2013-2014

Exploring Hybrid Buses

Students learn about hybrid electric buses and evaluate the economic and environmental advantages and disadvantages of such vehicles.

Grade Level:

- Int Intermediate
- Sec Secondary

Subject Areas:

- Science
- Social Studies
- Math
- Language Arts
- Technology

NEED
National Energy Education Development Project

Teacher Advisory Board

NEED Mission Statement

The mission of The NEED Project is to promote an energy conscious and educated society by creating effective networks of students, educators, business, government and community leaders to design and deliver objective, multi-sided energy education programs.

Teacher Advisory Board Statement

In support of NEED, the national Teacher Advisory Board (TAB) is dedicated to developing and promoting standards-based energy curriculum and training.

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Energy Data Used in NEED Materials

NEED believes in providing the most recently reported energy data available to our teachers and students. Most statistics and data are derived from the U.S. Energy Information Administration's Annual Energy Review that is published yearly. Working in partnership with EIA, NEED includes easy to understand data in our curriculum materials. To do further research, visit the EIA web site at www.eia.gov. EIA's Energy Kids site has great lessons and activities for students at www.eia.gov/kids.

NEED
National Energy Education Development

1.800.875.5029
www.NEED.org

Kentucky has the largest hybrid-electric school bus fleet in the nation with 170 in operation. The Kentucky Clean Fuels Coalition, a 501 (c)(3) organization, proposed the project to the U.S. Department of Energy. A $13 million grant was awarded and is administered by the U.S. Department of Education. This grant offsets the purchase price of the hybrid system and enables school districts to improve fuel efficiency by an average of 34%. With the addition of these materials, this project also provides students with the opportunity to learn about what it means to engage in energy conscious behaviors and how these choices are already having a positive effect in their own communities.

KENTUCKY CLEAN FUELS COALITION

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Exploring Hybrid Buses

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Correlations to National Science Education Standards: Grades 5-8

This book has been correlated to National Science Education Content Standards.
For correlations to individual state standards, visit **www.NEED.org**.

Content Standard A | *SCIENCE AS INQUIRY*

- **Abilities Necessary to Do Scientific Inquiry**
  - Identify questions that can be answered through scientific investigations.
  - Use appropriate tools and techniques to gather, analyze, and interpret data.
  - Develop descriptions, explanations, predictions, and models using evidence.
  - Think critically and logically to make the relationships between evidence and explanations.
  - Recognize and analyze alternative explanations and predictions.

Content Standard B | *PHYSICAL SCIENCE*

- **Transfer of Energy**
  - Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.
  - Electrical circuits provide a means of transferring electrical energy when heat, light, sound, and chemical changes are produced.
  - In most chemical and nuclear reactions, energy is transferred into or out of a system. Heat, light mechanical motion, or electricity might all be involved in such transfers.

Content Standard E | *SCIENCE AND TECHNOLOGY*

- **Understandings About Science and Technology**
  - Scientific inquiry and technological design have similarities and differences. Scientists propose explanations for questions about the natural world, and engineers propose solutions relating to human problems, needs, and aspirations. Technological solutions are temporary; technologies exist within nature and so they cannot contravene physical or biological principles; technological solutions have side effects; and technologies cost, carry risks, and provide benefits.
  - Perfectly designed solutions do not exist. All technological solutions have trade-offs, such as safety, cost, efficiency, and appearance. Engineers often build in back-up systems to provide safety. Risk is part of living in a highly technological world. Reducing risk often results in new technology.
  - Technological designs have constraints. Some constraints are unavoidable, for example, properties of materials, or effects of weather and friction; other constraints limit choices in the design, for example, environmental protection, human safety, and aesthetics.
  - Technological solutions have intended benefits and unintended consequences. Some consequences can be predicted, others cannot.

Content Standard F | *SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES*

- **Risks and Benefits**
  - Students should understand the risks associated with natural hazards (fires, floods, tornadoes, hurricanes, earthquakes, and volcanic eruptions), with chemical hazards (pollutants in air, water, soil, and food), with biological hazards (pollen, viruses, bacterial, and parasites), social hazards (occupational safety and transportation), and with personal hazards (smoking, dieting, and drinking).

- **Science and Technology in Society**
  - Societal challenges often inspire questions for scientific research, and social priorities often influence research priorities through the availability of funding for research.
  - Technology influences society through its products and processes. Technology influences the quality of life and the ways people act and interact. Technological changes are often
  - accompanied by social, political, and economic changes that can be beneficial or detrimental to individuals and to society. Social needs, attitudes, and values influence the direction of technological development.

Correlations to National Science Education Standards: Grades 9-12

This book has been correlated to National Science Education Content Standards.
For correlations to individual state standards, visit **www.NEED.org**.

Content Standard A | *SCIENCE AS INQUIRY*

- **Abilities Necessary to Do Scientific Inquiry**
  - Identify questions and concepts that guide scientific investigations.
  - Design and conduct scientific investigations.
  - Use technology and mathematics to improve investigations and communications.
  - Formulate and revise scientific explanations and models using logic and evidence.
  - Recognize and analyze alternative explanations and models.
  - Communicate and defend a scientific argument.

Content Standard B | *PHYSICAL SCIENCE*

- **Chemical Reactions**
  - Chemical reactions occur all around us, for example in health care, cooking, cosmetics, and automobiles. Complex chemical reactions involving carbon-based molecules take place constantly in every cell in our bodies.
  - Chemical reactions may release or consume energy. Some reactions such as the burning of fossil fuels release large amounts of energy by losing heat and by emitting light. Light can initiate many chemical reactions such as photosynthesis and the evolution of urban smog.
  - A large number of important reactions involve the transfer of either electrons (oxidation/reduction reactions) or hydrogen ions (acid/base reactions) between reacting ions, molecules, or atoms. In other reactions, chemical bonds are broken by heat or light to form very reactive radicals with electrons ready to form new bonds. Radical reactions control many processes such as the presence of ozone and greenhouse gases in the atmosphere, burning and processing of fossil fuels, the formation of polymers, and explosions.
- **Motions and Forces**
  - Electricity and magnetism are two aspects of a single electromagnetic force. Moving electric charges produce magnetic forces, and moving magnets produce electric forces. These effects help students to understand electric motors and generators.
- **Conservation of Energy and the Increase in Disorder**
  - The total energy of the universe is constant. Energy can be transferred by collisions in chemical and nuclear reactions, by light waves and other radiations, and in many other ways. However, it can never be destroyed. As these transfers occur, the matter involved becomes steadily less ordered

Content Standard E | *SCIENCE AND TECHNOLOGY*

- **Understandings About Science and Technology**
  - Science and technology are pursued for different purposes. Scientific inquiry is driven by the desire to understand the natural world, and technological design is driven by the need to meet human needs and solve human problems. Technology, by its nature, has a more direct effect on society than science because its purpose is to solve human problems, help humans adapt, and fulfill human aspirations. Technological solutions may create new problems. Science, by its nature, answers questions that may or may not directly influence humans. Sometimes scientific advances challenge people's beliefs and practical explanations concerning various aspects of the world.

