
- 10-20 minutes—Post-game discussion

Materials

- A set of Transportation Fuels Debate Sheets for each team
- A set of Yes/No cards for the judges
- A transparency of the Game Board

Teacher Information

Student teams will learn about transportation fuels and then will be assigned to represent the different fuels. Working cooperatively, the students develop arguments and debate the merits of their type of fuel over the others.

Nearly all of the energy used for transportation in the United States is petroleum-based. More than half of the fuel is gasoline, used in automobiles and other highway vehicles. The remainder comes from other fuel uses, like diesel for freight trucks and jet fuel for airplanes.

New information on the connections between GHGs and transportation is constantly being published. The game cards will provide you with information on various fuel sources, and you will find greater detail on biofuels below.

Biofuels are made from renewable biomass sources. Ethanol is a replacement for gasoline, while biodiesel is a replacement for diesel. Biofuels produce fewer GHG emissions at the tailpipe than their fossil fuel based counterparts. However, a look at the full lifecycle emissions of the fuels (often called a well to wheel analysis) that includes producing the feedstock, the manufacturing process, as well as land use changes from growing the feedstock provides a more robust picture of the emissions associated with all fuels. Research published by the California Environmental Protection Agency Air Resources Board reveals that when land use changes are included in the analysis, our current corn-based ethanol actually results in slightly higher emissions than gasoline. However, non-food crop based ethanol results in much lower emissions than gasoline, even when accounting for land-use changes.

Take a look at their website for the most up to date information: http://www.arb.ca.gov/fuels/lcfs/lcfs.htm

Source:
United States Environmental Protection Agency, "2009 US Greenhouse Gas Inventory Report." http://www.epa.gov/climatechange/emissions/usinventoryreport.html

Discussion:

This outline highlights the key points to be shared with students.

1. Transportation accounts for approximately 29% of the GHG emissions in the US.
   b. Transportation emissions are increasing every year.
   c. Transportation emissions would be even greater than 29% if lifecycle emissions, like those from fuel extraction and vehicle manufacture, were included in the count.
2. Many different types of fuel are available (brainstorm a list).
   a. Gasoline
   b. Diesel
   c. Ethanol
   d. Hybrid Electric
   e. Compressed or liquefied natural gas (CNG/LNG)
   f. Electricity
   g. Biodiesel
   h. Hydrogen
3. All sources have advantages and disadvantages (purpose of the game).

Preparation

- Decide which fuels you will be using for the debate depending upon the number of students in the class or group. You need a minimum of three students in each group.
- Make a copy of the Debate Sheets you will be using for each group.
- Make a transparency of the game board for the debate. Write in the fuels you have chosen for the debate in the blocks at the top of the board. The teacher can mark teams' progress on the game board, erasing past moves.
- Make sets of Yes/No cards for the judges.
- Divide the class into each of the fuel groups.

