Cars of Tomorrow and the American Community

High School Curriculum

Created by Northeast Sustainable Energy Association (NESEA)

Click on the links below to take you to the Chapter heading:

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CARS OF TOMORROW AND THE AMERICAN COMMUNITY

NESEA

Northeast Sustainable Energy Association

50 Miles Street, Suite 3, Greenfield, MA 01301

www.nesea.org

June, 2002

L E A D I N G   T H E   W A Y   T O   S U S T A I N A B L E   E N E R G Y

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NESEA
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The Northeast Sustainable Energy Association (NESEA) is the nation's leading regional membership organization focused on promoting the understanding, development, and adoption of energy conservation and non-polluting, renewable energy technologies. NESEA's Education Program engages students in thinking critically about clean electricity, green transportation, and healthy, efficient buildings in order to produce citizens who are able to care for the environment, protect human health, and nurture local economies. NESEA has worked successfully for more than a quarter century in the fields of transportation, building construction, and renewable energy.

CONTENTS

INTRODUCTION TO THE PROJECT

In *Cars of Tomorrow and the American Community,* Northeast Sustainable Energy Association's (NESEA's) high school curriculum, students investigate the impact of present-day transportation on their communities and explore the possible effects on the community of a shift to alternative-fueled vehicles. The unit provides guidelines for a typical class to research nine fuels in three major topic areas:

- **Availability and Distribution** (for example, fuel sources, production, security)
- **Health, Pollution, and Safety** (for example, air quality, global warming, public health and safety)
- **Operation, Maintenance, and Refueling** (for example, automotive technology, community planning, usability for consumers).

Cars of Tomorrow develops problem-solving, creative-thinking, and decision-making skills through approximately 35 hours of activities that involve teamwork, research, presentations, and debates. The activities can be combined in various ways, as described in the Unit Planning section below.

UNIT ORGANIZATION

GETTING ORIENTED

Cars of Tomorrow begins with an activity that helps students identify the energy and transportation issues important to them and their communities, and then introduces them to the research activities.

STUDENT RESEARCH AND EVALUATION OF FUELS

Cars of Tomorrow presents three research sections that address the three major fuel and transportation topics listed above. Each research section includes a background reading, presents related concerns of a wide variety of stakeholders, and contains reference materials and guidelines for two kinds of research activities.

1) The first research activity allows the class to investigate their community or region in order to develop a real-life context for their fuel research.

2) In the second activity, teams of students investigate the topic issues as they relate to one or more fuels. As the class experts, fuel teams present their findings to their classmates, who then evaluate the fuels in one of two ways:

- Individual students are assigned a stakeholder or interest group to represent. They listen to the presentations and compare and evaluate the fuels from that perspective.
- Evaluation panels of students are formed and assigned a stakeholder or interest group to represent. (We suggest that each evaluation panel consist of experts on several different fuels.) As a panel, students listen to the presentations and compare and evaluate the fuels from that perspective.

Once all the information has been presented, a final student debate may be needed to determine which fuel or combination of fuels would best serve their community.

PUBLIC PRESENTATION

In the final section of *Cars of Tomorrow,* students make a presentation to the community that describes the broad impact of the fuel or fuels and the adjustments that need to be made in the community to accommodate them.

The type of presentation should be tailored to your own community and the resources available to you and your students. It may take the form of a flip chart or poster presentation shown to parents at a library or a more ambitious video or PowerPoint presentation for a public Earth Day event.

EVALUATION

A suggested evaluation guide, "EVALUATING TEAM REPORTS AND PRESENTATIONS," is included on page 64. It addresses report content, community and global connections made, oral presentations, written report, and teamwork. Teachers are encouraged to adjust this evaluation tool to fit the needs of their own classes and curricula.

ABOUT THE FUELS

Nine fuels are recommended for research in this unit. For each fuel, a fact sheet provides basic information; a resource guide provides resources for additional research. The fuels were selected from lists of clean and alternative fuels recognized by the Clean Air Act Amendments of 1990 (CAAA) and the Energy Policy Act of 1992 (EPACT). (For more information, see the Background Reading for the Teacher.) In selecting the fuels, consideration was given to those fuels with the most readily available information (particularly on the Internet), to creating equitable research projects for fuel teams, and to ensuring a balance of fuels for internal combustion engines and power sources for electric motors.
The recommended fuels are:

Internal combustion engines
- biodiesel
- ethanol/E85
- liquefied petroleum gas (LPG)
- methanol/M85
- natural gas: compressed (CNG) and liquefied (LNG)

Electric motors
- battery
- fuel cell (hydrogen*)
- solar/photovoltaic cells

Others
- hybrid electric

** Hydrogen's most promising role in the near future is as an energy carrier for fuel cell/electric vehicles.*

UNIT PLANNING

Allow two days for Getting Oriented.

Allotted time for student research and class presentations is provided below:

	Availability and Distribution	Health, Pollution, and Safety	Operation, Maintenance, and Refueling
Presenting the problem (class)	1 day	1 day	1 day
Community research (class)	1 day	1 day	1 day
Fuel research (by fuel teams)	4 days	4 days	4 days
Presentations (by fuel teams) and comparison and evaluation of fuels (by evaluation panels)	4 days	4 days	4 days

Note: The unit is designed to be flexible, so that teachers can adapt the unit to fit the size of their class, the interests of their students, and the needs of their curricula. For example:

- Each research section can stand on its own. Teachers primarily interested in fuel security (Availability and Distribution), pollution and global warming (Health, Pollution, and Safety), or automotive technology (Operation, Maintenance, and Refueling) can focus research on one of those topics in a two-week unit.

- For teachers and students who have a special interest in one topic and only a few fuels, student research time may be reduced slightly and the class presentation time reduced greatly to form a six-day unit.

- The research questions presented in this unit may be applied to additional fuels. If you have a special interest in fuels or power sources that are not listed here (such as naptha or P-series), students may easily use the research guidelines to investigate them.

Allow three to five days to prepare for and give a public presentation.

ABOUT CLASS SPEAKERS

Although class speakers are not an essential part of this unit, environment, automotive, and fuel experts can provide strong connections to activities in the real world. If invited to the class or public presentations, they can also provide valuable insights into the issues and feedback about your students' conclusions. Suggestions for possible speakers are included at the beginning of each topic section.

MEETING STANDARDS FOR LEARNING

This unit supports these teaching/learning standards:

TECHNOLOGY CONTENT STANDARDS
International Technology Education Association (ITEA)

Students will develop:
Standard 4: an understanding of the cultural, social, economic, and political effects of technology.

Standard 5: an understanding of the effects of technology on the environment.

Standard 6: an understanding of the role of society in the development and use of technology.

Standard 7: an understanding of the influence of technology on history.

Standard 10: an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Standard 13: abilities to assess the impact of products and systems.

Standard 16: an understanding of and be able to select and use energy and power technologies.

CURRICULUM STANDARDS FOR SOCIAL STUDIES
National Council for Social Studies

Strand III g: People, Places, & Environment: Describe and compare how people create places that reflect culture, human needs, government policy, and current values and ideals as they design and build specialized buildings, neighborhoods, shopping centers, urban centers, industrial parks, and the like.

Strand VIII f: Science, Technology, & Society: Formulate strategies and develop policies for influencing public discussions associated with technology-society issues, such as the greenhouse effect.

Strand X c and d: Global Connections: Analyze and evaluate the effects of changing technologies on the global community. Analyze the causes, consequences, and possible solutions for persistent, contemporary, and emerging global issues, such as health, security, resource allocation, economic development, and environmental quality.

NATIONAL EDUCATION TECHNOLOGY STANDARDS FOR STUDENTS (GRADES 9–12)
International Society for Technology Education (ISTE)

1. Identify capabilities and limitations of contemporary and emerging technology resources and assess the potential of these systems and services to address personal, lifelong learning, and workplace needs.

3. Analyze advantages and disadvantages of widespread use and reliance on technology in the workplace and in society as a whole.

7. Routinely and efficiently use on-line information resources to meet needs for collaboration, research, publications, communications, and productivity.

SCANS FOUNDATION SKILLS AND WORKPLACE COMPETENCIES
Secretary's Commission on Achieving Necessary Skills

Basic skills: Reading, writing, listening, speaking.

Thinking skills: Creative thinking, decision making, problem solving, seeing things in the mind's eye, knowing how to learn, reasoning.

Works with others: Participates as member of a team, exercises leadership, negotiates.

Acquires and uses information: Acquires and evaluates, organizes and maintains, interprets and communicates information.

Understands complex interrelationships: Understands and improves or designs systems.

BACKGROUND READING FOR THE TEACHER

GASOLINE-POWERED ENGINES: TIME FOR A CHANGE

In most areas of the United States we depend on gasoline-powered, privately owned automobiles to get us where we want to go. Private cars have been part of the American lifestyle since they became affordable for the American family in the 1920s and replaced hay-powered horses as a way to move around. With the growing number of vehicles and the increasing number of miles we drive, the horseless carriage has created a wealth of problems that weren't imagined when cars first became an essential part of American life.

Population is increasing annually at home and abroad. Energy requirements are increasing even faster as standards of living rise throughout the world. Although the United States owns only two to three percent of the world's proven oil resources, it consumes 25 percent of the world's annual oil production. The global demand for oil has risen and created international tensions and even war between oil-exporting and oil-importing countries. Excessive amounts of carbon dioxide, produced when gasoline burns, are building up in the atmosphere and contributing to global warming and climate change. Rates of lung problems among young children and the elderly have risen, with fingers pointing to the emissions from automobile tailpipes. Despite the improvements in automotive technology that have made individual cars more efficient and less polluting, some problems continue to grow as more people drive more miles each year.

A MAJOR CHALLENGE FOR THE COUNTRY

There is no single solution to the challenge facing us. The various approaches generally fall into one or more of these three major categories:

- **Improving fuel efficiency and emissions controls**
  Designing more fuel-efficient and less polluting gasoline-powered vehicles, choosing to buy and use smaller and/or more fuel-efficient cars, and making good use of efficient technologies by keeping cars well maintained and driving them conscientiously.
- **Reducing the number of cars or miles driven**
  Reducing the number of miles driven per person by using alternative forms of transportation (mass transit, bicycling, walking), carpooling, combining multiple errands into single trips, and telecommuting.
- **Using alternative fuels**
  Developing and using alternative-fueled vehicles.

While meeting this challenge will require a combination of the three approaches, this unit focuses on the third—the adoption of alternative fuels—and issues related to it. Research and development of new fuels, power systems, and vehicles is very costly. Making informed decisions about the positive and negative impacts of alternative fuels is important if we are to avoid environmental, health, security, economic, and infrastructure problems that may arise with an alternative fuel.

In fact, the change to alternatives has been under way for many years. It now involves automotive engineers, automobile manufacturers, fuel companies, environmental policy makers, mechanics, city planners, and people in many other professions and roles. These groups have taken the following steps:

- Driven by the desire to make our sources of energy more secure, the federal government has encouraged fuel industries to develop domestic sources of power— that is, power that comes from fuel obtained within our national borders.

- With the goal of improving air quality in urban areas, the federal government has worked with industry and local governments to develop and field test buses, cars, trucks, and other vehicles that use various types of alternative fuels.
- By 2000 over 80 cities had joined the federally sponsored Clean Cities program, which aims to clear the air by working with local businesses and governments to expand use of alternative-fueled vehicles and supporting refueling infrastructure.
- Car manufacturers have developed a variety of prototype cars and begun to market and field test a few models in certain regions of the country where air pollution is worst and/or where alternative fuels are already available.
- Alternative-fueled vehicles have been road-tested and comparisons have been made between them. They include combustion engines powered by natural gas, propane, biofuels, methanol, and ethanol; electric motors powered by a variety of batteries and fuel cells; and hybrids that rely on both.

KEY PIECES OF LEGISLATION

Two pieces of legislation are currently moving the United States toward alternative fuels: the Clean Air Act Amendments of 1990 (CAAA) and the Energy Policy Act of 1992 (EPACT). The Clean Air Act is primarily focused on cleaning the air and promotes any power source for which a vehicle is certified to meet federal clean fuel vehicle emissions standards. The Energy Policy Act has a slightly different focus; it promotes the use of fuels that are substantially not petroleum that would yield substantial energy-security and environmental benefits. The fuels promoted by each act are listed below.

CLEAN FUELS AND ALTERNATIVE FUELS Promoted by federal legislation	***CAAA*** clean fuels	***EPACT*** alternative fuels
methanol (M85)	x	x
ethanol (E85)	x	x
other alcohols or alcohol blends	x	
other alcohols separately, or in mixtures containing 85% or more alcohol with gasoline (but no less than 70%, as determined necessary by rulemaking)	x	
natural gas	x	x
liquefied petroleum gas (propane)	x	x
electricity	x	x
hydrogen	x	x
clean diesel	x	
coal-derived liquid fuels	x	
reformulated gasoline	x	
biofuels (fuels derived from biological materials); "neat" (100%) biodiesel		x

WHAT TO EXPECT IN THE COMING 10 YEARS

Over the coming 10 years, automobile manufacturers will continue to market a small number of new cars powered by a variety of engines, motors, and fuels. They may market these and traditionally powered cars for specific purposes, such as long-distance road trips or short-distance commuting. New kinds of vehicles, including ultralight two-seater cars and electric bicycles, are likely to become more common. Cities may also provide a greater selection of walking and bicycling pathways and public transit. Automotive engineers will continue to develop devices for getting new fuels into cars. Fuel providers and electric utilities will continue to search for dependable and environmentally friendly supplies of fuel and to design distribution systems for bringing new fuels to our towns. Eventually two or three fuels will probably become most popular nationwide, and fueling infrastructures will be created to support the cars that use them. Other fuels may be widely used only in certain regions of the country. (Ethanol, for example, is already widely used in the Midwest, where corn, a feedstock for ethanol, is grown.)

The cars and fuels of the future will also greatly depend on the people buying new cars in 10 years. The type of cars that will become marketed throughout North America will depend a lot on the cars that today's teenagers choose to drive in their 20s and 30s. How informed will their decisions be?

GETTING ORIENTED

TIME	MATERIALS NEEDED
Two days	***Student handouts***

OBJECTIVES

- *To orient students to the major issues involved with transportation (specifically the shift to alternative fuels), to the six-week unit ahead, and to working in teams.*

MATERIALS NEEDED

Student handouts

- *Gasoline-Powered Engines: Time for a Change*
- *The Transportation Challenge*
- *In Your Community, How Important Is It?*

Recommended for students

Project notebooks or folders for organizing handouts and other information they obtain throughout the course of this unit

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STEP 1 - Class Discussion

WHAT DO STUDENTS ALREADY KNOW?

TIME: 30 minutes

Find out what your students know about our ever-changing transportation system and the move to alternative fuels through one of the following discussion activities.

Discussion: Home for the holidays

1) Ask students to think about getting their family together for a holiday dinner (or traveling 50 miles or more to see a grandparent): How do they travel? How long does it take? What equipment, fuel, and resources are needed? Describe the public infrastructure that exists to support travel. What food is on the table? (turkey? burgers? pasta? rice? fruit and vegetables?) Where did the food originate? How was it delivered to their community? How did they get it from the market to their home?

2) If this same dinner were held in 1850, 1890, 1920, or 1950, how would the answers change? What issues were probably raised when the internal combustion engine first replaced the horse and buggy (for example, noise, smell, danger, health, refueling)? How did the community and the country change to accommodate new forms of transportation?

3) If this same dinner were held in 2020 or 2050, what kinds of changes would the students expect to see?

Discussion: Why use gasoline?

1) Ask the class to brainstorm a list of fuels and identify the ones that are or might be used in vehicles. These may include the nine fuels listed in the teacher's introduction to this unit or many more.

2) Ask why gasoline, rather than any of the other fuels they've identified, is the fuel primarily used in cars.

3) Identify issues related to each that might deter its use. The students may raise issues such as lack of knowledge or technology, safety, environmental hazards, limited supplies, lobbying by industry, and so on.

Discussion: Traveling in the future

1) Read the following to students to stimulate their thinking about transportation in the future.

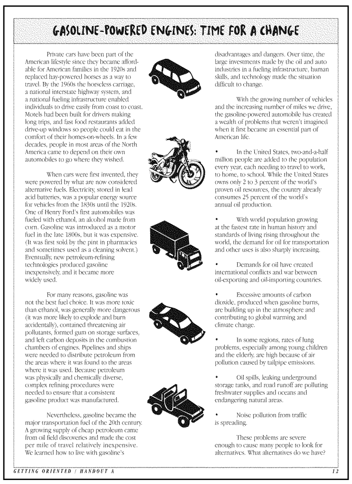
Picture yourself in 10 years as you leave your home to do daily errands or get to your place of work.

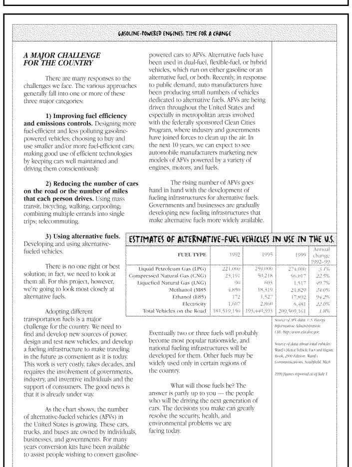
Will you enjoy revving the internal combustion engine of your car or experience the near silence of an electric motor? Will you decide to get some exercise by riding on the new bike path that runs directly to your office, studio, or shop, or to a convenient train stop that takes you to the next town?

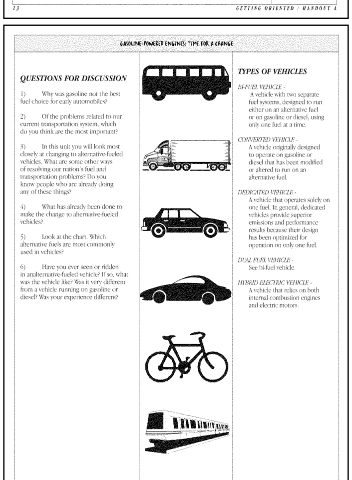
How often will you fuel (or charge) your car of the future? Where is the most convenient place to do it? At the service station next to the highway, while you do errands on foot after work, or at the drive-up or walk-up window as you buy your morning coffee?

As you turn on the radio or your Walkman, will you hear reports of severe weather problems due to climate change, or will the announcer have more optimistic news ('Declining automobile emissions are decreasing levels of greenhouse gases.')?

2) Ask the class what kind of vehicle will move them where they want to go. How will vehicles change? Will they be running on gasoline or some other fuel? What fuel might it be? Ask what reasons exist for changing from gasoline to some other fuel.







STEP 2 - Reading and Discussion

GASOLINE-POWERED ENGINES: TIME FOR A CHANGE

TIME: 20 minutes

1) Ask students why it's important for the United States to make a change from gasoline and other fossil fuels. They may raise many issues, such as the finite supplies of oil, global warming, and other environmental issues.

2) Distribute the student handout "GASOLINE-POWERED ENGINES: TIME FOR A CHANGE," which describes in more detail the reasons for learning about alternative fuels and the issues our country faces related to transportation. Provide students time to read the handout and discuss the questions at the end. Key points to make and possible answers to the questions include the following:

#1. At first gasoline was very expensive; it was shipped long distances; it was considered unsafe; and it was dirty, leaving residue on engines and other vehicle parts. Other fuels, such as ethanol, were safer, cleaner, and available domestically.

#2. Reasons to seek alternatives to fossil fuels include depleting oil reserves; increasing amounts of harmful emissions due to a growing population's growing use of energy; conflicts between oil-producing and oil-importing countries; global warming and rising sea levels due to a buildup of carbon dioxide in the atmosphere; pollution of freshwater supplies; noise pollution.

#3. Automobile manufacturers are developing alternative-fueled vehicles. Many cars, trucks, and buses are already using alternative fuels. Governments and industry are gradually developing new fueling infrastructures.

#4. Liquid petroleum gas (LPG, or "propane") is by far the most common alternative fuel; the numbers of other fuels are growing quickly, however, as new technologies are developed to better use them.

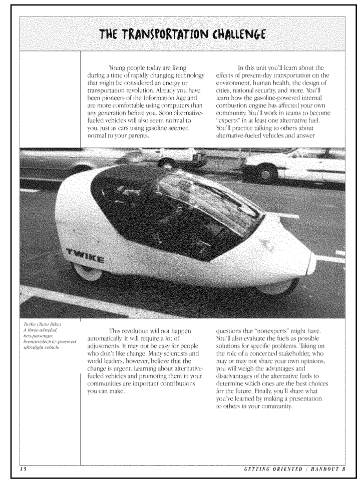
#5. Some students may have experience with alternative-fueled vehicles (AFVs), especially if they have been to car shows or an electric car race like the NESEA-hosted American Tour de Sol. Riding in most AFVs is similar to riding in a gasoline-powered car. Two differences may be the quiet of an electric vehicle or the french fry (or popcorn) smell associated with biodiesel.

STEP 3 - Class Discussion

PREPARING STUDENTS TO MEET THE TRANSPORTATION CHALLENGE

TIME: 20 minutes

1) Distribute the student handout "THE TRANSPORTATION CHALLENGE," which describes the six-week project ahead.



THE TRANSPORTATION CHALLENGE

Young people today are living during a time of rapidly changing technology that might be considered an energy or transportation revolution. Already you have been pioneers of the Information Age and are more comfortable using computers than any generation before you. Soon alternative-fueled vehicles will also seem normal to you, just as cars using gasoline seemed normal to your parents.

In this unit you'll learn about the effects of present-day transportation on the environment, human health, the design of cities, national security, and more. You'll learn how the gasoline-powered internal combustion engine has affected your own community. You'll work in teams to become "experts" in at least one alternative fuel. You'll practice talking to others about alternative-fueled vehicles and answer

Twike (Twin Bike) A three-wheeled, two-passenger, human/electric-powered ultralight vehicle

This revolution will not happen automatically. It will require a lot of adjustments. It may not be easy for people who don't like change. Many scientists and world leaders, however, believe that the change is urgent. Learning about alternative-fueled vehicles and promoting them in your communities are important contributions you can make.

questions that "nonexperts" might have. You'll also evaluate the fuels as possible solutions for specific problems. Taking on the role of a concerned stakeholder, who may or may not share your own opinions, you will weigh the advantages and disadvantages of the alternative fuels to determine which ones are the best choices for the future. Finally, you'll share what you've learned by making a presentation to others in your community.

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Explain to students that for the next six weeks they will work in teams to investigate alternative fuels in depth and become the class experts on at least one of them. The students will analyze the impact of widely adopting an alternative fuel in three major areas:

- its long-term availability and the ease of distribution
- its impact on emissions, human health, and the environment
- its ease of operation, maintenance, and refueling

While researching each of these three areas, the class as a whole will also analyze the needs of its own community and the impact on it of the current transportation system.

As the class experts, fuel teams present their findings to their classmates. The evaluation of the fuels can be done by the other students in one of two ways:

- Individual students are assigned a stakeholder or interest group to represent. They listen to the presentations and compare and evaluate the fuels from that perspective.
- Evaluation panels of students are formed and assigned a stakeholder or interest group to represent. (We suggest that each evaluation panel consist of experts on several different fuels.) As a panel, students listen to the presentations and compare and evaluate the fuels from that perspective.

The class will then decide which fuel or fuels should be adopted in their community and develop a final presentation to make to community representatives about their fuel choices.

2) Explain that their decision might be based on how well an alternative-fueled vehicle performs on the road, how far one can drive between fueling, or how well the car starts in cold weather. Encourage the class to also consider broader and longer term goals for the country, such as reducing environmental pollution, improving public health, slowing down global warming, and becoming more self-sufficient.

Whatever fuel the students choose, it should be appropriate for their own community. A fuel that's most appropriate in clearing the air in southern California (where people commute long distances and smog has been a problem for 50 years) may differ from the fuel that is most readily available in the agricultural areas of the Great Plains. Those fuels may differ again from what is cleanest and most convenient for East Coast inner-city residents who use cars for a few short trips during the week. As the students make their decisions, remind them of these questions: "What are the most important transportation issues our community is facing? Which fuels best resolve those issues?"

3) If you have already made arrangements for a public presentation, discuss with students what form their presentation may take and who will be in their audience. If not, discuss with students the possibilities for public presentations: where and when they might take place, who the audience would be, what form the presentations would take. Presentations may take one or more forms: a poster or series of posters, a video, a PowerPoint presentation, a web site posting, or a public forum using transparencies.

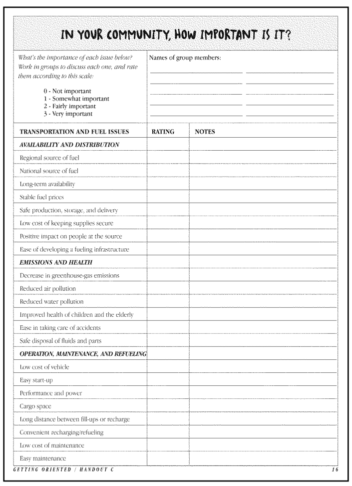
Possible venues include the school or public library, other public buildings, or at a community happening such as an Earth Day event. Throughout the unit, teams will have at least three opportunities to give mini-presentations to their classmates, which should help them prepare for the community presentation.

STEP 4 - Class Discussion
IN YOUR COMMUNITY, HOW IMPORTANT IS IT?

TIME: 45 minutes

1) Distribute the student handout “IN YOUR COMMUNITY, HOW IMPORTANT IS IT?”

2) Divide the class into groups of three or four students. Have them work in teams to rate the importance (from 0 to 3) of each of the issues listed. Ask them to come to consensus as a group by giving each person an opportunity to voice his or her opinion about each issue.


IN YOUR COMMUNITY, HOW IMPORTANT IS IT?

What's the importance of each issue below? Work in groups to discuss each one, and rate them according to this scale:

0 - Not important
1 - Somewhat important
2 - Fairly important
3 - Very important

Names of group members:

TRANSPORTATION AND FUEL ISSUES	RATING	NOTES
AVAILABILITY AND DISTRIBUTION		
Regional source of fuel		
National source of fuel		
Long-term availability		
Stable fuel prices		
Safe production, storage, and delivery		
Low cost of keeping supplies secure		
Positive impact on people at the source		
Ease of developing a fueling infrastructure		
EMISSIONS AND HEALTH		
Decrease in greenhouse-gas emissions		
Reduced air pollution		
Reduced water pollution		
Improved health of children and the elderly		
Ease in taking care of accidents		
Safe disposal of fluids and parts		
OPERATION, MAINTENANCE, AND REFUELING		
Low cost of vehicle		
Easy start-up		
Performance and power		
Cargo space		
Long distance between fill-ups or recharge		
Convenient recharging/refueling		
Low cost of maintenance		
Easy maintenance		

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3) When the teams are finished, have them share their answers and attempt to come to consensus as a class. Remind them to think about the importance of each issue in your unique community.

4) Explain that in the coming six weeks, their opinions may change as they learn more about each fuel and issue. Some issues may not seem as important; new issues may arise. The students should analyze what they learn about the issues as a scientist analyzes data in an experiment, with an open mind willing to look at the facts objectively. Throughout their research, their conclusions and opinions may change. What’s important is that their new opinions are supported with facts.

5) As students work through each of the three community research activities, refer back to this discussion and ask if their opinions are changing about the importance of each issue.

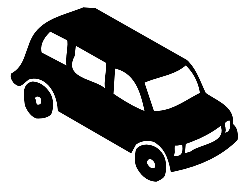
GASOLINE-POWERED ENGINES: TIME FOR A CHANGE

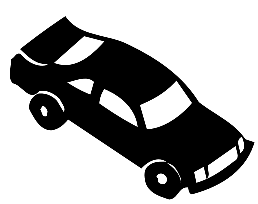
Private cars have been part of the American lifestyle since they became affordable for American families in the 1920s and replaced hay-powered horses as a way to travel. By the 1960s the horseless carriage, a national interstate highway system, and a national fueling infrastructure enabled individuals to drive easily from coast to coast. Motels had been built for drivers making long trips, and fast food restaurants added drive-up windows so people could eat in the comfort of their homes-on-wheels. In a few decades, people in most areas of the North America came to depend on their own automobiles to go where they wished.

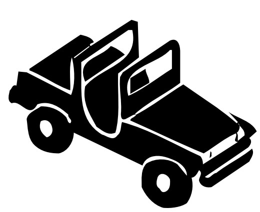
When cars were first invented, they were powered by what are now considered alternative fuels. Electricity, stored in lead acid batteries, was a popular energy source for vehicles from the 1830s until the 1920s. One of Henry Ford's first automobiles was fueled with ethanol, an alcohol made from corn. Gasoline was introduced as a motor fuel in the late 1800s, but it was expensive. (It was first sold by the pint in pharmacies and sometimes used as a cleaning solvent.) Eventually, new petroleum-refining technologies produced gasoline inexpensively, and it became more widely used.

For many reasons, gasoline was not the best fuel choice. It was more toxic than ethanol, was generally more dangerous (it was more likely to explode and burn accidentally), contained threatening air pollutants, formed gum on storage surfaces, and left carbon deposits in the combustion chambers of engines. Pipelines and ships were needed to distribute petroleum from the areas where it was found to the areas where it was used. Because petroleum was physically and chemically diverse, complex refining procedures were needed to ensure that a consistent gasoline product was manufactured.

Nevertheless, gasoline became the major transportation fuel of the 20th century. A growing supply of cheap petroleum came from oil field discoveries and made the cost per mile of travel relatively inexpensive. We learned how to live with gasoline's disadvantages and dangers. Over time, the large investments made by the oil and auto industries in a fueling infrastructure, human skills, and technology made the situation difficult to change.







With the growing number of vehicles and the increasing number of miles we drive, the gasoline-powered automobile has created a wealth of problems that weren't imagined when it first became an essential part of American life.

- In the United States, two-and-a-half million people are added to the population every year, each needing to travel to work, to home, to school. While the United States owns only 2 to 3 percent of the world's proven oil resources, the country already consumes 25 percent of the world's annual oil production.

- With world population growing at the fastest rate in human history and standards of living rising throughout the world, the demand for oil for transportation and other uses is also sharply increasing.

- Demands for oil have created international conflicts and war between oil-exporting and oil-importing countries.

- Excessive amounts of carbon dioxide, produced when gasoline burns, are building up in the atmosphere and contributing to global warming and climate change.

- In some regions, rates of lung problems, especially among young children and the elderly, are high because of air pollution caused by tailpipe emissions.

- Oil spills, leaking underground storage tanks, and road runoff are polluting freshwater supplies and oceans and endangering natural areas.

- Noise pollution from traffic is spreading.

These problems are severe enough to cause many people to look for alternatives. What alternatives do we have?

A MAJOR CHALLENGE FOR THE COUNTRY

There are many responses to the challenges we face. The various approaches generally fall into one or more of these three major categories:

1) Improving fuel efficiency and emissions controls. Designing more fuel-efficient and less polluting gasoline-powered vehicles; choosing to buy and use smaller and/or more fuel-efficient cars; making good use of efficient technologies by keeping cars well maintained and driving them conscientiously.

2) Reducing the number of cars on the road or the number of miles that each person drives. Using mass transit; bicycling; walking; carpooling; combining multiple errands into single trips; telecommuting.

3) Using alternative fuels. Developing and using alternative-fueled vehicles.

There is no one right or best solution; in fact, we need to look at them all. For this project, however, we're going to look most closely at alternative fuels.

Adopting different transportation fuels is a major challenge for the country. We need to find and develop new sources of power, design and test new vehicles, and develop a fueling infrastructure to make traveling in the future as convenient as it is today. This work is very costly, takes decades, and requires the involvement of governments, industry, and inventive individuals and the support of consumers. The good news is that it is already under way.

As the chart shows, the number of alternative-fueled vehicles (AFVs) in the United States is growing. These cars, trucks, and buses are owned by individuals, businesses, and governments. For many years conversion kits have been available to assist people wishing to convert gasoline-powered cars to AFVs. Alternative fuels have been used in dual-fuel, flexible-fuel, or hybrid vehicles, which run on either gasoline or an alternative fuel, or both. Recently, in response to public demand, auto manufacturers have been producing small numbers of vehicles dedicated to alternative fuels. AFVs are being driven throughout the United States and especially in metropolitan areas involved with the federally sponsored Clean Cities Program, where industry and governments have joined forces to clean up the air. In the next 10 years, we can expect to see automobile manufacturers marketing new models of AFVs powered by a variety of engines, motors, and fuels.

The rising number of AFVs goes hand in hand with the development of fueling infrastructures for alternative fuels. Governments and businesses are gradually developing new fueling infrastructures that make alternative fuels more widely available. Eventually two or three fuels will probably become most popular nationwide, and national fueling infrastructures will be developed for them. Other fuels may be widely used only in certain regions of the country.

What will those fuels be? The answer is partly up to you — the people who will be driving the next generation of cars. The decisions you make can greatly resolve the security, health, and environmental problems we are facing today.

ESTIMATES OF ALTERNATIVE-FUEL VEHICLES IN USE IN THE U.S.

FUEL TYPE	1992	1995	1999	Annual change 1992 99
Liquid Petroleum Gas (LPG)	221,000	259,000	274,000	*3.1%*
Compressed Natural Gas (CNG)	23,191	50,218	96,017	*22.5%*
Liquefied Natural Gas (LNG)	90	603	1,517	*49.7%*
Methanol (M85	4,850	18,319	21,829	*24.0%*
Ethanol (E85)	172	1,527	17,892	*94.2%*
Electricity	1,607	2,860	6,481	*22.0%*
Total Vehicles on the Road	181,519,150	193,440,393	209,509,161	*1.8%*

Source of AFV data: U.S. Energy Information Administration, URL: http://www.eia.doe.gov.

Source of data about total vehicles: Ward's Motor Vehicle Fact and Figure Book, *2000 Edition. Ward's Communications, Southfield, Mich.*

1999 figures reported as of July 1.

QUESTIONS FOR DISCUSSION

1) Why was gasoline not the best fuel choice for early automobiles?

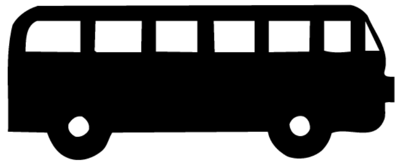
2) Of the problems related to our current transportation system, which do you think are the most important?

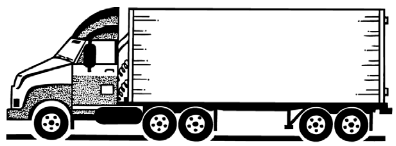
3) In this unit you will look most closely at changing to alternative-fueled vehicles. What are some other ways of resolving our nation's fuel and transportation problems? Do you know people who are already doing any of these things?

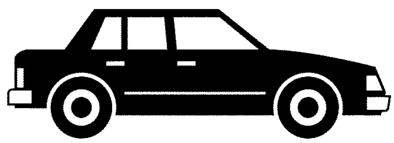
4) What has already been done to make the change to alternative-fueled vehicles?

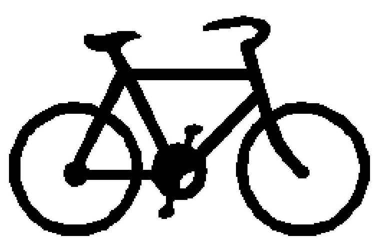
5) Look at the chart. Which alternative fuels are most commonly used in vehicles?

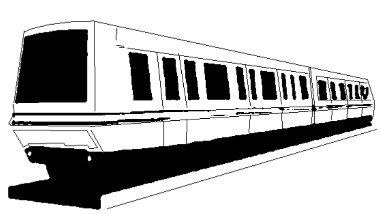
6) Have you ever seen or ridden in analternative-fueled vehicle? If so, what was the vehicle like? Was it very different from a vehicle running on gasoline or diesel? Was your experience different?











TYPES OF VEHICLES

BI-FUEL VEHICLE -
A vehicle with two separate fuel systems, designed to run either on an alternative fuel or on gasoline or diesel, using only one fuel at a time.

CONVERTED VEHICLE -
A vehicle originally designed to operate on gasoline or diesel that has been modified or altered to run on an alternative fuel.

DEDICATED VEHICLE -
A vehicle that operates solely on one fuel. In general, dedicated vehicles provide superior emissions and performance results because their design has been optimized for operation on only one fuel.

DUAL FUEL VEHICLE -
See bi-fuel vehicle.

HYBRID ELECTRIC VEHICLE -
A vehicle that relies on both internal combustion engines and electric motors.

THE TRANSPORTATION CHALLENGE

Young people today are living during a time of rapidly changing technology that might be considered an energy or transportation revolution. Already you have been pioneers of the Information Age and are more comfortable using computers than any generation before you. Soon alternative-fueled vehicles will also seem normal to you, just as cars using gasoline seemed normal to your parents.