Content Standard F | *SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES*

- **Natural Resources**
  - The earth does not have infinite resources; increasing human consumption places severe stress on the natural processes that renew some resources, and it depletes those resources that cannot be renewed.
- **Environmental Quality**
  - Materials from human societies affect both physical and chemical cycles of the earth.
- **Science and Technology in Local, National and Global Challenges**
  - Progress in science and technology can be affected by social issues and challenges. Funding priorities for specific health problems serve as examples of ways that social issues influence science and technology.

Correlations to Kentucky Science Education Standards: Grades 7-12

This book has been correlated to Kentucky Science Education Content Standards.
For correlations to individual state standards, visit **www.NEED.org**.

Kentucky

Big Idea: Energy Transformations | *UNIFYING CONCEPTS*

- Energy transformations are inherent in almost every system in the universe.

- **Grade 7:**
  - The transfer and transformation of energy can be examined in a variety of real life examples. Models are an appropriate way to convey the abstract/invisible transfer of energy in a system.
  - Describe the transfer and/or transformations of energy which occur in examples that involve several different forms of energy

- **Grade 8**
  - Energy can be transferred in many ways, but it can neither be created nor destroyed.
  - Describe or explain energy transfer and energy conservation
  - Evaluate alternative solutions to energy problems

- **Grades 9-12**
  - The universe becomes less orderly and less organized over time. Thus, the overall effect is that the energy is spread out uniformly. For example, in the operation of mechanical systems, the useful energy output is always less than the energy input; the difference appears as heat.

Big Idea: Structure and Transformation of Matter | *PHYSICAL SCIENCE*

- A basic understanding of matter is essential to the conceptual development of other big ideas in science

- **Grades 9-12**
  - In conducting materials, electrons flow easily; whereas, in insulating materials, they can hardly flow at all. Semiconducting materials have intermediate behavior. At low temperatures, some materials become superconductors and offer no resistance to the flow of electrons.
  - Chemical reactions (e.g., acids and bases, oxidation, combustion of fuels, rusting, tarnishing) occur all around us and in every cell in our bodies. These reactions may release or absorb energy

Big Idea: Motion and Forces | *PHYSICAL SCIENCE*

- Whether observing airplanes, baseballs, planets, or people, the motion of all bodies is governed by the same basic rules.

- **Grades 9-12**
  - Electricity and magnetism are two aspects of a single electromagnetic force. Moving electric charges produce magnetic forces or "fields" and moving magnets produce electric forces or "fields". This idea underlies the operation of electric motors and generators.
  - Electric force is a universal force that exists between any two charged objects. Opposite charges attract while like charges repel.

Teacher Guide

Students learn about hybrid electric buses and evaluate the economic and environmental advantages and disadvantages of such vehicles.

Background

School buses are the safest method of transporting students to and from school. Using hybrid electric school buses allows schools to capitalize on a technology that improves emissions from buses while decreasing fuel use and maintenance costs.

Preparation

1. Review the activities and determine which ones your students will be completing. The activities are divided into three sections. It is suggested that at least one activity is completed from each section. Make copies of student worksheets as needed for those activities.
2. Contact your school district transportation manager or energy manager. Discuss the unit and any activities that would benefit from his/her participation. Request bus data and route information, if needed. Request buses to come to the school for a tour, if needed.
3. Familiarize yourself with the Kentucky Clean Fuels Coalition's web site (http://www.kentuckycleanfuels.org/resources/hybridhorsepower.htm). The web site describes Hybrid Horsepower for KY schools and allows viewers to find helpful data and compare it to other districts.
4. Make copies of the student backgrounder for each student.
5. Review the map of Kentucky hybrid bus districts, and make copies or project for students as needed during activities.

Grade Level

- Intermediate
- Secondary

Time

- Each activity has its own time requirements that range from 15 minutes to three 45-minute class periods.

Web Resources

- www.Kentuckycleanfuels.org
- www.eaton.com
  - Seach "Kentucky"
- www.thomasbus.com
- www.icbus.com

Section 1

INTRODUCTION TO ENERGY AND TRANSPORTATION

Activity 1: Transportation Survey

✪ Objectives

- To determine the various modes of transportation students use to travel to and from school.
- To collect, graph, and interpret data.

Time

- 30-60 minutes (older students will have time divided over two days)

Materials

- Chart paper or science notebooks
- Copies of student-developed questionnaire

Preparation

- Determine if your school district has policies in place that govern transportation, for example, a policy may be in place to determine how students are included in bus routes.

✔ Procedure

1. Ask students to brainstorm the various ways they can travel to and from school. Be sure they include personal vehicles, school buses, public transportation systems, and non-fuel modes of transportation such as bikes, skateboards, and walking.
2. Gather data.
3. Develop a questionnaire as a class to gather data from other students in the school. Make copies and have students distribute and gather the questionnaire data during homeroom or science class the next day.
4. Graph the data. Depending on the level of your students, you can create a class graph using chart paper or allow them to compile the data and then determine the best type of graph to present the information on their own in their science notebooks.
5. Discuss reasons why the data looks the way it does. If your school district has policies that may impact student travel, such as students that live within one mile of school are not included in bus routes, be sure to factor that into the discussion.

Extensions

1. Have students poll their parents about how they typically traveled to and from school when they were the same age as the student. Graph the data. Compare to student data. Make sure to discuss how far parents traveled to school and what determined how they got to and from school.
2. Have students create an online survey about modes of transportation used by students within their district. Graph the data and compare.

Activity 2: School Bus Cost Comparison

Objectives

- To economically compare traditional and hybrid electric school buses.
- To graph and interpret data.