Lesson

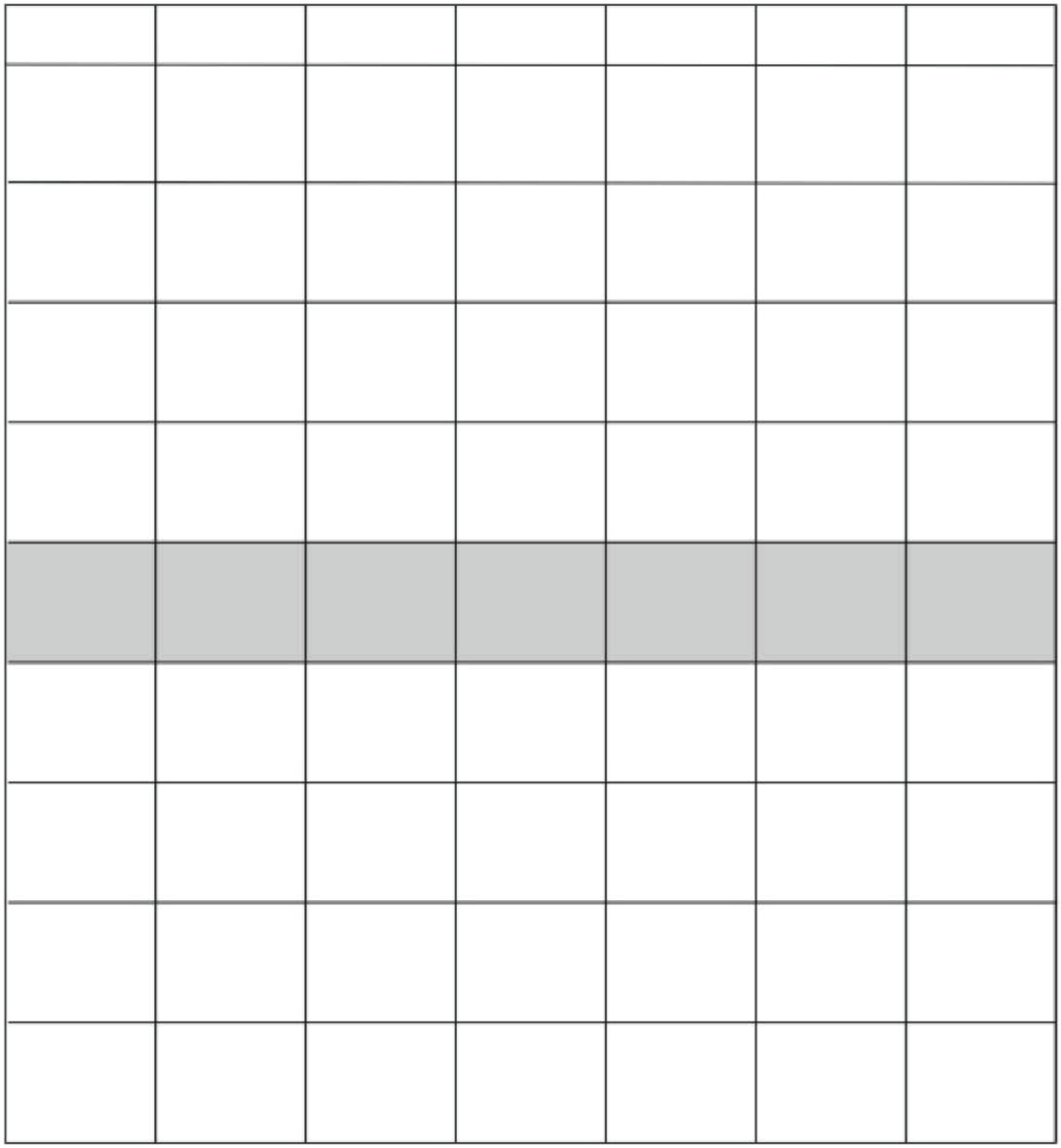
1. Introduce the game to the class and assign a fuel to each group.
2. Have the groups complete the sheets for all fuels.
3. Begin the game by sharing the goal of the game: to reach the top of the game board. Teams have two choices when it is their turn. They can present an advantage of their fuel, so as to advance their own team. Or, they can present a disadvantage of another team's fuel to move that team backwards on the game board.
4. Ask the first team to present an advantage of their fuel to initiate the game.
5. Each succeeding team decides whether to present an advantage or disadvantage.
6. An advanced version of the game would include allowing teams to contest an advantage or disadvantage posed by another team. If playing the game in this way, you may want to appoint judges or serve as a judge.
7. Action continues until one team reaches the top line.
8. If the game goes quickly, you may have time to play again, reassigning fuels or allowing a different team to start the game.

Discussion Questions

Discuss all or a few of the following questions after the game:

- Did all fuels have advantages and disadvantages?
- Was the winner the best fuel (in terms of GHG emissions or other factors)?
- If the game continued, would the results change? Why or why not?
- What are some other factors that we need to consider in our choice of transportation fuels?
- What fuel do you think would be the best for a personal vehicle and why?
- If all fuels have some drawbacks, how can we lessen our fuel use? (e.g., walk or carpool when possible, trip chain, avoid trips, maintain vehicles, etc.)
- Why do we use transportation fuels that have negative impacts on the environment? (This question could lead to a broader discussion of cost, infrastructure, and the history of transportation and our current mobility needs.

TRANSPORTATION FUELS DEBATE GAME BOARD



GASOLINE

	IT'S A FACT	RELEVANT	
		ADVANTAGE	DISADVANTAGE
1. Gasoline is a petroleum-based fossil fuel made of hydrogen and carbon.			
2. The chemical formula for gasoline is $C_8H_{15\text{-}18}$.			
3. Petroleum is a nonrenewable source of energy.			
4. Forty-five percent of crude oil is refined into gasoline in the U.S.			
5. The octane rating for gasoline is 86 to 94.			
6. Gasoline has a high energy content of 114,000 Btu/gallon and produces 19.6 lbs/gal of CO_2.			
7. More than 95 percent of the vehicles in the U.S. use petroleum-based fuels.			
8. The U.S. has a vast infrastructure of refineries, pipelines, and filling stations to distribute gasoline efficiently and conveniently.			
9. The U.S. imports about two-thirds of the crude oil it uses from other countries.			
10. There are about 170,000 gasoline fueling stations in the U.S.			
11. There are about 200 million cars in the U.S. that use gasoline.			
12. The average gasoline-powered vehicles travels 12,000 miles per year.			
13. Vehicles that use petroleum-based fuels emit air pollutants.			
14. In the last 50 years, gasoline-powered vehicle emissions have decreased an average of 95 percent.			
15. In many metropolitan areas, vehicles contribute about half of the air pollution.			
16. Almost half of the people in the U.S. live in areas that do not meet air quality standards.			