In this unit you'll learn about the effects of present-day transportation on the environment, human health, the design of cities, national security, and more. You'll learn how the gasoline-powered internal combustion engine has affected your own community. You'll work in teams to become "experts" in at least one alternative fuel. You'll practice talking to others about alternative-fueled vehicles and answer questions that "nonexperts" might have. You'll also evaluate the fuels as possible solutions for specific problems. Taking on the role of a concerned stakeholder, who may or may not share your own opinions, you will weigh the advantages and disadvantages of the alternative fuels to determine which ones are the best choices for the future. Finally, you'll share what you've learned by making a presentation to others in your community.

Twike (Twin Bike)
A three-wheeled, two-passenger, human/electric–powered ultralight vehicle

This revolution will not happen automatically. It will require a lot of adjustments. It may not be easy for people who don't like change. Many scientists and world leaders, however, believe that the change is urgent. Learning about alternative-fueled vehicles and promoting them in your communities are important contributions you can make.

IN YOUR COMMUNITY, HOW IMPORTANT IS IT?

What's the importance of each issue below? Work in groups to discuss each one, and rate them according to this scale: 0 - Not important 1 - Somewhat important 2 - Fairly important 3 - Very important	Names of group members: _______________ _______________ _______________ _______________ _______________ _______________ _______________ _______________ _______________ _______________

TRANSPORTATION AND FUEL ISSUES	RATING	NOTES
AVAILABILITY AND DISTRIBUTION		
Regional source of fuel		
National source of fuel		
Long-term availability		
Stable fuel prices		
Safe production, storage, and delivery		
Low cost of keeping supplies secure		
Positive impact on people at the source		
Ease of developing a fueling infrastructure		
EMISSIONS AND HEALTH		
Decrease in greenhouse-gas emissions		
Reduced air pollution		
Reduced water pollution		
Improved health of children and the elderly		
Ease in taking care of accidents		
Safe disposal of fluids and parts		
OPERATION, MAINTENANCE, AND REFUELING		
Low cost of vehicle		
Easy start-up		
Performance and power		
Cargo space		
Long distance between fill-ups or recharge		
Convenient recharging/refueling		
Low cost of maintenance		
Easy maintenance		

AVAILABILITY AND DISTRIBUTION

TIME

10 days

OBJECTIVES

- *To understand the extent and costs of our nation's dependence on foreign sources of oil.*
- *To understand how our communities are affected by fuel shortages and the fluctuating availability and pricing of fuel.*
- *To identify fuel alternatives that now exist in the community.*
- *To investigate alternatives, specifically their long-term availability and social and environmental costs, as well as the safety issues involved with their extraction, processing, storage, and delivery.*

MATERIALS NEEDED

For background reading and community research

Student handouts

- *Availability and Distribution: The Challenge*
- *Transportation Fuels, Engines, and Motors*
- *Who's Interested in AFVs? Who Cares About Availability and Distribution?*
- *Fuels That Power Your Community: Guide to Community Research*
- *Community map that shows primary roads*

Other useful resources

- *Sample utility bill describing sources of power in the power grid*
- *Yellow pages*
- *Access to the Internet*
- *Public relations departments of your local utility company, Public Transit Authority, Department of Transportation, or other companies and organizations that operate fleets of vehicles*

For fuel research and student presentations

Student handouts

- *Availability and Distribution: Guide to Fuel Team Research*
- *Fuel Review Worksheet: Availability, Distribution, and Pricing*
- *Alternative fuels fact sheets (to be distributed to appropriate teams)*
- *Resource Guide*
- *Evaluating Team Reports and Presentations*

Other useful resources for research

- *Access to the library and Internet publications listed as references for this unit*

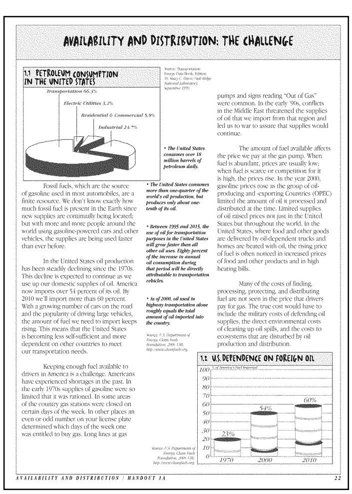
Useful resources for student presentations

- *Flip charts, poster board, transparencies, and use of an overhead projector*
- *Access to word processing or presentation software*

STEP 1 - Background Reading and Discussion

AVAILABILITY AND DISTRIBUTION: PRESENTING THE CHALLENGE

TIME: 45 minutes; to save time in class, readings may be assigned for homework


AVAILABILITY AND DISTRIBUTION: THE CHALLENGE

1.1 PETROLEUM CONSUMPTION IN THE UNITED STATES

1.2 U.S. DEPENDENCE ON FOREIGN OIL

1) Copy and distribute student handouts for this section. Students will be receiving two more packets of handouts in the next sections, plus some additional resources used throughout the course of this unit. Advise students to keep the handouts in a project notebook.

2) Refer to the student handout "AVAILABILITY AND DISTRIBUTION: THE CHALLENGE," to stimulate discussion about the need to secure sources of fuel. Introduce the discussion by explaining that our ability to keep cars on the road ultimately depends on the source of the fuel they use and its long-term availability.

3) Have students read the handout and analyze charts 1.1 and 1.2: "Petroleum Consumption in the United States" and "U.S. Dependence on Foreign Oil."

Key points for students to understand are the large fuel requirements of our transportation system, our growing dependence on foreign oil, the high costs of defending supplies originating in foreign countries, and the environmental cost of extracting and transporting fuel. Safety issues involved in the extraction, production, and delivery of fuel are additional considerations in changing to alternative fuels.

4) Refer to the handout "TRANSPORTATION FUELS, ENGINES, AND MOTORS," to be used as a reference for the activities in this unit. It lists the vocabulary that students may encounter while doing research, including brief descriptions of the alternative fuels they'll be studying in depth.

TRANSPORTATION FUELS, ENGINES, AND MOTORS

This sheet lists the major types of engines, motors, power conversion devices, and fuels being used or considered for transportation.

ALTERNATIVE FUELS

According to the federal government definition, alternative fuels are those determined to be "substantially not petroleum" and yielding "energy security benefits and substantial environmental benefits." The chief alternatives are methanol, denatured ethanol and other alcohols (separately or in mixtures of 85 percent by volume or more with gasoline or other fuels), CNG, LNG, LPG, hydrogen, coal-derived liquid fuels, fuels derived from biomass, electricity, neat (100 percent) biodiesel.

BIODIESEL - A liquid biodegradable fuel produced from renewable sources such as vegetable oils, animal fats, and used oil and fats.

ELECTRICITY - Electric current used as a power source. It can be generated from a variety of feedstocks including oil, coal, nuclear, hydro, natural gas, wind, and solar. In vehicles it is generally provided by rechargeable storage batteries, photovoltaic cells, or a fuel cell.

ETHANOL - A liquid alcohol produced from corn, grain, or agricultural waste. It is also called ethyl alcohol or grain alcohol. When mixed with gasoline in a ratio of 85 parts ethanol to 15 parts gasoline, it is called E85.

HYDROGEN - A colorless, highly flammable gas; the most abundant element in the universe. It is being researched for use in fuel cells.

LIQUEFIED PETROLEUM GAS (LPG) - A combination of hydrocarbons, such as propane, ethane, and butane. It is often referred to as "propane." Under moderate pressure the gaseous fuel turns to liquid.

METHANOL - A liquid alcohol that can be produced from just about anything containing carbon, including coal and biomass. It is also called methyl alcohol or wood alcohol. When mixed with gasoline in a ratio of 85 parts methanol to 15 parts gasoline, it is called M85.

NATURAL GAS - A naturally occurring gaseous mixture of simple hydrocarbons, primarily methane, which is the simplest hydrocarbon. When used as a fuel, it is either compressed by cooling (CNG) or liquefied (LNG).

OTHER VOCABULARY

BATTERY - A device kept aboard a vehicle used to store energy. The battery is restored with electrical charging from a generator powered by a gas engine, an electrical outlet, or photovoltaic panels.

BIOMASS - Renewable organic matter used for the production of energy. Biomass includes agricultural crops, crop-waste, wood, animal and municipal wastes, aquatic plants, etc.

DIESEL - A liquid fuel formed from a combination of petroleum and natural gas, a mixture of hydrocarbons (compounds that contain hydrogen and carbon atoms) that range from 12 to 24 carbon atoms in length.

FUEL CELL - An electrochemical system (no moving parts) that converts the chemical energy of a fuel, which is stored onboard a vehicle, directly to electricity.

GASOHOL - Gasoline that contains 10 percent ethanol by volume. Also called E10, super unleaded plus ethanol or unleaded plus ethanol.

GASOLINE - A liquid fuel formed from a combination of petroleum and natural gas, a mixture of hydrocarbons (compounds that contain hydrogen and carbon atoms) that are 7 to 11 carbon atoms in length. It is the most widely used fuel.

COMPRESSION IGNITION ENGINE - Internal compression engine in which injected fuel is ignited as rapid compression of air within the cylinders generates heat. Used with diesel fuels.

HYBRID-ELECTRIC VEHICLE (HEV) - A vehicle that is powered by two or more energy sources, one of which is electricity. HEVs may combine the engine and fuel system of a conventional vehicle with the batteries and electric motor of an electric vehicle in a single drivetrain.

PETROLEUM FUEL - Gasoline and diesel fuel.

SPARK IGNITION ENGINE - Internal combustion engine in which the charge is ignited electrically — for example, with a spark plug.

23 AVAILABILITY AND DISTRIBUTION / HANDOUT 1B

Briefly explain that according to the federal government definition, alternative fuels are those that are "substantially not petroleum" and yield "energy security benefits and substantial environmental benefits." The chief alternatives are methanol, denatured ethanol and other alcohols (separately or in mixtures of 85 percent by volume or more with gasoline or other fuels), CNG, LNG, LPG, hydrogen, coal-derived liquid fuels, fuels derived from biomass, electricity, neat (100 percent) biodiesel.

5) Ask students to identify various types of people who may be concerned with fuel availability and distribution, and with the hidden costs that are associated with our reliance on oil, and what their chief concerns might be.

WHO'S INTERESTED IN AFVS? WHO CARES ABOUT AVAILABILITY AND DISTRIBUTION?

A wide variety of people have a stake in a change to AFVs. They vary from human rights activists to auto salespeople to environmental scientists to physicians to diplomats.

This group is largely interested in the availability of fuels, their safe distribution, and the reduction of some of the hidden social and environmental costs related to gasoline-powered vehicles.

ADVOCATES FOR THE ENVIRONMENT, HUMAN RIGHTS, AND PEACE

Much of the fuel used in the United States comes from politically oppressive or unstable parts of the world. Conflicts over oil endanger our own soldiers and the people in the oil-producing countries. War over oil supplies inevitably results in massive environmental damage. If we develop domestic sources of fuel, we could reduce these losses to human life and the environment, and be in a better position to stand up to oil-producing countries that oppress their own people.

PETROLEUM INDUSTRY

As a business that employs a lot of people in drilling and refining oil for fuel, plastics, fertilizers, and other products, we want to keep the industry thriving. We expect to keep discovering new sources of fossil fuels for some time. Still, there is pressure from the government and environmental groups to change to alternatives that burn more cleanly and don't contribute to global climate change. With people demanding alternatives, should our industry be diversifying? If so, what other types of fuel should we be exploring?

NATIONAL SECURITY PERSONNEL: Advisers, Diplomats, FBI, CIA, Department of Defense

So much oil comes from unstable parts of the world. Our dependence on foreign oil led us to war in the early '90s when Iraq invaded Kuwait and threatened oil supplies there. Costly wars can't be the only answer to protecting our interests. If we develop domestic sources of fuel, we could reduce our military presence in unstable parts of the world and reduce the loss of life that results when fuel sources need protecting.

ECONOMIST

The cost of fuel has a large impact on industry and the strength of our economy. How can we keep that cost down? An increasing amount of oil is being bought overseas, leading the United States to send more money out of the country than it gets back. Which domestic sources of fuel could help us to balance imports and exports and reduce this trade deficit?

MARINE SCIENTISTS

The number of oil spills reported in the news is a fraction of those that actually occur. Methods for cleaning up have improved, but coast-lines suffer for years after a spill. Some areas are permanently damaged from frequent spills. People like to blame the spill on miscalculations at the ship's wheel, but we're interested in cutting down the risk of spills by finding safer, alternative fuels that don't need to be shipped.

BUSINESSES OF ALL SIZES AND CONSUMERS

We need energy for every aspect of our lives — to run industry so the economy is strong and people are employed, to produce goods, to transport goods and people, to meet heating and cooking needs. We need ongoing supplies of fuel we can depend on at stable prices. Which fuels provide us with that?

AMERICAN FARMER

Henry Ford wanted to run his Model T on fuel made from corn; diesel engines were designed to run on peanut oil. Is there a future for fuel crops? If so, which crops would they be? The Department of Agriculture's National Resources Inventory shows that we're losing almost two million acres of valuable farmland each year to urban sprawl and industry. That's almost four acres every day! If we were growing fuel crops on that land, wouldn't people be more willing to protect it?

AVAILABILITY AND DISTRIBUTION / HANDOUT 1C 24

Refer to the student handout "WHO'S INTERESTED IN AFVS? WHO CARES ABOUT AVAILABILITY AND DISTRIBUTION?" Have students read the various concerns and ask which of the people most reflect their own concerns. Which people are likely to be in their community? Who else in their community may have an interest in AFVs, and what would their concerns be? What people may be in the audience during their presentations?

EXTENSION: Ask students to make up a sheet similar to the "WHO'S INTERESTED IN AFVS?" handout for local residents.

STEP 2 - Class Mind Mapping Exercise

THE RIPPLING EFFECT ON THE COMMUNITY OF RISING FUEL PRICES

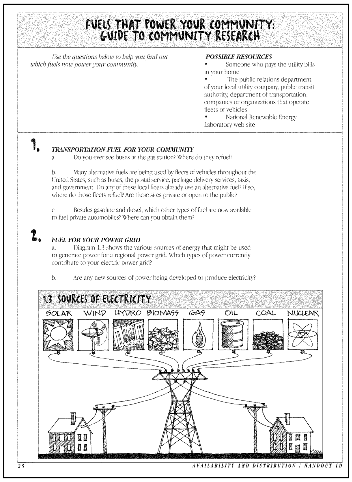
TIME: 10 minutes

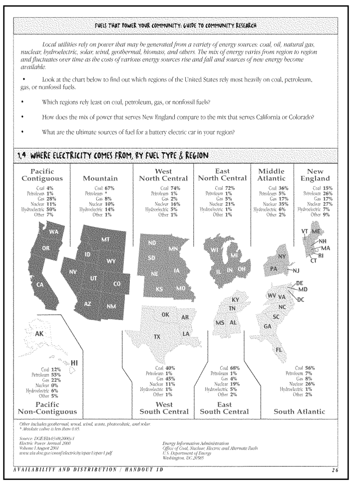
1) Bring the fuel issues home by developing a "mind map" on the chalkboard that demonstrates the rippling affect of rising prices of fuel. Start by presenting this situation:

Imagine the prices of gasoline rising to $4.00 a gallon (two to three times the cost in 2000) because of a fuel shortage. What effect would it have on you or your family, and on businesses?

If students need help, ask them if high prices would limit the amount of gasoline or diesel their family buys, or the amount of money spent on other things. Would they have to change their vacation plans or the number of car trips they make out of town? What businesses depend on transportation fuel? If your community depends on tourism, would rising prices of transportation fuel affect the number of travelers to your region?

2) Ask the students how people already conserve fuel. How often do they see people biking or waiting for a bus? Do they know anyone who carpools, cycles, or uses mass transit? If fuel prices went up, would more people do this? Why or why not?





STEP 3 - Class Community Research

DISCOVERING THE FUELS THAT POWER YOUR COMMUNITY

TIME: 30 minutes, plus 30 additional minutes of discussion over several days as the students report on their research; requires out-of-class time for some students.

1) Refer to the student handout "FUELS THAT POWER YOUR COMMUNITY: GUIDE TO COMMUNITY RESEARCH." In this class activity, students learn more about the effect of fuel shortages, the variety of fuels that power their community, and the alternatives being developed close to home. Briefly discuss the questions and diagrams.

2) If students are not able to answer all the questions, they may need to contact various people in the community. Help students generate a list of possible sources, and work with them to develop clear questions to obtain the information they need. Ideas for possible sources include:

TRANSPORTATION FUEL FOR YOUR COMMUNITY

#1a. Contact the maintenance department of the bus depot or the mass transit service.

#1b. Have students generate a list of fleets found in your town (package delivery services, postal service, police, government vehicles, private corporations, etc.) and call their maintenance or service departments.

#1c. Refer students to the list of alternative fuels included in the handout "TRANSPORTATION FUELS, ENGINES, AND MOTORS." Use the list as a basis for researching the availability of each. Call the state department of transportation or view the web site of the National Renewable Energy Laboratory (NREL). Maps showing locations of alternative fueling stations across the country are posted on the NREL web site at www.afdc.nrel.gov/refueling.html.

FUEL FOR YOUR POWER GRID

#2a. A list of power sources is sometimes found on utility bills. If not, call the community or public relations department of your utility company.

#2b. Contact the community or public relations department of your utility company.

Assign one or more students to make calls to various fleet operators (#1b), the department of transportation (#1c), the utility company (#2a and b), and so on. Help them formulate the questions they'll ask. Revisit this discussion over several days until all the questions have been answered. The answers will be useful in later activities.

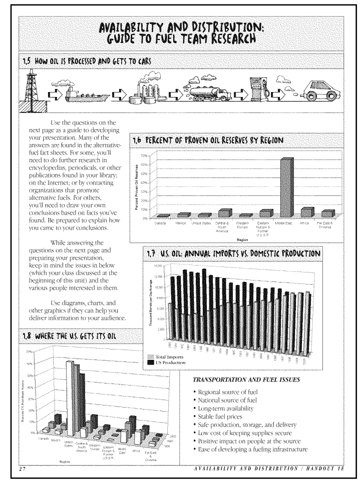
EXTENSIONS

- Regarding question #1c, your community may or may not have fueling sites for alternative fuels, which may or may not be open to the public. If they do exist, have the students mark them on a map of the community and display it in the classroom. Suggestion: Use symbols to represent the various kinds of alternative fuels found in your community.
- Have students talk to their parents or grandparents about the fuel crisis of the '70s to find out how people adapted to the shortage of fuels.

STEP 4 - Introduction to Fuel Team Research

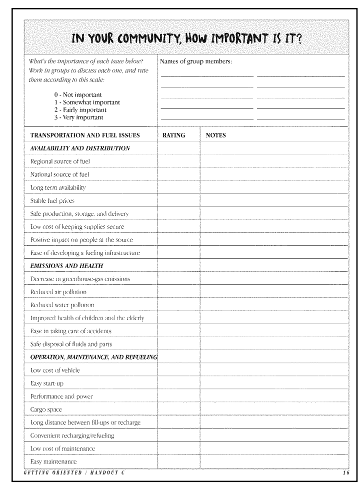
LEARNING ABOUT THE AVAILABILITY AND DISTRIBUTION OF ALTERNATIVE FUELS

TIME: One day



1) Refer to the handout "AVAILABILITY AND DISTRIBUTION: GUIDE TO FUEL TEAM RESEARCH." Introduce this research activity by discussing the flowchart and graphs, which show where we in the United States get our petroleum, where proven oil reserves exist, and how petroleum moves from well to wheels. Key discussion points include the complex infrastructure that has been developed to deliver fuel; the technology that has been developed to make distribution relatively safe and convenient; and the regional, national, and long-term availability of petroleum.

Explain that in this research activity, fuel teams will investigate how alternative fuels are developed, how they might be distributed to your community, which safety issues are involved with processing and distribution, and whether or not the fuels will be available over the long term. This research addresses the first section of the handout "IN YOUR COMMUNITY, HOW IMPORTANT IS IT?"



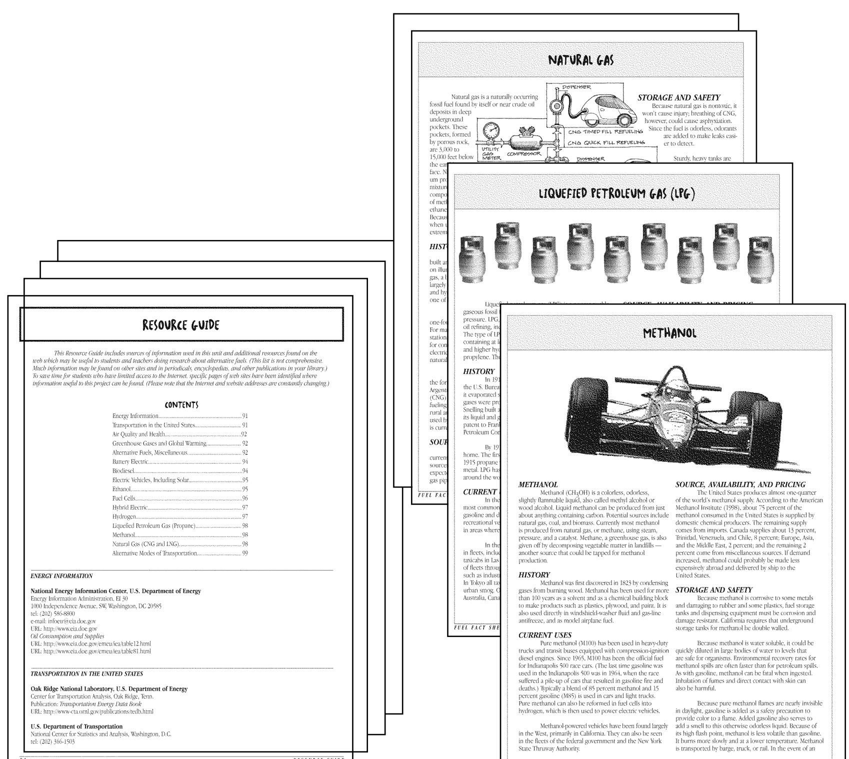
2) For this and the two other research sections in this unit, up to nine fuel teams will prepare mini-presentations (with or without a written report) on various alternative fuels. Each presentation will last 5 to 10 minutes, with additional time provided for their classmates to ask questions.

Divide the class into research teams to investigate and become experts on one of the alternative fuels listed below:

- biodiesel
- ethanol/E85
- liquefied petroleum gas (propane)
- methanol/M85
- natural gas: compressed (CNG) and liquefied (LNG)
- battery
- fuel cell (hydrogen)
- photovoltaic cells
- hybrid electric

Note: If you plan to do other research sections of *Cars of Tomorrow*, these teams should continue to work together.

3) Distribute to the appropriate teams copies of the alternative fuel fact sheets. Distribute to all researchers copies of the Resource Guide, which directs them to sites on the Internet with additional information they may need. Take time to review the headings in the Resource Guide so the students know which sites may have information about their particular fuels.



STEP 5 - Team Research and Preparation for Presentations

LEARNING TO SPEAK ABOUT THE AVAILABILITY AND DISTRIBUTION OF ALTERNATIVE FUELS

TIME: Three days

1) Once the teams have been selected, refer to the handout "AVAILABILITY AND DISTRIBUTION: GUIDE TO FUEL TEAM RESEARCH." Discuss where the students might find the answers to the questions. Much information is already available in the fact sheets. Some of the answers are found in encyclopedias. Additional information can be found at the web sites listed for the alternative fuels in the Resource Guide. Some organizations listed there provide 800 numbers or hotlines to call for additional help. Some questions require that students pull together information and form their own opinions. For question 4b, students may find a mechanic or recycling center helpful in thinking this through.

2) Over the next three days, provide students with the opportunity to meet in their teams, to divide up the research tasks, and to decide how they will present their findings and who will do it. Encourage them to develop diagrams and other graphics to help present their findings. Remind them that these presentation aids may be further developed for a public presentation.

3) Coach students as they do their research. It may be helpful for you to investigate some of the recommended web sites to have a better understanding of the information found there.

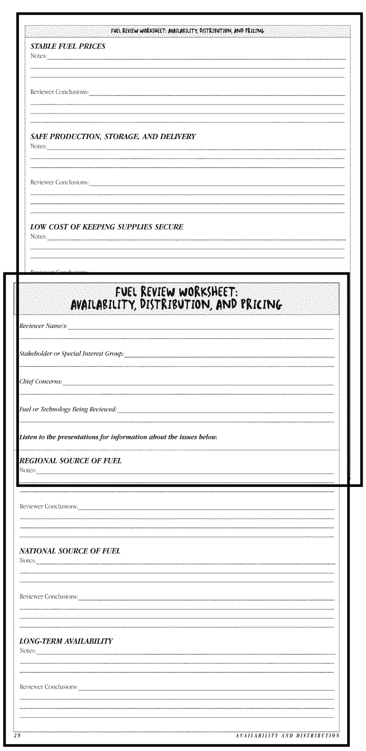
4) Distribute copies of the handout "EVALUATING TEAM REPORTS AND PRESENTATIONS" (page 64), so that students will know in advance what is expected in their presentations.

STEP 6 - Team Presentations and Class Discussions

AVAILABILITY AND DISTRIBUTION

TIME: Four days (10 to 15 minutes for each team's presentation and questions, plus 20 to 30 minutes for follow-up panel and class discussion)

1) Make a list of stakeholders or special interest groups for the students to represent while listening to and evaluating the fuels being presented. Remind students that a wide variety of people are interested in these issues: diplomats, environmental advocates, the petroleum industry, and so on, as you discussed earlier in "WHO'S INTERESTED IN AFVS? WHO CARES ABOUT AVAILABILITY AND DISTRIBUTION?"



FUEL REVIEW WORKSHEET: AVAILABILITY, DISTRIBUTION, AND PRICING

STABLE FUEL PRICES
Notes:
Reviewer Conclusions:

SAFE PRODUCTION, STORAGE, AND DELIVERY
Notes:
Reviewer Conclusions:

LOW COST OF KEEPING SUPPLIES SECURE
Notes:

FUEL REVIEW WORKSHEET:
AVAILABILITY, DISTRIBUTION, AND PRICING

Reviewer Name/s:
Stakeholder or Special Interest Group:
Chief Concerns:
Fuel or Technology Being Reviewed:

Listen to the presentations for information about the issues below.

REGIONAL SOURCE OF FUEL
Notes:
Reviewer Conclusions:

NATIONAL SOURCE OF FUEL
Notes:
Reviewer Conclusions:

LONG-TERM AVAILABILITY
Notes:
Reviewer Conclusions:

29 AVAILABILITY AND DISTRIBUTION

2) Decide if the students will evaluate the presentations as individuals or as part of a review panel. Then assign (or have the members of the class select) the stakeholders or special interest groups they will represent. If they're working in review panels, allow the panel members to sit together.

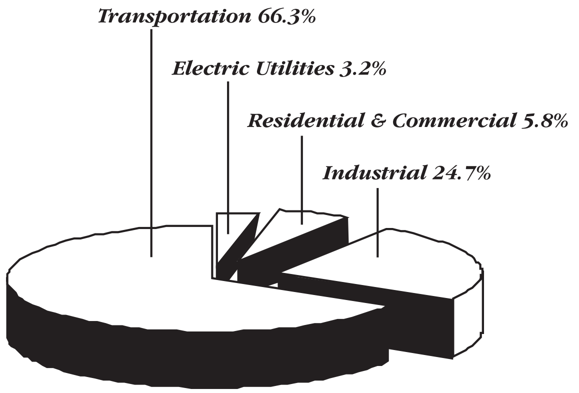
3) Refer students to the handout, "FUEL REVIEW WORKSHEET: AVAILABILITY, DISTRIBUTION, AND PRICING." They will use this worksheet as a guide for taking notes during a fuel presentation and writing down their (or their panel's) conclusions. (They will need one copy of this worksheet for each fuel presentation given.) Before the presentations, allow students time to make note of their interest group's chief concerns. After each presentation, allow them time to discuss and make note of their conclusions.

4) Remind presenters to keep in mind the concerns of the stakeholders in the audience. Presentations should last 5 to 10 minutes, with additional time for the audience to ask questions. Encourage students in their audience to ask follow-up questions from the points of view of the stakeholders they represent.

5) At the end of each day and again after all presentations have been given, allow time for the panels to compare the fuels and discuss the advantages and disadvantages of each with respect to safety, availability, and social and environmental costs.

AVAILABILITY AND DISTRIBUTION: THE CHALLENGE

1.1 PETROLEUM CONSUMPTION IN THE UNITED STATES



Source: Transportation Energy Data Book: Edition 19. *Stacy C. Davis. Oak Ridge National Laboratory. September 1999.*

Fossil fuels, which are the source of gasoline used in most automobiles, are a finite resource. We don't know exactly how much fossil fuel is present in the earth, since new supplies are continually being located; but with more and more people around the world using gasoline-powered cars and other vehicles, the supplies are being used faster than ever before.

In the United States, oil production has been steadily declining since the 1970s. This decline is expected to continue as we use up our domestic supplies of oil. America now imports over 54 percent of its oil. By 2010 we'll import more than 60 percent. With a growing number of cars on the road and the popularity of driving large vehicles, the amount of fuel we need to import keeps rising. This means that the United States is becoming less self-sufficient and more dependent on other countries to meet our transportation needs.

Keeping enough fuel available to drivers in America is a challenge. Americans have experienced shortages in the past. In the early 1970s, supplies of gasoline were so limited that gas was rationed. In some areas of the country, gas stations were closed on certain days of the week. In other places, an even or odd number on one's license plate determined which days of the week one was entitled to buy gas. Long lines at gas pumps and signs reading "Out of Gas" were common. In the early '90s, conflicts in the Middle East threatened the supplies of oil that we import from that region and led us to war to assure that supplies would continue.

The amount of fuel available affects the price we pay at the gas pump. When fuel is abundant, prices are usually low; when fuel is scarce or competition for it is high, the prices rise. In the year 2000, gasoline prices rose as the group of oil-producing and -exporting countries (OPEC) limited the amount of oil it processed and distributed at the time. Limited supplies of oil raised prices not just in the United States but throughout the world. In the United States, where food and other goods are delivered by oil-dependent trucks and homes are heated with oil, the rising price of fuel is often noticed in increased prices of food and other products and in high heating bills.

Many of the costs of finding, processing, protecting, and distributing fuel are not seen in the price that drivers pay for gas. The true cost would have to include the military costs of defending oil supplies, the direct environmental costs of cleaning up oil spills, and the costs to ecosystems that are disturbed by oil production and distribution.

• The United States consumes over 18 million barrels of petroleum daily.

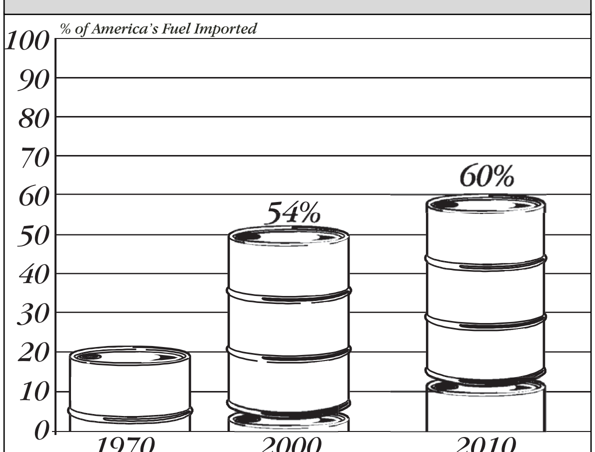
• The United States consumes more than one-quarter of the world's oil production, but produces only about one-tenth of its oil.

• Between 1995 and 2015, the use of oil for transportation purposes in the United States will grow faster than all other oil uses. Eighty percent of the increase in annual oil consumption during that period will be directly attributable to transportation vehicles.

• As of 2000, oil used in highway transportation alone roughly equals the total amount of oil imported into the country.

Source: U.S. Department of Energy, Clean Fuels Foundation, 2000. URL: http://www.cleanfuels.org.

1.2 U.S. DEPENDENCE ON FOREIGN OIL



Source: U.S. Department of Energy, Clean Fuels Foundation, 2000. URL: http://www.cleanfuels.org.

TRANSPORTATION FUELS, ENGINES, AND MOTORS

This sheet lists the major types of engines, motors, power conversion devices, and fuels being used or considered for transportation.

ALTERNATIVE FUELS

According to the federal government definition, alternative fuels are those determined to be "substantially not petroleum" and yielding "energy security benefits and substantial environmental benefits." The chief alternatives are methanol, denatured ethanol and other alcohols (separately or in mixtures of 85 percent by volume or more with gasoline or other fuels), CNG, LNG, LPG, hydrogen, coal-derived liquid fuels, fuels derived from biomass, electricity, neat (100 percent) biodiesel.

BIODIESEL -
A liquid biodegradable fuel produced from renewable sources such as vegetable oils, animal fats, and used oil and fats.

ELECTRICITY -
Electric current used as a power source. It can be generated from a variety of feedstocks including oil, coal, nuclear, hydro, natural gas, wind, and solar. In vehicles it is generally provided by rechargeable storage batteries, photovoltaic cells, or a fuel cell.

ETHANOL -
A liquid alcohol produced from corn, grain, or agricultural waste. It is also called ethyl alcohol or grain alcohol. When mixed with gasoline in a ratio of 85 parts ethanol to 15 parts gasoline, it is called E85.

HYDROGEN -
A colorless, highly flammable gas; the most abundant element in the universe. It is being researched for use in fuel cells.

LIQUEFIED PETROLEUM GAS (LPG) -
A combination of hydrocarbons, such as propane, ethane, and butane. It is often referred to as "propane." Under moderate pressure the gaseous fuel turns to liquid.

METHANOL -
A liquid alcohol that can be produced from just about anything containing carbon, including coal and biomass. It is also called methyl alcohol or wood alcohol. When mixed with gasoline in a ratio of 85 parts methanol to 15 parts gasoline, it is called M85.

NATURAL GAS -
A naturally occurring gaseous mixture of simple hydrocarbons, primarily methane, which is the simplest hydrocarbon. When used as a fuel, it is either compressed by cooling (CNG) or liquefied (LNG).

OTHER VOCABULARY

BATTERY -
A device kept aboard a vehicle used to store energy. The battery is restored with electrical charging from a generator powered by a gas engine, an electrical outlet, or photovoltaic panels.

BIOMASS -
Renewable organic matter used for the production of energy. Biomass includes agricultural crops, crop waste, wood, animal and municipal wastes, aquatic plants, etc.

DIESEL -
A liquid fuel formed from a combination of petroleum and natural gas, a mixture of hydrocarbons (compounds that contain hydrogen and carbon atoms) that range from 12 to 24 carbon atoms in length.

FUEL CELL -
An electrochemical system (no moving parts) that converts the chemical energy of a fuel, which is stored onboard a vehicle, directly to electricity.

GASOHOL -
Gasoline that contains 10 percent ethanol by volume. Also called E10, super unleaded plus ethanol or unleaded plus ethanol.

GASOLINE -
A liquid fuel formed from a combination of petroleum and natural gas, a mixture of hydrocarbons (compounds that contain hydrogen and carbon atoms) that are 7 to 11 carbon atoms in length. It is the most widely used fuel.

COMPRESSION IGNITION ENGINE -
Internal compression engine in which injected fuel is ignited as rapid compression of air within the cylinders generates heat. Used with diesel fuels.

HYBRID-ELECTRIC VEHICLE (HEV) -
A vehicle that is powered by two or more energy sources, one of which is electricity. HEVs may combine the engine and fuel system of a conventional vehicle with the batteries and electric motor of an electric vehicle in a single drivetrain.

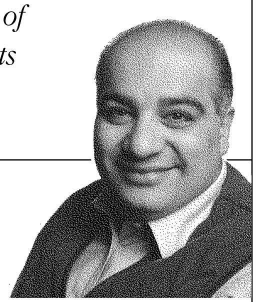
PETROLEUM FUEL -
Gasoline and diesel fuel.

SPARK IGNITION ENGINE -
Internal combustion engine in which the charge is ignited electrically — for example, with a spark plug.

WHO'S INTERESTED IN AFVS? WHO CARES ABOUT AVAILABILITY AND DISTRIBUTION?

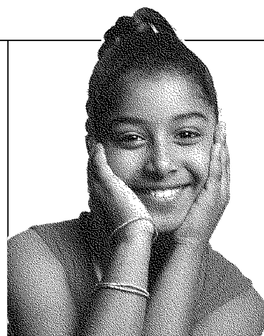
A wide variety of people have a stake in a change to AFVs. They vary from human rights activists to auto salespeople to environmental scientists to physicians to diplomats.

This group is largely interested in the availability of fuels, their safe distribution, and the reduction of some of the hidden social and environmental costs related to gasoline-powered vehicles.



ADVOCATES FOR THE ENVIRONMENT, HUMAN RIGHTS, AND PEACE

Much of the fuel used in the United States comes from politically oppressive or unstable parts of the world. Conflicts over oil endanger our own soldiers and the people in the oil-producing countries. War over oil supplies inevitably results in massive environmental damage. If we develop domestic sources of fuel, we could reduce these losses to human life and the environment, and be in a better position to stand up to oil-producing countries that oppress their own people.