Time

- 90 minutes, divided over two days

Materials

- Student backgrounder
- School bus mileage and fuel consumption data
- Copies of student worksheet (optional)

Preparation

- Contact (or have your students contact) your school district transportation manager or energy manager. Request data for traditional and hybrid electric school buses in terms of mileage traveled, fuel consumption, and fuel costs. If your school does not have that data available, you can download data from Kentucky Clean Fuels Coalition at http://www.kentuckycleanfuels.org/resources/hybridhorsepower.htm using the School Bus Data link. Current diesel prices can be found by visiting www.eia.gov/oog/info/wohdp/diesel.asp.
- Divide students into groups of three.

✔ Procedure

1. Instruct students to read the student backgrounder (or assign as homework the day before), on pages 17-19.
2. Discuss financial costs associated with transporting students safely to and from school. Examples include: length of route, fuel price, driver wages, etc. Your discussion should also ask students to think about how schools can manage their transportation costs.
3. Put the students into small groups. Give each group the raw data for buses in the district. Explain that the students will compare buses in terms of fuel cost and fuel economy, focusing on traditional versus hybrid electric school buses. Give each group time to determine how to best manipulate and represent the data. For students who struggle to organize data, a sample chart can be found on page 20.
4. Have each group prepare a report for the transportation manager about the costs associated with the fuel efficiency of the fleet. Groups should include graphs and analysis of data.

Extensions

1. If available, include maintenance costs, age of buses, and number of stops or other data in the bus comparison. Encourage students to use multiple data sets to compare traditional and hybrid electric school buses.
2. Compare data from before the school district had hybrid electric buses to after. Determine the savings to the school district.
3. Give students raw data from other school districts by visiting http://www.kentuckycleanfuels.org/resources/hybridhorsepower.htm. Have students compare your district with other districts in Kentucky. Identify reasons districts might have different savings.

Activity 3: School Bus Math

✪ Objective

- To economically compare traditional and hybrid electric school buses.

Time

- 15 minutes

Materials

- Copies of the student worksheet

Preparation

- Make one copy of the student worksheet on page 20 for each student.

✔ Procedure

1. Pass out the worksheets to each student. Circulate as needed.

Extension

1. Request fuel economy and route data from your transportation manager or energy manager to use in the word problems.

Activity 4: Payback Period

✪ Objective

- To determine the payback period of hybrid electric buses.

Time

- 20 minutes

Materials

- Copies of the student worksheet
- Calculators

Preparation

- Make one copy of the student worksheet on page 21 for each student.

✔ Procedure

1. Discuss factors that contribute to consumer decisions about vehicles (number of passengers, fuel type, maintenance costs, purpose of vehicle, etc). Include in the discussion fuel and maintenance costs, as these are major expenses for a district.
2. Explain the concept of a payback period for a more expensive but more fuel-efficient vehicle. A payback is a cost/benefit analysis. A payback occurs when you receive a return on your investment. For example, purchasing more expensive, more efficient lighting will save you money in electrical costs over time. It may save enough to pay for the cost of the lighting. The period of time it takes to see the return or savings is called the payback period.
3. Gather purchase price, fuel economy, and fuel cost information for buses in your school district. Information can also be found at www.kentuckycleanfuels.org.
4. Pass out the student worksheets. Instruct students to determine the payback period for the hybrid electric bus.

5. Discuss student results. Ask students to consider what variables change the length of the payback period. Ask students what they think a reasonable payback period might be. Ask students to explain why a person or district might consider purchasing more expensive vehicles or technologies, even if the payback were long.

Important Note

Depending on the purchase price of a hybrid bus, and whether or not grants or subsidies were utilized, your students ***may not*** find a payback period within time frame presented in the activity. This is largely because the cost of hybrid buses can be double that of traditional buses. It is important to remind students that newer technologies are usually more expensive at the start of their use, but their cost decreases over time, (for example: iPods, digital cameras, hybrid vehicles, etc.). It is also important to remind students that they should consider hidden benefits that were not calculated in the payback activity. Maintenance costs were never calculated, but play a major role in the savings for a school district. Traditional buses typically require more frequent maintenance and brake repair. If students want to enhance their activity, encourage them to contact the transportation manager or mechanic to incorporate brake repair costs and maintenance into the payback calculation.

Extensions

1. Have students input the worksheet data into a data program such as Excel and use it to create the completed payback period chart.
2. Have students visit www.fueleconomy.gov to determine payback periods for other hybrid electric vehicles. While at the site, students can also compare environmental aspects of driving the vehicles.
3. Have students research brake replacement costs and frequency of replacement for each type of bus. Have them factor this into the payback period. Students can use their own research to find the replacement period, or you can provide them with the following example:
   - hybrid bus brake replacement/reline—every 3 to 6 years
   - traditional bus brake replacement/reline every 1 to 2 years

Activity 5: Cost of Personal Transportation

Objective

- To determine the financial cost of driving a vehicle versus riding the bus to school.

Time

- 40 minutes, divided over two days

Materials

- Copies of the student worksheet

Preparation

- Make one copy of the student worksheet on page 22 for each student.

✔ Procedure

1. Review results of the survey completed in *Activity 1*. Discuss how many students ride the bus to school and compare with those that are driven or drive themselves to school in a vehicle. Discuss reasons students choose to ride the bus or drive. Include any school district policies that may impact student choices about travel to and from school. For example, in some districts, students that live within one mile of school are not included in bus routes.
2. Have students consider the financial cost of driving to school. Ask students that drive or are driven to give estimates of how much it costs each week to drive to and from school.
3. Pass out the student worksheet and instruct students to complete it for homework.
4. Compare class results from the worksheet. Sum what the class could save each year by riding the bus instead of driving to school.
5. Discuss nonfinancial savings of riding the bus. Include vehicle emissions and student safety.

Extension

1. Download the intermediate activity *Calculating Fuel Economy* or the secondary activity *Analyzing Fuel Economy* from www.NEED.org/newsletters using the September 2008 link under *Energy Exchange*.
2. Have students discuss their environmental footprint and how getting to and from school could be involved with making a bigger or smaller impact on the environment.

Activity 6: School Bus Routes

Objectives

- To determine the best route for which to use a hybrid electric bus.
- To analyze multiple variables to determine a solution.

Time

- 135 minutes, divided over three days

Materials

- Copies of school bus route information
- Maps of the area for the bus routes
- Copies of the student worksheet

Preparation

- Ask your transportation manager or energy manager to speak to your class about the school bus fleet and how bus routes are created. Invite him or her back to your class to hear presentations.
- If not available online, contact your school secretary or transportation manager to acquire bus routes for your school.
- Secure enough maps for each group to have one.
- Divide students into groups of three.
- Make one copy of the student worksheet on page 23 for each student.