DIESEL

	IT'S A FACT	RELEVANT	
		ADVANTAGE	DISADVANTAGE
1. Diesel is a petroleum-based fossil fuel made of hydrogen and carbon.			
2. The chemical formula for diesel is $C_{16}H_{34}$.			
3. Petroleum is a nonrenewable source of energy.			
4. Diesel has a very high energy content; it contains 18-20 percent more energy per gallon than gasoline, and produces 22.4 lbs/gal of CO2.			
5. About ten gallons of diesel are produced from every 42-gallon barrel of crude oil.			
6. Diesel is used in internal combustion engines designed specifically for diesel fuel.			
7. Diesel is used in more than two-thirds of all farm equipment because it can power demanding work.			
8. Ninety-four percent of the goods in the U.S. are moved by diesel-powered vehicles.			
9. The U.S. has a vast infrastructure of refineries, pipelines, and filling stations to distribute diesel efficiently and conveniently.			
10. The construction industry uses diesel-powered vehicles to perform heavy-duty jobs.			
11. Vehicles that use petroleum-based fuels emit air pollutants.			
12. In the last 50 years, petroleum-fueled vehicle emissions have decreased an average of 95 percent per vehicle.			
13. Today, there are approximately seven million commercial trucks and 700,000 buses on U.S. roads that use diesel.			
14. Diesel vehicles built today are eight times cleaner than those built 15 years ago.			
15. Using low sulfur diesel fuel and advanced exhaust control systems can reduce particulate emissions by 90 percent and nitrogen compounds by 25-50 percent.			
16. Almost half of the people in the U.S. live in areas that do not meet air quality standards.			

PROPANE (LPG)

	IT'S A FACT	RELEVANT	
		ADVANTAGE	DISADVANTAGE
1. Propane is a fossil fuel, sometimes called liquefied petroleum gas or LPG.			
2. The chemical formula for propane is C_3H_8; propane is a hydrocarbon.			
3. Propane is a by-product of petroleum refining and natural gas processing.			
4. Propane is a nonrenewable source of energy.			
5. Under normal pressure and temperature, propane is a gas. Under moderate pressure or lower temperature, propane can be converted into a liquid and stored in pressurized tanks.			
6. As a liquid, propane is 270 times more compact than as a gas.			
7. There is an infrastructure of pipelines and distribution terminals in the U.S. to transport propane.			
8. There are about 2,300 propane vehicle fueling stations in the U.S.			
9. Propane has been used as a transportation fuel for more than 75 years.			
10. About three percent of propane consumption is for transportation.			
11. After petroleum-based fuels, propane is the most widely used and accessible transportation fuel.			
12. Today, about 270,000 vehicles, mostly fleet vehicles such as mail trucks, use propane fuel.			
13. For fleet vehicles, the cost of using propane is five to 30 percent less than gasoline.			
14. Propane is cleaner burning than gasoline and produces less air pollution.			
15. The octane rating for propane (104) is equal to or higher than that of gasoline.			
16. It costs about $2,500 to convert a conventional automobile engine to use propane fuel.			

ETHANOL

	IT'S A FACT	RELEVANT	
		ADVANTAGE	DISADVANTAGE
1. Ethanol is an alcohol fuel made by fermenting the sugars in grains and other plants.			
2. The chemical formula for ethanol is C_2H_5OH.			
3. The most commonly used processes today use yeast to ferment the sugars to produce ethanol.			
4. A new process being developed uses enzymes to break down the cellulose in woody fibers, making it possible to produce ethanol from trees, grasses, and crop residues.			
5. Ethanol is made from renewable sources of energy.			
6. The use of ethanol provides new markets for U.S. agriculture.			
7. Since ethanol contains oxygen, adding it to gasoline reduces ozone-forming and carbon monoxide emissions.			
8. Gasoline containing 10 percent ethanol--E10--is used in many urban areas that fail to meet air quality standards for carbon monoxide and ozone.			
9. Vehicles can use E10 without any changes to their engines.			
10. The Federal government provides incentives to use ethanol.			
11. E-85 is a mixture of 85% ethanol and 15% gasoline—but only specially designed vehicles can use it.			
12. Flexible fuel vehicles (FFVs) are manufactured to use any combination of ethanol and gasoline up to E85.			
13. Today there are about 7 million FFVs that can use E85.			
14. The octane rating for ethanol is 100, slightly higher than that of gasoline.			
15. The energy content of E-85 is about 27% less than that of gasoline, but ethanol produces 19-52% less CO_2 per gallon than gasoline, depending on the feedstock.			
16. There are more than 2,200 E85 fueling stations in the U.S., mainly in the Midwest and South.			