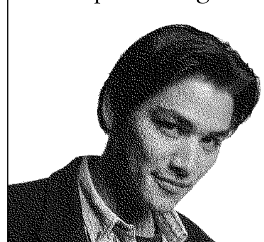


PETROLEUM INDUSTRY

As a business that employs a lot of people in drilling and refining oil for fuel, plastics, fertilizers, and other products, we want to keep the industry thriving. We expect to keep discovering new sources of fossil fuels for some time. Still, there is pressure from the government and environmental groups to change to alternatives that burn more cleanly and don't contribute to global climate change. With people demanding alternatives, should our industry be diversifying? If so, what other types of fuel should we be exploring?

NATIONAL SECURITY PERSONNEL: Advisers, Diplomats, FBI, CIA, Department of Defense

So much oil comes from unstable parts of the world. Our dependence on foreign oil led us to war in the early '90s when Iraq invaded Kuwait and threatened oil supplies there. Costly wars can't be the only answer to protecting our interests. If we develop domestic sources of fuel, we could reduce our military presence in unstable parts of the world and reduce the loss of life that results when fuel sources need protecting.

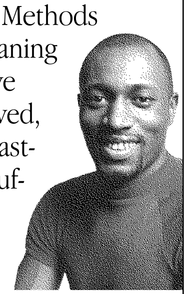


ECONOMIST

The cost of fuel has a large impact on industry and the strength of our economy. How can we keep that cost down? An increasing amount of oil is being bought overseas, leading the United States to send more money out of the country than it gets back. Which domestic sources of fuel could help us to balance imports and exports and reduce this trade deficit?

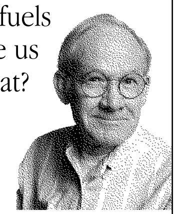
MARINE SCIENTISTS

The number of oil spills reported in the news is a fraction of those that actually occur. Methods for cleaning up have improved, but coastlines suffer for years after a spill. Some areas are permanently damaged from frequent spills. People like to blame the spill on miscalculations at the ship's wheel, but we're interested in cutting down the risk of spills by finding safer, alternative fuels that don't need to be shipped.



BUSINESSES OF ALL SIZES AND CONSUMERS

We need energy for every aspect of our lives — to run industry so the economy is strong and people are employed, to produce goods, to transport goods and people, to meet heating and cooking needs. We need ongoing supplies of fuel we can depend on at stable prices. Which fuels provide us with that?



AMERICAN FARMER

Henry Ford wanted to run his Model T on fuel made from corn; diesel engines were designed to run on peanut oil. Is there a future for fuel crops? If so, which crops would they be? The Department of Agriculture's National Resources Inventory shows that we're losing almost two million acres of valuable farmland each year to urban sprawl and industry. That's almost four acres every day! If we were growing fuel crops on that land, wouldn't people be more willing to protect it?

FUELS THAT POWER YOUR COMMUNITY: GUIDE TO COMMUNITY RESEARCH

Use the questions below to help you find out which fuels now power your community.

POSSIBLE RESOURCES

- Someone who pays the utility bills in your home
- The public relations department of your local utility company, public transit authority, department of transportation, companies or organizations that operate fleets of vehicles
- National Renewable Energy Laboratory web site

1.

TRANSPORTATION FUEL FOR YOUR COMMUNITY

a. Do you ever see buses at the gas station? Where do they refuel?

b. Many alternative fuels are being used by fleets of vehicles throughout the United States, such as buses, the postal service, package delivery services, taxis, and government. Do any of these local fleets already use an alternative fuel? If so, where do those fleets refuel? Are these sites private or open to the public?

c. Besides gasoline and diesel, which other types of fuel are now available to fuel private automobiles? Where can you obtain them?

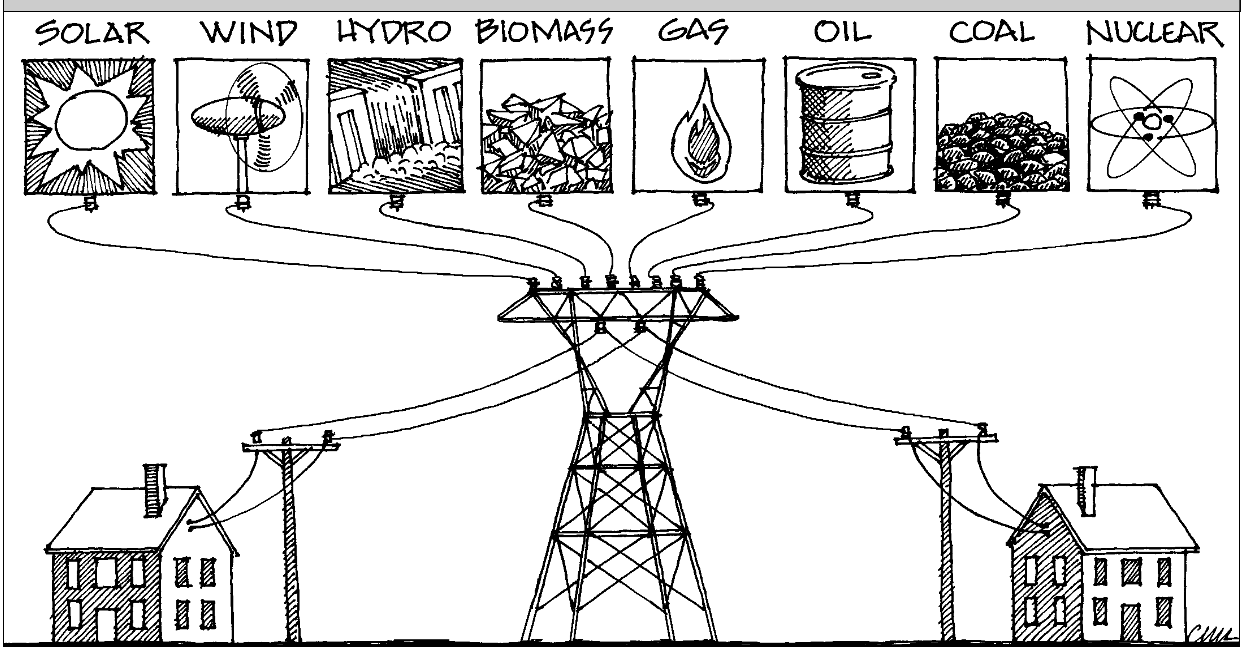
2.

FUEL FOR YOUR POWER GRID

a. Diagram 1.3 shows the various sources of energy that might be used to generate power for a regional power grid. Which types of power currently contribute to your electric power grid?

b. Are any new sources of power being developed to produce electricity for your community?

1.3 SOURCES OF ELECTRICITY

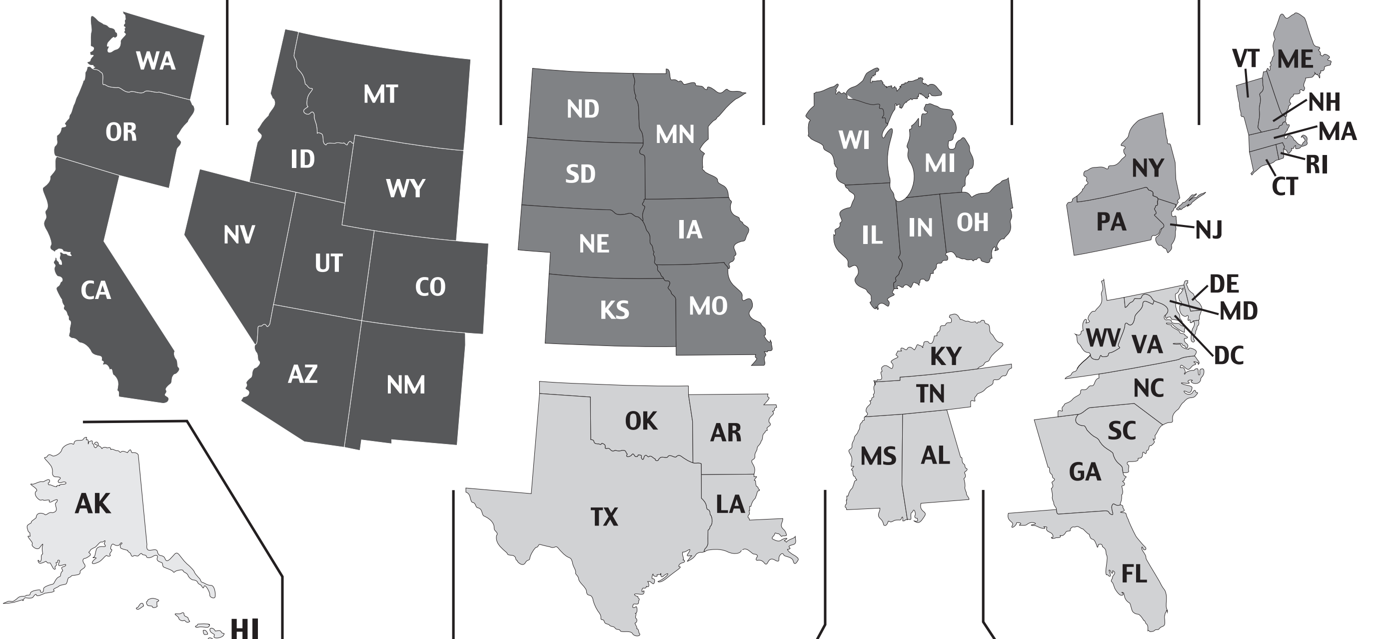


Local utilities rely on power that may be generated from a variety of energy sources: coal, oil, natural gas, nuclear, hydroelectric, solar, wind, geothermal, biomass, and others. The mix of energy varies from region to region and fluctuates over time as the costs of various energy sources rise and fall and sources of new energy become available.

- Look at the chart below to find out which regions of the United States rely most heavily on coal, petroleum, gas, or nonfossil fuels.
- Which regions rely least on coal, petroleum, gas, or nonfossil fuels?
- How does the mix of power that serves New England compare to the mix that serves California or Colorado?
- What are the ultimate sources of fuel for a battery electric car in your region?

1.4 WHERE ELECTRICITY COMES FROM, BY FUEL TYPE & REGION

Region	Coal	Petroleum	Gas	Nuclear	Hydroelectric	Other
Pacific Contiguous	**4%**	**1%**	**28%**	**11%**	**50%**	**7%**
Mountain	**67%**	*****	**8%**	**10%**	**14%**	**1%**
West North Central	**74%**	**1%**	**2%**	**16%**	**5%**	**1%**
East North Central	**72%**	**1%**	**5%**	**21%**	**1%**	**1%**
Middle Atlantic	**36%**	**5%**	**17%**	**35%**	**6%**	**2%**
New England	**15%**	**26%**	**17%**	**27%**	**7%**	**9%**
Pacific Noncontiguous	**12%**	**55%**	**22%**	**0%**	**6%**	**5%**
West South Central	**40%**	**1%**	**45%**	**11%**	**1%**	**1%**
East South Central	**68%**	**1%**	**4%**	**19%**	**5%**	**2%**
South Atlantic	**56%**	**7%**	**8%**	**26%**	**1%**	**2%**



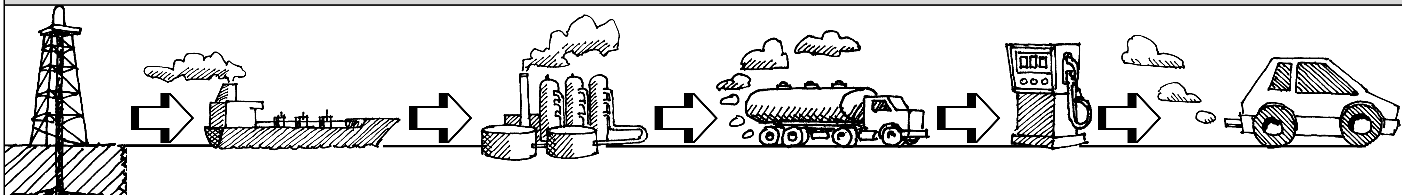
Other includes geothermal, wood, wind, waste, photovoltaic, and solar.
** Absolute value is less than 0.05.*

Source: DOE/EIA-0348(2000)/1
Electric Power Annual 2000
Volume I, August 2001
www.eia.doe.gov/cneaf/electricity/epav1/epav1.pdf

Energy Information Administration
Office of Coal, Nuclear, Electric and Alternate Fuels
U.S. Department of Energy
Washington, DC 20585

AVAILABILITY AND DISTRIBUTION: GUIDE TO FUEL TEAM RESEARCH

1.5 HOW OIL IS PROCESSED AND GETS TO CARS

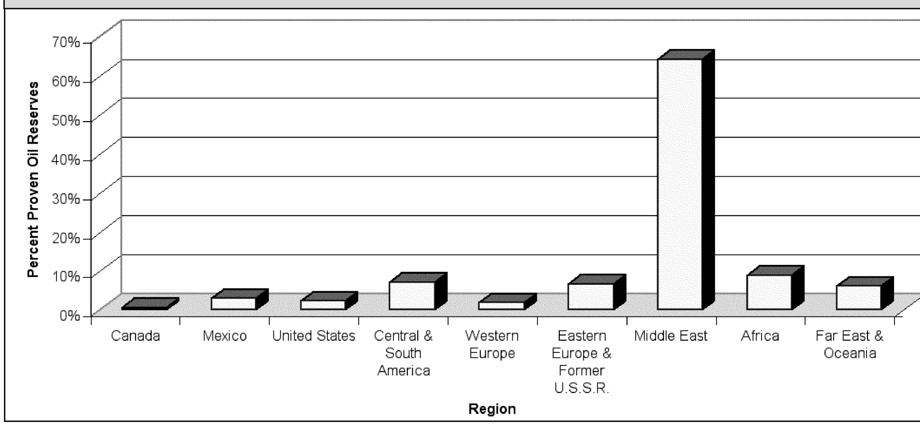


Use the questions on the next page as a guide to developing your presentation. Many of the answers are found in the alternative-fuel fact sheets. For some, you'll need to do further research in encyclopedias, periodicals, or other publications found in your library; on the Internet; or by contacting organizations that promote alternative fuels. For others, you'll need to draw your own conclusions based on facts you've found. Be prepared to explain how you came to your conclusions.

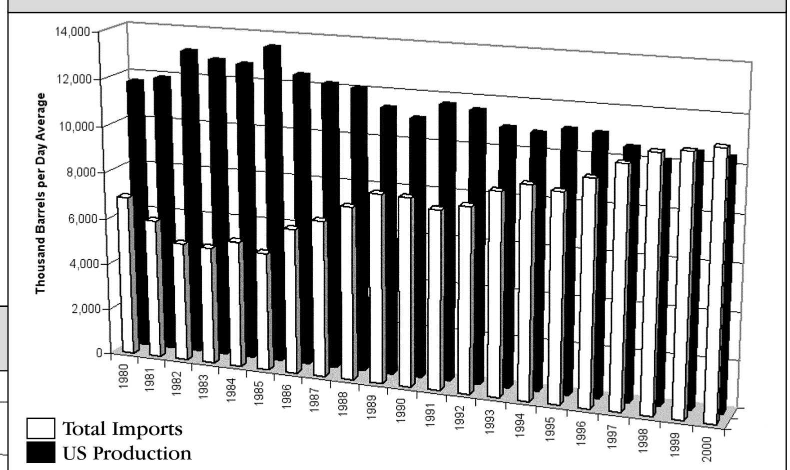
While answering the questions on the next page and preparing your presentation, keep in mind the issues below (which your class discussed at the beginning of this unit) and the various people interested in them.

Use diagrams, charts, and other graphics if they can help you deliver information to your audience.

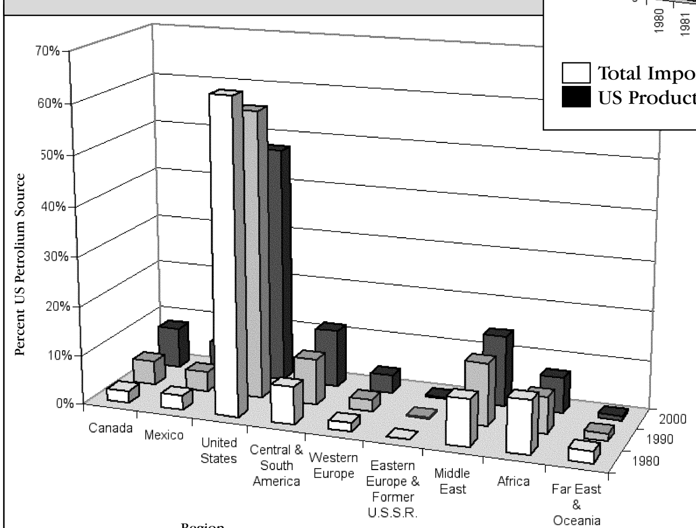
1.6 PERCENT OF PROVEN OIL RESERVES BY REGION



1.7 U.S. OIL: ANNUAL IMPORTS VS. DOMESTIC PRODUCTION



1.8 WHERE THE U.S. GETS ITS OIL



TRANSPORTATION AND FUEL ISSUES

- Regional source of fuel
- National source of fuel
- Long-term availability
- Stable fuel prices
- Safe production, storage, and delivery
- Low cost of keeping supplies secure
- Positive impact on people at the source
- Ease of developing a fueling infrastructure

1. *FUEL DESCRIPTION*

The physical state of a fuel — solid, liquid, or gaseous — is important because traditional engine technologies are designed to burn fuels only in liquid forms. The physical state and its chemical makeup—simple, complex, small, or large molecules — also influences the way it is distributed and stored. Each fuel is characterized by other properties that determine whether it is safe for widescale use, such as ignitability, explosiveness, and flammability. All fuels have the potential to be used safely, but necessary precautions must be taken. They may involve design modifications to the vehicles, the fueling infrastructure, or both.

a. What are the physical properties of your fuel?

b. Explain how its physical properties affect how it is stored, transported, and used.

2. *GETTING THE FUEL*

a. Where on the earth is the fuel found; that is, in what region/s of the world and in what part of the earth's core or surface? Is it found in the region where you live? Is it found in the United States?

b. How is the fuel extracted (or grown) and processed? Is the environment damaged in the process? What safety concerns need to be addressed during extraction and processing? How are people and the environment protected?

c. Does the fuel originate in a politically unstable region of the world, in which the fuel's extraction might require careful diplomacy or military protection? How might this affect fuel prices and the costs of keeping supplies secure?

d. How might extracting (or growing) and processing the fuel change the lives of the people who live nearby? (For example, new fuels might create new jobs for certain people or disrupt their environment.)

3. *DISTRIBUTING THE FUEL*

a. How would the fuel be distributed from the source to your community? Are there any safety or environmental concerns to consider during distribution?

b. Where in your community could fueling stations and fuel tanks be safely located?

4. *ABUNDANCE AND AVAILABILITY*

a. Is this fuel currently abundant enough for widespread use by transportation? If not, might supplies increase? If so, will supplies continue to be available in the future?

b. Which other sectors of society (domestic heating and cooking, agriculture, shipping, fishing, manufacturing) use this fuel? How might prices of transportation fuel be affected by competing demands for it?

TERMS YOU MAY ENCOUNTER

ALCOHOLS -
Organic compounds that include a hydroxyl group; the two simplest alcohols are methanol and ethanol.

CORROSIVE -
Apt to chemically decompose another substance.

CRYOGENIC STORAGE -
Extreme low-temperature storage.

EXPLOSIVENESS -
The likelihood of exploding under certain conditions.

FEEDSTOCK -
Any material converted to another form of fuel or energy product; e.g., cornstarch can be used as a feedstock for ethanol.

ESTER -
An organic compound formed by reacting an acid with an alcohol. Biodiesel is an ester.

IGNITABILITY -
The ability to start to burn.

FLAMMABLE -
Capable of being easily ignited and of burning with extreme rapidity.

REACTIVE -
Tending to react with other chemicals.

TOXICITY -
The harmfulness of a fuel to living organisms. Measures of a fuel's toxicity include exposure limits for inhalation, ingestion, skin absorption, and contact over time.

VOLATILE -
Easily changing into a vapor at normal temperatures and pressures.

FUEL REVIEW WORKSHEET:
AVAILABILITY, DISTRIBUTION, AND PRICING

Reviewer Name/s: ______________________________

____

Stakeholder or Special Interest Group: ______________________________

____

Chief Concerns: ______________________________

____

Fuel or Technology Being Reviewed: ______________________________

____

Listen to the presentations for information about the issues below.

REGIONAL SOURCE OF FUEL

Notes: ______________________________

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Reviewer Conclusions: ______________________________

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NATIONAL SOURCE OF FUEL

Notes: ______________________________

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Reviewer Conclusions: ______________________________

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LONG-TERM AVAILABILITY

Notes: ______________________________

____

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Reviewer Conclusions: ______________________________

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____

STABLE FUEL PRICES

Notes:

Reviewer Conclusions:

SAFE PRODUCTION, STORAGE, AND DELIVERY

Notes:

Reviewer Conclusions:

LOW COST OF KEEPING SUPPLIES SECURE

Notes:

Reviewer Conclusions:

POSITIVE IMPACT ON PEOPLE AT THE SOURCE

Notes:

Reviewer Conclusions:

EASE OF DEVELOPING FUELING INFRASTRUCTURE

Notes:

Reviewer Conclusions:

HEALTH, POLLUTION, AND SAFETY

TIME

10 days

OBJECTIVES

- *To understand the impact of our current transportation system on public safety and on the human and environmental health of our communities.*
- *To understand the global importance of reducing carbon dioxide emissions.*
- *To identify ways that alternative fuels can alter local and global impacts.*

MATERIALS NEEDED

For background reading and community research

Student handouts

- *Health, Pollution, and Safety: The Challenge*
- *Automobile-Related Emissions*
- *Who's Interested in AFVs? Who Cares About Health, Pollution, and Safety?*
- *Health, Pollution, and Safety: Guide to Community Research*

Other useful resources

- *Access to the library and Internet*
- *Telephone directory or list of phone numbers for these local resources: local or state police or fire department; Coast Guard; local or regional planning department; state department of environmental protection or management; board of health; American Lung Association and its web site; a regional Environmental Protection Agency office and its web site; service stations*
- *In-class speaker to talk about automobile emissions, air quality, global warming, or releases of toxic substances (Regional EPA offices or state environmental agencies often have people available for educational outreach if booked far enough in advance.)*

For fuel research and student presentations

Student handouts

- *Health, Pollution, and Safety: Guide to Fuel Team Research*
- *Comparing Alternative Fuels for Pollutants and Greenhouse Gases*
- *Fuel Review Worksheet: Health, Pollution, and Safety*
- *Alternative fuels fact sheets (to be distributed to appropriate teams)*
- *Resource Guide*
- *Evaluating Team Reports and Presentations*

Other useful resources

- *Access to the library and Internet*
- *Publications listed as references for this unit*
- *Flip charts, poster board, transparencies, and use of an overhead projector*
- *Access to word processing or presentation software*

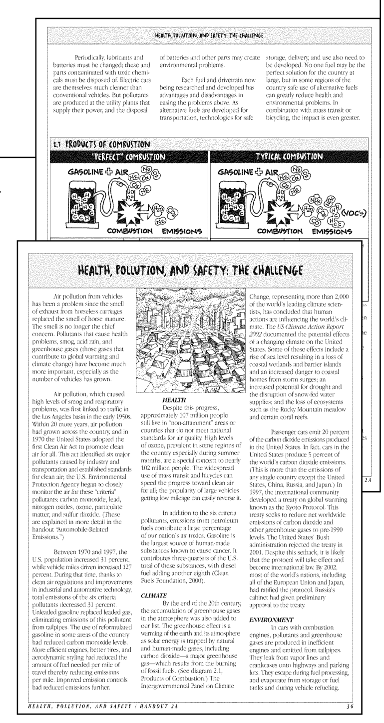
STEP 1 - Background Reading and Discussion

HEALTH, POLLUTION, AND SAFETY: PRESENTING THE CHALLENGE

TIME: 45 minutes, depending on students' prior knowledge of air pollutants and global warming; may be assigned for homework

1) Copy and distribute the student handouts listed above for background reading and community research. Have students identify the major health and environmental issues related to a transportation system made up of private gasoline-powered cars. To stimulate discussion, refer to the student handout "HEALTH, POLLUTION, AND SAFETY: THE CHALLENGE."

A key point for students to understand is that with small numbers of vehicles in operation, their impact on public health and the environment is relatively small.



HEALTH, POLLUTION, AND SAFETY: THE CHALLENGE

Periodically, lubricants and batteries must be changed; these and parts contaminated with toxic chemicals must be disposed of. Electric cars are themselves much cleaner than conventional vehicles. But pollutants are produced at the utility plants that supply their power, and the disposal of batteries and other parts may create environmental problems.

Each fuel and drivetrain now being researched and developed has advantages and disadvantages in easing the problems above. As alternative fuels are developed for transportation, technologies for safe storage, delivery, and use also need to be developed. No one fuel may be the perfect solution for the country at large, but in some regions of the country safe use of alternative fuels can greatly reduce health and environmental problems. In combination with mass transit or bicycling, the impact is even greater.

HEALTH, POLLUTION, AND SAFETY: THE CHALLENGE

Air pollution from vehicles has been a problem since the smell of exhaust from horseless carriages replaced the smell of horse manure. The smell is no longer the chief concern. Pollutants that cause health problems, smog, acid rain, and greenhouse gases (those gases that contribute to global warming and climate change) have become much more important, especially as the number of vehicles has grown.

Air pollution, which caused high levels of smog and respiratory problems, was first linked to traffic in the Los Angeles basin in the early 1950s. Within 20 more years, air pollution had grown across the country, and in 1970 the United States adopted the first Clean Air Act to promote clean air for all. This act identified six major pollutants caused by industry and transportation and established standards for clean air; the U.S. Environmental Protection Agency began to closely monitor the air for these "criteria" pollutants: carbon monoxide, lead, nitrogen oxides, ozone, particulate matter, and sulfur dioxide. (These are explained in more detail in the handout "Automobile-Related Emissions.")

Between 1970 and 1997, the U.S. population increased 31 percent, while vehicle miles driven increased 127 percent. During that time, thanks to clean air regulations and improvements in industrial and automotive technology, total emissions of the six criteria pollutants decreased 31 percent. Unleaded gasoline replaced leaded gas, eliminating emissions of this pollutant from tailpipes. The use of reformulated gasoline in some areas of the country had reduced carbon monoxide levels. More efficient engines, better tires, and aerodynamic styling had reduced the amount of fuel needed per mile of travel thereby reducing emissions per mile. Improved emission controls had reduced emissions further.

HEALTH

Despite this progress, approximately 107 million people still live in "non-attainment" areas or counties that do not meet national standards for air quality. High levels of ozone, prevalent in some regions of the country especially during summer months, are a special concern to nearly 102 million people. The widespread use of mass transit and bicycles can speed the progress toward clean air for all; the popularity of large vehicles getting low mileage can easily reverse it.

In addition to the six criteria pollutants, emissions from petroleum fuels contribute a large percentage of our nation's air toxics. Gasoline is the largest source of human-made substances known to cause cancer. It contributes three-quarters of the U.S. total of these substances, with diesel fuel adding another eighth (Clean Fuels Foundation, 2000).

CLIMATE

By the end of the 20th century, the accumulation of greenhouse gases in the atmosphere was also added to our list. The greenhouse effect is a warming of the earth and its atmosphere as solar energy is trapped by natural and human-made gases, including carbon dioxide—a major greenhouse gas—which results from the burning of fossil fuels. (See diagram 2.1, Products of Combustion.) The Intergovernmental Panel on Climate Change, representing more than 2,000 of the world's leading climate scientists, has concluded that human actions are influencing the world's climate. The *US Climate Action Report 2002* documented the potential effects of a changing climate on the United States. Some of these effects include a rise of sea level resulting in a loss of coastal wetlands and barrier islands and an increased danger to coastal homes from storm surges; an increased potential for drought and the disruption of snow-fed water supplies; and the loss of ecosystems such as the Rocky Mountain meadow and certain coral reefs.

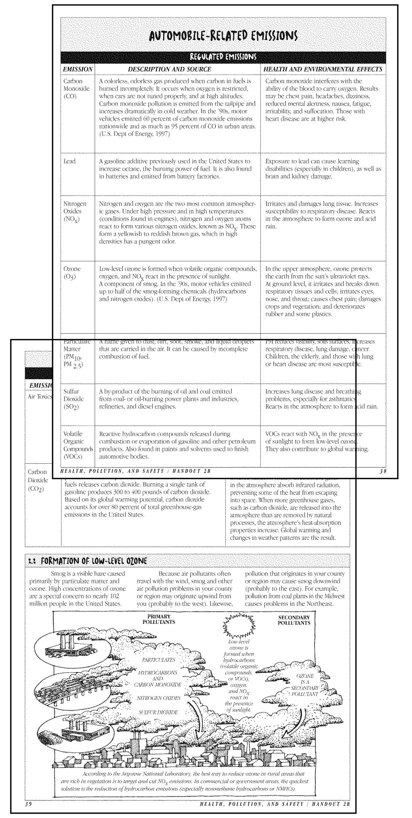
Passenger cars emit 20 percent of the carbon dioxide emissions produced in the United States. In fact, cars in the United States produce 5 percent of the world's carbon dioxide emissions. (This is more than the emissions of any single country except the United States, China, Russia, and Japan.) In 1997, the international community developed a treaty on global warming known as the Kyoto Protocol. This treaty seeks to reduce net worldwide emissions of carbon dioxide and other greenhouse gases to pre-1990 levels. The United States' Bush administration rejected the treaty in 2001. Despite this setback, it is likely that the protocol will take effect and become international law. By 2002, most of the world's nations, including all of the European Union and Japan, had ratified the protocol. Russia's cabinet had given preliminary approval to the treaty.

ENVIRONMENT

In cars with combustion engines, pollutants and greenhouse gases are produced in inefficient engines and emitted from tailpipes. They leak from vapor lines and crankcases onto highways and parking lots. They escape during fuel processing, and evaporate from storage or fuel tanks and during vehicle refueling.

HEALTH, POLLUTION, AND SAFETY / HANDOUT 2A 36

With large numbers of vehicles in use, the problem grows. In choosing new fuels for vehicles, we need to consider the health and environmental impacts of an ever-growing number of vehicles using them. In 1999, the world population reached 6 billion; it is expected to reach 9 billion by 2050. In addition to the rapidly growing world population is the even faster growth of energy consumption taking place as standards of living rise throughout the world, making it urgent to find ways to reduce our use of fossil fuels.



Use diagram 2.1, "Products of Combustion," to discuss the combustion process and past and current efforts to make gasoline burn more cleanly. A key point for students to understand is the contribution of gasoline-powered vehicles to global warming (through the emission of carbon dioxide). In 2000, new studies were released by the Intergovernmental Panel on Climate Change that demonstrate the connection between human-made greenhouse-gas emissions, global warming, melting of the ice caps, and a rise in sea levels.

2) Refer to the student handout "AUTOMOBILE-RELATED EMISSIONS," which describes the health and environmental effects of various emissions and includes the diagram "Formation of Low-Level Ozone." Use the diagram to help students understand how ozone is formed and how it travels, and that large numbers of people live in areas that do not meet clean air standards for ozone. Make sure that students understand the difference between the high atmospheric ozone—needed to protect us from ultraviolet cancer-causing rays—and low-level ozone, which is a respiratory irritant. A key point is that automobiles contribute directly to the development of low-level ozone, a pollutant with serious health effects, which threatens 107 million people in the United States. Through the Community Research Activity, students will discover if their own region meets EPA air-quality standards for ozone.

Make sure students understand how to read the chart "Automobile Emissions," by asking them to identify the health effects and environmental effects of ozone. Students will use this chart much more when doing the research in this section.

3) Ask students to identify various types of people who may be concerned with health and environmental issues, such as global warming, that are related to our transportation system. What would their chief concerns be? Refer to the student handout "WHO'S INTERESTED IN AFVS? WHO CARES ABOUT HEALTH, POLLUTION, AND SAFETY?" Do students identify with any of the people on this list? Which of these people are likely to live or work in their community? Which of these people may be in the audience during the students' presentations? Who else in their community may have an interest in AFVs, and what would their concerns be?

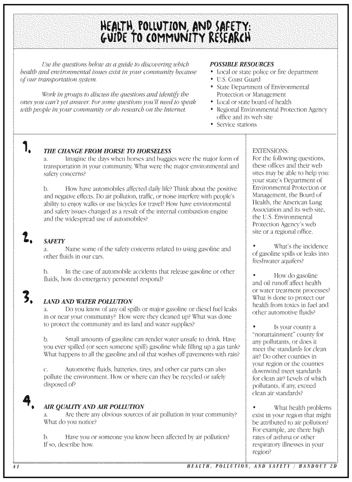
EXTENSION: Have students make up a sheet similar to the "WHO'S INTERESTED IN AFVS?" handout that represents actual people in your community.

STEP 2 - Discussion and Community Research

DISCOVERING HEALTH, POLLUTION, AND SAFETY ISSUES IN YOUR COMMUNITY

TIME: 45 minutes of discussion, followed by another 45 minutes over several days for research, coaching, and student reporting; requires out-of-class time for some students

1) In this exercise, students will discuss the impact of our current transportation system on the safety and health of their community and collect information (about levels of air pollution, occurrence of related health problems, the community's response to traffic accidents, and procedures for proper disposal of auto parts and fluids) from local or state resources.



HEALTH, POLLUTION, AND SAFETY: GUIDE TO COMMUNITY RESEARCH

Use the questions below as a guide to discovering which health and environmental issues exist in your community because of our transportation system.

Work in groups to discuss the questions and identify the ones you can't yet answer. For some questions you'll need to speak with people in your community or do research on the Internet.

POSSIBLE RESOURCES
- Local or state police or fire department
- U.S. Coast Guard
- State Department of Environmental Protection or Management
- Local or state board of health
- Regional Environmental Protection Agency office and its web site
- Service stations

1. ***THE CHANGE FROM HORSE TO HORSELESS***

a. Imagine the days when horses and buggies were the major form of transportation in your community. What were the major environmental and safety concerns?

b. How have automobiles affected daily life? Think about the positive and negative effects. Do air pollution, traffic, or noise interfere with people's ability to enjoy walks or use bicycles for travel? How have environmental and safety issues changed as a result of the internal combustion engine and the widespread use of automobiles?

2. ***SAFETY***

a. Name some of the safety concerns related to using gasoline and other fluids in our cars.

b. In the case of automobile accidents that release gasoline or other fluids, how do emergency personnel respond?

3. ***LAND AND WATER POLLUTION***

a. Do you know of any oil spills or major gasoline or diesel fuel leaks in or near your community? How were they cleaned up? What was done to protect the community and its land and water supplies?

b. Small amounts of gasoline can render water unsafe to drink. Have you ever spilled (or seen someone spill) gasoline while filling up a gas tank? What happens to all the gasoline and oil that washes off pavements with rain?

c. Automotive fluids, batteries, tires, and other car parts can also pollute the environment. How or where can they be recycled or safely disposed of?

4. ***AIR QUALITY AND AIR POLLUTION***

a. Are there any obvious sources of air pollution in your community? What do you notice?

b. Have you or someone you know been affected by air pollution? If so, describe how.

EXTENSIONS:
For the following questions, these offices and their web sites may be able to help you: your state's Department of Environmental Protection or Management, the Board of Health, the American Lung Association and its web site, the U.S. Environmental Protection Agency's web site or a regional office.

- What's the incidence of gasoline spills or leaks into freshwater aquifers?
- How do gasoline and oil runoff affect health or water treatment processes? What is done to protect our health from toxics in fuel and other automotive fluids?
- Is your county a "nonattainment" county for any pollutants, or does it meet the standards for clean air? Do other counties in your region or the counties downwind meet standards for clean air? Levels of which pollutants, if any, exceed clean air standards?
- What health problems exist in your region that might be attributed to air pollution? For example, are there high rates of asthma or other respiratory illnesses in your region?

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Divide the class into groups or four to six students and refer them to the student handout "HEALTH, POLLUTION, AND SAFETY: GUIDE TO COMMUNITY RESEARCH," which presents a mixture of questions for discussion and for out-of-class research. Provide student groups with 20 minutes to discuss the questions they can answer, identify the questions they can't answer, and think about places they might find the information they need.

2) Have student groups report a summary of their discussions to the class. They should be able to answer questions 1a and b, 2a, 3b, and 4a and b. For the questions that they may not be able to answer (especially 2c, 3a and c), ask where they might find the answers and work with them to develop clear questions to obtain the information they need. Possible answers and references to outside sources are listed below.

THE CHANGE FROM HORSE TO HORSELESS

#1a. Smell of horse manure, manure in the street, muddy shoes and clothing, infectious disease.

#1b. Change in odor and pollutants, change from infectious diseases to cancers and respiratory problems, more serious accidents, global warming.

SAFETY

#2a. Leaky storage tanks can contaminate aquifers; spilling of gas during fill-up exposes people to carcinogens; poorly designed cars can blow up; highway runoff of fluids can contaminate streams.

#2b. Refer students to the state or local police or fire department to get detailed information.