✔ Procedure

1. Have your transportation manager or energy manager speak to the students. Be sure he/she is prepared to talk about what variables are considered when creating a bus route, how long a bus is typically kept in service, and what process is used to find replacement buses. Allow time for students to ask questions.
2. Put students into their groups. Pass out the worksheet and explain to the students a scenario in which your school district has purchased one hybrid electric bus and must now determine how best to use that bus. Explain that they will be presenting their plan in groups to the transportation manager. Explain your presentation expectations.
3. Allow students time to work in their groups.
4. Have each group present their plan to the class and the transportation manager. Encourage feedback from both the class and the manager.

Extension

1. Have students calculate the fuel savings for the year for their chosen bus route if the hybrid bus were utilized instead of a traditional bus.
2. Have students consider how the terrain of the route could also impact the design of a route and efficiency of a bus. Encourage them to research the changes in topography of different areas and view the map (if needed) of where districts are located.

Activity 7: Using Hybrid Bus Data

✪ Objectives

- To analyze and interpret data.
- To determine the factors that might influence the benefits of using a hybrid bus.

Time

- 1 class period

Materials

- Student activity page
- Calculator
- Internet access
- Kentucky Hybrid Bus Districts Map

Preparation

- Make a copy of the student worksheet on page 24 for each student
- Project or make copies of the *Kentucky Hybrid Bus Districts Map* on page 16
- Divide students into groups if desired

✔ Procedure

1. If you have not already done so, use the student backgrounder on pages 17-19 to help students understand hybrid school buses.
2. Distribute activity page to students. Explain the activity.
3. Have students calculate the mileage improvement for each bus listed.
4. Direct students to compute the average mileage improvement for each district.
5. Use the map of Kentucky to locate each district.

Extension

Go to the Kentucky Clean Fuel Coalition web site (www.Kentuckycleanfuels.org) and click on the school bus under "Quick Links". Choose "Performance Data" then click on "View the Performance Data". This will open a spreadsheet that lists all of the hybrid school bus data for Kentucky. Have students choose more districts to study from around the state and compare the data listed from each of those districts. Encourage students to look at the trends they saw originally and discuss if they continued to see the same trends when studying the other district's data.

Section 3

EDUCATING OTHERS ABOUT HYBRID ELECTRIC SCHOOL BUSES

Activity 8: Teaching Others About Hybrid Electric School Buses

✪ Objectives

- To share information about hybrid electric buses with others.
- To incorporate new vocabulary.

Time

- 60-135 minutes, divided over two to three days

Materials

- Student backgrounder
- Copies of the student worksheet

Preparation

- Make a copy of the student worksheet on page 25 for each student.
- Students should be divided into groups and project activities should be predetermined (or allow student groups to choose).

✔ Procedure

1. Pass out the student worksheet. Review and discuss with students new and important vocabulary they have learned during the course of the unit. Ensure students have the correct understanding of each word. Make a class list of words to include in the project. Idea: create a "word wall" as you go to highlight and keep track of important vocabulary.
2. Explain that students will create a public service announcement, brochure, news segment, or multimedia presentation about hybrid electric buses in their school district. Remind students to appropriately use vocabulary. Students may use the bottom of the worksheet to organize information they plan to include in their project.
3. Allow students time to work on their project.
4. Have each student read his/her letter or each group present its project to the class.

Extensions

1. Have students take their letters home and discuss with their parents.
2. Have students create a display to show what they have learned. Display the projects at parent or community events like a science fair or parents night.
3. Have groups submit their PSA, news segment, or multimedia presentation to the local cable channel.

Evaluation

Evaluate individual student performance using student worksheets and science notebooks.

Evaluate the entire unit with your students using the *Evaluation Form* on page 27 and fax to The NEED Project at 800-847-1820 or mail to The NEED Project, P.O. Box 10101, Manassas, VA 20108.

Answer Keys

Intermediate School Bus Math

1. 288 gallons (287.8 gallons)
2. Answers will vary, but students should choose either Route B or Route C.

Payback Period

Answers will vary based on the data used by your district or the data obtained from www.kentuckycleanfuels.org. A sample answer key is provided with basic numbers to use if you do not have access to all data.

Payback Period

SAMPLE ANSWER KEY

Question

- What is the payback period for a more fuel-efficient but more expensive vehicle?
- You are purchasing a new school bus for your district. You still need to decide if you are going to purchase a traditional diesel engine bus or a hybrid electric version. Use the information below to determine the payback period for the hybrid vehicle.

	Hybrid Electric Bus	Traditional Diesel Bus
MSRP	$110,000	$60,000
Average MPG	9.3	6.5
Miles Per Year	8,000	8,000
Current Fuel Cost (Per Gallon)	$4.00	$4.00

Prediction

- Based on the information above, predict how long the payback period of the hybrid vehicle will be.