CNG/LNG

	IT'S A FACT	RELEVANT	
		ADVANTAGE	DISADVANTAGE
1. Natural gas can be used as a vehicle fuel when it is compressed (CNG) or liquefied (LNG) by lowering its temperature to -259°F.			
2. The formula for natural gas is CH_4.			
3. Natural gas is a nonrenewable fossil fuel.			
4. Natural gas is a clean-burning fuel. It emits 25% less CO_2 and up to 99% less particulate emissions than gasoline.			
5. Methane--the main ingredient in natural gas--can be produced from biomass, a renewable energy source.			
6. When compressed, natural gas has less energy per gallon than gasoline, so vehicle range is shorter unless additional tanks are added, which reduces payload capacity.			
7. CNG has an octane rating of 120+, which provides good power and acceleration to vehicles.			
8. Today, there are about 140,000 vehicles in the U.S. that run on CNG.			
9. Conventional vehicle engines can be converted to use CNG at a cost of $2,000 - $3,000, depending on the number of pressurized tanks installed.			
10. The production and distribution systems for natural gas are in place, but the delivery system of fueling stations is not extensive.			
11. CNG vehicles are well suited for fleets that have their own refueling stations.			
12. There are about 3,100 vehicles in the U.S. that run on LNG.			
13. LNG takes up much less space than CNG, so the tanks are much smaller.			
14. LNG tanks must be kept cold, which uses energy.			
15. CNG and LNG tanks are designed to be safe in case of accidents.			
16. There are about 1100 natural gas refueling stations in the U.S.			
17. There are significant emissions released in processing and transporting CNG, much of this comes from the process of liquefying the gas for transport in LNG tankers.			

ELECTRICITY

	IT'S A FACT	RELEVANT	
		ADVANTAGE	DISADVANTAGE
1. Electricity can be produced by many sources of energy.			
2. Electric vehicles must have batteries that can be discharged and recharged repeatedly.			
3. Most batteries cannot store large amounts of electricity, so electric vehicles must carry several batteries.			
4. In some electric vehicles, the batteries constitute half the weight of the vehicle.			
5. The batteries in electric vehicles must be replaced every three–six years.			
6. A typical electric vehicle can travel 50 - 130 miles between charges.			
7. Weather conditions, terrain, and accessory use can reduce the range of an electric vehicle.			
8. Electric vehicles are best suited for neighborhood vehicle use, for consumers going short distances at 30 mph or less.			
9. Extensive research is ongoing to develop longer-lived batteries that will also extend the range of electric vehicles.			
10. Electric vehicles produce no tailpipe emissions.			
11. Some power plants that generate electricity, such as coal-fired plants, produce air pollution and GHGs.			
12. It is easier to control the emissions from power plants than from vehicles.			
13. Electric vehicles are low maintenance; they require no tune-ups, oil changes, water pumps, radiators, injectors, or tailpipes.			
14. Electric vehicles can be recharged at home at night when electricity rates and demand are low.			
15. There are about 440 electricity refueling stations, mostly in California and Arkansas.			
16. Consumers who drive electric vehicles receive tax incentives.			

HYBRID ELECTRIC

	IT'S A FACT	RELEVANT	
		ADVANTAGE	DISADVANTAGE
1. Hybrid vehicles have two power sources--an energy conversion unit (such as an internal combustion engine) and an energy storage device (such as a battery).			
2. The typical hybrid on the market today has a gasoline-powered engine and an electric motor with a battery.			
3. Hybrid electric vehicles (HEVs) can have either a series or parallel design.			
4. In a parallel design, the engine and motor are connected directly to the vehicle's wheels. The primary engine is used for highway driving; the electric motor provides added power during periods of high demand.			
5. In a series design, the primary engine is connected to a generator that produces electricity. The electricity charges the batteries and drives a motor that powers the wheels.			
6. HEVs can function as purely electric vehicles for short trips, using the internal combustion engine only when longer range or more power is required.			
7. HEVs can get twice the fuel economy of comparable conventional vehicles.			
8. HEVs have generators powered by the internal combustion engines to recharge the batteries when they are low.			
9. HEVs have regenerative braking systems that capture excess energy when the brakes are engaged; this recovered energy is also used to recharge the batteries.			
10. HEVs still produce 19.6 lbs CO_2/gal of gasoline burned but reduce air pollutants over gasoline powered vehicle due to better fuel economy.			
11. HEVs have a higher purchase price than comparable gasoline-powered vehicles.			
12. Tax incentives and superior fuel economy produce savings over the life of the vehicles to make them competitive with gasoline-powered vehicles.			
13. Today, there are several hybrids available to consumers, including the Toyota Prius, Honda Insight and Civic, and Ford Escape SUV.			
14. HEVs on the market today average 40-60 mpg and can travel 500-700 miles on one tank of gasoline.			
15. Within the next few years, there will be many models of HEVs to meet consumer needs, including trucks and SUVs.			
16. Hybrids use established gasoline fueling stations.			