LAND AND WATER POLLUTION

#3a. Refer students to the Coast Guard, the state Department of Environmental Protection or Management, the regional office of the U.S. EPA.

#3b. Runoff from roadways, driveways, parking lots, and other paved surfaces can enter the watershed and pollute freshwater sources.

#3c. Refer students to the local or regional planning department, the state Department of Environmental Protection or Management, and the Board of Health. Some service stations have capabilities for recycling some fluids and parts.

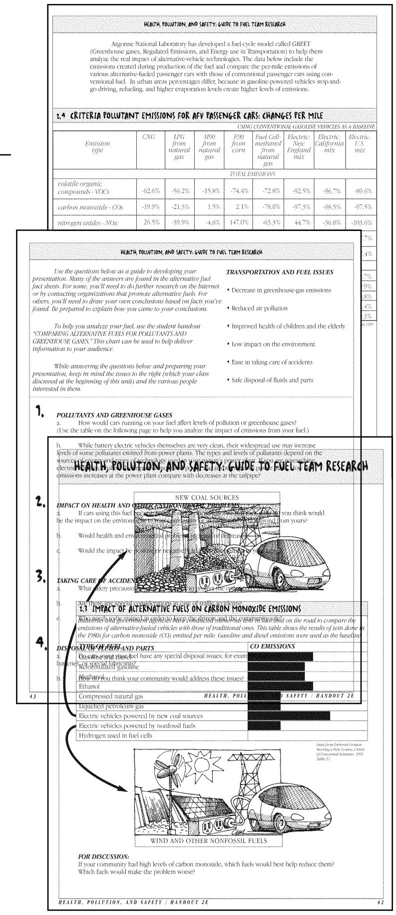
AIR QUALITY AND AIR POLLUTION

#4a. Answers depend on your own community. In polluted areas students may notice soot or gray or yellow atmosphere due to the presence of particulates or smog. Possible places where pollution is evident: highways, downtown, tunnels, drive-through windows, bus terminal, around the school or other buildings where people wait for riders.

#4b. Answers will vary. Possible responses describing the effects of pollution: burning or watery eyes, coughing, asthma, other respiratory infections.

3) Assign several students to make calls to the various agencies and offices and/or to research their Internet sites. (To avoid duplicate calls to the same agency, ask one student to get all the information needed from a particular agency. For example, one student may call the regional EPA for questions #3a and c; a second may contact state environmental agencies for the same information.) Coach students as they try to find this information. It may take several days for them to find their way through these complex organizations and obtain useful responses.

OPTIONAL: This may be a good time to have an in-class speaker to talk about automobile emissions, air quality, global warming, or releases of toxic substances. Regional EPA offices or state environmental agencies often have people available for educational outreach if booked far enough in advance.



STEP 3 - Class Discussion

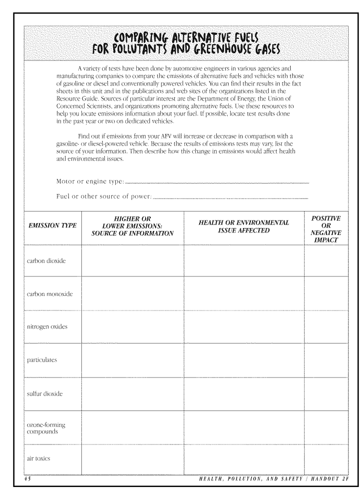
LEARNING HOW AFVS CAN AFFECT HEALTH, POLLUTION, AND SAFETY

TIME: 30 minutes

1) Distribute the student handouts listed above for fuel research and presentations. Explain that in the fuel research activity for this section, teams will investigate the impact of alternative fuels on public health and the environment. (Note: If this is the first or only research section you are teaching, please refer to the section "Availability and Distribution" for a list of alternative fuels and information about preparing teams to research a particular fuel.)

2) Introduce this research activity by discussing chart 2.3, "Impact of Alternative Fuels on Carbon Monoxide Emissions," found on the handout "HEALTH, POLLUTION, AND SAFETY: GUIDE TO FUEL TEAM RESEARCH." The chart compares the carbon monoxide emissions of various fuels to those of gasoline and diesel. (Remind students that carbon monoxide is a serious pollutant that interferes with the ability of blood to carry oxygen. High levels of carbon monoxide are a special concern to people in urban areas. For more information about its description, source, and effects, refer to the handout "AUTOMOBILE-RELATED EMISSIONS.") Ask students to identify the fuels that would increase (or decrease) carbon monoxide levels and consequently increase (or decrease) the associated health problems. If high carbon monoxide levels were a problem in your community, which fuels would alleviate the problem? Which fuels would make it worse?

3) In the section "Availability and Distribution," students researched the sources of fuel used in their own power grid. (If they didn't do this section, refer them to the regional information provided in diagram 1.4, "Where Electricity Comes From, by Fuel Type & Region.") Keeping in mind the makeup of your own power grid, have students compare the two listings for electric vehicles in chart 2.3. How would the widespread use of electric vehicles affect air quality in your region?



4) Refer students to the handout "COMPARING ALTERNATIVE FUELS FOR POLLUTANTS AND GREENHOUSE GASES." This worksheet will help them analyze the impact of their alternative fuel on pollutants and greenhouse gases. Explain that tests have been done on various types of vehicles, and the results are widely published, but they are not always consistent. Where possible, students should describe the test done on vehicles and identify the type of vehicle tested and the source of their data.

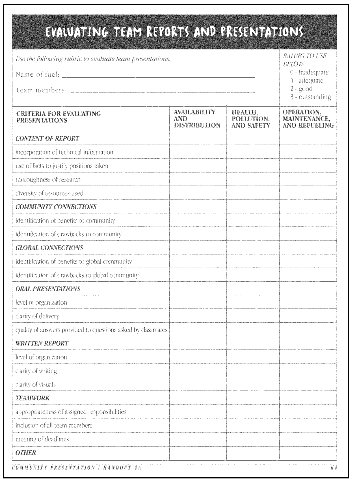
STEP 4 - Team Research and Preparation for Presentations

LEARNING TO SPEAK ABOUT HEALTH, POLLUTION, AND SAFETY

TIME: Three days

1) As they did in the section "Availability and Distribution," fuel teams will use the questions provided in their "GUIDE TO FUEL TEAM RESEARCH" to prepare a written report and a mini-presentation lasting 5 to 10 minutes. Discuss where the students might find the answers to the questions. Much information is already available in the fact sheets. Additional information can be found at the web sites listed for the alternative fuels in the Resource Guide. Some questions require that students pull together information and form their own opinions.

2) Over the next three days, provide students with the opportunity to meet in their teams, divide up the research tasks, and decide how they will present their findings and who will do it. Encourage them to develop diagrams and other graphics to help present their findings. Remind them that these presentation aids may be further developed for a public presentation.


EVALUATING TEAM REPORTS AND PRESENTATIONS

Use the following rubric to evaluate team presentations.

Name of fuel:

Team members:

RATING TO USE BELOW: 0 - inadequate, 1 - adequate, 2 - good, 3 - outstanding

CRITERIA FOR EVALUATING PRESENTATIONS	AVAILABILITY AND DISTRIBUTION	HEALTH, POLLUTION, AND SAFETY	OPERATION, MAINTENANCE, AND REFUELING
CONTENT OF REPORT			
incorporation of technical information			
use of facts to justify positions taken			
thoroughness of research			
diversity of resources used			
COMMUNITY CONNECTIONS			
identification of benefits to community			
identification of drawbacks to community			
GLOBAL CONNECTIONS			
identification of benefits to global community			
identification of drawbacks to global community			
ORAL PRESENTATIONS			
level of organization			
clarity of delivery			
quality of answers provided to questions asked by classmates			
WRITTEN REPORT			
level of organization			
clarity of writing			
clarity of visuals			
TEAMWORK			
appropriateness of assigned responsibilities			
inclusion of all team members			
meeting of deadlines			
OTHER			

COMMUNITY PRESENTATION / HANDOUT 6A 64

3) Coach students as they do their research. It may be helpful for you to investigate some of the recommended web sites to have a better understanding of the information found there.

4) Distribute copies of "EVALUATING TEAM REPORTS AND PRESENTATIONS" (page 64), so students will know in advance what is expected in their presentations.

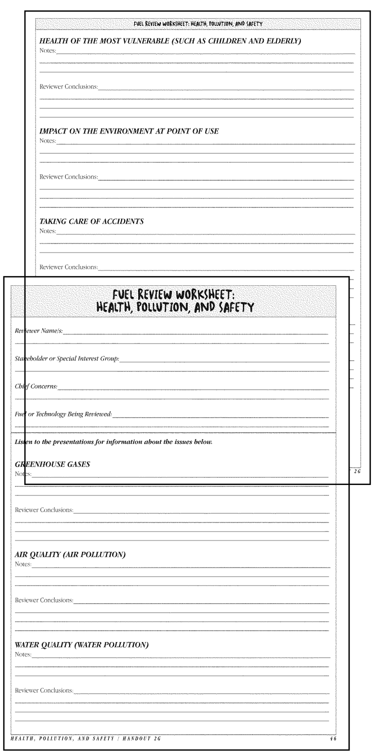
STEP 5 - Team Presentations and Class Discussions

HEALTH, POLLUTION, AND SAFETY

TIME: Four days (10 to 15 minutes for each team's presentation and questions, plus 20 to 30 minutes for follow-up panel and class discussion)

1) Make a list of stakeholders or special interest groups for the students to represent while listening to and evaluating the fuels being presented. Remind students that a wide variety of people are interested in these issues: physicians, resource managers, atmospheric scientists, emergency personnel, even the insurance industry, as you discussed earlier in "WHO'S INTERESTED IN AFVS? WHO CARES ABOUT HEALTH, POLLUTION, AND SAFETY?"

2) Decide if the students will evaluate the presentations as individuals or as part of a review panel. Then assign (or have the members of the class select) the stakeholders or special interest groups they will represent. If they're working in review panels, allow the panel members to sit together.


FUEL REVIEW WORKSHEET: HEALTH, POLLUTION, AND SAFETY

HEALTH OF THE MOST VULNERABLE (SUCH AS CHILDREN AND ELDERLY)

Notes:

Reviewer Conclusions:

IMPACT ON THE ENVIRONMENT AT POINT OF USE

Notes:

Reviewer Conclusions:

TAKING CARE OF ACCIDENTS

Notes:

Reviewer Conclusions:

FUEL REVIEW WORKSHEET: HEALTH, POLLUTION, AND SAFETY

Reviewer Name/s:

Stakeholder or Special Interest Group:

Chief Concerns:

Fuel or Technology Being Reviewed:

Listen to the presentations for information about the issues below.

GREENHOUSE GASES

Notes:

Reviewer Conclusions:

AIR QUALITY (AIR POLLUTION)

Notes:

Reviewer Conclusions:

WATER QUALITY (WATER POLLUTION)

Notes:

Reviewer Conclusions:

HEALTH, POLLUTION, AND SAFETY / HANDOUT 26

3) Refer students to the handout "FUEL REVIEW WORKSHEET: HEALTH, POLLUTION, AND SAFETY." They will use this worksheet as a guide for taking notes during a fuel presentation and writing down their (or their panel's) conclusions. (They will need one copy of this worksheet for each fuel presentation given.) Before the presentations, allow students time to make note of their interest group's chief concerns. After each presentation, allow them time to discuss and make note of their conclusions. How would each fuel affect their community and world?

4) Presentations should last 5 to 10 minutes, with additional time for the audience to ask questions. Remind presenters to keep in mind the concerns of the stakeholders in the audience. Encourage students in their audience to ask questions from the points of view of the stakeholders they represent.

5) At the end of each day and again after all presentations have been given, allow time for the panels to compare the fuels and discuss the advantages and disadvantages of each regarding its effect on emissions, health, and other environmental issues. Decide if the fuels would ease (or worsen) the health and environmental problems important to your community.

6) Have the review panels report their conclusions to the class and allow time for debate on their conclusions.

HEALTH, POLLUTION, AND SAFETY: THE CHALLENGE

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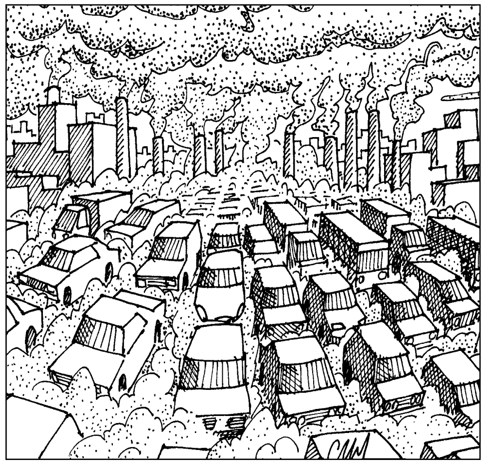

HEALTH

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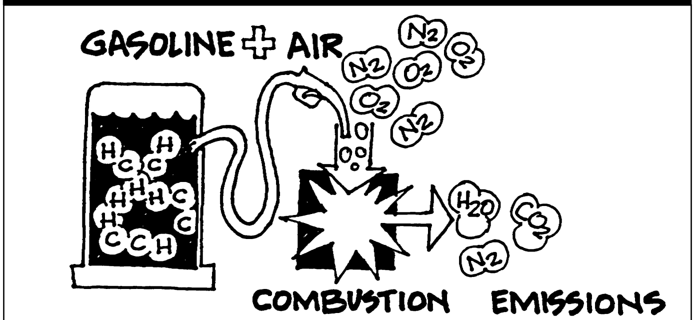
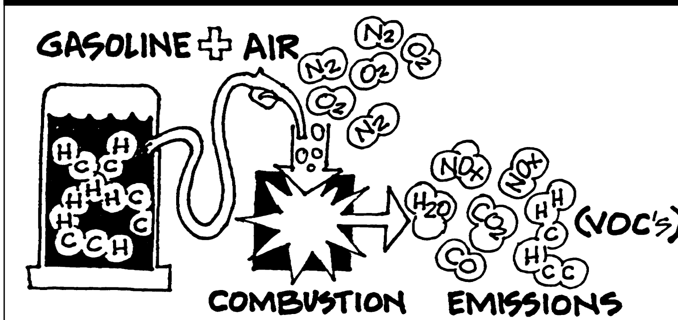
2.1 PRODUCTS OF COMBUSTION

"PERFECT" COMBUSTION



fuel (hydrocarbons) + air (oxygen and nitrogen)	=	carbon dioxide + water + unaffected nitrogen

TYPICAL COMBUSTION



fuel (hydrocarbons) + air (oxygen and nitrogen)	=	unburned hydrocarbons + nitrogen oxides + carbon dioxide + carbon monoxide + water

Source: EPA Office of Transportation Technologies, previously the Office of Mobile Sources.

PRODUCTS OF COMBUSTION

Gasoline and diesel fuels are formed from a combination of petroleum and natural gas. They are mixtures of hydrocarbons, compounds that contain hydrogen and carbon atoms.

In a "perfect" engine, oxygen in the air would combine with all the hydrogen in the fuel to produce water, and with all the carbon to produce carbon dioxide, a greenhouse gas. Nitrogen, which is naturally found in the air, would remain unaffected.

In reality, the combustion process is not perfect. The result is a mix of unburned hydrocarbons, nitrogen oxides, and carbon monoxide, which have ill effects on human health, on crops and vegetation, and consequently on animals.

All gasoline is not the same. While some fuels have additives that increase octane for more power, others contain ingredients to change the end products of combustion. For example, oxygenates (additives containing hydrogen, carbon, and oxygen) promote more complete combustion, reducing tailpipe emissions. Common oxygenates include ethanol and methyl tertiary butyl ether (MTBE), which is made from methanol. Oxygenated fuels are especially useful during cold winter months, when carbon monoxide levels increase.

Some fuel additives have been found to present serious health risks. At one time lead was added to gasoline to increase power, but it was phased out of use in the 1970s because of the health risks it presented, especially to children. MTBE is now being found unburned in the environment and is appearing in freshwater supplies. It is being phased out in some states because of its high toxicity.

"Reformulated gasoline," or RFG, is a blend of gasoline with a minimum of 2 percent oxygen and a maximum of 1 percent benzene (an air toxic), but no heavy metal additives such as lead (which increase octane). This formula reduces hydrocarbons and toxic emissions. It is considered a clean fuel, not an alternative fuel.

AUTOMOBILE-RELATED EMISSIONS

REGULATED EMISSIONS

EMISSION	*DESCRIPTION AND SOURCE*	*HEALTH AND ENVIRONMENTAL EFFECTS*
Carbon Monoxide (CO)	A colorless, odorless gas produced when carbon in fuels is burned incompletely. It occurs when oxygen is restricted, when cars are not tuned properly, and at high altitudes. Carbon monoxide pollution is emitted from the tailpipe and increases dramatically in cold weather. In the '90s, motor vehicles emitted 60 percent of carbon monoxide emissions nationwide and as much as 95 percent of CO in urban areas. (U.S. Dept of Energy, 1997)	Carbon monoxide interferes with the ability of the blood to carry oxygen. Results may be chest pain, headaches, dizziness, reduced mental alertness, nausea, fatigue, irritability, and suffocation. Those with heart disease are at higher risk.
Lead	A gasoline additive previously used in the United States to increase octane, the burning power of fuel. It is also found in batteries and emitted from battery factories.	Exposure to lead can cause learning disabilities (especially in children), as well as brain and kidney damage.
Nitrogen Oxides (NO_x)	Nitrogen and oxygen are the two most common atmospheric gases. Under high pressure and in high temperatures (conditions found in engines), nitrogen and oxygen atoms react to form various nitrogen oxides, known as NO_x. These form a yellowish to reddish-brown gas, which in high densities has a pungent odor.	Irritates and damages lung tissue. Increases susceptibility to respiratory disease. Reacts in the atmosphere to form ozone and acid rain.
Ozone (O_3)	Low-level ozone is formed when volatile organic compounds, oxygen, and NO_x react in the presence of sunlight. A component of smog. In the '90s, motor vehicles emitted up to half of the smog-forming chemicals (hydrocarbons and nitrogen oxides). (U.S. Dept of Energy, 1997)	In the upper atmosphere, ozone protects the earth from the sun's ultraviolet rays. At ground level, it irritates and breaks down respiratory tissues and cells; irritates eyes, nose, and throat; causes chest pain; damages crops and vegetation; and deteriorates rubber and some plastics.
Particulate Matter (PM_{10}, $PM_{2.5}$)	A name given to dust, dirt, soot, smoke, and liquid droplets that are carried in the air. It can be caused by incomplete combustion of fuel.	PM reduces visibility, soils surfaces, increases respiratory disease, lung damage, cancer. Children, the elderly, and those with lung or heart disease are most susceptible.
Sulfur Dioxide (SO_2)	A by-product of the burning of oil and coal emitted from coal- or oil-burning power plants and industries, refineries, and diesel engines.	Increases lung disease and breathing problems, especially for asthmatics. Reacts in the atmosphere to form acid rain.
Volatile Organic Compounds (VOCs)	Reactive hydrocarbon compounds released during combustion or evaporation of gasoline and other petroleum products. Also found in paints and solvents used to finish automotive bodies.	VOCs react with NO_x in the presence of sunlight to form low-level ozone. They also contribute to global warming.

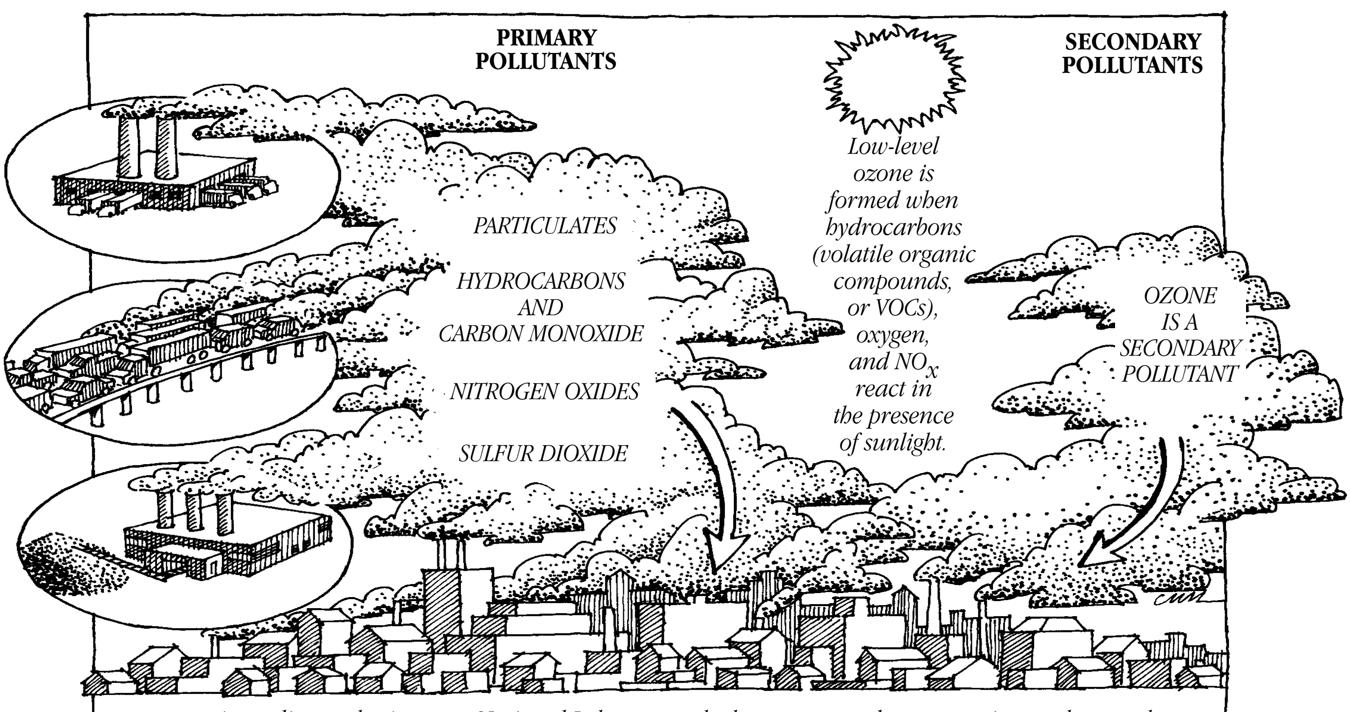
OTHER EMISSIONS

EMISSION	*DESCRIPTION AND SOURCE*	*HEALTH AND ENVIRONMENTAL EFFECTS*
Air Toxics	Most air toxics are hydrocarbon compounds. Some air toxics, including benzene, toluene, and xylene, are added to gasoline to increase power. Others, such as formaldehyde, are by-products of incomplete combustion. Air toxics are emitted with exhaust and/or evaporation and refueling. In the '90s, motor vehicles emitted more than half of the toxic chemicals classified as hazardous air pollutants. (U.S. Dept of Energy, 1997)	Adverse health affects include cancer, poisoning, or other immediate illness.
Carbon Dioxide (CO_2)	The most important human-made greenhouse gas. Any process that burns plant- and animal-based fuels or fossil fuels releases carbon dioxide. Burning a single tank of gasoline produces 300 to 400 pounds of carbon dioxide. Based on its global warming potential, carbon dioxide accounts for over 80 percent of total greenhouse-gas emissions in the United States.	The earth, warmed by the sun's rays, radiates infrared radiation (heat). Greenhouse gases in the atmosphere absorb infrared radiation, preventing some of the heat from escaping into space. When more greenhouse gases, such as carbon dioxide, are released into the atmosphere than are removed by natural processes, the atmosphere's heat-absorption properties increase. Global warming and changes in weather patterns are the result.

2.2 FORMATION OF LOW-LEVEL OZONE

Smog is a visible haze caused primarily by particulate matter and ozone. High concentrations of ozone are a special concern to nearly 102 million people in the United States.

Because air pollutants often travel with the wind, smog and other air pollution problems in your county or region may originate upwind from you (probably to the west). Likewise, pollution that originates in your county or region may cause smog downwind (probably to the east). For example, pollution from coal plants in the Midwest causes problems in the Northeast.



According to the Argonne National Laboratory, the best way to reduce ozone in rural areas that are rich in vegetation is to target and cut NO_x emissions. In commercial or government areas, the quickest solution is the reduction of hydrocarbon emissions (especially nonmethane hydrocarbons or NMHCs).

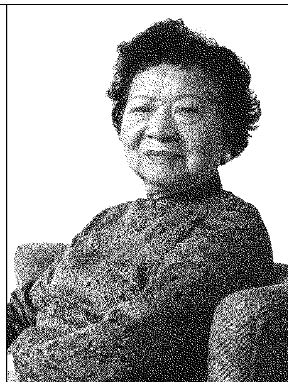
WHO'S INTERESTED IN AFVS? WHO CARES ABOUT HEALTH, POLLUTION, AND SAFETY?

A wide variety of people have a stake in a change to AFVs. They vary from human rights activists to auto salespeople to environmental scientists to physicians to diplomats.

This group wants to reduce the impact of transportation on the environment, reduce emissions of greenhouse gases, and improve the health of people in our communities.

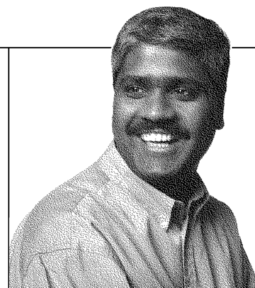
RESOURCE MANAGER

Many costs of fuel don't show up at the gas pump. Oil spills are degrading stocks of fish; large tracts of forests and other ecosystems have already been damaged by acid rain; the runoff from highways and seeping underground fuel tanks is making our job of providing freshwater supplies difficult. Would using alternative fuels reduce the carcinogens in our water supplies? Would alternatives be less deadly to wildlife that drink from polluted rivers?



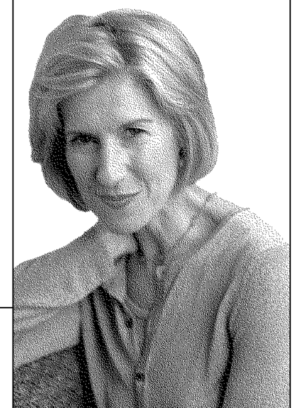
PHYSICIANS

We often treat young children with asthma and elderly patients who suffer from fatigue and heart disease, especially during months when ozone levels are high. Some of our patients can't go outside during hot weather. Our transportation system contributes a great deal to the pollution that irritates the lungs of young children. Could alternative fuels improve the quality of life for our patients?



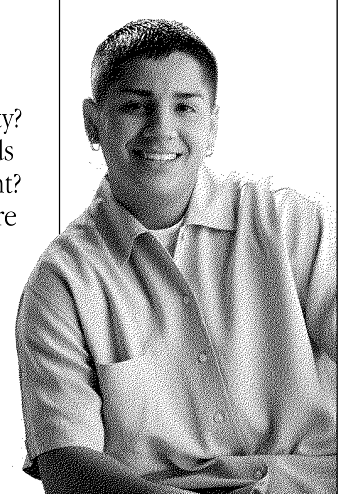
EMERGENCY PERSONNEL: Police, Fire, Rescue, Medical

In case of accidents, we need to secure the area, get people out of their cars safely, and provide them with the care they need as soon as possible. How do alternative fuels behave? Does exposure to alternative fuels affect the human body differently from exposure to gasoline or diesel fuel? How do we protect ourselves and the community? What safety hazards might AFVs present? How do we prepare for them? What training will we need to provide the appropriate treatment?



INTERNATIONAL DIPLOMAT

As part of the international agreements to reduce global warming, the United States and other industrial countries have been asked to reduce carbon dioxide emissions. If the United States is to be seen as a responsible member of the international community, we need to reduce our use of fossil fuels. Could alternative-fueled vehicles be part of the answer?



ATMOSPHERIC SCIENTIST

Our chief concerns are reducing the levels of carbon dioxide and other greenhouse gases. Global warming and weather changes due to the buildup of atmospheric greenhouse gases could alter the planet considerably, bringing melting ice caps, rising sea levels, and changing crop patterns. Which fuels would most greatly reduce carbon dioxide emissions?

INSURANCE INDUSTRY

Where changing weather patterns have caused destruction to homes and businesses, we've had to review and modify insurance policies to keep our own industry profitable. Reducing carbon dioxide emissions and other greenhouse gases is essential to protecting our clients and their property from rising sea levels, hurricanes, and other storms.

HEALTH, POLLUTION, AND SAFETY: GUIDE TO COMMUNITY RESEARCH

Use the questions below as a guide to discovering which health and environmental issues exist in your community because of our transportation system.

Work in groups to discuss the questions and identify the ones you can't yet answer. For some questions you'll need to speak with people in your community or do research on the Internet.

POSSIBLE RESOURCES

- Local or state police or fire department
- U.S. Coast Guard
- State Department of Environmental Protection or Management
- Local or state board of health
- Regional Environmental Protection Agency office and its web site
- Service stations

1. *THE CHANGE FROM HORSE TO HORSELESS*

a. Imagine the days when horses and buggies were the major form of transportation in your community. What were the major environmental and safety concerns?

b. How have automobiles affected daily life? Think about the positive and negative effects. Do air pollution, traffic, or noise interfere with people's ability to enjoy walks or use bicycles for travel? How have environmental and safety issues changed as a result of the internal combustion engine and the widespread use of automobiles?

2. *SAFETY*

a. Name some of the safety concerns related to using gasoline and other fluids in our cars.

b. In the case of automobile accidents that release gasoline or other fluids, how do emergency personnel respond?

3. *LAND AND WATER POLLUTION*

a. Do you know of any oil spills or major gasoline or diesel fuel leaks in or near your community? How were they cleaned up? What was done to protect the community and its land and water supplies?

b. Small amounts of gasoline can render water unsafe to drink. Have you ever spilled (or seen someone spill) gasoline while filling up a gas tank? What happens to all the gasoline and oil that washes off pavements with rain?

c. Automotive fluids, batteries, tires, and other car parts can also pollute the environment. How or where can they be recycled or safely disposed of?

4. *AIR QUALITY AND AIR POLLUTION*

a. Are there any obvious sources of air pollution in your community? What do you notice?

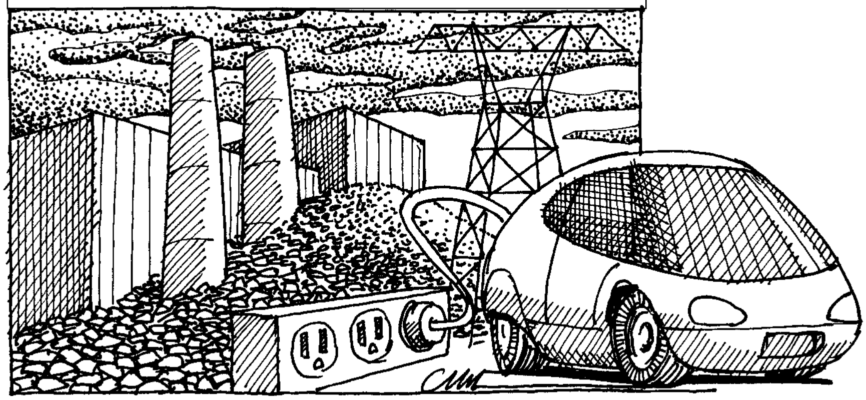
b. Have you or someone you know been affected by air pollution? If so, describe how.

EXTENSIONS:
For the following questions, these offices and their web sites may be able to help you: your state's Department of Environmental Protection or Management, the Board of Health, the American Lung Association and its web site, the U.S. Environmental Protection Agency's web site or a regional office.

- What's the incidence of gasoline spills or leaks into freshwater aquifers?
- How do gasoline and oil runoff affect health or water treatment processes? What is done to protect our health from toxics in fuel and other automotive fluids?
- Is your county a "nonattainment" county for any pollutants, or does it meet the standards for clean air? Do other counties in your region or the counties downwind meet standards for clean air? Levels of which pollutants, if any, exceed clean air standards?
- What health problems exist in your region that might be attributed to air pollution? For example, are there high rates of asthma or other respiratory illnesses in your region?

HEALTH, POLLUTION, AND SAFETY: GUIDE TO FUEL TEAM RESEARCH

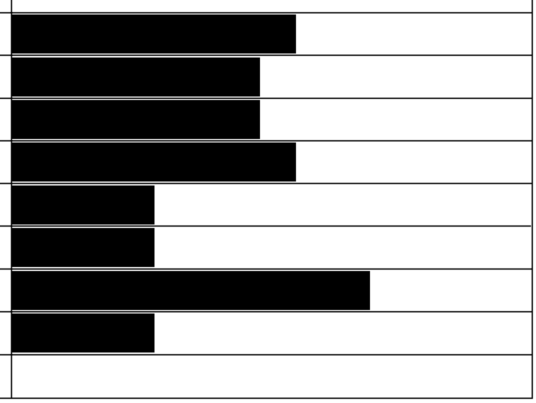
NEW COAL SOURCES



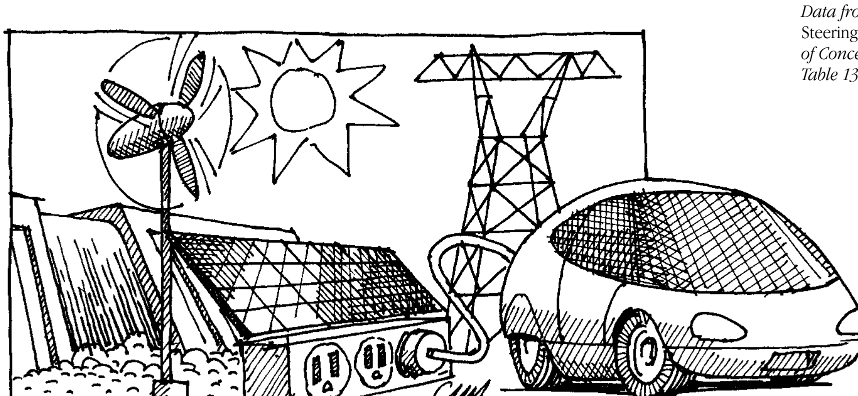
2.3 IMPACT OF ALTERNATIVE FUELS ON CARBON MONOXIDE EMISSIONS

Industries and government agencies have conducted numerous tests in labs and on the road to compare the emissions of alternative-fueled vehicles with those of traditional ones. This table shows the results of tests done in the 1980s for carbon monoxide (CO) emitted per mile. Gasoline and diesel emissions were used as the baseline.

TYPE OF FUEL	***CO EMISSIONS***
Gasoline and diesel	
Reformulated gasoline	
Methanol	
Ethanol	
Compressed natural gas	
Liquefied petroleum gas	
Electric vehicles powered by new coal sources	
Electric vehicles powered by nonfossil fuels	
Hydrogen used in fuel cells	



Data from Deborah Gordon, Steering a New Course, *Union of Concerned Scientists. 1991. Table 13.*



WIND AND OTHER NONFOSSIL FUELS

FOR DISCUSSION:
If your community had high levels of carbon monoxide, which fuels would best help reduce them? Which fuels would make the problem worse?

HEALTH, POLLUTION, AND SAFETY: GUIDE TO FUEL TEAM RESEARCH

Use the questions below as a guide to developing your presentation. Many of the answers are found in the alternative fuel fact sheets. For some, you'll need to do further research on the Internet or by contacting organizations that promote alternative fuels. For others, you'll need to draw your own conclusions based on facts you've found. Be prepared to explain how you came to your conclusions.

To help you analyze your fuel, use the student handout "COMPARING ALTERNATIVE FUELS FOR POLLUTANTS AND GREENHOUSE GASES." This chart can be used to help deliver information to your audience.

While answering the questions below and preparing your presentation, keep in mind the issues to the right (which your class discussed at the beginning of this unit) and the various people interested in them.

TRANSPORTATION AND FUEL ISSUES

- Decrease in greenhouse-gas emissions
- Reduced air pollution
- Improved health of children and the elderly
- Low impact on the environment
- Ease in taking care of accidents
- Safe disposal of fluids and parts

1. ***POLLUTANTS AND GREENHOUSE GASES***

a. How would cars running on your fuel affect levels of pollution or greenhouse gases? (Use the table on the following page to help you analyze the impact of emissions from your fuel.)

b. While battery electric vehicles themselves are very clean, their widespread use may increase levels of some pollutants emitted from power plants. The types and levels of pollutants depend on the sources of energy and types of technology used in your region's power plant. If you are researching electric vehicles, analyze the impact of increased power use at your region's power plant. How do emissions increases at the power plant compare with decreases at the tailpipe?

2. ***IMPACT ON HEALTH AND OTHER ENVIRONMENTAL PROBLEMS***

a. If cars using this fuel became popular and replaced gasoline-run cars, what do you think would be the impact on the environment in your community or in communities downwind from yours?

b. Would health and environmental problems increase or decrease?

c. Would the impact be positive or negative? (Add this information to your table.)

3. ***TAKING CARE OF ACCIDENTS***

a. What safety precautions would be needed to protect the community from fuel leaks?

b. Are there any special considerations in case of traffic accidents?

c. Who needs to be trained in order to keep the drivers and the community safe?