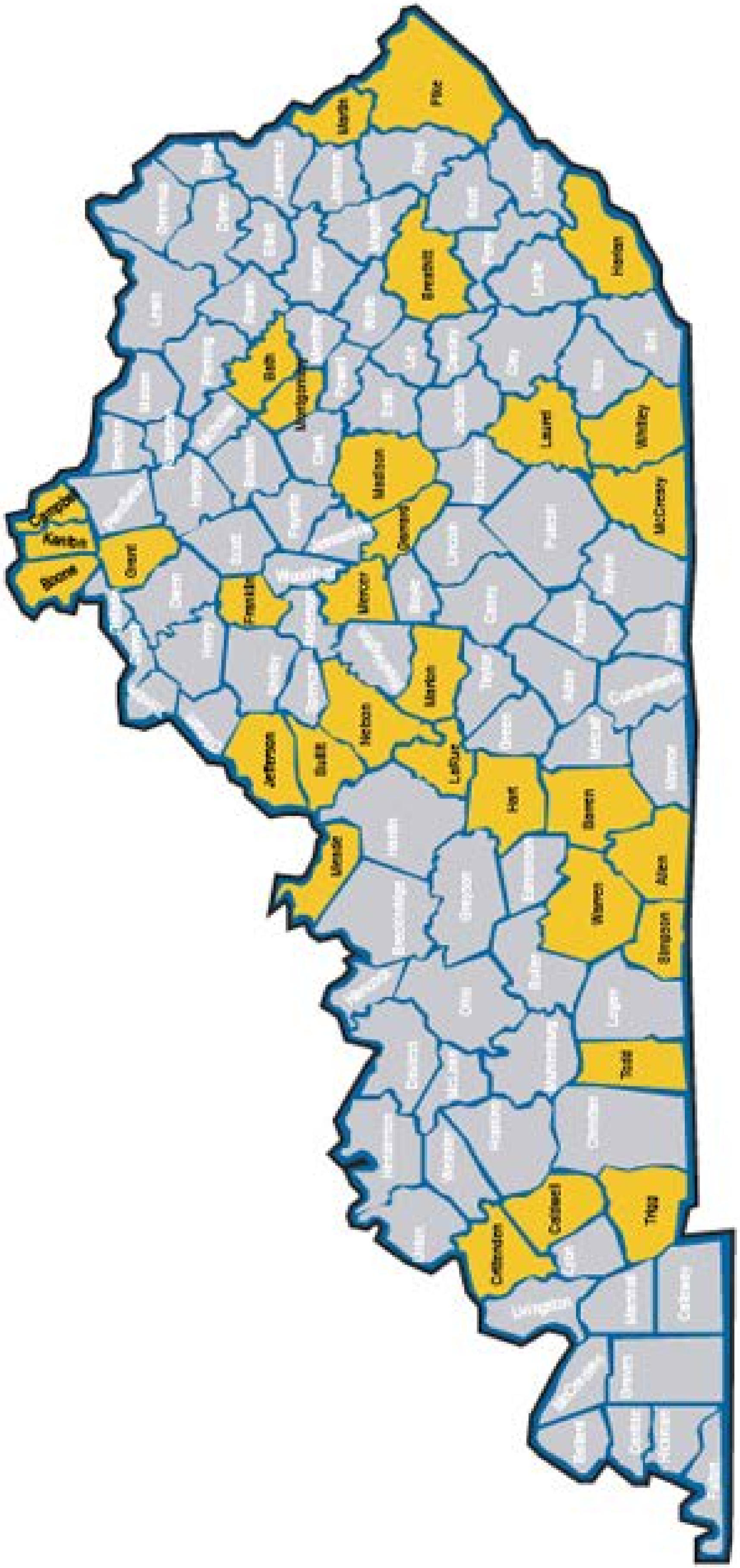
Data Manipulation

	Hybrid Electric Bus		Traditional Diesel Bus	
	Expenses	**Cost to Date**	**Expenses**	**Cost to Date**
Purchase Price	$110,000	$113,441	$60,000	$60,000
Year 1	$3,441	$116,882	$4,923	$64,923
Year 2	$3,441	$120,323	$4,923	$69,846
Year 3	$3,441	$123,764	$4,923	$74,769
Year 4	$3,441	$127,205	$4,923	$79,692
Year 5	$3,441	$130,646	$4,923	$84,615
Year 6	$3,441	$134,087	$4,923	$89,538
Year 7	$3,441	$137,528	$4,923	$94,461
Year 8	$3,441	$140,969	$4,923	$99,384
Year 9	$3,441	$144,410	$4,923	$104,307
Year 10	$3,441	$147,851	$4,923	$109,230
Year 11	$3,441	$151,292	$4,923	$114,153
Year 12	$3,441	$154,733	$4,923	$119,076
Year 13	$3,441	$158,174	$4,923	$123,999
Year 14	$3,441	$161,615	$4,923	$128,922

Conclusions

1. What is the payback period for the hybrid bus?
2. Why is the payback period so long? Is the amount of time reasonable in your opinion? Explain your answers.
3. What variable(s) would need to change to make the payback period a smaller amount of time?
4. How much does fuel economy really contribute to the payback period?
5. Brakes are not "touched" as frequently in hybrid models. How might maintenance costs differ due to this factor? Is this an advantage or disadvantage of hybrids?
6. Would brake repair and maintenance impact the payback period calculation? Explain your answer.
7. What other factors besides overall cost might influence a district's decision to purchase or not purchase a hybrid bus?

Kentucky Hybrid Bus Districts Map



Student Backgrounder

History of Buses

The idea of students sharing a ride to school has been around for a long time. In the late 1800s states started passing laws that provided for student transportation. At first school buses weren't buses, they were horse drawn wagons. Then, as cars and trucks became more common, a school truck often picked up students along a route and brought them to school. The kind of vehicle that transported students to and from school often depended on the geography of the community and the resources available.

In 1939 a group of transportation officials, automotive manufacturers, and paint companies gathered together and created a set of standards for what a school bus should look like. Ever since that time, school buses have been painted the now-familiar yellow and black. Today, there are 1,970,100 school buses transporting 26 million students to and from school each day. It is a very safe and reliable way for students to get to school each day.

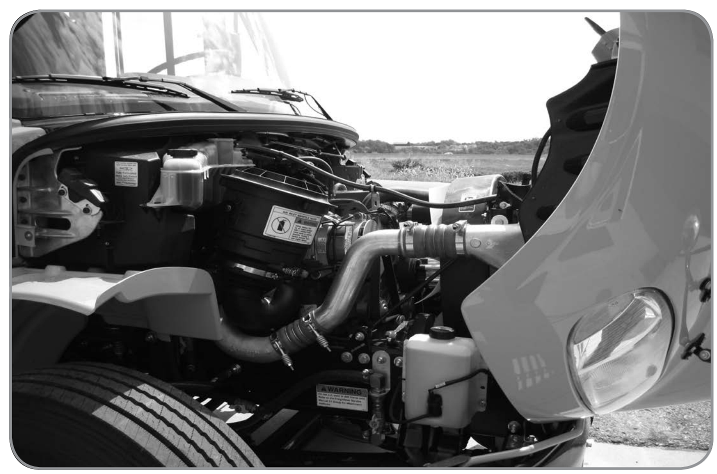
Every year, one bus travels an average of 5,000 miles. Most school buses use **diesel fuel** and, because they are large and heavy, the average fuel consumption is 6.5 miles per gallon. This adds up to more than 1,500 million gallons of diesel fuel being consumed by school buses across the U.S. each year. Diesel fuel is a **petroleum** product that must be burned to produce energy. The U.S. imports nearly half of the petroleum we use to power our vehicles, like buses. As with other fossil fuels that must be burned, diesel fuel does contribute to air pollution.