BIODIESEL

	IT'S A FACT	RELEVANT	
		ADVANTAGE	DISADVANTAGE
1. Biodiesel is a fuel made by chemically reacting alcohol with organic fats, oil, or grease. Most biodiesel is made from soybeans.			
2. Biodiesel is a renewable fuel.			
3. Biodiesel is usually blended with diesel fuel in different percentages, such as B20, which is 20 percent biodiesel.			
4. Neat (or pure) biodiesel (B100) can also be used as a transportation fuel.			
5. Biodiesel fuels can be used in regular diesel engines without modifications.			
6. Biodiesel fuel can be used in the existing fuel infrastructure.			
7. Biodiesel is the fastest growing alternative transportation fuel.			
8. Biodiesel contains no sulfur and can reduce the amount of sulfur in the nation's diesel fuel supply.			
9. Adding biodiesel in small amounts to regular diesel fuel improves the lubrication qualities of diesel fuel without sulfur.			
10. Biodiesel can improve the smell of diesel fuel.			
11. Biodiesel emits 75% less CO2 than diesel and reduces air pollutants such as particulates, carbon monoxide, hydrocarbons and air toxics compared to regular diesel.			
12. Using biodiesel slightly increases the emissions of nitrogen oxides.			
13. There are approximately 1600 biofuel fueling stations in the nation.			
14. Biodiesel is well suited for fleets with their own refueling stations.			
15. Biodiesel fuel is more expensive than regular diesel fuel.			
16. Using biodiesel can reduce maintenance cost because of its good lubricating characteristics.			

METHANOL

	IT'S A FACT	RELEVANT	
		ADVANTAGE	DISADVANTAGE
1. Methanol, or wood alcohol, is a simple alcohol fuel.			
2. Methanol (CH_3OH) is made by replacing one hydrogen atom of methane with a hydroxyl radical (OH).			
3. Methanol can be produced from natural gas, coal, oil, or biomass.			
4. Today, most methanol is made from natural gas.			
5. Most methanol plants are located in conjunction with ammonia plants, since both use the same gas in the production process.			
6. Methanol was widely used to produce MTBE, a gasoline additive in declining use because of concerns about ground water pollution.			
7. Methanol can be used in its pure form (M100) or blended with 15 percent gasoline (M85).			
8. No major auto manufacturers offer methanol-compatible vehicles at this time.			
9. The cost of M85 is equal to or slightly higher than premium gasolines.			
10. There is no distribution infrastructure for methanol today.			
11. With an octane rating of 105, methanol can provide superior power to vehicles and is used in several racing classes.			
12. Methanol is a cleaner burning fuel than gasoline, producing fewer hydrocarbon emissions.			
13. Methanol produces more formaldehyde emissions than gasoline.			
14. Today, there are about 4,600 vehicles in the U.S. that use M85.			
15. M85 has lower energy content than gasoline, so vehicle mileage is reduced.			
16. Vehicles that use methanol must use a special, expensive lubricant.			

HYDROGEN

	IT'S A FACT	RELEVANT: ADVANTAGE	RELEVANT: DISADVANTAGE
1. Hydrogen is the most abundant element in the universe.			
2. Pure hydrogen does not exist on Earth; it is only found in molecules with other elements.			
3. Hydrogen is a gas at normal temperature and pressure.			
4. Hydrogen can be produced from water by electrolysis, a process in which water molecules are separated into hydrogen and oxygen using electricity. The generation of electricity typically produces GHGs.			
5. Today, it takes more electricity to electrolyze water than is produced by the hydrogen fuel.			
6. Hydrogen can be produced from natural gas, coal, or biomass.			
7. Today, most hydrogen comes from the steam reforming of natural gas, a nonrenewable energy source.			
8. Fuel cells use hydrogen and oxygen to produce electricity without harmful emissions; water is the main by-product.			
9. No hydrogen production or distribution infrastructure exists at this time.			
10. Hydrogen gas takes up six times as much space as gasoline per energy equivalent.			
11. The production of hydrogen is very expensive today.			
12. Fuel cells are an expensive method of producing electricity today.			
13. Hydrogen is the fuel used in the space shuttles.			
14. There no hydrogen fuel cell vehicles on the market today and only 35 fueling stations for test vehicles.			
15. There is ongoing research into hydrogen fuel cell technology.			
16. The Bush administration has launched a hydrogen fuel cell initiative to support research and development of new technologies.			