4. ***DISPOSAL OF FLUIDS AND PARTS***

a. Do cars using your fuel have any special disposal issues; for example, fuel cells, batteries, or special lubricants?

b. How do you think your community would address these issues?

Argonne National Laboratory has developed a fuel-cycle model called GREET (Greenhouse gases, Regulated Emissions, and Energy use in Transportation) to help them analyze the real impact of alternative-vehicle technologies. The data below include the emissions created during production of the fuel and compare the per-mile emissions of various alternative-fueled passenger cars with those of conventional passenger cars using conventional fuel. In urban areas percentages differ, because in gasoline-powered vehicles stop-and-go driving, refueling, and higher evaporation levels create higher levels of emissions.

2.4 CRITERIA POLLUTANT EMISSIONS FOR AFV PASSENGER CARS: CHANGES PER MILE

USING CONVENTIONAL GASOLINE VEHICLES AS A BASELINE

Emission type	*CNG*	*LPG from natural gas*	*M90 from natural gas*	*E90 from corn*	*Fuel Cell: methanol from natural gas*	*Electric: New England mix*	*Electric: California mix*	*Electric: U.S. mix*
TOTAL EMISSIONS								
volatile organic compounds - VOCs	-62.6%	-56.2%	-15.8%	-74.4%	-72.8%	-92.5%	-96.7%	-89.6%
carbon monoxide - CO	-19.9%	-21.3%	1.5%	2.1%	-78.0%	-97.3%	-98.5%	-97.5%
nitrogen oxides - NO_x	26.5%	-39.9%	-4.8%	147.0%	-63.3%	44.7%	-36.8%	-103.6%
particulate matter -PM_{10}	-34.2%	-39.0%	-25.4%	409.1%	-49.5%	-8.2%	-36.7%	17.7%
sulfur oxides - SO_x	-34.1%	-71.8%	-60.0%	120.0%	-87.8%	147.0%	-26.2%	377.4%
URBAN EMISSIONS								
VOCs	-55.1%	-45.3%	-11.1%	-8.9%	-73.6%	-99.5%	-99.7%	-99.7%
CO	-19.4%	-20.0%	-0.2%	0.0%	-80.0%	-99.8%	-99.9%	-99.9%
NO_x	102.8%	-3.7%	-17.2%	9.4%	-82.8%	-60.2%	-75.5%	-80.8%
PM_{10}	-24.6%	-25.2%	-14.5%	-12.2%	-34.0%	-30.5%	-32.0%	-32.4%
SO_x	-80.6%	-91.5%	-77.9%	-82.9%	-97.0%	-78.7%	-96.5%	-89.3%

Source: Michael Q. Wang, GREET Model Results, Argonne National Laboratory, Argonne, Ill., August 1999.

FOR DISCUSSION:

1. If your primary concern were reducing particulate matter, which alternative fuels would be the best choice?
2. If your primary concern were reducing low-level ozone, which alternative fuels would be the best choice?
3. Given the current mix of power in the electric power grids of New England and California, in which area would electric cars produce fewer emissions?

COMPARING ALTERNATIVE FUELS FOR POLLUTANTS AND GREENHOUSE GASES

A variety of tests have been done by automotive engineers in various agencies and manufacturing companies to compare the emissions of alternative fuels and vehicles with those of gasoline or diesel and conventionally powered vehicles. You can find their results in the fact sheets in this unit and in the publications and web sites of the organizations listed in the Resource Guide. Sources of particular interest are the Department of Energy, the Union of Concerned Scientists, and organizations promoting alternative fuels. Use these resources to help you locate emissions information about your fuel. If possible, locate test results done in the past year or two on dedicated vehicles.

Find out if emissions from your AFV will increase or decrease in comparison with a gasoline- or diesel-powered vehicle. Because the results of emissions tests may vary, list the source of your information. Then describe how this change in emissions would affect health and environmental issues.

Motor or engine type: ______________________________

Fuel or other source of power: ______________________________

EMISSION TYPE	***HIGHER OR LOWER EMISSIONS: SOURCE OF INFORMATION***	***HEALTH OR ENVIRONMENTAL ISSUE AFFECTED***	***POSITIVE OR NEGATIVE IMPACT***
carbon dioxide			
carbon monoxide			
nitrogen oxides			
particulates			
sulfur dioxide			
ozone-forming compounds			
air toxics			

FUEL REVIEW WORKSHEET: HEALTH, POLLUTION, AND SAFETY

Reviewer Name/s: ____________________

Stakeholder or Special Interest Group: ____________________

Chief Concerns: ____________________

Fuel or Technology Being Reviewed: ____________________

Listen to the presentations for information about the issues below.

GREENHOUSE GASES

Notes: ____________________

Reviewer Conclusions: ____________________

AIR QUALITY (AIR POLLUTION)

Notes: ____________________

Reviewer Conclusions: ____________________

WATER QUALITY (WATER POLLUTION)

Notes: ____________________

Reviewer Conclusions: ____________________

HEALTH OF THE MOST VULNERABLE (SUCH AS CHILDREN AND ELDERLY)

Notes:____

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Reviewer Conclusions:____

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IMPACT ON THE ENVIRONMENT AT POINT OF USE

Notes:____

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Reviewer Conclusions:____

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TAKING CARE OF ACCIDENTS

Notes:____

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Reviewer Conclusions:____

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DISPOSAL OF FLUIDS AND PARTS

Notes:____

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Reviewer Conclusions:____

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OPERATION, MAINTENANCE, AND REFUELING

TIME

10 days

OBJECTIVES

- *To understand that the adoption of alternative-fueled vehicles will require changes in technology, consumer use, fueling infrastructure, and community design.*
- *To understand how traffic patterns and the need to service and park cars have influenced the design and growth of our communities.*
- *To identify performance characteristics, special maintenance problems, potential costs, and refueling schedules of an AFV.*
- *To identify the audiences who would appreciate these characteristics.*

MATERIALS NEEDED

For background reading and community research

Student handouts

- *Operation, Maintenance, and Refueling: The Challenge*
- *Who's Interested in AFVs? Who Cares About Operation, Maintenance, and Refueling?*
- *Getting Around Your Community: Guide to Community Research*

Other useful resources

- *Four to six maps of your community or region showing major roadways, shopping areas, and centers of employment.*

For fuel research and student presentations

Student handouts

- *Energy Content of Various Fuels*
- *Operation, Maintenance, and Refueling: Guide to Fuel Team Research*
- *How Do Typical 20th Century Vehicles Work?*
- *Fuel Review Worksheet: Operation, Maintenance, and Refueling*
- *Alternative fuels fact sheets (to be distributed to appropriate teams)*
- *Resource Guide*
- *Evaluating Team Reports and Presentations*

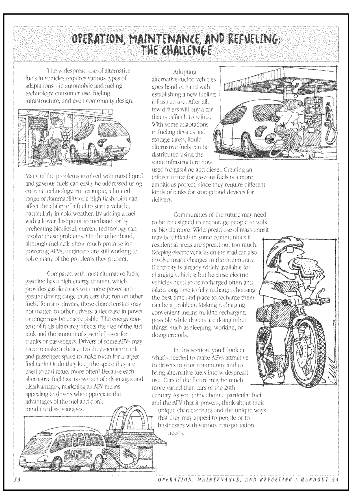
Other useful resources

- *Access to the library and Internet*
- *Publications listed as references for this unit*
- *Flip charts, poster board, transparencies, and use of an overhead projector*
- *Access to word processing or presentation software*

STEP 1 - Background Reading and Discussion

OPERATION, MAINTENANCE, AND REFUELING: PRESENTING THE CHALLENGE

TIME: 30 minutes; to save in-class time, readings may be assigned for homework



OPERATION, MAINTENANCE, AND REFUELING: THE CHALLENGE

The widespread use of alternative fuels in vehicles requires various types of adaptations—in automobile and fueling technology, consumer use, fueling infrastructure, and even community design.

Many of the problems involved with most liquid and gaseous fuels can easily be addressed using current technology. For example, a limited range of flammability or a high flashpoint can affect the ability of a fuel to start a vehicle, particularly in cold weather. By adding a fuel with a lower flashpoint to methanol or by preheating biodiesel, current technology can resolve these problems. On the other hand, although fuel cells show much promise for powering AFVs, engineers are still working to solve many of the problems they present.

Compared with most alternative fuels, gasoline has a high energy content, which provides gasoline cars with more power and greater driving range than cars that run on other fuels. To many drivers, these characteristics may not matter; to other drivers, a decrease in power or range may be unacceptable. The energy content of fuels ultimately affects the size of the fuel tank and the amount of space left over for trunks or passengers. Drivers of some AFVs may have to make a choice: Do they sacrifice trunk and passenger space to make room for a larger fuel tank? Or do they keep the space they are used to and refuel more often? Because each alternative fuel has its own set of advantages and disadvantages, marketing an AFV means appealing to drivers who appreciate the advantages of the fuel and don't mind the disadvantages.

Adopting alternative-fueled vehicles goes hand in hand with establishing a new fueling infrastructure. After all, few drivers will buy a car that is difficult to refuel. With some adaptations in fueling devices and storage tanks, liquid alternative fuels can be distributed using the same infrastructure now used for gasoline and diesel. Creating an infrastructure for gaseous fuels is a more ambitious project, since they require different kinds of tanks for storage and devices for delivery.

Communities of the future may need to be redesigned to encourage people to walk or bicycle more. Widespread use of mass transit may be difficult in some communities if residential areas are spread out too much. Keeping electric vehicles on the road can also involve major changes in the community. Electricity is already widely available for charging vehicles; but because electric vehicles need to be recharged often and take a long time to fully recharge, choosing the best time and place to recharge them can be a problem. Making recharging convenient means making recharging possible while drivers are doing other things, such as sleeping, working, or doing errands.

In this section, you'll look at what's needed to make AFVs attractive to drivers in your community and to bring alternative fuels into widespread use. Cars of the future may be much more varied than cars of the 20th century. As you think about a particular fuel and the AFV that it powers, think about their unique characteristics and the unique ways that they may appeal to people or to businesses with various transportation needs.

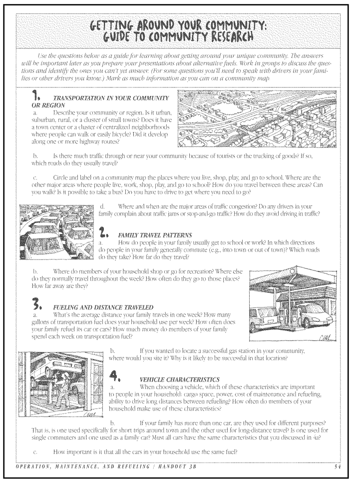
53 OPERATION, MAINTENANCE, AND REFUELING / HANDOUT 3A

1) Ask students to put themselves behind the wheel of an AFV and imagine driving it throughout the week or maintaining it throughout the year. How would the experience differ from driving a gasoline powered-vehicle? Encourage them to think about the sound of the car, about refueling, about finding mechanics to fix a problem with their fuel tanks or motors. Explain that alternative-fueled vehicles (AFVs) are already in use around the world and their numbers are rising, but their full acceptance by the American public depends on the convenience of driving and refueling them.

2) Distribute the student handouts for background reading and community research. Have students read the student handout " OPERATION, MAINTENANCE, AND REFUELING: THE CHALLENGE." Ask if they would be willing to depend on an alternative- fueled vehicle to get them where they needed to go. If not, why not? Which vehicle characteristics are they most interested in (power, long distance between refueling, reliability, etc.)?

STEP 2 - *Group Discussions and Community Research*
GETTING AROUND YOUR COMMUNITY

TIME: 45 minutes of discussion, with another 20 minutes the following day for student reporting of research done at home


GETTING AROUND YOUR COMMUNITY:
GUIDE TO COMMUNITY RESEARCH

1) Divide the class into four groups and distribute a map of the community to each group. Refer to the student handout "GETTING AROUND YOUR COMMUNITY: GUIDE TO COMMUNITY RESEARCH." Through this exercise students will better understand the transportation issues in their unique communities. Point out that traffic patterns and service requirements of gasoline-powered cars have influenced the way that many American communities have grown and developed.

Allow 30 minutes for students to discuss the questions on the handout and to mark their maps as requested in the handout. Have the students make a key that describes any symbols they may use on their maps (to designate schools, working areas, traffic, etc.). Note: For questions 2 and 3a students may need to question their family members and report back to the class.

2) Spend 15 minutes having the teams briefly describe and compare their maps to the class. Explain that when alternative-fueled vehicles are more widely used, the community may need to provide additional fueling stations or service stations. Ask them to keep this in mind as they research their alternative fuels.

3) Have students answer questions 2 and 3a with the help of their family members and report back to class the following day. Ask them to keep in mind their family's driving habits when researching and judging the best alternative fuels for local drivers.


WHO'S INTERESTED IN AFVS?
WHO CARES ABOUT OPERATION, MAINTENANCE, AND REFUELING?

COMMUTER

AUTO SALESPEOPLE

SERVICE STATION MANAGER

AUTO MECHANIC

STATE DEPARTMENTS OF ENVIRONMENTAL PROTECTION

CITY PLANNER

4) Ask students to identify various types of people who may be interested in driving, maintaining, and refueling cars. What would their chief concerns be? Refer to the student handout "WHO'S INTERESTED IN AFVS? WHO CARES ABOUT OPERATION, MAINTENANCE, AND REFUELING?" Do students identify with any of the people on this list? Who else in their community may have an interest in AFVs, and what might their concerns be?

EXTENSIONS:

- Have students keep a transportation log for the next two weeks that will answer questions 2 and 3a in the handout "GETTING AROUND YOUR COMMUNITY: GUIDE TO COMMUNITY RESEARCH."
- Have students make up a sheet similar to the "WHO'S INTERESTED IN AFVS?" handout that represents actual people in your community.

STEP 3 - *Class Discussion*
IMAGES THAT SELL CARS

TIME: 30 minutes

1) Ask the class to identify characteristics of cars that appeal to them (and/or to various other people, such as an adventurer, a businessman/woman, a "soccer mom," a single man, or an environmentalist). Their answers may include power, easy handling, body design, mileage, trunk space, ease of maintenance, low mileage, and so on. Write the answers down where the class can see them.

2) Ask students what images car companies use to market their vehicles. Their answers may include personal freedom (an individual driving on an open road), independence (a car parked on a cliff or mountaintop), comfort and luxury (a couple

listening to their favorite music, a passenger sleeping on the reclined seat, a family watching a video in their car), toughness (a man or woman driving a pickup truck on rough terrain), family values (families enjoying a road trip or vacation), friendship (friends eating, talking, laughing, listening to music together), the ability to easily do everyday things (grocery shopping, taking kids to school). Write down these ideas so everyone can see them. What images appeal most to them?

3) Remind students of the list of important issues they analyzed in the section "Getting Oriented," including national self-sufficiency, protecting the health of children or the elderly, and protecting the environment. Ask how the images they identified above relate to the issues that they think are important. (They may find that their issues are not addressed.)

4) Present this issue for discussion: Most Americans think of themselves as environmentalists, yet many Americans drive large, energy-intensive cars. We want to protect our families, yet some of the most popular cars have poor safety records. Are marketing images more powerful than our own values?

5) What images are associated with using mass transit, bicycling, or walking? Do these images appeal to you?

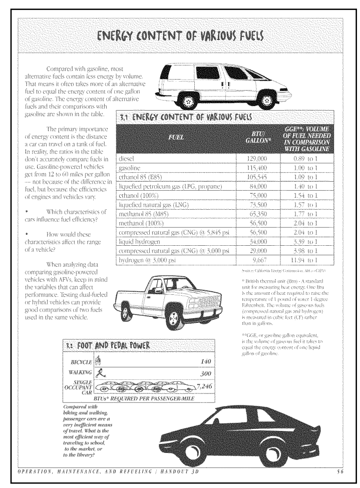
6) How might transportation of the future be marketed to promote its advantages and benefits? Explain that in the next fuel team research activity students will need to identify an image to market their alternative-fueled vehicle to a particular audience.

STEP 4 - Fuel Team Research and Preparation for Presentations

OPERATION, MAINTENANCE, AND REFUELING

TIME: Three days

1) Distribute the student handouts listed above for fuel research and presentations and refer to student handout "ENERGY CONTENT OF VARIOUS FUELS." Explain that the energy content of a fuel influences how far a car can travel on a tank of fuel, which in turn influences how often a driver has to refuel the car. The efficiency and range of a car are also affected by other characteristics, however. Ask students to identify the characteristics that influence fuel efficiency. (Possible answers: the size and weight of the car and fuel tank, efficiency of the engine, aerodynamic styling, the extras commonly used, such as air conditioning and heat.) How would these characteristics affect the range of a vehicle? (Answer: Large and heavy cars, heavy fuel tanks, inefficient engines, boxy styling, and the use of extras will reduce the range. Large fuel tanks and aerodynamic styling expand the range.)


ENERGY CONTENT OF VARIOUS FUELS

Compared with gasoline, most alternative fuels contain less energy by volume. That means it often takes more of an alternative fuel to equal the energy content of one gallon of gasoline. The energy content of alternative fuels and their comparisons with gasoline are shown in the table.

The primary importance of energy content is the distance a car can travel on a tank of fuel. In reality, the ratios in the table don't accurately compare fuels in use. Gasoline-powered vehicles get from 12 to 60 miles per gallon — not because of the difference in fuel, but because the efficiencies of engines and vehicles vary.

- Which characteristics of cars influence fuel efficiency?
- How would these characteristics affect the range of a vehicle?

When analyzing data comparing gasoline-powered vehicles with AFVs, keep in mind the variables that can affect performance. Testing dual-fueled or hybrid vehicles can provide good comparisons of two fuels used in the same vehicle.

3.1 ENERGY CONTENT OF VARIOUS FUELS

FUEL	BTU/ GALLON*	GGE**: VOLUME OF FUEL NEEDED IN COMPARISON WITH GASOLINE
diesel	129,000	0.89 to 1
gasoline	115,400	1.00 to 1
ethanol 85 (E85)	105,545	1.09 to 1
liquefied petroleum gas (LPG, propane)	84,000	1.40 to 1
ethanol (100%)	75,000	1.54 to 1
liquefied natural gas (LNG)	73,500	1.57 to 1
methanol 85 (M85)	65,350	1.77 to 1
methanol (100%)	56,500	2.04 to 1
compressed natural gas (CNG) @ 5,845 psi	56,500	2.04 to 1
liquid hydrogen	34,000	3.39 to 1
compressed natural gas (CNG) @ 3,000 psi	29,000	3.98 to 1
hydrogen @ 3,000 psi	9,667	11.94 to 1

* British thermal unit (Btu) - A standard unit for measuring heat energy. One Btu is the amount of heat required to raise the temperature of 1 pound of water 1 degree Fahrenheit. The volume of gaseous fuels (compressed natural gas and hydrogen) is measured in cubic feet (CF) rather than in gallons.

**GGE, or gasoline gallon equivalent, is the volume of gaseous fuel it takes to equal the energy content of one liquid gallon of gasoline.

3.2 FOOT AND PEDAL POWER

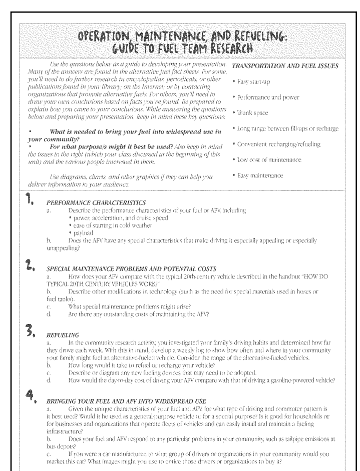
	BTUs* REQUIRED PER PASSENGER-MILE
BICYCLE	140
WALKING	300
SINGLE OCCUPANT CAR	7,246

Compared with biking and walking, passenger cars are a very inefficient means of travel. What is the most efficient way of traveling to school, to the market, or to the library?

OPERATION, MAINTENANCE, AND REFUELING / HANDOUT 3D 56

Help students analyze the chart by asking which fuel has the energy content most similar to gasoline. (Answer: ethanol 85.) Vehicles running on which fuels would need to be refueled most often? (Answer: those at the bottom of the list.)

2) Refer to student handout "OPERATION, MAINTENANCE, AND REFUELING: GUIDE TO FUEL TEAM RESEARCH." Explain that in this research activity teams will investigate the performance characteristics of alternative fuels, the design or modifications of the drivetrain, special maintenance and refueling issues, and the special audiences for various AFVs of the future. Students should keep in mind these key questions:


OPERATION, MAINTENANCE, AND REFUELING: GUIDE TO FUEL TEAM RESEARCH

Use the questions below as a guide to developing your presentation. Many of the answers are found in the alternative fuel fact sheets. For some, you'll need to do further research in encyclopedias, periodicals, or other publications found in your library; on the Internet; or by contacting organizations that promote alternative fuels. For others, you'll need to draw your own conclusions based on facts you've found. Be prepared to explain how you came to your conclusions. While answering the questions below and preparing your presentation, keep in mind these key questions:

- ***What is needed to bring your fuel into widespread use in your community?***
- ***For what purpose/s might it best be used?*** *Also keep in mind the issues to the right (which your class discussed at the beginning of this unit) and the various people interested in them.*

Use diagrams, charts, and other graphics if they can help you deliver information to your audience.

TRANSPORTATION AND FUEL ISSUES

- Easy start-up
- Performance and power
- Trunk space
- Long range between fill-ups or recharge
- Convenient recharging/refueling
- Low cost of maintenance
- Easy maintenance

1. ***PERFORMANCE CHARACTERISTICS***
   a. Describe the performance characteristics of your fuel or AFV, including
      - power, acceleration, and cruise speed
      - ease of starting in cold weather
      - payload
   b. Does the AFV have any special characteristics that make driving it especially appealing or especially unappealing?
2. ***SPECIAL MAINTENANCE PROBLEMS AND POTENTIAL COSTS***
   a. How does your AFV compare with the typical 20th-century vehicle described in the handout "HOW DO TYPICAL 20TH CENTURY VEHICLES WORK?"
   b. Describe other modifications in technology (such as the need for special materials used in hoses or fuel tanks).
   c. What special maintenance problems might arise?
   d. Are there any outstanding costs of maintaining the AFV?
3. ***REFUELING***
   a. In the community research activity, you investigated your family's driving habits and determined how far they drove each week. With this in mind, develop a weekly log to show how often and where in your community your family might fuel an alternative-fueled vehicle. Consider the range of the alternative-fueled vehicles.
   b. How long would it take to refuel or recharge your vehicle?
   c. Describe or diagram any new fueling devices that may need to be adopted.
   d. How would the day-to-day cost of driving your AFV compare with that of driving a gasoline-powered vehicle?
4. ***BRINGING YOUR FUEL AND AFV INTO WIDESPREAD USE***
   a. Given the unique characteristics of your fuel and AFV, for what type of driving and commuter pattern is it best used? Would it be used as a general-purpose vehicle or for a special purpose? Is it good for households or for businesses and organizations that operate fleets of vehicles and can easily install and maintain a fueling infrastructure?
   b. Does your fuel and AFV respond to any particular problems in your community, such as tailpipe emissions at bus depots?
   c. If you were a car manufacturer, to what group of drivers or organizations in your community would you market this car? What images might you use to entice those drivers or organizations to buy it?

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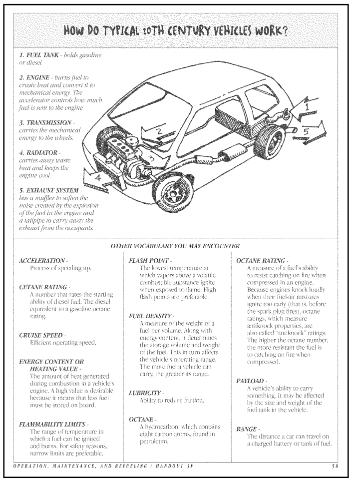
- What is needed to bring your fuel into widespread use in the community?
- For what purpose/s might the alternative fuel or AFV best be used?
- Can it resolve any special problems (such as tailpipe emissions in areas where they are particularly worrisome)?



HOW DO TYPICAL 20TH CENTURY VEHICLES WORK?

1. FUEL TANK - holds gasoline or diesel.

2. ENGINE - burns fuel to create heat and convert it to mechanical energy. The accelerator controls how much fuel is sent to the engine.

3. TRANSMISSION - carries the mechanical energy to the wheels.

4. RADIATOR - carries away waste heat and keeps the engine cool.

5. EXHAUST SYSTEM - has a muffler to soften the noise created by the explosion of the fuel in the engine and a tailpipe to carry away the exhaust from the occupants.

OTHER VOCABULARY YOU MAY ENCOUNTER

ACCELERATION - Process of speeding up.

CETANE RATING - A number that rates the starting ability of diesel fuel. The diesel equivalent to a gasoline octane rating.

CRUISE SPEED - Efficient operating speed.

ENERGY CONTENT OR HEATING VALUE - The amount of heat generated during combustion in a vehicle's engine. A high value is desirable because it means that less fuel must be stored on board.

FLAMMABILITY LIMITS - The range of temperature in which a fuel can be ignited and burns. For safety reasons, narrow limits are preferable.

FLASH POINT - The lowest temperature at which vapors above a volatile combustible substance ignite when exposed to flame. High flash points are preferable.

FUEL DENSITY - A measure of the weight of a fuel per volume. Along with energy content, it determines the storage volume and weight of the fuel. This in turn affects the vehicle's operating range. The more fuel a vehicle can carry, the greater its range.

LUBRICITY - Ability to reduce friction.

OCTANE - A hydrocarbon, which contains eight carbon atoms, found in petroleum.

OCTANE RATING - A measure of a fuel's ability to resist catching on fire when compressed in an engine. Because engines knock loudly when their fuel-air mixtures ignite too early (that is, before the spark plug fires), octane ratings, which measure antiknock properties, are also called "antiknock" ratings. The higher the octane number, the more resistant the fuel is to catching on fire when compressed.

PAYLOAD - A vehicle's ability to carry something. It may be affected by the size and weight of the fuel tank in the vehicle.

RANGE - The distance a car can travel on a charged battery or tank of fuel.

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- Can it be used by individual commuters; or is it best for fleets of vehicles operated by organizations that can install and maintain their own fueling infrastructure? The student handout "HOW DO TYPICAL 20TH CENTURY VEHICLES WORK?" provides a baseline drawing needed to answer question 2a in their guide to fuel team research. It also lists possible new vocabulary students may encounter.

3) As they did for the sections "Availability and Distribution" and "Health, Pollution, and Safety," the fuel teams will use the questions provided in this section to prepare a written report and a mini-presentation lasting about 10 minutes. During that time, other students will be able to ask related questions about the fuel. Refer students to the handout "EVALUATING TEAM REPORTS AND PRESENTATIONS" (page 64), so that students will know in advance what is expected in their presentations.

4) Provide students with the opportunity to meet in their teams, to divide up the research tasks, and to decide how they will present their findings and who will do it. Encourage them to develop diagrams and other graphics to help present their findings. Remind them that these presentation aids may be further developed for a public presentation.

5) Coach students as they do their research. Much information is already available in the fact sheets. Additional information can be found at the web sites listed for the alternative fuels in the Resource Guide. Especially helpful are publications of the U.S. Department of Energy, the Union of Concerned Scientists, car manufacturers, and organizations that promote alternative fuels (such as NESEA, the American Methanol Institute, and others listed in the Resource Guide) as well as their Internet sites (especially those pages listed in the Resource Guide). It may be helpful for you to investigate some of the recommended web sites to have a better understanding of the information found there.

EXTENSIONS:

- Have each fuel team build a physical model that represents how their fuel is converted into energy. For more information, check out www.howstuffworks.com.
- How do the fuel's physical and chemical characteristics affect its practical use? For example, how well can it be transferred via a pipeline? Can it be compressed? Is it explosive or not? Does it contain or produce toxic materials?

STEP 5 - Team Presentations and Class Discussions

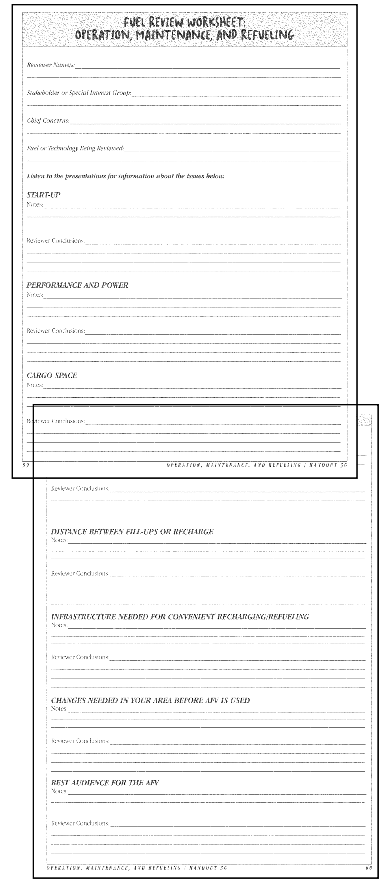
OPERATION, MAINTENANCE, AND REFUELING

TIME: Four days (10 to 15 minutes for each team's presentation and questions, plus 20 to 30 minutes for follow-up panel and class discussion)

1) Make a list of stakeholders or special interest groups for the students to represent while listening to and evaluating the fuels being presented. Remind students that a wide variety of people are interested in these issues: physicians, resource managers, atmospheric scientists, emergency personnel, even the insurance industry, as you discussed earlier in "WHO'S INTERESTED IN AFVS? WHO CARES ABOUT OPERATION, MAINTENANCE, AND REFUELING?"

2) Decide if the students will evaluate the presentations as individuals or as part of a review panel. Then assign (or have the members of the class select) the stakeholders or special interest groups they will represent. If they're working in review panels, allow the panel members to sit together.

3) Refer students to the handout “FUEL REVIEW WORKSHEET: OPERATION, MAINTENANCE, AND REFUELING.” They will use this worksheet as a guide for taking notes during a fuel presentation and writing down their (or their panel’s) conclusions. (They will need one copy of this worksheet for each fuel presentation given.) Before the presentations, allow students time to make note of their interest group’s chief concerns. After each presentation, allow them time to discuss and make note of their conclusions. How would each fuel affect their community and world?



FUEL REVIEW WORKSHEET:
OPERATION, MAINTENANCE, AND REFUELING

Reviewer Name/s:

Stakeholder or Special Interest Group:

Chief Concerns:

Fuel or Technology Being Reviewed:

Listen to the presentations for information about the issues below:

START-UP
Notes:
Reviewer Conclusions:

PERFORMANCE AND POWER
Notes:
Reviewer Conclusions:

CARGO SPACE
Notes:
Reviewer Conclusions:

OPERATION, MAINTENANCE, AND REFUELING / HANDOUT 36

Reviewer Conclusions:

DISTANCE BETWEEN FILL-UPS OR RECHARGE
Notes:
Reviewer Conclusions:

INFRASTRUCTURE NEEDED FOR CONVENIENT RECHARGING/REFUELING
Notes:
Reviewer Conclusions:

CHANGES NEEDED IN YOUR AREA BEFORE AFV IS USED
Notes:
Reviewer Conclusions:

BEST AUDIENCE FOR THE AFV
Notes:
Reviewer Conclusions:

OPERATION, MAINTENANCE, AND REFUELING / HANDOUT 36

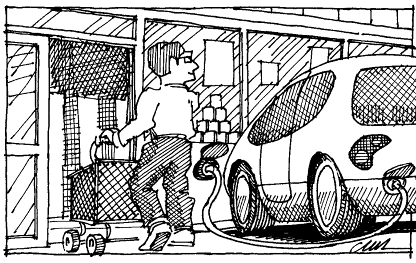
4) Presentations should last 5 to 10 minutes, with additional time for the audience to ask questions. Remind presenters to keep in mind the concerns of the stakeholders in the audience. Encourage students in their audience to ask questions from the points of view of the stakeholders they represent.

5) At the end of each day and again after all presentations have been given, allow time for the panels to compare the fuels and discuss the advantages and disadvantages of each. Taking into account the information gathered in all three sections of this unit, which are the best fuels for their community? Which are the best audiences for each fuel and AFV?

6) Have the review panels report their conclusions to the class and allow time for debate on their conclusions.

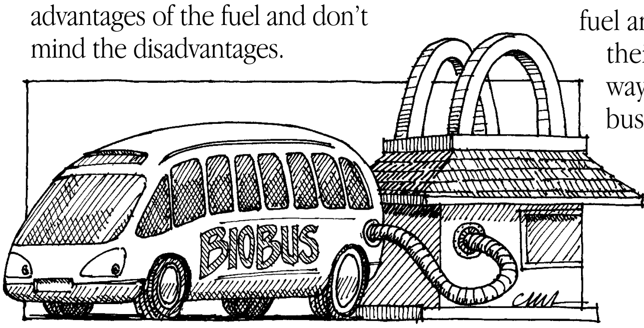
OPERATION, MAINTENANCE, AND REFUELING: THE CHALLENGE

The widespread use of alternative fuels in vehicles requires various types of adaptations—in automobile and fueling technology, consumer use, fueling infrastructure, and even community design.

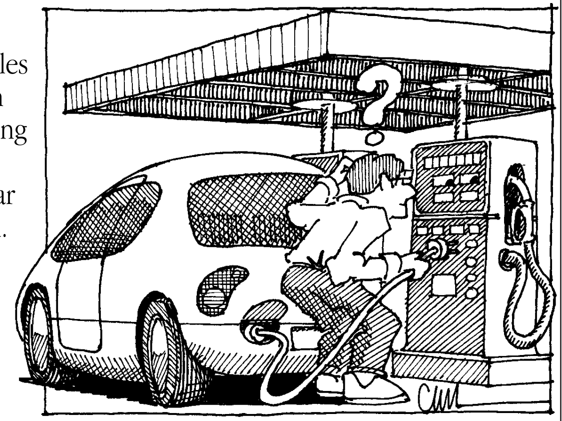


Many of the problems involved with most liquid and gaseous fuels can easily be addressed using current technology. For example, a limited range of flammability or a high flashpoint can affect the ability of a fuel to start a vehicle, particularly in cold weather. By adding a fuel with a lower flashpoint to methanol or by preheating biodiesel, current technology can resolve these problems. On the other hand, although fuel cells show much promise for powering AFVs, engineers are still working to solve many of the problems they present.

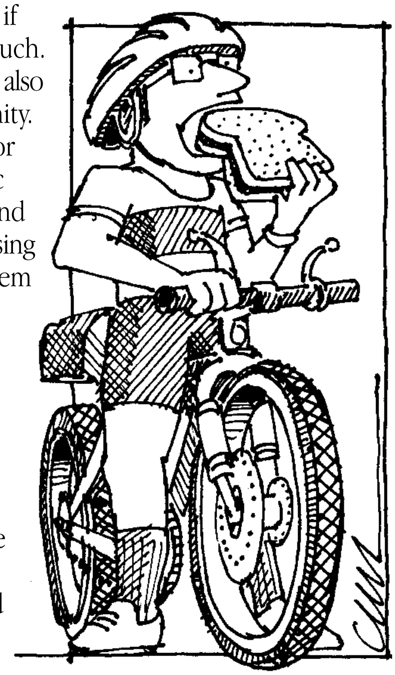
Compared with most alternative fuels, gasoline has a high energy content, which provides gasoline cars with more power and greater driving range than cars that run on other fuels. To many drivers, these characteristics may not matter; to other drivers, a decrease in power or range may be unacceptable. The energy content of fuels ultimately affects the size of the fuel tank and the amount of space left over for trunks or passengers. Drivers of some AFVs may have to make a choice: Do they sacrifice trunk and passenger space to make room for a larger fuel tank? Or do they keep the space they are used to and refuel more often? Because each alternative fuel has its own set of advantages and disadvantages, marketing an AFV means appealing to drivers who appreciate the advantages of the fuel and don't mind the disadvantages.



Adopting alternative-fueled vehicles goes hand in hand with establishing a new fueling infrastructure. After all, few drivers will buy a car that is difficult to refuel. With some adaptations in fueling devices and storage tanks, liquid alternative fuels can be distributed using the same infrastructure now used for gasoline and diesel. Creating an infrastructure for gaseous fuels is a more ambitious project, since they require different kinds of tanks for storage and devices for delivery.



Communities of the future may need to be redesigned to encourage people to walk or bicycle more. Widespread use of mass transit may be difficult in some communities if residential areas are spread out too much. Keeping electric vehicles on the road can also involve major changes in the community. Electricity is already widely available for charging vehicles; but because electric vehicles need to be recharged often and take a long time to fully recharge, choosing the best time and place to recharge them can be a problem. Making recharging convenient means making recharging possible while drivers are doing other things, such as sleeping, working, or doing errands.