Costs of Busing

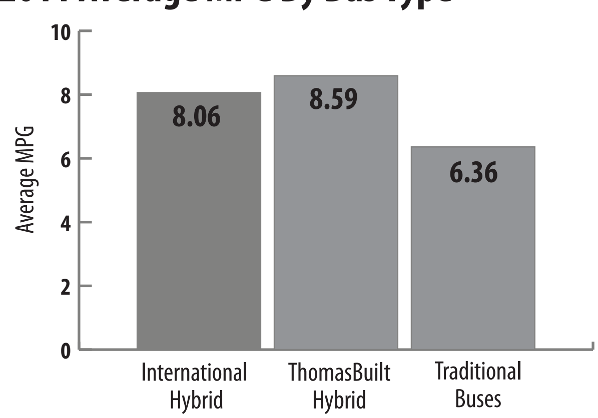
Fuel costs are a large part of a school district's transportation budget. Some factors that can influence a transportation budget include: size of vehicles, age of vehicles, how long they spend idling, number of bus routes, length of bus routes, number of stops on a route, and district geography and terrain. Many districts have implemented fuel saving measures, such as having buses turn off their engines while loading and unloading students at school. In many areas older school buses are being **retrofitted** with new technologies that will make them cleaner, or are replacing older buses with new ones. Besides the newer, cleaner-burning technology, school bus manufacturers are also producing hybrid models.

STUDENTS WITH THE BUS

HYBRID BUS ENGINE



2011 Average MPG By Bus Type



Data: Kentucky Clean Fuels Coalition

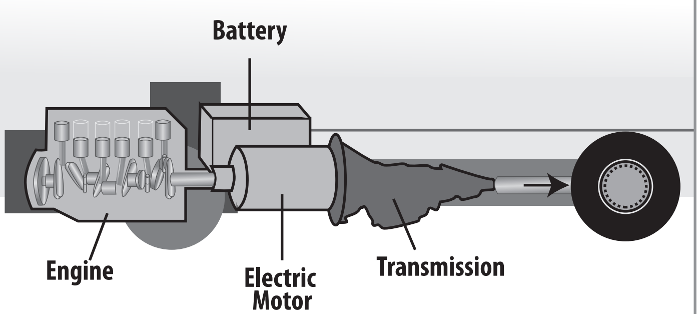
Internal Combustion Engines

Traditional vehicles, like buses, work with the help of an **internal combustion engine**. These engines allow fuel, such as diesel, into a chamber. The pressure in the chamber is increased and the fuel reaches its flash point, causing it to ignite or explode. The energy in the fuel is released as it is burned and an expanding gas is released. This gas pushes on moving parts in the engine called pistons. Those moving pistons connect to a series of other moving parts that eventually allow the wheels on the vehicle to turn. Internal combustion engines take the chemical energy stored in the molecules of a fuel and turn it into useful motion energy.

Developments in new engine technologies and pollution control devices have made new school buses 60 times cleaner than those built before 1990. Significant progress has been made in reducing **emissions** from diesel engines. With new clean diesel technologies, today's buses are eight times cleaner than those built just a dozen years ago. As of 2010, new buses have near zero emission levels. **Ultra-low sulfur diesel** (ULSD) fuel is highly refined for clean, complete combustion and low emissions, enabling the use of emission treatment systems. In 2006 the EPA lowered the legal limit of sulfur in diesel from 500 parts per million (ppm) to 15 ppm. Today, refiners reduce the sulfur content in diesel fuel by 97 percent. This new, ultra-clean fuel is important because sulfur tends to hamper emission control devices in diesel engines, like lead once impeded the catalytic converters on gasoline cars. Removing the sulfur from diesel has helped usher in a new generation of clean diesel technology.

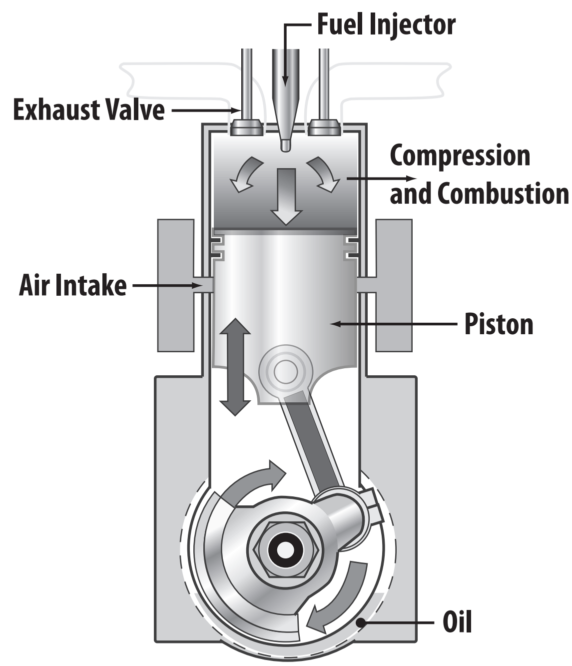
Advanced technologies such as electronic controls, high-pressure fuel injection, variable injection timing, improved combustion chamber configuration, and turbo-charging have made diesel engines cleaner, quieter, and more powerful. Using low sulfur diesel fuel and **exhaust control systems** such as particulate traps and diesel specific catalytic converters can reduce particulate emissions by up to 90 percent and **nitrogen oxide** (NOx) by 25-50 percent.