Lesson 3A Assessment

Aspect	Expert (4)	Practitioner (3)	Apprentice (2)	Novice (1)	**Score**
Rules of the game	Follows rules correctly without guidance.	Follows rules correctly with some guidance.	Does not follow rules without guidance.	Does not follow rules and required a great deal of guidance.	
Knowledge of the purpose of the game.	Understands the purpose of the game without significant guidance.	Has a general understanding of the purpose with some guidance.	Has very little understanding of the purpose of the game even with guidance.	Does not try to understand the purpose of the game even with guidance.	
Participation in the game	Participates fully in the game without guidance.	Participates in the game with some guidance.	Participates with a great deal of guidance.	Does not participate in the game.	
Game/ Teamwork	Collaborates with, seeks views of, and exchanges ideas with others in order to integrate them into the task.	Requires guidance to collaborate with others, acknowledges some views, and exchanges some ideas.	Requires guidance to collaborate with others, does not acknowledge others and does not exchange ideas.	Is unsuccessful when working with others, disregards the views of others and does not contribute.	
	Clearly communicates subject understanding during class discussion.	Clearly communicates some subject understanding during class discussion.	Communicates minimal subject understanding and needed to be called upon during class discussion.	Shows no subject understanding and did not participate in class discussion.	
				Total Score	**/20**

Objective Check

1. Name four of the different types of transportation fuels that are available. (Answers will vary but should include gasoline, diesel, ethanol, hybrid electric, CNG/LNG, electricity, biodiesel, hydrogen)
2. Choose one of the types of fuel and list two advantages and two disadvantages of using this fuel. (Answers will vary. Example: Hydrogen advantages—low CO_2 emissions, great abundance, disadvantages—expensive technology, difficult to carry.)

Lesson 3B—Lowering Our Transportation Emissions

Objectives

- Students will develop an understanding of the impact of their transportation choices on CO_2 emissions.
- Students will be introduced to the term "CO_2 footprint" and will consider how to reduce their footprint size.

Suggested Timeframe

- 10 minutes—Discussion
- 30 minutes—Activity
- 20 minutes—Post-activity discussion

Materials

- Computer with Internet access
- School population data (how many students attend your school?)
- Pencil

Teacher Information

According to the US EPA, passenger cars and light trucks account for more than half of all transportation emissions. Therefore, the way we get to and from school can affect our personal and collective greenhouse gas emissions.

Another factor to consider is cost; the average US vehicle that is driven 10,000 miles per year costs $0.70 per mile, or over $7,000 per year. These costs, however, do not account for the social and environmental impacts of driving. Each mile of driving an average passenger vehicle emits about a pound of CO_2, but it's extremely difficult to calculate the direct and indirect costs that pound of CO_2 has on individuals, communities and ecosystems.

By analyzing the mode of transportation they use to get to and from school students can identify ways to reduce their GHG emissions, save money and even improve their health (if they choose to use a human powered mode of transportation.)

Sources:

American Automobile Association "Your Driving Costs" (2009) http://www.aaaexchange.com/Assets/Files/200948913570.DrivingCosts2009.pdf

United States Environmental Protection Agency, "2009 US Greenhouse Gas Inventory Report." http://www.epa.gov/climatechange/emissions/usinventoryreport.html

Discussion:

This outline highlights the key points to be shared with students.

1. Review the fact that nearly 30% of US GHG emissions come from transportation.
   a. Fastest growing sector for GHG emissions
   b. More than half those transportation emissions are from passenger cars and light trucks.
   c. In communities using low-emissions sources of home energy, transportation can play a greater role in the overall GHG emissions profile.
2. Many modes of transportation produce a lower per capita emission than a solo car trip
   a. Bus
   b. Light rail
   c. Carpooling
3. Human powered modes produce no GHG emissions outside of those associated with the production of the bike, skateboard, etc.
4. Students may not currently have the ability or option to travel by a low-emissions mode, due to where they live, their family's comfort level with alternative modes, physical disabilities, or other reasons. However, as their life circumstances change, so might their transportation options.
5. Introduce Activity

Sources:

EPA http://www.epa.gov/ttn/chief/conference/ei16/session5/davies_pres.pdf

Sightline http://www.sightline.org/maps/charts/Climate-EmBySector Data from 2003

Preparation

1. Photocopy a class set of the Student Worksheets.
2. Make a copy of the section choices (different modes of transportation) and write/post it so all students can see it.
3. Write the address of the school where all students can see it.
4. Create a poster, overhead or other way of displaying the **Class Data Summary** so that students may add their data.

Lesson

1. Distribute the Student Worksheets.
2. Ask the students to think about the response to the following question: How do you typically get to and from school?
3. Refer them to the four stacks of worksheets based on the transportation modes (below) and have them select and fill out the Student Worksheet: Transportation Emissions that corresponds with the way they typically get to school.

If you get to and from school by:
Answer the following worksheet:

Car, alone (with driver)
Worksheet A

Carpool – with other students, or dropped off by a parent/guardian/other on the way to work or elsewhere
Worksheet B

Walk, bike or other zero-emission mode
Worksheet C

Bus – public or school bus
Worksheet D

4. Once students are finished, have them anonymously record their data on the appropriate Class Data Summary, depending on their mode of transportation. Responding anonymously will decrease the chance of students feeling singled out because of their transportation choices.
5. The teacher then discusses the results of the four Class Data Summary sheets. See discussion questions listed.