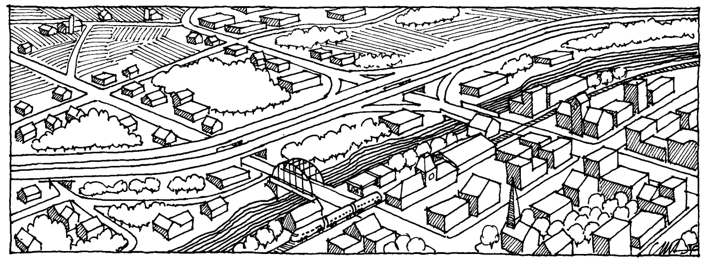


In this section, you'll look at what's needed to make AFVs attractive to drivers in your community and to bring alternative fuels into widespread use. Cars of the future may be much more varied than cars of the 20th century. As you think about a particular fuel and the AFV that it powers, think about their unique characteristics and the unique ways that they may appeal to people or to businesses with various transportatio needs.

GETTING AROUND YOUR COMMUNITY: GUIDE TO COMMUNITY RESEARCH

Use the questions below as a guide for learning about getting around your unique community. The answers will be important later as you prepare your presentations about alternative fuels. Work in groups to discuss the questions and identify the ones you can't yet answer. (For some questions you'll need to speak with drivers in your families or other drivers you know.) Mark as much information as you can on a community map.

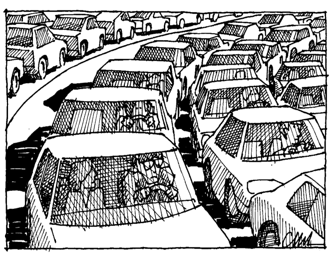
1. ***TRANSPORTATION IN YOUR COMMUNITY OR REGION***



a. Describe your community or region. Is it urban, suburban, rural, or a cluster of small towns? Does it have a town center or a cluster of centralized neighborhoods where people can walk or easily bicycle? Did it develop along one or more highway routes?

b. Is there much traffic through or near your community because of tourists or the trucking of goods? If so, which roads do they usually travel?

c. Circle and label on a community map the places where you live, shop, play, and go to school. Where are the other major areas where people live, work, shop, play, and go to school? How do you travel between these areas? Can you walk? Is it possible to take a bus? Do you have to drive to get where you need to go?

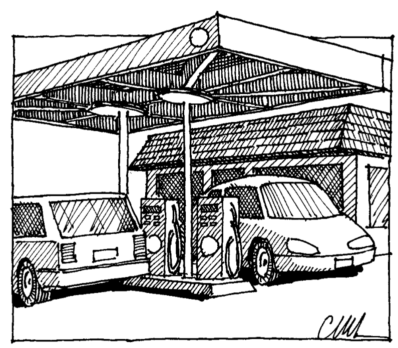


d. Where and when are the major areas of traffic congestion? Do any drivers in your family complain about traffic jams or stop-and-go traffic? How do they avoid driving in traffic?

2. ***FAMILY TRAVEL PATTERNS***

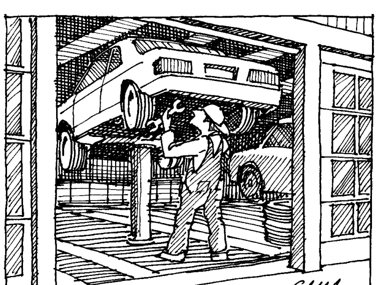
a. How do people in your family usually get to school or work? In which directions do people in your family generally commute (e.g., into town or out of town)? Which roads do they take? How far do they travel?

b. Where do members of your household shop or go for recreation? Where else do they normally travel throughout the week? How often do they go to those places? How far away are they?



3. ***FUELING AND DISTANCE TRAVELED***

a. What's the average distance your family travels in one week? How many gallons of transportation fuel does your household use per week? How often does your family refuel its car or cars? How much money do members of your family spend each week on transportation fuel?



b. If you wanted to locate a successful gas station in your community, where would you site it? Why is it likely to be successful in that location?

4. ***VEHICLE CHARACTERISTICS***

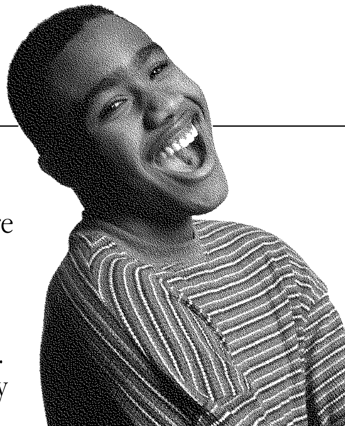
a. When choosing a vehicle, which of these characteristics are important to people in your household: cargo space, power, cost of maintenance and refueling, ability to drive long distances between refueling? How often do members of your household make use of these characteristics?

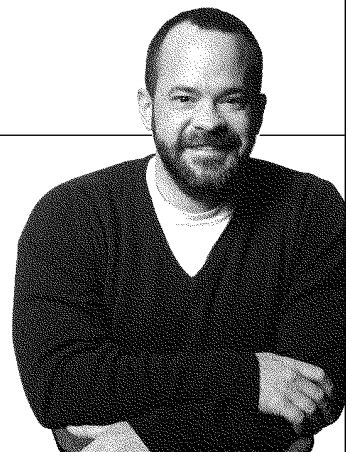
b. If your family has more than one car, are they used for different purposes? That is, is one used specifically for short trips around town and the other used for long-distance travel? Is one used for single commuters and one used as a family car? Must all cars have the same characteristics that you discussed in 4a?

c. How important is it that all the cars in your household use the same fuel?

WHO'S INTERESTED IN AFVS?
WHO CARES ABOUT OPERATION, MAINTENANCE, AND REFUELING?

A wide variety of people have a stake in a change to AFVs. This group is mainly interested in buying and selling AFVs, fueling and maintaining them, and recycling fluids and auto parts.



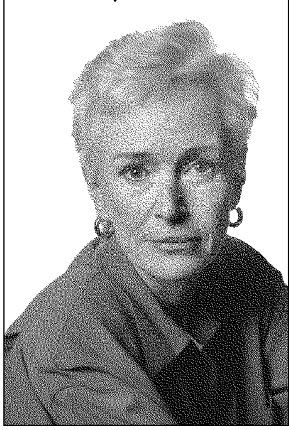


COMMUTER

I need to get where I'm going when I need to get there with the least amount of trouble. Dependability, easy maintenance, and a comfortable ride are what I want. Will AFVs provide this? How would an AFV change my daily routine? How easy would it be to adjust?

CITY PLANNER

With alternative-fueled vehicles being marketed in the United States, people are going to need places to conveniently refuel their vehicles. Can they refuel in the same place as gasoline-powered cars? If not, where will they do it?



AUTO SALESPEOPLE

With new kinds of cars coming on the market, we've got to learn more about how they perform and what kind of cars people in this area might want to buy. Should we be selling the same kind of car to a salesperson that travels 1,000 miles a week as to someone who just needs a car to get to the grocery store? It's not too early to do some research.

SERVICE SATION MANAGER

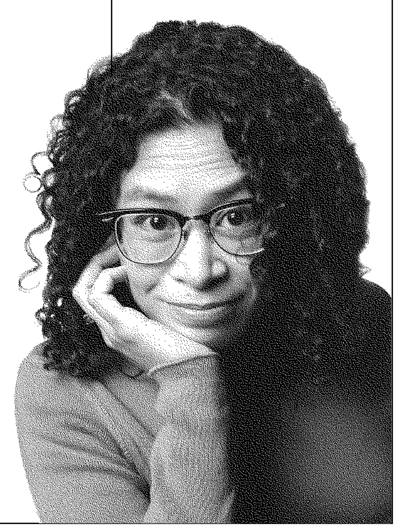
Can new fuels be stored in the tanks I now have, or will I need to replace them? Will I need to connect to a pipeline infrastructure, or will fuels be delivered in tanks, as they are today? What are the safety issues related to hydrogen, compressed gas, electricity, or other fuels? Will I need to provide electrical outlets for recharging cars?

AUTO MECHANIC

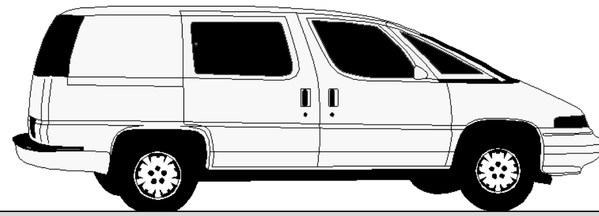
In 10 years will I be tuning up internal combustion engines or adjusting battery management systems? Maintaining new cars will probably require different equipment. There will probably be new safety certifications to get for the shop and new regulations to meet for recycling parts. What kind of training will I need?

STATE DEPARTMENTS OF ENVIRONMENTAL PROTECTION

In order to protect the environment and human health, we'll need to adjust the regulations (about disposing or recycling various automotive fluids and parts) to take into account the new AFV technologies. Mechanics will need training to meet the new regulations. What kinds of AFVs will be most popular with drivers around here? What kind of additional recycling facilities should we be investigating?



ENERGY CONTENT OF VARIOUS FUELS



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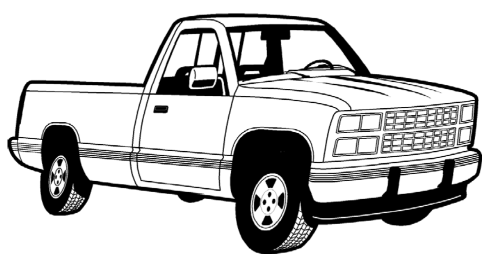
3.1 ENERGY CONTENT OF VARIOUS FUELS

FUEL	*BTU/ GALLON**	*GGE**: VOLUME OF FUEL NEEDED IN COMPARISON WITH GASOLINE*
diesel	129,000	0.89 to 1
gasoline	115,400	1.00 to 1
ethanol 85 (E85)	105,545	1.09 to 1
liquefied petroleum gas (LPG, propane)	84,000	1.40 to 1
ethanol (100%)	75,000	1.54 to 1
liquefied natural gas (LNG)	73,500	1.57 to 1
methanol 85 (M85)	65,350	1.77 to 1
methanol (100%)	56,500	2.04 to 1
compressed natural gas (CNG) @ 5,845 psi	56,500	2.04 to 1
liquid hydrogen	34,000	3.39 to 1
compressed natural gas (CNG) @ 3,000 psi	29,000	3.98 to 1
hydrogen @ 3,000 psi	9,667	11.94 to 1

Source: California Energy Commission, ABCs of AFVs.

* British thermal unit (Btu) - A standard unit for measuring heat energy. One Btu is the amount of heat required to raise the temperature of 1 pound of water 1 degree Fahrenheit. The volume of gaseous fuels (compressed natural gas and hydrogen) is measured in cubic feet (CF) rather than in gallons.

**GGE, or gasoline gallon equivalent, is the volume of gaseous fuel it takes to equal the energy content of one liquid gallon of gasoline.



3.2 FOOT AND PEDAL POWER

BICYCLE	***140***
WALKING	***300***
SINGLE OCCUPANT CAR	***7,246***

BTUs* REQUIRED PER PASSENGER-MILE

Compared with biking and walking, passenger cars are a very inefficient means of travel. What is the most efficient way of traveling to school, to the market, or to the library?

OPERATION, MAINTENANCE, AND REFUELING: GUIDE TO FUEL TEAM RESEARCH

Use the questions below as a guide to developing your presentation. Many of the answers are found in the alternative fuel fact sheets. For some, you'll need to do further research in encyclopedias, periodicals, or other publications found in your library; on the Internet; or by contacting organizations that promote alternative fuels. For others, you'll need to draw your own conclusions based on facts you've found. Be prepared to explain how you came to your conclusions. While answering the questions below and preparing your presentation, keep in mind these key questions:

- ***What is needed to bring your fuel into widespread use in your community?***

- ***For what purpose/s might it best be used?*** *Also keep in mind the issues to the right (which your class discussed at the beginning of this unit) and the various people interested in them.*

Use diagrams, charts, and other graphics if they can help you deliver information to your audience.

TRANSPORTATION AND FUEL ISSUES

- Easy start-up
- Performance and power
- Trunk space
- Long range between fill-ups or recharge
- Convenient recharging/refueling
- Low cost of maintenance
- Easy maintenance

1. ***PERFORMANCE CHARACTERISTICS***

a. Describe the performance characteristics of your fuel or AFV, including
- power, acceleration, and cruise speed
- ease of starting in cold weather
- payload

b. Does the AFV have any special characteristics that make driving it especially appealing or especially unappealing?

2. ***SPECIAL MAINTENANCE PROBLEMS AND POTENTIAL COSTS***

a. How does your AFV compare with the typical 20th-century vehicle described in the handout "HOW DO TYPICAL 20TH CENTURY VEHICLES WORK?"

b. Describe other modifications in technology (such as the need for special materials used in hoses or fuel tanks).

c. What special maintenance problems might arise?

d. Are there any outstanding costs of maintaining the AFV?

3. ***REFUELING***

a. In the community research activity, you investigated your family's driving habits and determined how far they drove each week. With this in mind, develop a weekly log to show how often and where in your community your family might fuel an alternative-fueled vehicle. Consider the range of the alternative-fueled vehicles.

b. How long would it take to refuel or recharge your vehicle?

c. Describe or diagram any new fueling devices that may need to be adopted.

d. How would the day-to-day cost of driving your AFV compare with that of driving a gasoline-powered vehicle?

4. ***BRINGING YOUR FUEL AND AFV INTO WIDESPREAD USE***

a. Given the unique characteristics of your fuel and AFV, for what type of driving and commuter pattern is it best used? Would it be used as a general-purpose vehicle or for a special purpose? Is it good for households or for businesses and organizations that operate fleets of vehicles and can easily install and maintain a fueling infrastructure?

b. Does your fuel and AFV respond to any particular problems in your community, such as tailpipe emissions at bus depots?

c. If you were a car manufacturer, to what group of drivers or organizations in your community would you market this car? What images might you use to entice those drivers or organizations to buy it?

HOW DO TYPICAL 20TH CENTURY VEHICLES WORK?

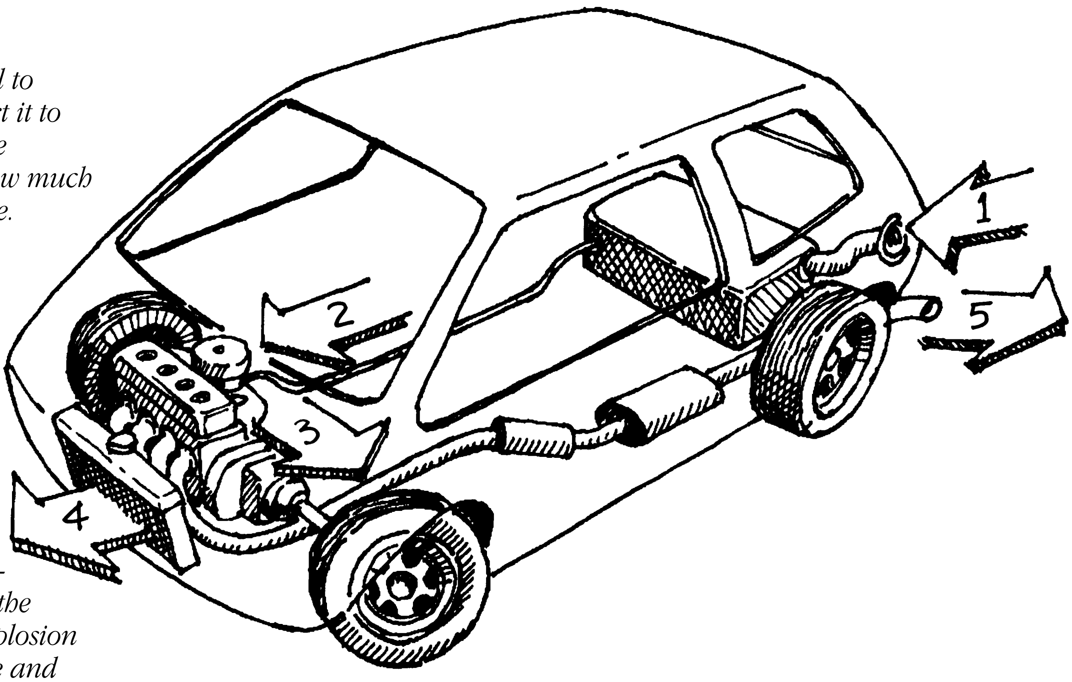
***1. FUEL TANK** - holds gasoline or diesel.*

***2. ENGINE** - burns fuel to create heat and convert it to mechanical energy. The accelerator controls how much fuel is sent to the engine.*

***3. TRANSMISSION** - carries the mechanical energy to the wheels.*

***4. RADIATOR** - carries away waste heat and keeps the engine cool.*

***5. EXHAUST SYSTEM** - has a muffler to soften the noise created by the explosion of the fuel in the engine and a tailpipe to carry away the exhaust from the occupants.*



OTHER VOCABULARY YOU MAY ENCOUNTER

***ACCELERATION** -*
Process of speeding up.

***CETANE RATING** -*
A number that rates the starting ability of diesel fuel. The diesel equivalent to a gasoline octane rating.

***CRUISE SPEED** -*
Efficient operating speed.

***ENERGY CONTENT OR HEATING VALUE** -*
The amount of heat generated during combustion in a vehicle's engine. A high value is desirable because it means that less fuel must be stored on board.

***FLAMMABILITY LIMITS** -*
The range of temperature in which a fuel can be ignited and burns. For safety reasons, narrow limits are preferable.

***FLASH POINT** -*
The lowest temperature at which vapors above a volatile combustible substance ignite when exposed to flame. High flash points are preferable.

***FUEL DENSITY** -*
A measure of the weight of a fuel per volume. Along with energy content, it determines the storage volume and weight of the fuel. This in turn affects the vehicle's operating range. The more fuel a vehicle can carry, the greater its range.

***LUBRICITY** -*
Ability to reduce friction.

***OCTANE** -*
A hydrocarbon, which contains eight carbon atoms, found in petroleum.

***OCTANE RATING** -*
A measure of a fuel's ability to resist catching on fire when compressed in an engine. Because engines knock loudly when their fuel-air mixtures ignite too early (that is, before the spark plug fires), octane ratings, which measure antiknock properties, are also called "antiknock" ratings. The higher the octane number, the more resistant the fuel is to catching on fire when compressed.

***PAYLOAD** -*
A vehicle's ability to carry something. It may be affected by the size and weight of the fuel tank in the vehicle.

***RANGE** -*
The distance a car can travel on a charged battery or tank of fuel.

FUEL REVIEW WORKSHEET: OPERATION, MAINTENANCE, AND REFUELING

Reviewer Name/s: ______________________________

____

Stakeholder or Special Interest Group: ______________________________

____

Chief Concerns: ______________________________

____

Fuel or Technology Being Reviewed: ______________________________

____

Listen to the presentations for information about the issues below.

START-UP

Notes: ______________________________

____

____

Reviewer Conclusions: ______________________________

____

____

____

PERFORMANCE AND POWER

Notes: ______________________________

____

____

Reviewer Conclusions: ______________________________

____

____

____

CARGO SPACE

Notes: ______________________________

____

____

Reviewer Conclusions: ______________________________

____

____

____

COST AND EASE OF MAINTENANCE

Notes:

Reviewer Conclusions:

DISTANCE BETWEEN FILL-UPS OR RECHARGE

Notes:

Reviewer Conclusions:

INFRASTRUCTURE NEEDED FOR CONVENIENT RECHARGING/REFUELING

Notes:

Reviewer Conclusions:

CHANGES NEEDED IN YOUR AREA BEFORE AFV IS USED

Notes:

Reviewer Conclusions:

BEST AUDIENCE FOR THE AFV

Notes:

Reviewer Conclusions:

COMMUNITY PRESENTATION

TIME

Three to five days, depending on the type of presentation and the amount of class time available. Allow at least one class period for preparation and one class period for rehearsal before students make a public presentation.

OBJECTIVES

- *To prepare and inform your community about alternative transportation technologies and fuels.*
- *To provide an opportunity for students to teach others.*

MATERIALS NEEDED

Student Handouts

- *Community Presentation: Transportation of the Future*
- *Evaluating Team Reports and Presentations*
- *Transportation of the Future: Presentation Report*

Other useful resources

- *Flip charts, poster board, transparencies, and use of an overhead projector*
- *Access to word processing or presentation software*

STEP 1

CHOOSING THE BEST FUELS FOR THE COMMUNITY AND WORLD AT LARGE

TIME: One to two days (If students were successful in analyzing the benefits and drawbacks of each of the nine fuels throughout the mini-presentations and the follow-up discussions, this step will be a review of choices they've already made.)

1) When all the teams have given their mini-presentations, ask them to review the list of issues they discussed at the beginning of this unit in "Getting Oriented." Ask if their opinions about these issues have changed. Have any issues lost or gained importance? Is this list complete or should other issues be added?

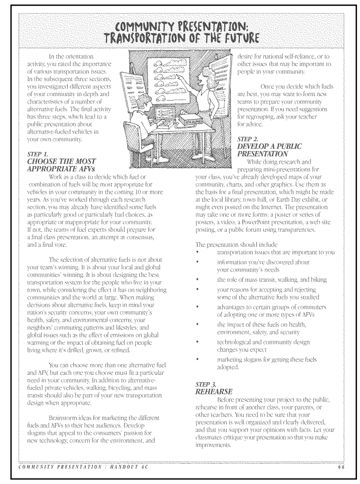
2) Ask the students to identify the types of transportation that may best meet the various needs of community members. Remind them to consider the role of bicycling, mass transit, and walking as ways to meet their community's needs and to resolve the issues important to them.

3) Ask the class to select one, two, or more fuels to power the future transportation system they envision for their community. Have students defend their choices using information from each of the three research sections. If the students do not agree or the best choices are not clear, have the students review the information in the "FUEL REVIEW WORKSHEETS" that they collected during the mini-presentations of each fuel. If students still have difficulty deciding which fuels to promote, the teams of fuel experts should present a summary of the benefits and drawbacks for using their fuel in their community and the world at large, the class should attempt consensus, and then the students should select the fuels with a final vote.

STEP 2
PREPARING FOR THE PRESENTATION

TIME: 30 minutes, plus two to three 10-minute team meetings during class time over several days; individual students will likely need additional preparation time outside of class

1) As a reminder of the points covered here, distribute the student handout "COMMUNITY PRESENTATION: TRANSPORTATION OF THE FUTURE."



COMMUNITY PRESENTATION: TRANSPORTATION OF THE FUTURE

In the orientation activity, you rated the importance of various transportation issues. In the subsequent three sections, you investigated different aspects of your community in depth and characteristics of a number of alternative fuels. The final activity has three steps, which lead to a public presentation about alternative-fueled vehicles in your own community.

STEP 1.
CHOOSE THE MOST APPROPRIATE AFVs

Work as a class to decide which fuel or combination of fuels will be most appropriate for vehicles in your community in the coming 10 or more years. As you've worked through each research section, you may already have identified some fuels as particularly good or particularly bad choices, as appropriate or inappropriate for your community. If not, the teams of fuel experts should prepare for a final class presentation, an attempt at consensus, and a final vote.

The selection of alternative fuels is not about your team's winning. It is about your local and global communities' winning. It is about designing the best transportation system for the people who live in your town, while considering the effect it has on neighboring communities and the world at large. When making decisions about alternative fuels, keep in mind your nation's security concerns; your own community's health, safety, and environmental concerns; your neighbors' commuting patterns and lifestyles; and global issues such as the effect of emissions on global warming or the impact of obtaining fuel on people living where it's drilled, grown, or refined.

You can choose more than one alternative fuel and AFV, but each one you choose must fit a particular need in your community. In addition to alternative-fueled private vehicles, walking, bicycling, and mass transit should also be part of your new transportation design when appropriate.

Brainstorm ideas for marketing the different fuels and AFVs to their best audiences. Develop slogans that appeal to the consumers' passion for new technology, concern for the environment, and desire for national self-reliance, or to other issues that may be important to people in your community.

Once you decide which fuels are best, you may want to form new teams to prepare your community presentation. If you need suggestions for regrouping, ask your teacher for advice.

STEP 2.
DEVELOP A PUBLIC PRESENTATION

While doing research and preparing mini-presentations for your class, you've already developed maps of your community, charts, and other graphics. Use them as the basis for a final presentation, which might be made at the local library, town hall, or Earth Day exhibit, or might even posted on the Internet. The presentation may take one or more forms: a poster or series of posters, a video, a PowerPoint presentation, a web site posting, or a public forum using transparencies.

The presentation should include

- transportation issues that are important to you
- information you've discovered about your community's needs
- the role of mass transit, walking, and biking
- your reasons for accepting and rejecting some of the alternative fuels you studied
- advantages to certain groups of commuters of adopting one or more types of AFVs
- the impact of these fuels on health, environment, safety, and security
- technological and community design changes you expect
- marketing slogans for getting these fuels adopted.

STEP 3.
REHEARSE

Before presenting your project to the public, rehearse in front of another class, your parents, or other teachers. You need to be sure that your presentation is well organized and clearly delivered, and that you support your opinions with facts. Let your classmates critique your presentation so that you make improvements.

COMMUNITY PRESENTATION / HANDOUT 4C 66

2) In Step 3 of the section "Getting Oriented," you and your students decided where and when a presentation would take place, who the audience would be, and what form the presentation would take. Review your decisions with the class and decide how long the presentation should be. (For example, students may develop a flip chart or poster presentation to show to parents at a school or public library, or they may develop a more ambitious video or PowerPoint presentation for a public Earth Day event.)

3) Throughout the unit, students have already collected information to be used in a public presentation. This information may need to be cleaned up or reformatted, however, for delivery to a public audience. To adequately prepare and deliver the presentations, students may wish to restructure their teams. One possibility is to have each fuel team present the advantages and disadvantages of each fuel. Another possibility is to have one team summarize the community research activities and the transportation-related issues your community faces, a second team discuss the reasons for rejecting certain fuels and types of transportation, and a third team present the selected fuels and a vision for an improved transportation system. A third possibility is to have one team prepare visuals for the presentation, a second team finalize a written report, and a third team prepare the oral presentation.

4) Remind the class that the purpose of this presentation is to inform their community about the best transportation for the future of the community and the world at large. Students should explain the reasons for making a change away from petroleum fuels, present the important issues, and explain why certain fuels are appropriate in resolving them (and others are not appropriate). The students' presentations should include information they have collected from each of the three research sections: "Availability and Distribution"; "Health, Pollution, and Safety"; and "Operation, Maintenance, and Refueling." Student presentations should help the community visualize a better transportation system — one that relies on alternative fuels, biking, walking, and mass transit as appropriate. This system should include a description of new fueling infrastructures if they are needed.

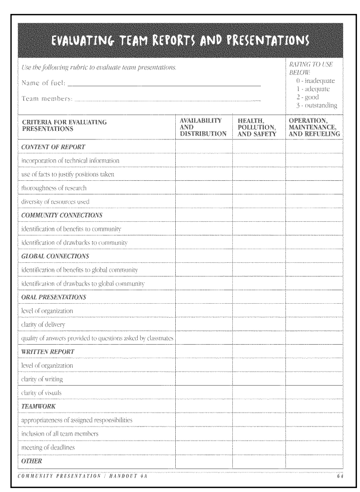
5) Provide teams with several opportunities to meet during class time to prepare their part of the presentation.

STEP 3
REHEARSAL

TIME: 45 minutes

1) Set up a rehearsal presentation with another class, with parents, or with teachers.

2) Prior to the rehearsal presentation, distribute copies of "EVALUATING TEAM REPORTS AND PRESENTATIONS" to students in your class and ask them to use the handout as a basis for evaluating the presentation.



EVALUATING TEAM REPORTS AND PRESENTATIONS

Use the following rubric to evaluate team presentations.

Name of fuel: ____________________

Team members: ____________________

RATING TO USE BELOW:
0 - inadequate
1 - adequate
2 - good
3 - outstanding

CRITERIA FOR EVALUATING PRESENTATIONS	AVAILABILITY AND DISTRIBUTION	HEALTH, POLLUTION, AND SAFETY	OPERATION, MAINTENANCE, AND REFUELING
CONTENT OF REPORT			
incorporation of technical information			
use of facts to justify positions taken			
thoroughness of research			
diversity of resources used			
COMMUNITY CONNECTIONS			
identification of benefits to community			
identification of drawbacks to community			
GLOBAL CONNECTIONS			
identification of benefits to global community			
identification of drawbacks to global community			
ORAL PRESENTATIONS			
level of organization			
clarity of delivery			
quality of answers provided to questions asked by classmates			
WRITTEN REPORT			
level of organization			
clarity of writing			
clarity of visuals			
TEAMWORK			
appropriateness of assigned responsibilities			
inclusion of all team members			
meeting of deadlines			
OTHER			

COMMUNITY PRESENTATION / HANDOUT 4A 64

3) Students deliver the presentation. Allow time for questions and answers.

4) After the presentation, have the class critique it and suggest improvements.

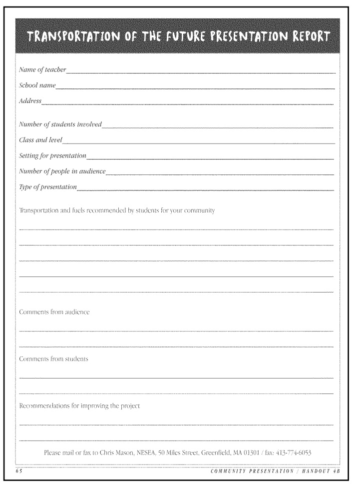
STEP 4
MAKING THE PRESENTATION

TIME: presentation length will vary depending on the venue

1) Presentations may be given in a variety of settings, such as Earth Day celebrations, school assemblies, parent-teacher association meetings, and at the public library.

2) Allow time for questions and answers.

STEP 5
FOLLOW-UP FOR TEACHERS


TRANSPORTATION OF THE FUTURE PRESENTATION REPORT

*Name of teacher*__________
*School name*__________
*Address*__________

*Number of students involved*__________
*Class and level*__________
*Setting for presentation*__________
*Number of people in audience*__________
*Type of presentation*__________

Transportation and fuels recommended by students for your community

Comments from audience

Comments from students

Recommendations for improving the project

Please mail or fax to Chris Mason, NESEA, 50 Miles Street, Greenfield, MA 01301 / fax: 413-774-6053

65 COMMUNITY PRESENTATION / HANDOUT 4B

TIME: 30 minutes (out-of-class time)

1) NESEA is willing to promote student work associated with these presentations. Send copies of presentations to Chris Mason, NESEA, 50 Miles Street, Suite 3, Greenfield MA 01301, or cmason@nesea.org.

2) Following the presentation, complete the "TRANSPORTATION OF THE FUTURE PRESENTATION REPORT" and mail it to NESEA.

EVALUATING TEAM REPORTS AND PRESENTATIONS

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RATING TO USE BELOW:
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OTHER			

TRANSPORTATION OF THE FUTURE PRESENTATION REPORT

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School name ______________________________

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Number of students involved ______________________________

Class and level ______________________________

Setting for presentation ______________________________

Number of people in audience ______________________________

Type of presentation ______________________________

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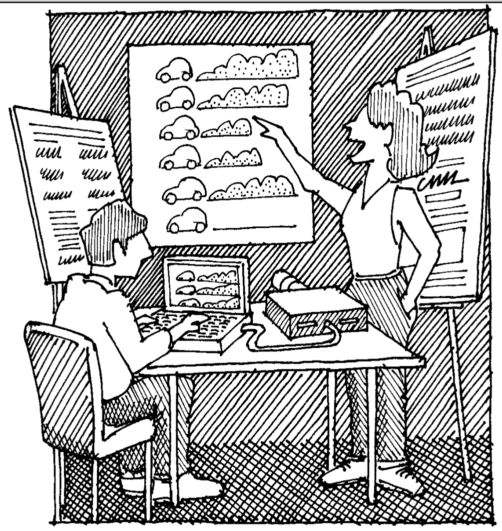

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FUEL FACT SHEETS

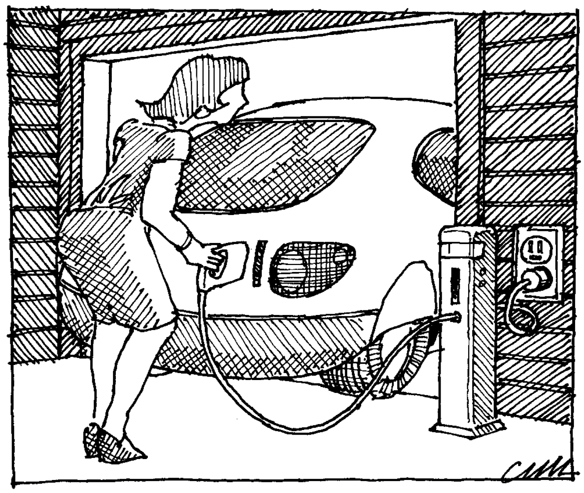
Use these fact sheets to help students get started on their research.

CONTENTS

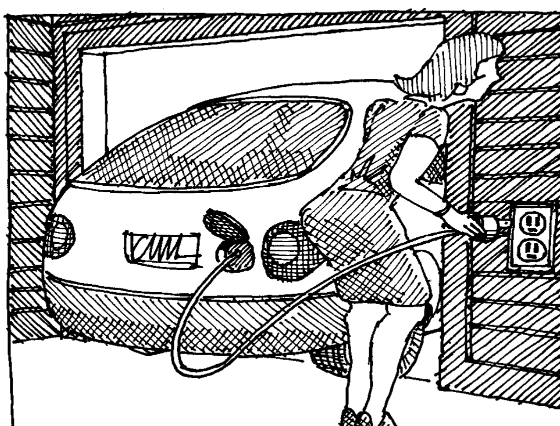
BATTERY ELECTRIC

Electric vehicles (EVs) use electric motors instead of an internal combustion engine to provide motive force. In a battery electric vehicle, the power is stored on board vehicles in rechargeable battery packs, which power electronic drive systems. The electricity required to recharge the batteries may be provided by utility-generated power or by any other available source of electricity. Utilities generate power from a variety of sources, including coal, natural gas, nuclear energy, hydropower, and renewables.

HISTORY



Professor Sibrandus Stratingh is credited with building the first model of an electric car in the Netherlands in 1835. The first practical electric road vehicles were made soon after by Robert Davidson in Scotland and by Thomas Davenport in the United States. Both inventors used nonrechargeable electric cells. When the Frenchmen Gaston Plante and Camille Faure invented (in 1865) and improved (in 1881) the electric storage battery, common use of electric vehicles became a possibility. In 1899, when the Belgian Camille Jenatzy set a record of over 100 kph (62 mph) in a streamlined electric racing car, the potential of the electric car was brought to the world's attention. By 1900, there were more electric than gas-powered cars on the road.



CURRENT USES

Before the widespread use of gasoline-fueled internal combustion engines and into the 1920s, electricity, stored in lead-acid batteries, was a popular energy source for vehicles. Only in recent years has serious attention returned to electric vehicles for automobile transportation purposes. Battery technology for vehicles is now changing with the support of the U.S. Advanced Battery Consortium (USABC), a partnership of the Department of Energy, DaimlerChrysler, Ford, and General Motors. The USABC predicts use in the near future of four types of batteries: advanced lead-acid, nickel metal hydride, lithium-ion, and lithium-polymer.

When gasoline became the more popular fuel for on-road vehicles, EVs continued to be used off-road and for specialized functions. Even now, electric vehicles can be seen in factories and warehouses, where internal combustion engine exhaust could endanger worker health or damage products, and on golf courses, where their quiet operation provides a more relaxing environment. They are used in airports to move luggage, people, and planes; in law enforcement to enable a quiet approach by electric bicycle while expanding the range of the rider; on work sites to ferry employees between buildings; and on college campuses. To reduce pollution and noise in urban areas, cities are bringing back electric transit buses and trolleys.

SOURCES AND EFFICIENCY

Over 95 percent of the electricity used in the United States comes from domestic sources of energy. The nation's existing power plants are capable of producing the electricity needed to operate millions of EVs if these vehicles are charged during off-peak hours. Widespread daytime charging of EVs will have an impact on the amount of electricity that will need to be produced.

According to the California Energy Commission, EVs are 0 to 25 percent more efficient than gasoline vehicles, and 10 to 30 percent less efficient than diesel vehicles. This comparison accounts for the entire fuel cycle — the energy used to extract, produce, and transport gasoline to the pump or to get the electricity to the plug, plus the energy used by the vehicle. Just taking the vehicle efficiency into account, an EV uses 66 percent of the electricity delivered to the charger for forward movement. An internal-combustion-engine vehicle uses approximately 22 to 33 percent of the gasoline's energy at the pump to move forward.

VEHICLE ALTERATIONS

The primary differences between a battery EV and a conventional vehicle are detailed below. A battery EV has an electric motor instead of an engine, a battery pack and management system instead of a fuel tank, electronic controls instead of an ignition system, and the addition of a high-voltage electrical system. An EV is propelled when the electric motor receives sufficient electricity from the battery pack to provide the torque needed to turn the wheels at the rate desired. The accelerator pedal is connected to an electronic control module, which regulates the amount of current or voltage drawn from the battery system. Most EVs use regenerative braking — slowing the vehicle by capturing kinetic energy, converting it back into electrical energy, and then channeling it to the battery pack for later use.