Parallel Hybrid

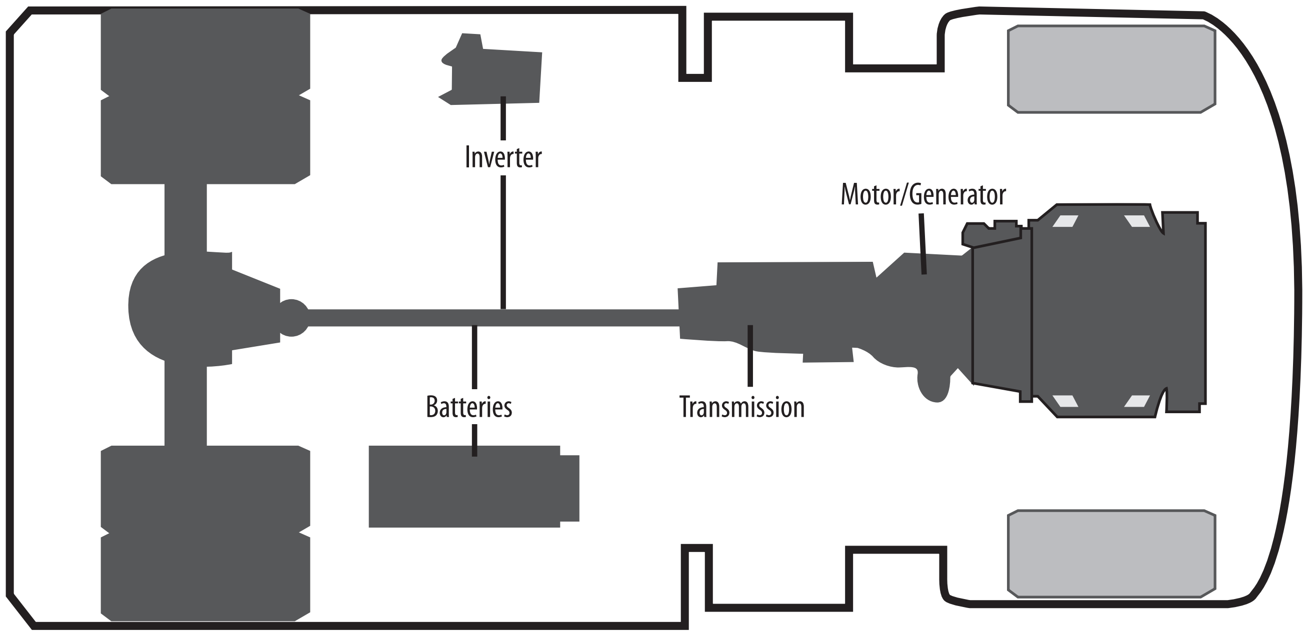


HYBRID ELECTRIC BUS

Internal Combustion Engine, Diesel



Electric Only Mode



Hybrid Electric Buses

Hybrid electric vehicles are powered by an internal combustion engine and an electric motor that uses energy stored in a battery. The electric motor is turned by the wheels of the vehicle and acts as a generator. This allows the motion energy to be stored in the battery to be used later, by way of an inverter. The energy in the battery provides extra power to the engine, so the engine can be smaller. Hybrid vehicles have better fuel economy due to this set-up and release fewer emissions than their traditional counterparts.

Hybrid school buses are similar to hybrid cars. In a parallel hybrid design the buses use a traditional diesel engine and an electric motor/generator to power the vehicle. On a hybrid school bus the electric motor is used to start the engine, assists in launching the bus into motion, and helps with acceleration. While the bus is moving down the road, the electric motor provides power to the **drivetrain,** which makes the engine run more efficiently. As the bus uses the energy from the motor, the combustion engine can be smaller than other conventional buses. The battery is recharged through **regenerative braking**, while the bus is coasting, in idle, or while the brake is being pressed. Hybrid buses are most efficient on routes where there are many stops.

Advantages and Disadvantages

The features of the engine enable hybrid buses to increase fuel mileage and run cleaner than their diesel engine counterparts. Hybrid buses emit 22 fewer pounds of **CO_2** per gallon of diesel. This is a good thing for the school community, as students and drivers are, as a result, exposed to less harmful emissions. On average, a hybrid bus saves 600 gallons of diesel each year. Hybrid buses can be expensive at first, and require extra training for maintenance workers, drivers, and first responders. If a battery needs to be replaced, it can also be costly and require special disposal. Despite the battery replacement, there are generally fewer maintenance costs, and hybrid buses are quieter than diesel-only buses. Brakes, for example, last 20-30% longer in a hybrid electric bus due to the regenerative braking system. As often as a bus uses its brakes, this can mean that brake pads are replaced far less frequently than with conventional buses.

Be on the lookout for more hybrid school buses on the road to be safely transporting students to and from school.

School Bus Cost Comparison

	Hybrid	Conventional
Number of Buses		
Average Fuel Efficiency		
Average Distance Traveled		
Fuel Used		
Fuel Price		

School Bus Math

1. Campbell City Schools use both a traditional and a hybrid electric school bus. The buses travel an average of 1,325 miles each month. The traditional school bus has a fuel economy of 6.5 miles per gallon. The hybrid electric bus has a fuel economy of 8.5 miles per gallon. How much more diesel is used in six months by the traditional bus?

2. Jefferson School District purchased one hybrid electric school bus. Which bus route would you recommend they put the bus on and why?
   a. Route A takes 40 minutes to drive 15 miles with 13 stops.
   b. Route B takes 80 minutes to drive 41 miles with 24 stops.
   c. Route C takes 95 minutes to drive 52 miles with eight stops.

Payback Period

Question

- What is the payback period for a more fuel-efficient but more expensive vehicle?
- You are purchasing a new school bus for your district. You still need to decide if you are going to purchase a traditional diesel engine bus or a hybrid electric version. Use the information below to determine the payback period for the hybrid vehicle.

	Hybrid Electric Bus	Traditional Diesel Bus
MSRP		
Average MPG		
Miles Per Year	8,000	8,000
Current Fuel Cost (Per Gallon)		

Prediction

- Based on the information above, predict how long the payback period of the hybrid vehicle will be.

Data Manipulation

	Hybrid Electric Bus		Traditional Diesel Bus	
	Expenses	Cost to Date	Expenses	Cost to Date
Purchase Price				
Year 1				
Year 2				
Year 3				
Year 4				
Year 5				
Year 6				
Year 7				
Year 8				
Year 9				
Year 10				
Year 11				
Year 12				
Year 13				
Year 14				

Conclusions

1. What is the payback period for the hybrid bus?
2. Why is the payback period so long? Is the amount of time reasonable in your opinion? Explain your answers.
3. What variable(s) would need to change to make the payback period a smaller amount of time?
4. How much does fuel economy really contribute to the payback period?
5. Brakes are not "touched" as frequently in hybrid models. How might maintenance costs differ due to this factor? Is this an advantage or disadvantage of hybrids?
6. Would brake repair and maintenance impact the payback period calculation? Explain your answer.
7. What other factors besides overall cost might influence a district's decision to purchase or not purchase a hybrid bus?

Cost of Personal Transportation

Question

- What is the financial cost of driving to and from school instead of riding the bus?

Prediction

- Make a prediction as to how much it costs each month to drive to and from school.