Discussion Questions

Once every student has completed the data summary, discuss results. Some suggested questions:

- Looking at the Class Data Summary, what is the most common way students in your class get to and from school? Why do you think this is the case?
- Which mode of transportation generates the most CO_2 per person in your class?
- Which mode of transportation generates the most CO_2 as a category in your class?
- How many students generated "zero" pounds of CO_2 from their commute?
- If the rest of the school is like your class, what would the school's commuting emissions be? (Multiply the class total by the number of classes in the school.)
- If the rest of the district/state is like your school, what would the district/state's commuting emissions be? (Multiply the school total by the number of schools in the district/state).
- What are some of the obstacles to using alternative transportation and how can they be overcome?
- Does your school or community offer incentives to students who carpool, ride the bus, bike or walk? What are these incentives and how effective are they?
- What are some other ways to encourage alternative modes of transportation?
- List the benefits of using alternative transportation.
- How might your class/school/district/state decrease its transportation CO_2 footprint?

Student Worksheet A: Name:_____

Car/driving alone

Answer

1. **How many miles do you drive to school each day?**
   Find out the round trip distance from your home to school. You can do this by going to either *www.mapquest.com* or *http://maps.google.com/* and put in the address of your home and school to calculate the distance. _____**miles**

2. **How many miles per gallon does your vehicle get?**
   Determine the average fuel economy of the vehicle being used in miles per gallon by checking *www.fueleconomy.gov* _____**mpg**

3. **Estimate gallons of gas consumed each day** getting to and from school by dividing the miles driven by the miles per gallon (miles driven/miles per gallon = gallons of fuel consumed). _____**gallons**

4. **Calculate the CO_2 emissions each day** of your round trip commute. Each gallon of gasoline burned emits about 20 lbs of CO_2. _____**lbs CO_2**

5. **Estimate your annual CO_2 emissions each year** getting to and from school. Multiply your total from #4 above by 180 school days. Record the answer anonymously in the Class Data Summary. _____**lbs CO_2**

6. **Estimate the CO_2 footprint of your school from transportation.** What if every student at your school produced the same amount of CO_2 as you in their commute to and from school? What would your school's CO_2 footprint from transportation be? Multiply your answer from #5 by the number of students at your school. _____**lbs CO_2**

Student Worksheet B: Carpool

Name:_____

Answer

1. **How many miles do you drive to school each day?**
   Find out the round trip distance from your home to school. You can do this by going to either *www.mapquest.com* or *http://maps.google.com/* and put in the address of your home and school to calculate the distance. _____**miles**

2. **How many miles per gallon does your vehicle get?**
   Determine the average fuel economy of the vehicle being used in miles per gallon by checking *www.fueleconomy.gov* _____**mpg**

3. **Estimate gallons of gas consumed each day getting to and from school** by dividing the miles driven by the miles per gallon (miles driven/miles per gallon = gallons of fuel consumed). _____**gallons**

4. **Calculate the CO_2 emissions each day of your round trip** commute. Each gallon of gasoline burned emits about 20 lbs of CO_2. _____**lbs CO_2**

5. **Estimate your annual CO_2 emissions each year** getting to and from school. Multiply your total from #4 above by 180 school days. _____**lbs CO_2**

6. **Calculate your individual impact.** How many people shared your ride? Divide your total from #5 by the number of people in your carpool (include yourself!) to calculate the individual CO_2 emissions of each person in the carpool. (Remember, your driver does not count as a member of your carpool if he/she does not stay at school with you!) Record the answer anonymously in the Class Data Summary. _____**lbs CO_2**

7. **Estimate the CO_2 footprint of your school from transportation.** What if every student at your school produced the same amount of CO_2 as you, just from their commute? What would your school's transportation CO_2 footprint be? Multiply your answer from #6 by the number of students at your school. _____**lbs CO_2**

Student Worksheet C: Name:_____

Bus (public or school bus)

	Answer
1. **Estimate the amount of fuel used by the bus.** The average bus drives 40 miles round trip. Buses get about 5 miles per gallon. Calculate the gallons of diesel used by your bus per trip.	_____ **gallons**
2. **Calculate the CO_2 emissions of your commute.** Each gallon of diesel burned creates 22 pounds (lbs) of CO_2. Calculate the amount of CO_2 generated by the bus for each roundtrip journey.	_____**lbs CO_2**
3. **Calculate the CO_2 emissions per passenger.** How many people shared your ride? Estimate the number of students who rode the bus with you today and divide the lbs CO_2 from #2 by the number of students on the bus.	_____**lbs CO_2**
4. **Estimate your annual CO_2 emissions from** getting to and from school. Multiply the total from #3 by 180 school days per year and record your answer anonymously in "Class Data Summary."	_____**lbs CO_2**
5. **Estimate the CO_2 footprint of your school from transportation**. What if every student at your school produced the same amount of CO_2 as you, just by getting to and from school? What would your school's CO_2 footprint from transportation be? Multiply your answer from #4 by the number of students at your school.	_____**lbs CO_2**

Student Worksheet D: Name:_____

Walk, bike, skateboard, or other human-powered mode of transportation

Your CO_2 footprint from your travel each day equals zero!