MAINTENANCE

Because an EV has few moving parts, service requirements are less than for conventional cars. An EV does not have an internal combustion engine, liquid fuel tank, fuel lines, carburetor, spark system, muffler, or pollution-control equipment. No timing belts, water pumps, radiators, fuel injectors, or tailpipes are required. No tune-ups, emission control adjustments, oil changes, or oil filter replacements are needed.

Lead-acid battery packs cost thousands of dollars and need replacement on average about every 30,000 miles or three years. Nickel-metal-hydride batteries may last up to 100,000 miles.

SAFETY

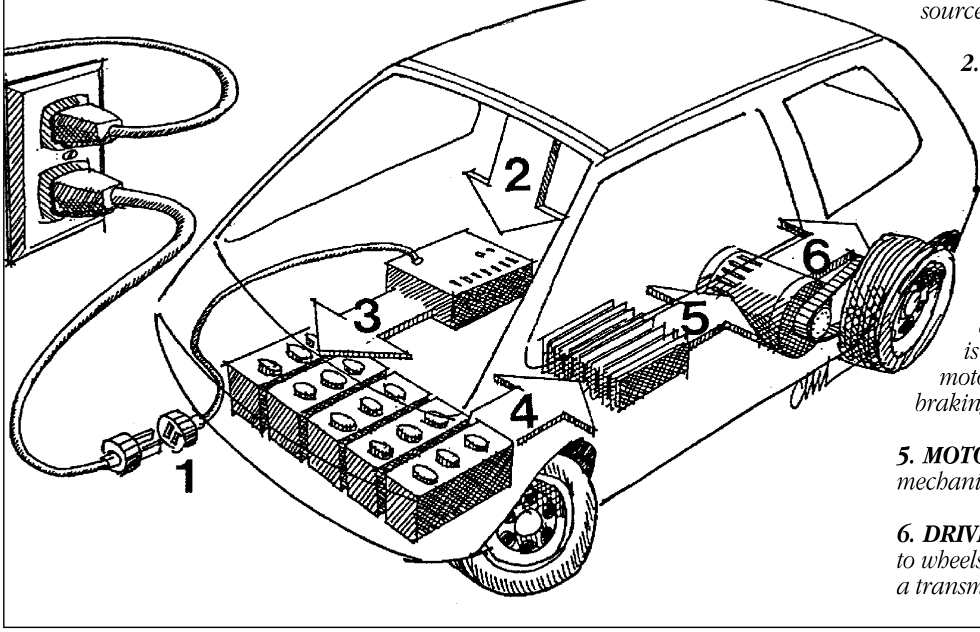
To promote safe use, vehicle manufacturers are using a number of disconnect systems in the high-voltage circuits, which isolate the rest of the vehicle from the battery voltage. Lethal levels of electricity may be present in the battery pack, however, so it should be treated with the same caution and respect as a full fuel tank in an internal combustion vehicle. In case of accidents, emergency response personnel will need special training to handle such hazards as exposure to high-voltage systems and possible leakage of flammable, toxic, or corrosive battery chemicals.

PERFORMANCE

A major difference between battery electric and internal-combustion-powered vehicles is the level of noise produced. Battery EVs are silent when idling and offer almost silent driving.

Acceleration, speed, and handling for well-designed EVs are equivalent to, or better than, those of comparable internal-combustion-powered vehicles. As of 1996, the world land-speed record for an electric car was just under 200 mph, and electric trains in Japan go even faster. In 1997, the top driving speed was 75 to 80 miles per hour, which may be limited by manufacturers in order to conserve battery power and extend the driving range. New battery EVs can accelerate from 0 to 60 mph in just 8.5 seconds and easily maintain highway speeds.

HOW A BATTERY ELECTRIC CAR WORKS



*1. **ELECTRICAL CONNECTION** - enables the energy-storage system to be charged by plugging into utility-generated power or other available sources of electricity.*

*2. **CHARGER** - may be on or off the vehicle.*

*3. **ENERGY-STORAGE SYSTEM** - stores electricity until it is needed. The system may include batteries, supercapacitors, and/or a flywheel.*

*4. **MOTOR CONTROLLER** - sends electricity smoothly and efficiently to the motor as needed. It is controlled by an accelerator pedal. If regenerative braking is installed, the controller will allow the motor to act as a generator and return braking energy to the energy-storage system.*

*5. **MOTOR** - converts electrical energy to mechanical energy and vice versa.*

*6. **DRIVETRAIN** - transfers mechanical energy to wheels through a differential and sometimes a transmission.*

RANGE AND RECHARGING

The average daily use of private vehicles in the major U.S. cities is 40 miles. Battery EVs average 40 to 125 miles per charge, depending on the vehicle's weight, engineering and design features, and type of battery. Weather extremes, terrain, and use of accessories such as heating and air conditioning also affect the range.

When the battery powers the motor, it discharges; that is, an electrical current flows, reducing the amount of electric charge stored in chemical form in the battery. Recharging a battery reverses this process. An electric current is passed through the battery and reforms the active materials in the battery to their high-energy charge state. Most homes, government facilities, fleet garages, and businesses have enough electrical power to charge EVs, but additional sources of power on the street, at shopping malls, or in parking structures would make recharging more convenient for battery EV drivers.

The time needed for charging depends on the voltage of the electrical source, and the temperature, size, type, and remaining state-of-charge of the batteries. Most EV batteries can be recharged using a grounded 120-volt, 15-amp, three-prong outlet found in most homes and buildings. This mode of charging is categorized as level 1 charging and takes 10 to 15 hours. Level 2 charging uses a 240-volt, 40-amp circuit, and takes 3 to 8 hours. The use of 480-volt equipment (level 3 charging) would enable recharging in as little as 5 to 10 minutes. This type of charging may be used in the future for public recharging sites.

Safely recharging an EV may require special hookups or upgrades to existing electrical outlets. To make the most efficient use of existing capacity, utilities will likely encourage home-based, overnight charging during off-peak hours.

EMISSIONS

Battery-powered electric vehicles produce no emissions in operation. This makes EVs a good choice for highly polluted urban areas, where human exposure to pollutants is greatest. EVs use virtually no energy while idling. In contrast, stop-and-go driving and idling increase the amount of pollutants per mile emitted from internal combustion engines. EVs can also help reduce the urban pollution that stems from running car air conditioners, carrying heavy loads, or driving in cold temperatures — all of which increase pollution from internal combustion engines.

Emissions do occur at the power-generating facilities that supply the electricity needed to recharge the battery, and the amount of emissions depends on the efficiency of recharging the batteries and the type of fuel used to produce power. An advantage of shifting emissions from tailpipes to power plants is that the emissions can be more easily controlled at a central location.

Electric drivetrains are more energy-efficient than are internal combustion engines. According to the California Energy Commission, EVs produce 90 percent fewer emissions than an internal combustion engine, even when emissions from power plants are considered.

The Argonne National Laboratory and the Union of Concerned Scientists (1995) have analyzed how the emissions of greenhouse gases would change if electric cars replaced gasoline-powered cars. The actual reduction of greenhouse gases depends on how the electricity used for charging is generated. The projected percentage of emissions reductions is shown below for each method of power production:

Coal-fired power plants: reductions of 17 to 22 percent.

Natural gas plants: reductions of 48 to 52 percent.

South Coast Air Basin of California, which relies on many sources of renewable energy: reduction of 71.2 percent.

Utilities using renewable energy sources (such as hydroelectric, wind, solar, or geothermal): reductions of almost 100 percent.

Nationwide: reductions of 31 to 46 percent.

OTHER ENVIRONMENTAL CONCERNS

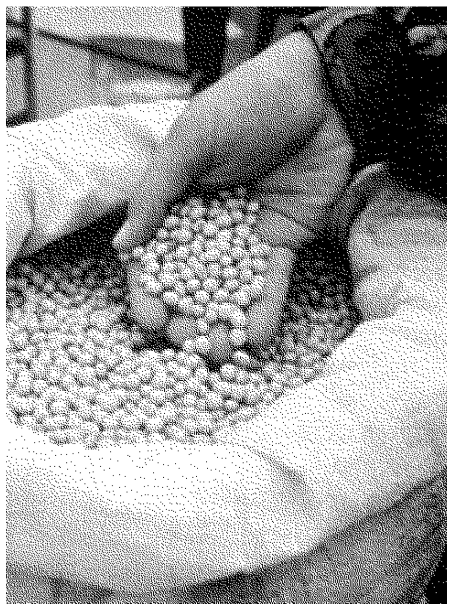
No oil- or gasoline-caused water pollution is associated with EVs. Proper and safe disposal of batteries is important. Proper handling methods for lead-acid batteries are already in use, however, and more than 90 percent of lead-acid batteries are recycled in the United States. The acid is drained from the battery, cleaned, and recycled as electrolyte in new batteries; the lead is taken out and reused; even the plastic can be recycled. As other types of batteries are brought into use, similar environmentally responsible mechanisms for proper disposal and recycling will need to be developed and used.

BIODIESEL

Biodiesel (mono alkyl esters) is a renewable liquid fuel produced from new or used vegetable oils or animal fats. It is typically made by a chemical process called trans-esterfication, which relies on an alcohol, such as methanol, and a catalyst. The main form of biodiesel in the United States is soydiesel, or methyl soyate, which is made from soybean oil. It can also be made from cottonseed, peanut, canola (a variety of rapeseed), sunflower oils, waste animal fats, and used cooking oil. The City of Chicago has made waste oil from restaurants into biodiesel fuel for use by the city's transit buses and marine police boats.

HISTORY

The concept of using vegetable oil as a fuel dates back to 1895, when Dr. Rudolf Diesel developed the first diesel engine to run on vegetable oil. Diesel demonstrated his engine at the World Exhibition in Paris in 1900, using peanut oil as fuel. Before World War II, biodiesel was introduced in South Africa to power heavy-duty vehicles.



Recently environmental and economic concerns have renewed the interest in biodiesel throughout the world, especially in Europe, where it has been used for 20 years. It is used by diesel-powered vehicles such as transit buses, heavy-duty trucks, and marine engines.

CURRENT USES

Biodiesel can be used alone or mixed in any ratio with petroleum diesel fuel. Biodiesel in its pure form is called "neat biodiesel." It is used in stationary generators in hospitals and police stations.

A number of fleets across the United States have adopted biodiesel blends. B20, a blend of 80 percent diesel and 20 percent biodiesel, is widely used in transit systems and in federal and municipal fleets such as postal vehicles, snowplows, road graders, and other highway maintenance vehicles. It is powering school bus systems in some U.S. cities and mass transit systems in national parks such as the Grand Canyon. Biodiesel blends are available in most marinas, where replacing diesel normally used in boats can help keep lakes, bays, and estuaries cleaner.

SOURCE, PRICING, AND AVAILABILITY

France is the world's largest producer of biodiesel, using it as heating oil and also in 50-percent blends with petrodiesel. Currently all the biodiesel used in the United States comes from domestic feedstocks. The price varies greatly depending on the type and cost of the feedstock and the scale of production. (Prices are high when biodiesel is produced in small quantities.)

A variety of people are interested in developing biodiesel and in finding better, less-expensive feedstocks. Some food producers are interested because health-conscious Americans are eating less high-oil food, and biodiesel could provide another market for their products. Scientists with the U.S. Departments of Energy and Agriculture are trying to develop soybean hybrids with a higher oil content. (Soybeans contain about 20 percent oil, whereas some oil seeds contain 50 percent; rapeseed used in Europe contains 40 percent.) The National Renewable Energy Laboratory (NREL) is researching the production of oil from aquatic plants, such as microalgae, a source that may greatly lower the cost of biodiesel.

STORAGE AND SAFETY

Biodiesel can be stored anywhere that petroleum diesel fuel is stored; neat biodiesel begins to freeze at about 25˚ F, however, so it needs to be used or stored at temperatures above that. (Underground storage tanks are usually about 50˚F.) Biodiesel has a high flash point and does not produce explosive vapors, making it safer to store and handle than diesel, but biodiesel has a shelf life of about six months, after which its fuel properties should be reanalyzed.

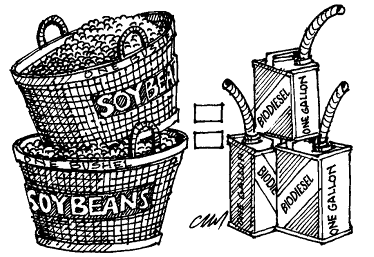
Biodiesel fuel can be distributed through the existing diesel supply infrastructure. Because it softens and dissolves some substances, fuel hoses may need modification. Biodiesel can also dissolve certain types of paints.

Neat biodiesel is biodegradable, degrading four times faster than diesel and at the same rate as dextrose (a sugar). Compared with diesel, it has substantially lower toxic, mutagenic, and carcinogenic emissions; it is relatively nontoxic to mammals.

In the late '90s, Yellowstone National Park conducted a "bear attraction test," successfully dispelling the notion that the french fry smell of biodiesel would attract bears to cars.

PERFORMANCE

The energy content, viscosity and phase changes, horsepower, torque, and fuel economy are similar to those for conventional and low-sulfur diesel. Biodiesel has a significantly higher cetane number, a number that rates its starting ability and antiknock properties.



2 BUSHELS OF SOYBEANS **3 GALLONS OF BIODIESEL**

At higher temperature extremes, biodiesel is advantageous because its flash point is over 300°F, compared with 125°F for low-sulfur diesel and 176°F for conventional diesel. Compared with regular diesel, biodiesel is more susceptible to cold-weather fuel-flow problems. These problems can be overcome by installing engine or fuel-filter heaters, storing vehicles near or in a building, or blending biodiesel with conventional diesel.

REFUELING

Fueling is the same as with diesel fuel.

MAINTENANCE AND VEHICLE ALTERATIONS

An engine using biodiesel requires little modification. But since biodiesel is a natural solvent that can dissolve some rubber, vehicle fuel lines and fuel pump seals that come in contact with the fuel could be affected by pure or high-percent blends. For many new cars, the recent switch to low-sulfur diesel fuel has caused most original engine manufacturers to switch to components that are already suitable for use with biodiesel. Because the fuel clouds and stops flowing at higher temperatures than does diesel, fuel-heating systems may be needed in cold climates.

The use of biodiesel, even in small percentages, can extend the life of diesel engines because it is more lubricating than petroleum diesel fuel.

EMISSIONS

A 1998 biodiesel life-cycle study, jointly sponsored by the U.S. Department of Energy and the U.S. Department of Agriculture, concluded that producing and using biodiesel reduces net CO_2 emissions by 78 percent compared with petroleum diesel. This is due to biodiesel's closed carbon cycle. Growing plants that are later processed into fuel recycles the CO_2 released into the atmosphere when biodiesel is burned.

In the late '90s, Yellowstone National Park tested biodiesel by successfully driving a park truck more than 92,000 miles. Compared with diesel trucks, toxicity, emissions, smoke, and unpleasant odors were reduced; safety and biodegradability were increased.

Other tests comparing biodiesel with diesel show these results:

Carbon monoxide: 50 percent reduction

Total unburned hydrocarbons: 93 percent reduction

Ozone-forming potential due to reactive hydrocarbons: 50 percent reduction

Toxic hydrocarbons: most were reduced by 75 to 85 percent.

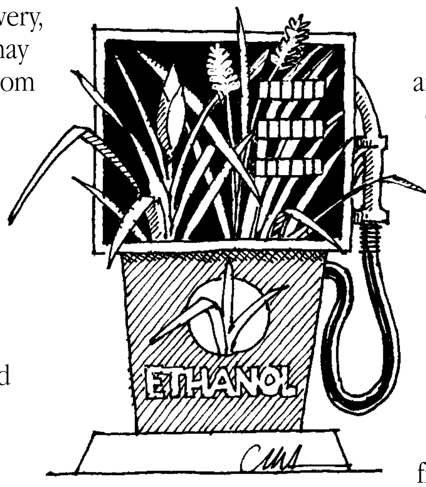
Nitrogen oxides: Either slightly reduced or slightly increased, depending on the engine family and testing procedures. The National Biodiesel Board reports that a 13 percent increase can be remedied through changes in ignition timing and the use of proper catalytic converter technology.

Particulate matter: 30 percent reduction

Sulfur: 100 percent reduction.

ETHANOL

Ethanol is a clear, colorless liquid alcohol, which is also called ethyl alcohol, grain alcohol, or ETOH. Ethanol is a renewable source of energy made by fermenting any biomass high in carbohydrates (starch, sugar, and cellulose) through a process similar to brewing beer. It is most commonly produced from field corn, sugar cane, or wheat, but is also being made from other grains, cheese whey, and waste from the beverage, brewery, and wine industries. New technologies may soon enable the production of ethanol from cellulose from rice straw, forest residue, sawdust, pulp and paper sludge, and dedicated energy crops such as switch-grass, prairie grass, and fast-growing poplar trees.



HISTORY

Ethanol has been used as a transportation fuel since Henry Ford and other transportation pioneers began developing automobiles. In the 1880s, Ford used ethanol to fuel one of his first automobiles, the quadricycle. In 1908, the Ford Model T was designed with a carburetor adjustment that could allow the vehicle to run on ethanol fuel produced by American farmers. Ford's vision was to "build a vehicle affordable to the working family and powered by a fuel that would boost the rural farm economy."

During the 1930s, more than 2,000 service stations in the Midwest sold ethanol made from corn, but the ethanol industry closed down in the '40s with the coming of low-priced petroleum. During World War I and II in both the United States and in Europe, alcohol fuels supplemented supplies of oil-based fuels. During World War II, the government even commandeered whiskey distilleries for alcohol fuel production. In recent history, public interest in alcohol as a transportation fuel has changed with periods of war and the fluctuating supply and price of oil. The oil crisis in the 1970s raised the price of oil and gas and gave birth to the gasohol era, when gasoline was extended with the addition of 10 percent ethanol. (Gasohol is not considered an alternative fuel.) When gasoline became more plentiful, ethanol was blended with gasoline to increase the octane rating, and the name gasohol was replaced with names reflecting the increased octane. Unleaded plus or super unleaded are two examples of names used today.

CURRENT USES

Ethanol-powered vehicles have been used in countries that produce crops suitable for ethanol production; for example, in Brazil more than four million ethanol vehicles run on ethanol produced from sugar cane. In the United States, vehicles using mixtures of ethanol and gasoline can be found in the Midwest, where much of the corn used to make ethanol is grown and processed into fuel. Ethanol fueling sites were first established in Illinois, Iowa, South Dakota, Minnesota, and Colorado.

Ethanol is most commonly used in cars and light trucks in a blend of 85 percent ethanol and 15 percent gasoline called E85. E95, a blend of 95 percent ethanol and 5 percent gasoline, is used in heavy vehicles. Ethanol is also a component of reformulated gasoline and is used in some regions of the country to reduce carbon monoxide emissions.

SOURCE, PRICING, AND AVAILABILITY

In the United States, most ethanol is made from corn. In the 1990s, all of the ethanol used for vehicle fuel originated within U.S. borders. The price of ethanol is influenced by seasonal changes in the availability and price of feedstocks used to make it. For example, flooding of the Mississippi River in 1993 resulted in a smaller corn crop, which briefly raised the price of corn and the regional price of ethanol fuel. Prices are also affected by competing demands for ethanol, such as its use in reformulated gasoline or gasohol.

STORAGE AND SAFETY

Because ethanol is toxic if ingested, it is denatured to prevent consumption. It may also contain additives that could be harmful if inhaled or consumed. Although ethanol is harmful to organisms, it rapidly biodegrades in surface water, groundwater, and soil, thus rendering it harmless. Because ethanol can be corrosive to some metals and damaging to rubbers (gaskets and seals), fuel-storage tanks and dispensing equipment must be corrosion and damage resistant. Ethanol has a low vapor pressure and a broad range of flammability. Ethanol burns in air with a visible blue flame.

PERFORMANCE

Power, acceleration, payload, and cruise speed are comparable with those of other fuels. Ethanol is a high-octane fuel. When added to gasoline, it boosts the octane levels to help the car run more smoothly.

RANGE AND REFUELING

If the compression ratio is optimized for a higher octane rating, ethanol has approximately 80 percent or more of the energy density of gasoline. The lower energy content yields a slightly lower driving range per gallon (75 to 90 percent); therefore, an ethanol-powered vehicle requires more frequent fueling. As with gasoline or diesel fuel, ethanol is dispensed from pumps.

MAINTENANCE AND VEHICLE ALTERATIONS

Maintenance of ethanol-powered vehicles is similar if not identical to that of gasoline-powered vehicles; some of the parts and lubricants must be specially designed, however. For example, because ethanol is corrosive, noncorroding hoses must be used, and stainless-steel fuel tanks are required. The compression and timing features must be modified. Ethanol doesn't leave waxy deposits, as does gasoline, so the fuel system remains cleaner.

Diesel engines cannot simply be converted to ethanol operation. Ethanol has a very low cetane number, which describes the ability of a fuel to be ignited in compression-ignition diesel engines. One conversion approach is using the direct injection of ethanol, which will, after other slight adjustments to the engine, allow proper ignition of ethanol.

EMISSIONS

In December 1997, the U.S. Department of Energy conducted a fuel-cycle study that included the energy required to grow and harvest the corn, distill it into ethanol, and transport the ethanol to gasoline terminals. Plants grown for ethanol production absorb carbon dioxide during growth, which partially offsets the carbon dioxide emitted during fuel combustion. Studies concluded that compared with conventional gasoline, ethanol produced from corn reduces fossil energy use by 50 to 60 percent and greenhouse-gas emissions by 35 to 46 percent. Ethanol produced from cellulose materials can reduce greenhouse gas emissions even more.

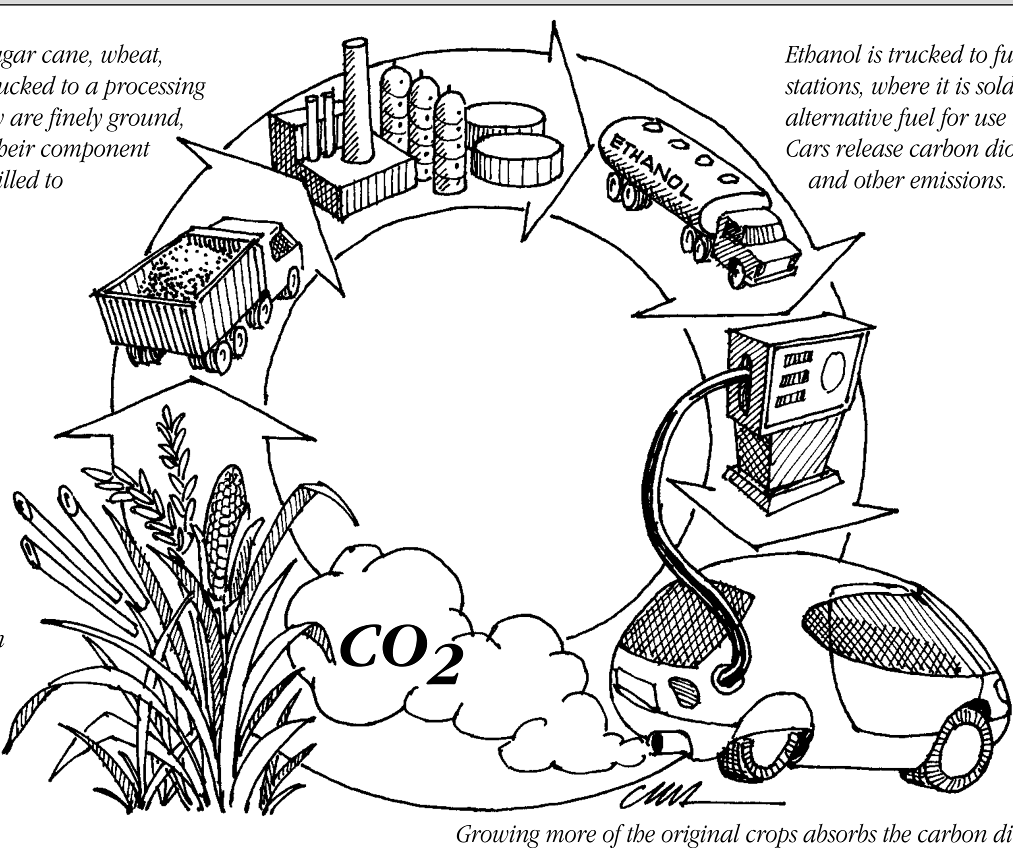
Ethanol contains no sulfur, an element that reduces the effectiveness of emissions control devices. Without sulfur, emissions control devices work better, thereby reducing emissions of other pollutants.

Ethanol contains 35percent oxygen by weight. When added to gasoline, ethanol (and other oxygenates) enhances combustion, resulting in a more efficient burn. This greatly reduces exhaust emissions, including hydrocarbons, NO_X and CO (precursors to ozone), fine particulates, and toxics.

ETHANOL IN THE CARBON CYCLE

Crops such as sugar cane, wheat, and corn are trucked to a processing plant where they are finely ground, separated into their component sugars, and distilled to make ethanol.

Ethanol is trucked to fueling stations, where it is sold as an alternative fuel for use in cars. Cars release carbon dioxide and other emissions.



Sugar cane, wheat, and corn

Growing more of the original crops absorbs the carbon dioxide. The other emissions are less than those of a gasoline-powered car.

FUEL CELL ELECTRIC

Electric vehicles use electric motors instead of an internal combustion engine to provide motive force. In development are vehicles that use an electrochemical system, known as a fuel cell, to produce onboard power. Unlike batteries, where electrical energy is converted into stored chemical energy through electrical charging, fuel cells use chemical energy coming from a fuel, which is stored on board, to produce electric energy. Fuel cells continuously convert the chemical energy of hydrogen from the fuel and oxygen from the air to produce electric energy, heat, and water. This electricity is used by motors connected to axles to power the wheels of the vehicle.

HISTORY

William Grove, a British jurist and amateur physicist, first discovered the principle of the fuel cell in 1839. A hundred and twenty years later, NASA developed fuel cells for use during space flight, where they have provided electricity and drinking water for astronauts. Since the space program demonstrated the potential for fuel cell technology, industry has been interested in developing it further. Since 1984, the U.S. Department of Energy has been supporting fuel cell research and development.

Fuel cells are expected to be used widely because they can produce power much more efficiently and cleanly than can fossil or nuclear fuel. Some large office buildings use stationary fuel cells for their own electricity and for hot water and supplemental space heating. Fuel cell technology is being developed to meet similar electrical and heating energy needs on the smaller scale appropriate for individual homes. In March 1998, Chicago became the first city in the world to power buses with hydrogen fuel cells.

CURRENT RESEARCH IN TRANSPORTATION

There are five distinct types of fuel cells, two of which are being seriously considered for land-based vehicles: the phosphoric acid fuel cell (PAFC) and the polymer electrolyte membrane, or proton exchange membrane (PEM).

- PAFC, already used by stationary power generators, may be used in larger vehicles such as transit buses.

- Vehicle manufacturers around the world are investigating the PEM fuel cell because it provides a continuous electrical energy supply at a high level of efficiency and power density.

SOURCES

All fuel cell vehicles (FCVs) currently require some form of hydrogen — either in a pure state or in combination with other elements. Hydrogen is the lightest and most abundant element on earth, making up about 93 percent

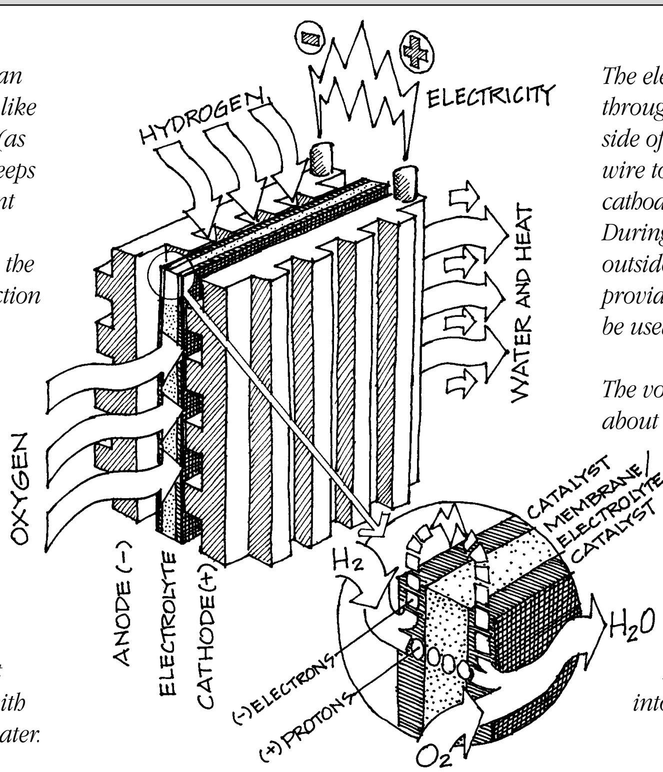
PEM FUEL CELL

At the center of the PEM fuel cell is an electrolyte membrane, which looks like a moist piece of thick plastic wrap (as thick as 2 to 7 pieces of paper). It keeps hydrogen fuel separate from oxidant air. Fuel cell operation depends on movement of hydrogen ions though the membrane (electrolyte) in one direction only (from anode to cathode).

As hydrogen flows into the fuel cell on the anode side, a platinum catalyst facilitates the separation of the hydrogen gas into electrons and protons (hydrogen ions).

The hydrogen ions pass through the membrane.

With the help of a platinum catalyst on the cathode side, they combine with oxygen and electrons, producing water.



The electrons (which cannot pass through the membrane) flow from one side of the cell (the anode) through a wire to the other side of the cell (the cathode) in order to complete the circuit. During their route through the circuits outside the fuel cell, the electrons provide electrical power, which can be used to run a car.

The voltage from one single cell is just about enough for a light bulb. When cells are stacked in series, the operating voltage increases. A fuel cell stack can consist of a few cells to a hundred or more cells connected in series, depending on the amount of power needed. Fuel cell stacks are integrated into a fuel cell engine.

of all atoms and 76 percent of the mass of the universe. It is found in water, all plants and animals, and fossil fuels.

Although hydrogen is abundant in many compounds, obtaining enough pure hydrogen for popular use and developing the infrastructure for fueling private cars with pure hydrogen pose a challenge. Dispensing hydrogen fuel for fleets of large trucks or buses is easier to envision. In that case, liquid hydrogen would be trucked from central production facilities to fuel dispensing facilities, where cryogenic pumps would be used to load gaseous hydrogen fuel onto vehicles.

Fuel cells can also operate on hydrogen that is stripped on board the vehicle from hydrocarbons found in gasoline, methanol, or other fuels.

- Methanol, a simple fuel made of four hydrogen molecules, one carbon molecule, and one oxygen molecule, is an excellent source of hydrogen and can be easily distributed through the existing fuel infrastructure with minor modifications.

- Natural gas (methane) is also an excellent hydrogen carrier, although a widespread natural gas distribution system for cars does not yet exist.

- Gasoline, formulated without sulfur, could also be used. It could be distributed through the same distribution system as other gasoline products. Although reliance on gasoline would prolong U.S. dependence on foreign oil, fuel cells would reduce the amount of gasoline used because they are two to three times more efficient than internal combustion engines in converting fuel to power.

- Sodium borohydride, a derivative of borax, has also shown promise in powering fuel cells. Borax is found throughout the world in substantial natural reserves. In a chemical process that releases pure hydrogen for fuel cells, the only by-products are water and naturally occurring minerals called borates, which can be reclaimed as a source of fuel. It could be distributed, with minor modifications, through the existing fuel infrastructure.

VEHICLE ALTERATIONS

Vehicle alterations depend on the type of fuel that is used by the fuel cell to produce power. A direct hydrogen fuel cell would involve no combustion and would not need any pollution- or noise-control devices. Hydrogen may be stored on board in compressed high-pressure gas cylinders, as a liquid in insulated storage tanks at low temperature and pressure, as a metal hydride, or as some other hydrogen-rich solid or liquid fuel, such as sodium borohydride. A fuel cell–based propulsion system relying on gasoline, methanol, or methane for hydrogen includes a fuel cell stack, a reformer and catalytic burner, a cooling device, and an air compressor/expander. (The onboard reformer is a device that uses heat and catalysts to break the strong hydrocarbon bonds in the gasoline, methanol, or methane used as a source of hydrogen.) A high-pressure cylinder is needed if methane is used. A fuel tank or gas cylinder is needed to carry hydrogen or hydrogen-rich liquid fuel. Cars using sodium borohydride as a source of hydrogen would need a waste tank to hold the spent fuel until it could be recycled into new fuel.

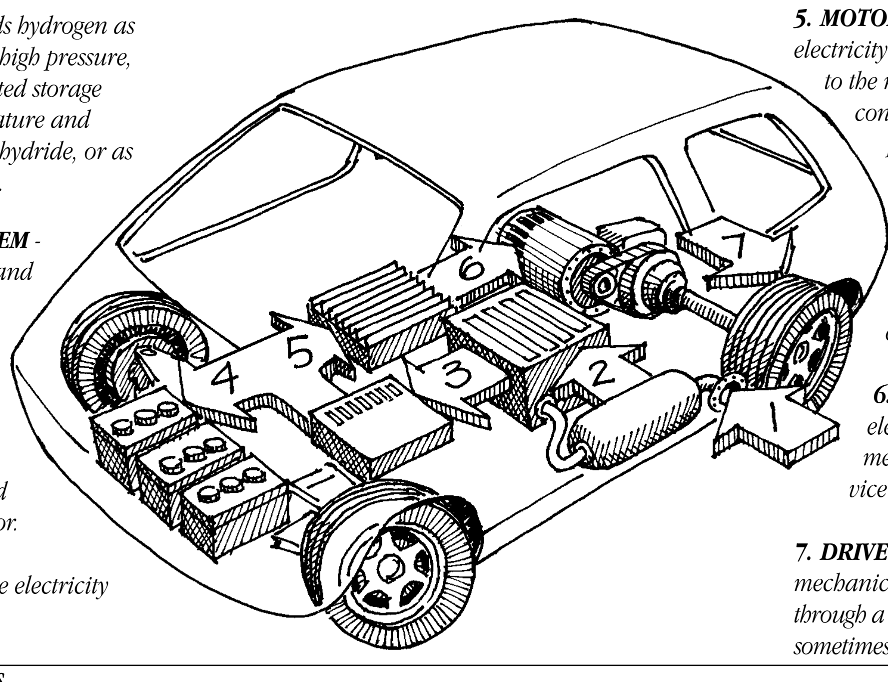
HOW A HYDROGEN FUEL CELL ELECTRIC CAR WORKS

1. FUEL TANK *- holds hydrogen as a compressed gas at high pressure, as a liquid in insulated storage tanks at low temperature and pressure, as a metal hydride, or as some other solid fuel.*

2. FUEL CELL SYSTEM *- combines hydrogen and oxygen to generate electricity.*

3. COMPUTER *- decides whether to store electricity in the battery or send it directly to the motor.*

4. BATTERIES *- store electricity until it is needed.*



5. MOTOR CONTROLLER *- sends electricity smoothly and efficiently to the motor as needed. It is controlled by an accelerator pedal. If regenerative braking is installed, the controller will allow the motor to act as a generator and return braking energy to the energy-storage system.*

6. MOTOR *- converts electrical energy to mechanical energy and vice versa.*

7. DRIVETRAIN *- transfers mechanical energy to wheels through a differential and sometimes a transmission.*

As with other EVs, a typical fuel cell vehicle has an electric motor instead of an internal combustion engine, electronic controls instead of an ignition system, and the addition of a high-voltage electrical system. Fuel cell systems for automobiles also include a small battery pack as a buffer between the fuel cell stack and the electric motor.

An EV is propelled when the electric motor receives sufficient electricity from the battery pack to provide the torque needed to turn the wheels at the rate desired. The accelerator pedal is connected to an electronic control module that regulates the amount of current or voltage drawn from the battery system. Most EVs use regenerative braking — slowing the vehicle by capturing kinetic energy, converting it back into electrical energy, and then channeling it to the battery pack for later use.

MAINTENANCE

Because a PEM fuel cell stack has no moving parts, maintenance is minimal. An FCV's reformer and catalytic burner, cooling device, and air compressor/expander need regular maintenance, however.

STORAGE AND SAFETY

Care needs to be taken in transporting and refueling whatever gaseous, liquid, or solid fuel is used to power the fuel cell. Hydrogen storage and transportation systems will need to be engineered to be as safe as the fuel systems in current automobiles. Storage and transportation of methanol are similar to those of gasoline. Yet, because methanol is corrosive to some metals and damaging to rubber and some plastics, fuel storage tanks and dispensing equipment must be corrosion and damage resistant. California requires that underground storage tanks for methanol be double walled. Unlike other hydrogen carriers, sodium borohydride is not flammable. Storage and transportation are similar to those of gasoline.

With high-voltage circuits, vehicle manufacturers are using a number of disconnect systems to isolate the rest of the vehicle from the fuel cell's voltage. Lethal levels of electricity may be present, however, so the fuel cell's electrical system should be treated with the same caution and respect as a full fuel tank in an internal combustion engine.