Materials

- Map
- Vehicle odometer or internet-based mapping program

Procedure

1. Using a map, vehicle odometer, or internet-based mapping program, determine the distance from your home to the school.
2. Gather data for the current cost of fuel needed by the vehicle you use most to travel to and from school. If you currently ride the bus to school, gather data for the vehicle you would most likely use.
3. Determine the cost of fuel for your vehicle for one month of round trips to school.
4. Compare class data.

Data

Create a data table for your information.

Conclusions

1. How accurate was your prediction?
2. Will you change your travel decisions knowing the financial cost of driving to school instead of riding the bus? Why or why not?
3. What other factors besides finances should be included in a decision to drive or ride the bus to and from school?

School Bus Routes

Question

- What is the most effective use of a hybrid electric school bus?
- Your school district has purchased a new hybrid electric school bus. Now a plan must be put in place to best utilize the bus and its fuel-saving features. As a group, determine the best bus route for the hybrid bus. Prepare three reasons to justify your plan.

Materials

- Map
- School bus routes

Procedure

1. Brainstorm factors that influence the fuel economy of a hybrid electric school bus. Decide which factors you believe are most critical.
2. Review the current bus routes using the schedules and a map.
3. Using your critical factors, compare bus routes and determine which is the best choice to use the hybrid electric bus.
4. Prepare a three to five-minute presentation about your plan. Include visual aides and three reasons to support your plan.

Critical Factors

Reasons for Plan

Conclusions

1. Which factors influenced your choice of a bus route?
2. Did all groups choose the same route? If not, which factors influenced the decisions of the groups?
3. How might hidden factors like topography and individual driver behaviors impact route decisions and cost effectiveness?

Using Hybrid Bus Data

Questions

- How can using a parallel hybrid drive system on a school bus help a district save money and be more environmentally friendly?
- What factors might influence or enhance the benefits of using hybrid school buses?
- This activity uses data available online to compare districts and see which are realizing the greatest benefit by using hybrid buses. Which districts will benefit most from using hybrid school buses?

Materials

- Kentucky Hybrid Bus Districts Map
- Calculator
- Internet access

✔ Procedure

1. Look at the data table below that shows the fuel mileage for several buses from different school districts across Kentucky.
2. Calculate the mileage improvement for each bus shown.
3. Using your calculator, find the average mileage improvement of all buses in each district.
4. Locate each school district on the map of Kentucky. Write the district's average mileage improvement on the map beside the district name.

Data

School District	Bus Number	Baseline Mileage	Hybrid Average Mileage April 2012	Mileage Improvement	Average Mileage Improvement (District)
Breathitt	30	5.80	8.8		
	1060	6.20	9.2		
	1336	6.50	9.5		
Caldwell	1184	8.70	7.8		
Campbell	53	6.10	9.0		
Crittenden	111	7.00	7.7		
Jefferson	1137	5.97	8.0		
	1152	5.97	8.3		
	1125	5.97	9.2		
Martin	1001	7.00	9.3		
Pike	396	6.30	9.4		
	422	6.30	8.7		
	438	6.30	9.0		
Todd	310	7.80	9.9		
Warren	1101	7.40	7.7		
	1103	6.90	7.1		
	1104	7.20	7.7		

Study the map and averages you wrote into the table. Look for any trends.

Conclusions

1. Which district had the best average mileage improvement of its hybrid school buses? How much, on average, did using a hybrid system improve the fuel mileage for that district?
2. Look at your map. Are there any regional differences suggested by your calculations? If so, what are they? What connection, if any, might there be between region and mileage improvement?

Teaching Others About Hybrid Electric School Buses

List the vocabulary to be included in your project.

Organize the important information you would like to present.

	Hybrid Electric School Buses	

Glossary

carbon dioxide (CO_2)	product of combustion, a greenhouse gas
diesel fuel	a petroleum product used in diesel engines
drivetrain	an assembly of parts in a motor vehicle that generates power and motion
emissions	gaseous products of combustion, some are pollutants
exhaust control system	a device that regulates the amount of exhaust gas produced by controlling the temperature in the chamber and lowering (NO_x) formation
hybrid electric vehicle (HEV)	a vehicle that is powered by 2 or more fuels, one of which is electricity
idling	when an engine is running but is not in motion. An idling vehicle still emits pollution and uses fuel.
internal combustion engine (ICE)	an engine in which a fuel is burned within the chamber, creating motion
nitrogen oxides (NO_x)	regulated air pollutants, primarily NO and NO_2, which contribute to smog and acid rain
petroleum	a fossil fuel that can be refined to produce many products, including gasoline, diesel, and plastics
regenerative braking	converts wasted energy from braking into electricity that can then be stored in a battery
retrofitting	the process of updating technology or parts on a used vehicle, often to comply with regulations, standards, or more efficient technologies
ultra-low sulfur diesel (ULSD)	a highly refined form of diesel fuel that is cleaner burning with lower sulfur content and emissions

Exploring Hybrid Buses Evaluation Form

State: ____________ **Grade Level:** ____________ **Number of Students:** ___________

1. **Did you conduct the entire unit?**	❑ Yes	❑ No
2. **Were the instructions clear and easy to follow?**	❑ Yes	❑ No
3. **Did the activities meet your academic objectives?**	❑ Yes	❑ No
4. **Were the activities age appropriate?**	❑ Yes	❑ No
5. **Were the allotted times sufficient to conduct the activities?**	❑ Yes	❑ No
6. **Were the activities easy to use?**	❑ Yes	❑ No
7. **Was the preparation required acceptable for the activities?**	❑ Yes	❑ No
8. **Were the students interested and motivated?**	❑ Yes	❑ No
9. **Was the energy knowledge content age appropriate?**	❑ Yes	❑ No
10. **Would you teach this unit again?**	❑ Yes	❑ No

Please explain any 'no' statement below.

How would you rate the unit overall?	❑ excellent	❑ good	❑ fair	❑ poor
How would your students rate the unit overall?	❑ excellent	❑ good	❑ fair	❑ poor

What would make the unit more useful to you?

Other Comments:

Please fax or mail to: **The NEED Project**
P.O. Box 10101
Manassas, VA 20108
FAX: 1-800-847-1820

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- Michigan Oil and Gas Producers Education Foundation
- Miller Energy
- Mississippi Development Authority–Energy Division
- Montana Energy Education Council
- NADA Scientific
- NASA
- National Association of State Energy Officials
- National Fuel
- National Grid
- National Hydropower Association
- National Ocean Industries Association
- National Renewable Energy Laboratory
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- New Mexico Landman's Association
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- Offshore Technology Conference
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