Record a "0" in the Class Transportation Data Summary.

If everyone in your school traveled as you typically do, this part of the CO_2 school footprint would be zero!

Pick one of the other modes of transportation and calculate what your emissions would be if you used that mode. Congratulations for avoiding those emissions!

Class Data Summary

Record each student's data in the table below and add up the CO_2 emissions for the entire class.

Student	Miles (round-trip)	Mode of Travel	Pounds CO_2 per year
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
25			
26			
27			
28			
Class Total:			

Lesson adapted from: *http://www.coolschoolchallenge.org*

Lesson 3B Assessment

Aspect	Expert (4)	Practitioner (3)	Apprentice (2)	Novice (1)	Score
Individual Transportation Data	Individual data is recorded appropriately.	Some individual data is recorded.	The wrong data is recorded.	No data is recorded.	
Worksheet	Worksheet is complete with all entries showing thoughtfulness.	Worksheet is complete with most entries showing thoughtfulness.	Worksheet is incomplete and lacks thoughtfulness.	Worksheet is not attempted.	
Post Worksheet Communication	Clearly communicates subject understanding during class discussion.	Clearly communicates some subject understanding during class discussion.	Communicates minimal subject understanding and needed to be called upon during class discussion.	Shows no subject understanding and did not participate in class discussion.	
				Total Score	**/12**

Objective Check

1. How does driving in a car differ from taking the bus in terms of CO_2 footprint? (A bus may produce more GHGs but a car produces more PER PERSON.)
2. What advantage is there to take alternative modes (walking, biking, carpooling, busing) to school? (Answers will vary. Less GHG emissions, healthier, saving money.)

Transportation Quiz

Name:_____

Multiple Choice: Read all possible responses and select the best answer.

1. **In the United States, the transportation sector produces what percent of the annual greenhouse gas emission?**
   a. 10%
   b. 15%
   c. 30%
   d. 50%

2. **Biofuels come from all of the following sources EXCEPT?**
   a. Corn
   b. Soybeans
   c. Petroleum
   d. Used vegetable oils

3. **Which of the following statements about fuels is true?**
   a. Biofuels have no disadvantages
   b. Buying a fuel-efficient car is the only way to reduce fuel consumption
   c. It does not matter what source of fuels you choose to use
   d. There are advantages and disadvantages to all sources of fuels

4. **Which of the following activities reduces GHG emissions compared to riding in a car?**
   a. Walking
   b. Biking
   c. Taking public transportation
   d. All of the above

5. **Which of the following transportation modes usually produces the most GHG emissions per person?**
   a. Riding in your car alone
   b. Carpooling with fellow students/friends
   c. Biking
   d. Taking public transportation

6. **True or false: transportation is the fastest growing source of GHG emissions in the United States?**
   a. True
   b. False

7. **Which of the following transportation modes produces the fewest GHG emissions PER PERSON?**
   a. Riding in your car alone
   b. Carpooling with fellow students/friends
   c. Biking
   d. Taking public transportation

8. **What is NOT usually a benefit of walking to school over driving to school?**
   a. Decreased GHGs
   b. Time savings
   c. Improved health
   d. Get to know the neighborhood

9. **Most of the GHG emissions from transportation are caused by:**
   a. Organic materials decomposing
   b. Burning fossil fuels
   c. Generating electricity
   d. Burning biofuels

10. **Public transportation can be useful for**
   a. Getting to the mall
   b. Getting to school
   c. Getting to your friend's house
   d. All of the above

Short Answer

11. **List four ways of getting to school that does not include riding alone in a passenger car:**
   1.
   2.
   3.
   4.

12. **Name four types of fuel used for transportation:**
   1.
   2.
   3.
   4.

Unit 3 Quiz Key

1. C
2. C
3. D
4. D
5. A
6. A
7. C
8. B
9. B
10. D
11. Answers will vary but might include:

- Biking
- Walking
- Skateboarding
- Car pooling
- Busing

12. Answers will vary but might include:

- Gas
- Diesel
- CNG/LNG
- Hydrogen
- Biodiesel

Transportation Appendix 1

New information on the connections between GHGs and transportation is constantly being researched and published. The California Environmental Protection Agency shares their latest research at: *http://www.arb.ca.gov/fuels/lcfs/lcfs.htm*

A new report on emissions and long distance travel from the Union of Concerned Scientists: *http://www.ucsusa.org/assets/documents/clean_vehicles/greentravel_slick_opt_web.pdf*

The EPA has a page filled with tips for decreasing your emissions of GHGs. Go to their On the Road page to find out for yourself: *http://www.epa.gov/climatechange/wycd/road.html*

Fuel our Future Now, from the US Department of Energy, has a list of lesson plans that will challenge your students at: *http://fuelourfuturenow.com/resources-9-12.cfm*