PERFORMANCE

Acceleration, speed, and handling for well-designed EVs are equivalent to, or better than, those of comparable internal-combustion-powered vehicles. As with other electric-drive vehicles, fuel cell cars are quiet.

RANGE AND REFUELING

PEM fuel cells, which rely on liquid fuel, provide an acceptable driving range. Compared with conventional vehicles, FCVs will use fuel more efficiently, traveling as far as 80 miles per gallon. This longer range is due in part to the efficiency of the fuel cell power system and in part to the lighter weight of an FCV. (It has a smaller fuel tank and lacks a large internal combustion engine. For larger scale applications, fuel cells are smaller and lighter than batteries.)

Refueling a private automobile will likely involve replacing the hydrogen-rich fuel, such as liquid gasoline, methanol, or sodium borohydride, at existing fueling stations. This refueling takes much less time than recharging a battery.

If using compressed natural gas (CNG), refueling can be "slow" (generally taking six to eight hours and commonly done overnight) or "quick" (about five minutes, which is comparable to a gasoline fill-up). Overnight refueling is possible in individual homes with small compressors, which may be located in a home's garage and connected to the natural gas supply of the house.

EMISSIONS

In order to make a clear comparison with other fuels and fuel systems, the entire life cycle of a fuel cell must be analyzed. That includes the process of manufacturing and of safely disposing of fuel cells that have limited use. The fuel cell itself is potentially a pollution-free energy technology, even when idling in stop-and-go traffic. In contrast, conventional vehicles produce most of their emissions under such conditions. There are no evaporative emissions from the fuel cell stack. Only water vapors are produced.

When run on pure hydrogen, fuel cells are true zero-emission vehicles. In these systems, hydrogen chemically combines with oxygen, producing only electricity, water, and waste heat. Since no carbon is involved, emissions of carbon monoxide, carbon dioxide, and ozone-forming compounds are eliminated. There are no nitrogen oxides.

Fuel cells that rely on gasoline, methanol, or other carbon-based fuels as a source of hydrogen produce small amounts of tailpipe emissions (e.g., sulfur dioxide and nitrogen oxides), with water and carbon dioxide being the major by-products. Compared with traditional combustion engines, methanol fuel cells cut smog-forming pollution more than 90 percent. Because of their efficiency, fuel cell vehicles can cut greenhouse-gas emissions by more than half.

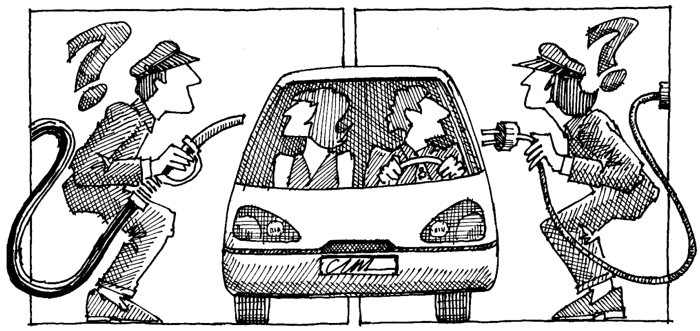
As fuel cell vehicle technology develops, emissions levels are expected to be further reduced. As fuel reformers become smaller and more optimized for low emissions, FCVs operating on methanol are expected to have nearly zero emissions.

HYBRID ELECTRIC

A hybrid electric vehicle (HEV, or "hybrid") uses both electrical and mechanical energy to propel it. It combines the efficiency of electrical drive systems with the longer driving range provided by liquid or gaseous fuels.

HISTORY

From the 1830s until the 1920s, electricity, stored in lead-acid batteries, was a popular energy source for vehicles. Electricity is a highly efficient means of propelling vehicles; the range of battery electric vehicles is relatively short, however, because the energy density of batteries is low compared with that of liquid or gaseous fuels. When petroleum became an inexpensive and widely available fuel, electric vehicles lost their popularity as long-distance vehicles. Because of their quiet operation and lack of exhaust, they continued to be used off road in factories, warehouses, and golf courses.



Hybrid power systems were conceived as a way to extend the range of electric vehicles for on-road use. Early designs assumed that HEVs would get most of their power from wall-plug electricity. For longer trips, an onboard generator powered by an internal combustion engine would extend the power needed. This system was expected to be as efficient and emission free as possible until better batteries were developed that made hybrids unnecessary.

In recent years, design approaches for HEVs have changed. They no longer rely on wall-plug electricity and are no longer seen as transitional vehicles. Most experts feel that the car of the near future will be an HEV of some kind.

RESEARCH

From 1993 to 2002, two programs supported research and development of hybrid vehicles in the United States: the Department of Energy's HEV Program and the Partnership for a New Generation of Vehicles (PNGV) Program. The latter was a collaboration between the federal government and the Big Three automakers — Ford, General Motors, and DaimlerChrysler. The goals of the two programs were closely aligned. The HEV Program aimed to develop HEV drivetrains and other internal components that would be twice as fuel efficient as those of conventional vehicles. The PNGV Program researched vehicle characteristics that affect fuel efficiency — such as the chassis, body, aerodynamics, and rolling resistance — with the goal of developing HEVs that achieve up to 80 miles per gallon, or three times the fuel economy of conventional 1993 vehicles.

Auto manufacturers throughout the world are interested in HEVs. The Japanese were the first to market them: Toyota introduced the first HEV in Japan in 1997. In 1999, Honda sold the first gasoline-electric hybrid in the United States.

SOURCES

The first model hybrids depended on gasoline, but hybrids can be designed to operate on a wide variety of gaseous or liquid fuels, including fossil fuels or a renewable alternative fuel such as biodiesel or ethanol.

VEHICLE ALTERATIONS

Hybrids essentially combine a mechanical power unit, an electrical energy storage system, and a propulsion system. Many combinations or configurations are possible. The power unit may be a spark-ignition engine, compression ignition direct-injection engine, gas turbine, or fuel cell. The energy storage system may be a battery, ultracapacitor, or flywheel. Propulsion may come entirely from the electric motor or from both the motor and power unit.

Several vehicle alterations lead to greater fuel economy for hybrids than with traditional vehicles. If an internal combustion engine is used, the engine can be smaller and lighter because it shares the workload with the electrical motor. The engine can be optimized to operate within a speed range where fuel economy is greatest. HEVs typically use regenerative braking, which slows the vehicle by capturing kinetic energy, converting it to electricity, and channeling it to the battery pack, thus minimizing the energy lost when slowing down.

MAINTENANCE

Because HEVs have combined systems, they are more complex than either battery-powered or conventional vehicles. Maintenance schedules and the cost of parts and service are expected to be higher than for other types of vehicles.

SAFETY

Care needs to be taken in transporting and refueling whatever gaseous or liquid fuel is used to power the hybrid. For batteries, vehicle manufacturers are using a number of

HOW A HYBRID ELECTRIC CAR WORKS

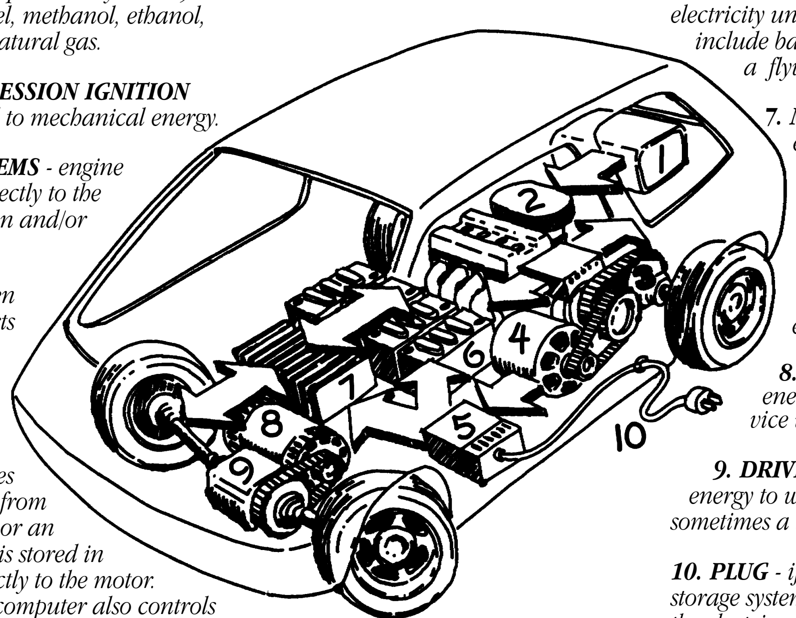
*1. **FUEL TANK** (or high-pressure cylinders) - contains gasoline, diesel, methanol, ethanol, compressed or liquid natural gas.*

*2. **SPARK OR COMPRESSION IGNITION ENGINE** - converts fuel to mechanical energy.*

*3. **IN PARALLEL SYSTEMS** - engine may provide power directly to the drivetrain (transmission and/or differential)*

*4. **GENERATOR** - driven by the engine, it converts mechanical energy to electrical energy in both parallel and series hybrids.*

*5. **COMPUTER** - decides whether electric power from the onboard generator or an external power source is stored in the battery or sent directly to the motor. (In parallel systems, a computer also controls when power to the drivetrain comes from the engine and from the motor.)*



*6. **ENERGY-STORAGE SYSTEM** - stores electricity until it is needed. The system may include batteries, supercapacitors, and/or a flywheel.*

*7. **MOTOR CONTROLLER** - sends electricity smoothly and efficiently to the motor as needed. It is controlled by an accelerator pedal. If regenerative braking is installed, the controller will allow the motor to act as a generator and return braking energy to the energy-storage system.*

*8. **MOTOR** - converts electrical energy to mechanical energy and vice versa.*

*9. **DRIVETRAIN** - transfers mechanical energy to wheels through a differential and sometimes a transmission.*

*10. **PLUG** - if installed, enables the energy-storage system to be charged by plugging into the electric grid, or by home-mounted solar collectors.*

disconnect systems in the high-voltage circuits, which isolate the rest of the vehicle from the battery voltage. Lethal levels of electricity may be present in the battery pack, however, so it should be treated with the same caution and respect as a full fuel tank in an internal combustion vehicle. In case of accidents, emergency response personnel will need special training to handle such hazards as exposure to high-voltage systems and possible leakage of flammable, toxic, or corrosive battery chemicals and/or fuel.

PERFORMANCE

HEVs are meeting or exceeding the performance of conventional vehicles.

RANGE AND REFUELING

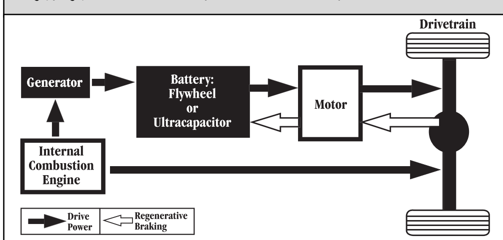
Gasoline-powered HEVs are rapidly refueled and need fueling less often. Toyota Motor Company reports that its Prius, the first gasoline-powered HEV, gets 48 combined highway/city miles per gallon. According to Honda, its Insight — the first hybrid sold in the United States — gets 61/68 city/highway miles per gallon. U.S. automakers aim to create a vehicle getting 80 miles per gallon.

EMISSIONS

Because hybrids are two to three times as fuel efficient as conventional vehicles, emissions per mile are greatly decreased. The type of emissions depends on the by-products of the specific fuel used. The first hybrids, which use gasoline, cut emissions of greenhouse gases by a third to a half; later models may cut emissions even more.

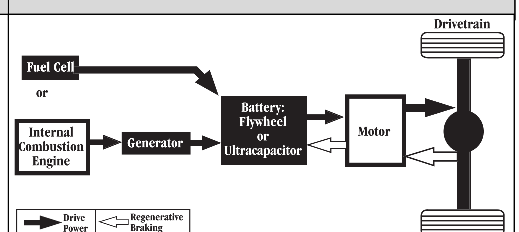
Toyota Motor company reports that the Prius greatly reduces emissions: 50 percent for carbon dioxide and 90 percent for carbon monoxide, hydrocarbons, and nitrogen oxides. The Prius is rated by the California Air Resources Board as a super ultra low-emission vehicle (SULEV), and the Insight is rated as an ultra low-emission vehicle (ULEV).

PARALLEL HYBRID ELECTRIC VEHICLE



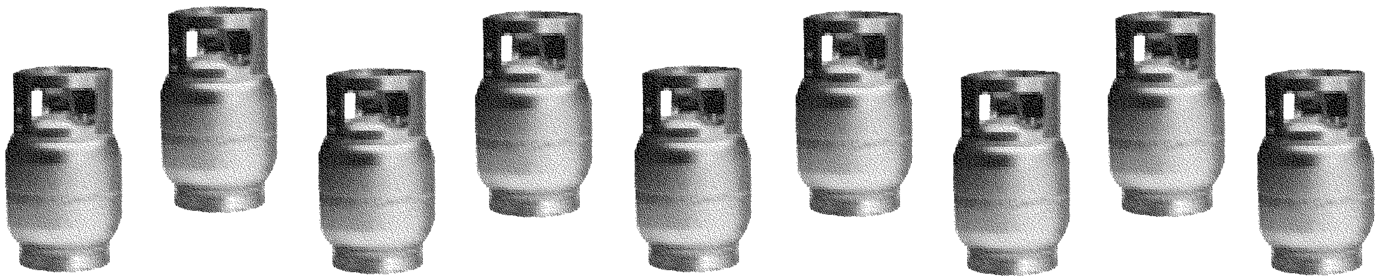
In a parallel configuration, the drive system can be powered simultaneously by the electric motor and the mechanical device. For example, during acceleration, passing, or hill climbing, the electric motor and internal combustion engine can both provide power to the drivetrain. Once the vehicle reaches cruising speed, the hybrid relies solely on the the engine to maintain speed.

SERIES HYBRID ELECTRIC VEHICLE



In a series configuration, the drivetrain is powered solely from the motor, which is connected to the electrical storage device. The power unit (internal combustion engine, turbine, or fuel cell) generates electricity to charge the electrical storage device (e.g., battery, flywheel, or ultracapacitor).

LIQUEFIED PETROLEUM GAS (LPG)



Liquefied petroleum gas (LPG) is a nonrenewable gaseous fossil fuel, which turns to liquid under moderate pressure. LPG, a by-product of natural gas processing and oil refining, includes various mixtures of hydrocarbons. The type of LPG used as a vehicle fuel is a liquid mixture containing at least 90 percent propane, 2.5 percent butane and higher hydrocarbons, and the balance ethane and propylene. The mixture is commonly called "propane."

HISTORY

In 1910, under the direction of Dr. Walter Snelling, the U.S. Bureau of Mines investigated gasoline to see why it evaporated so fast and discovered that the evaporating gases were propane, butane, and other hydrocarbons. Dr. Snelling built a still that could separate the gasoline into its liquid and gaseous components and sold his propane patent to Frank Phillips, the founder of Phillips Petroleum Company.

By 1912, propane gas was cooking food in the home. The first car powered by propane ran in 1913. By 1915 propane was being used in torches to cut through metal. LPG has been used as a transportation fuel around the world for more than 60 years.

CURRENT USES

In the United States, LPG is currently the third most commonly used transportation fuel, ranked behind gasoline and diesel. It is also used for home barbecues, recreational vehicle appliances, and heating and cooking in areas where natural gas is not available.

In the United States, LPG has been used mostly in fleets, including school buses in Kansas and Oregon, taxicabs in Las Vegas, sheriff and police cars, and dozens of fleets throughout California. Many nonroad vehicles, such as industrial forklifts and farm vehicles, use propane. In Tokyo all taxis are required to run on propane to reduce urban smog. Other countries widely using LPG include Australia, Canada, the Netherlands, Italy, and Japan.

SOURCE, AVAILABILITY, AND PRICING

The United States is one of the world's largest producers of LPG. Over 90 percent of the LPG used in the United States originates within the country. Texas is a major producer of LPG. An infrastructure for delivering propane is well established throughout the United States; publicly accessible fueling stations exist in all states. Propane prices are often tied to oil prices and tend to fluctuate widely. In areas where LPG is used as a heating fuel, seasonal rates during the winter season tend to increase LPG prices. Extended periods of unusually cold weather ("cold waves") may cause sudden increases in the price of LPG.

STORAGE AND SAFETY

For storage and transportation, LPG is pressurized and LPG tanks are sealed. Sealed tanks eliminate evaporative emissions or spillage. Using outage valves incorrectly during refueling, however, could cause excess vapor discharge.

The weight of LPG vapors at ambient temperatures is approximately 150 percent the weight of air. If there is a leak, LPG vapors tend to sink to the ground and pool, creating a potentially hazardous situation. An odorant is added to make leaks more detectable. (In some areas in North America, LPG vehicles are not allowed in tunnels or in enclosed parking garages.)

Because LPG vaporizes when released from the tank and is not water soluble, LPG does not pollute underground water sources. LPG is extremely volatile and burns twice as hot as a gasoline fire. Vehicle fuel tanks in LPG vehicles are of relatively thick-wall steel construction. In the event of a vehicle crash, they are much less prone to rupture or to cause fires than gasoline tanks.

PERFORMANCE

Power, acceleration, payload, and cruise speed are comparable to those of an equivalent internal combustion engine. Propane has a high octane rating of 104 (compared with 87 for regular unleaded gasoline).

When introduced into a vehicle engine, LPG turns into a gas. In cold conditions, starting could be a problem because of the low vapor pressure of propane at low temperatures. A properly designed system enables quick starting in cold weather, however.

RANGE AND REFUELING

Refueling a propane vehicle is similar to filling a gas grill tank; the time it takes is comparable with that needed to fill a gasoline or diesel fuel tank. LPG refueling stations consist of a storage tank, a transfer pump, metering and dispensing equipment, and a hose. At the end of the hose is a coupling that connects to the coupling on the vehicle fuel tank. During refueling, the tank should be filled to no more than 80 percent capacity, to allow for liquid expansion as ambient temperature rises.

One gallon of LPG contains less energy than a gallon of gasoline. The driving range of a propane vehicle is about 86 percent that of a gasoline-powered vehicle. It takes 1.4 gallons of propane to provide the same amount of energy as one gallon of gasoline.

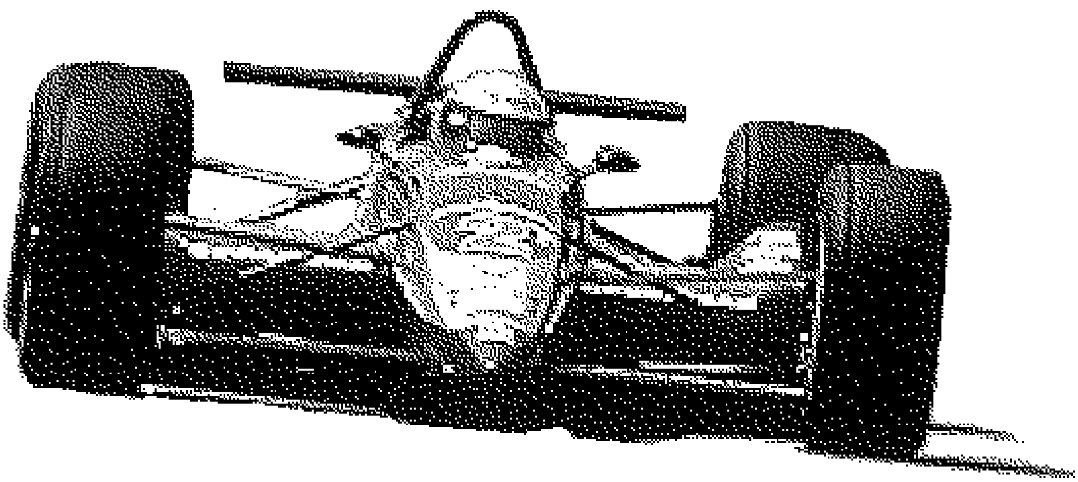
MAINTENANCE AND VEHICLE ALTERATIONS

Propane is stored on board in liquefied form under moderate pressure (about 200 pounds per square inch at 100°F). When it is drawn from the tank, it changes back into a gas before it is burned in the engine. Because it combusts in the gaseous phase, propane results in less corrosion and engine wear than does gasoline. Its high octane rating enables it to mix better with air and to burn more completely than does gasoline, generating less carbon. With less carbon buildup, spark plugs often last longer and oil changes are needed less frequently. According to the National Propane Gas Association, spark plugs from a propane vehicle last from 80,000 to 100,000 miles, and propane engines can last two to three times longer than gasoline or diesel engines.

EMISSIONS

Sealed tanks eliminate evaporative emissions or spillage. Refueling can be a source of LPG hydrocarbon emissions, however. Such emissions can be controlled through the use of special refueling valves. Certain toxics, especially benzene and butadiene, as well as regulated emissions, are generally lower than those of gasoline-fueled vehicles. Carbon dioxide emission levels are reduced by up to 40 percent over those of gasoline-fueled vehicles.

METHANOL



METHANOL

Methanol (CH_3OH) is a colorless, odorless, slightly flammable liquid, also called methyl alcohol or wood alcohol. Liquid methanol can be produced from just about anything containing carbon. Potential sources include natural gas, coal, and biomass. Currently most methanol is produced from natural gas, or methane, using steam, pressure, and a catalyst. Methane, a greenhouse gas, is also given off by decomposing vegetable matter in landfills — another source that could be tapped for methanol production.

HISTORY

Methanol was first discovered in 1823 by condensing gases from burning wood. Methanol has been used for more than 100 years as a solvent and as a chemical building block to make products such as plastics, plywood, and paint. It is also used directly in windshield-washer fluid and gas-line antifreeze, and as model airplane fuel.

CURRENT USES

Pure methanol (M100) has been used in heavy-duty trucks and transit buses equipped with compression-ignition diesel engines. Since 1965, M100 has been the official fuel for Indianapolis 500 race cars. (The last time gasoline was used in the Indianapolis 500 was in 1964, when the race suffered a pile-up of cars that resulted in a gasoline fire and deaths.) Typically, a blend of 85 percent methanol and 15 percent gasoline (M85) is used in cars and light trucks. Pure methanol can also be reformed in fuel cells into hydrogen, which is then used to power electric vehicles.

Methanol-powered vehicles have been found largely in the West, primarily in California. They can also be seen in the fleets of the federal government and the New York State Thruway Authority.

SOURCE, AVAILABILITY, AND PRICING

The United States produces almost one-quarter of the world's methanol supply. According to the American Methanol Institute (1998), about 75 percent of the methanol consumed in the United States is supplied by domestic chemical producers. The remaining supply comes from imports. Canada supplies about 13 percent, Trinidad, Venezuela, and Chile, 8 percent; Europe, Asia, and the Middle East, 2 percent; and the remaining 2 percent come from miscellaneous sources. If demand increased, methanol could probably be made less expensively abroad and delivered by ship to the United States.

STORAGE AND SAFETY

Because methanol is corrosive to some metals and damaging to rubber and some plastics, fuel storage tanks and dispensing equipment must be corrosion and damage resistant. California requires that underground storage tanks for methanol be double walled.

Because methanol is water soluble, it could be quickly diluted in large bodies of water to levels that are safe for organisms. Environmental recovery rates for methanol spills are often faster than for petroleum spills. As with gasoline, methanol can be fatal when ingested. Inhalation of fumes and direct contact with skin can also be harmful.

Because pure methanol flames are nearly invisible in daylight, gasoline is added as a safety precaution to provide color to a flame. Added gasoline also serves to add a smell to this otherwise odorless liquid. Because of its high flash point, methanol is less volatile than gasoline. It burns more slowly and at a lower temperature. Methanol is transported by barge, truck, or rail. In the event of an accident, a pure methanol (M100) fire can be extinguished with water, while a M85 fire, because of the 15 percent gasoline content, cannot. (Water on gasoline spreads fires.)

PERFORMANCE

Power, acceleration, and payload are comparable with those of other fuels in equivalent internal combustion engines. M85 has a high octane rating of 102, compared with 87 for regular unleaded gasoline and 92 for premium unleaded; properly tuned vehicles may experience 7 to 10 percent higher horsepower.

Vehicles using methanol have difficulty starting in temperatures below 0°F. M85 includes 15 percent gasoline, which improves the starting ability in cold weather.

RANGE AND REFUELING

Methanol has about half the energy content of gasoline. With current engine technology, it takes about 1.64 to 1.7 gallons of M85 to go the same distance as with a gallon of gasoline. Because mileage using M85 is lower than mileage using gasoline, fueling is needed more frequently.

M85 can be dispensed from pumps in the same manner as gasoline or diesel. Because methanol is corrosive, however, fuel storage tanks and dispensing equipment must be corrosion resistant.

MAINTENANCE AND VEHICLE ALTERATIONS

Methanol is especially damaging to rubber and plastic parts. Parts that come in contact with the fuel need to be damage resistant. These include the fuel tank, fuel lines, fuel injectors, fuel pumps, and filters.

M85 is commonly used in fuel-flexible vehicles, which are specially designed to use combinations of methanol or regular unleaded gasoline stored in a single tank. The vehicles have a special sensor on the fuel line that can detect the ratio of methanol to gasoline in the fuel tank. The sensor conveys this information to an onboard computer, which automatically adjusts the vehicle's fuel injection and ignition timing devices.

EMISSIONS

The methanol molecule has a simple chemical structure, which leads to clean combustion; reports from emissions studies, however, vary more widely for methanol than for other fuels probably because of differences among fuel blends used across the country and because vehicles may not be optimized for using methanol. Comparisons of M100 with gasoline and diesel have shown these results:

Carbon monoxide: Emissions vary — sometimes lower, but are usually equal or slightly higher.

Ground-level-ozone-forming potential: 30 to 60 percent less. (In order to take advantage of this characteristic, vehicles must be properly adjusted.)

Nonmethane evaporative hydrocarbons: Usually less.

Toxics: M100 contains none of the carcinogenic ingredients such as benzene, 1,3-butadiene, and acetaldehyde. M85 (with 15 percent gasoline) has 50 percent fewer toxic air pollutants than gasoline.

Formaldehyde levels: Much higher, although still low. The toxicity of formaldehyde is lower than that of other toxics, and formaldehyde emissions can be reduced dramatically with new technology, such as improved catalytic converters.

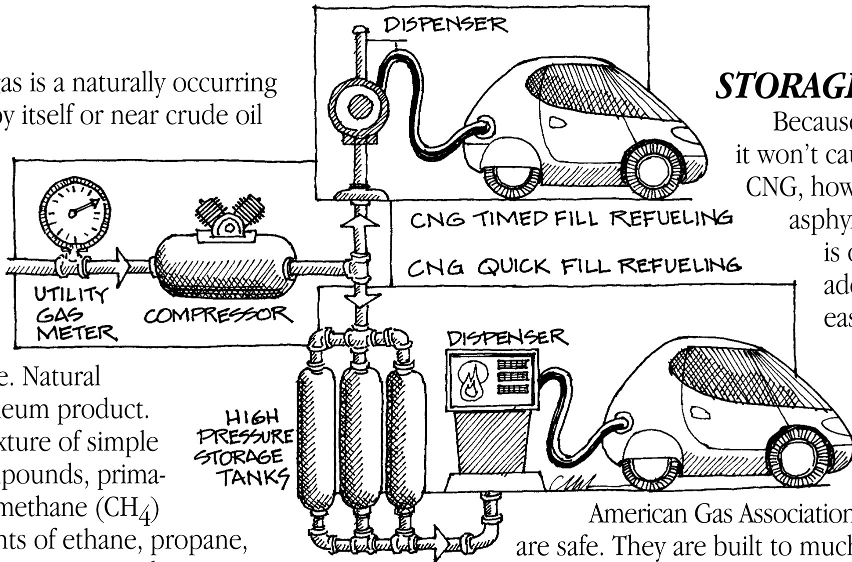
Nitrogen oxides: Usually comparable or less.

Greenhouse gases: Comparable to gasoline.

Particulate matter: Buses using M100 emit significantly less than diesel-fueled buses.

NATURAL GAS

Natural gas is a naturally occurring fossil fuel found by itself or near crude oil deposits in deep underground pockets. These pockets, formed by porous rock, are 3,000 to 15,000 feet below the earth's surface. Natural gas is not a petroleum product. It is a gaseous mixture of simple hydrocarbon compounds, primarily composed of methane (CH_4) with minor amounts of ethane, propane, butane, and pentane. Because the energy density of natural gas is low, when used as a fuel it is either compressed or liquefied by extreme cooling.



HISTORY AND CURRENT USES

In 1860, Etienne Lenoir of France developed and built an engine of a design practical for natural gas that ran on illuminating coal gas stored in a rubber bladder. Coal gas, a by-product of the production of coke, is made up largely of methane, the primary component of natural gas, and hydrogen. In 1862 Lenoir built a vehicle powered by one of his engines.

Natural gas now accounts for approximately one-fourth of the energy consumed in the United States. For many years it has been used reliably and efficiently in stationary internal combustion engines, supplying energy for commercial and industrial processes, home heating, and electricity generation. Many households use compressed natural gas for cooking and heating.

Natural gas vehicles are widely used in Italy, the former Soviet Union, New Zealand, Australia, Canada, Argentina, and the United States. Compressed natural gas (CNG) is used in vehicles of all weights and sizes; CNG fueling stations are located in most major cities and in many rural areas. Liquefied natural gas (LNG) is most suitably used by large trucks, locomotives, and transit buses; LNG is currently available through suppliers of cryogenic liquids.

SOURCE AND AVAILABILITY

There is a finite supply of natural gas. Natural gas currently used in the United States comes from domestic sources. At current levels of consumption, reserves are expected to last 120 years. An extensive network of natural gas pipelines can deliver fuel directly to many sites, including individual homes.

STORAGE AND SAFETY

Because natural gas is nontoxic, it won't cause injury; breathing of CNG, however, could cause asphyxiation. Since the fuel is odorless, odorants are added to make leaks easier to detect.

Sturdy, heavy tanks are used for safe high-pressure storage. According to the American Gas Association, CNG cylinders themselves are safe. They are built to much more rigorous standards than are gasoline tanks. During their development, they have undergone stringent tests, including being dropped from heights, exposed to explosions, being shot at with high-powered weapons, and burning in fires.

Danger to the environment is possible during extraction and processing, and through accidental releases of gas in distribution systems, fueling hook-ups, tank venting, or vehicle emissions. Mishaps can occur when corrosion causes the pressure-relief devices on fuel tanks to vent gas prematurely.

Gasoline and diesel fuels are heavier than air and stay near the surface. Natural gas is lighter than air and rises, a characteristic that creates a possible risk of explosion in enclosed areas. (LNG vehicles should never be parked indoors where possible ignition sources exist.)

PERFORMANCE

CNG burns more completely than gasoline and has a high octane rating of 130 (compared with 87 for regular unleaded gasoline). In a dedicated light-duty CNG vehicle, whose compression ratio is changed to take advantage of the higher octane rating, there may be up to a 10 percent increase in power. CNG also performs better than gasoline-powered vehicles under cold-start conditions.

The location and number of fuel cylinders may reduce the payload capacity, particularly in converted or dual-fuel vehicles.

RANGE AND REFUELING

When stored at a pressure of 3,600 psi, CNG provides about one-fourth the energy density of gasoline. The range of a CNG vehicle depends on the capacity to store fuel, but generally it is less than (about one-half) that of gasoline-fueled vehicles.

Refueling of CNG vehicles can be “slow” (generally taking six to eight hours and commonly done overnight) or “quick” (about five minutes, which is comparable with a gasoline fill-up). Overnight refueling is possible in individual homes with small compressors, which may be located in a home’s garage and connected to the natural gas supply of the house. Because of the gaseous nature of the fuel, the ambient air temperature can affect the amount of fuel that can be compressed into a tank. If a driver filled CNG cylinders on a hot afternoon, in the cool of the morning they might be only 75 to 85 percent full. CNG refueling dispensers are similar to gasoline or diesel dispensers, except the nozzles have positive-connect pressure fittings.

MAINTENANCE AND VEHICLE ALTERATIONS

Recommended maintenance schedules for CNG vehicles are similar to those for gasoline-fueled automobiles. Because CNG burns more cleanly than gasoline, CNG-powered vehicles require less maintenance, including fewer oil changes and less-frequent spark plug replacement. High-pressure tanks require periodic inspection.

Dedicated CNG vehicles are equipped with high-pressure storage tanks capable of storing natural gas at 3,000 psi to 3,600 psi. They are usually secured to the bottom of the vehicle. The gas travels from the tank through a high-pressure fuel line leading to the engine compartment. The gas is reduced to about 100 psi before being discharged or injected into the engine intake manifold and finally burned in the engine cylinders. These cylindrical tanks are constructed of high-strength steel, aluminum wrapped with a composite material, or all-composite materials. They are designed to withstand severe impact, high external temperatures, and environmental exposure.

EMISSIONS

CNG burns more completely than gasoline and emits lower amounts of all the regulated exhaust pollutants. Evaporative emissions are lower because CNG is stored in a sealed system. Carbon dioxide emissions are also lower than emissions from gasoline-powered vehicles, but methane levels are higher. Methane’s ability to trap heat in the atmosphere, or its global warming potential, is 21 times greater than that of carbon dioxide.

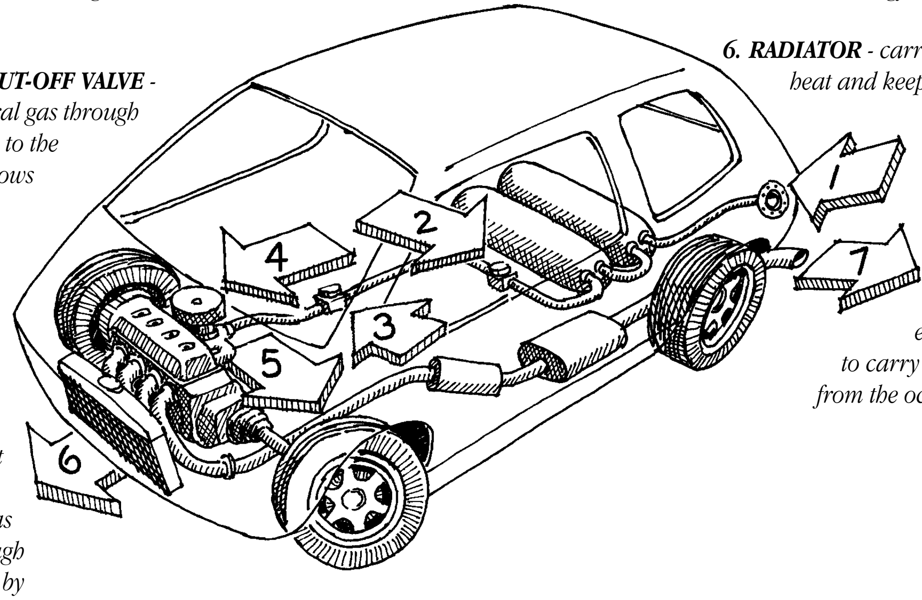
HOW A NATURAL GAS CAR WORKS

1. HIGH-PRESSURE CYLINDERS *- are filled with compressed natural gas through a fill valve.*

2. MASTER MANUAL SHUT-OFF VALVE *- can stop the flow of natural gas through the high-pressure fuel line to the engine. When open, gas flows to the engine as needed.*

3. REGULATOR *- reduces gas pressure to approximately air pressure.*

4. ENGINE *- burns gas to create heat and convert it to mechanical energy. A solenoid valve controls gas flow into the engine through fuel injectors, as signaled by the accelerator pedal.*



5. TRANSMISSION *- carries the mechanical energy to the wheels.*

6. RADIATOR *- carries away waste heat and keeps the engine cool.*

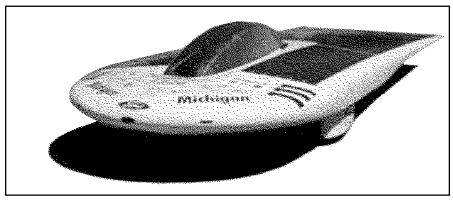
7. EXHAUST SYSTEM *- has a muffler to soften the noise created by the explosion of the gas in the engine, and a tailpipe to carry away the exhaust from the occupants.*

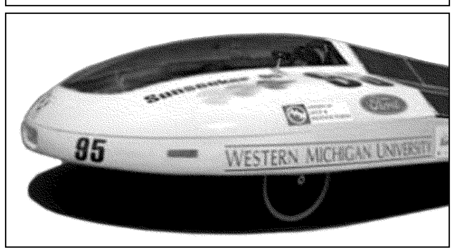
SOLAR ELECTRIC

Electric vehicles use electric motors instead of an internal combustion engine to provide motive force. Solar-powered vehicles (SPVs) use photovoltaic (PV) cells to convert sunlight into electricity. The electricity goes either directly to an electric motor powering the vehicle, or to a special storage battery. PV cells produce electricity only when the sun is shining. Without sunlight, a solar-powered car depends on electricity stored in its batteries.

HISTORY

Since the 1970s, inventors, government, and industry have invested their time, skill, and knowledge to develop solar-powered cars, boats, bicycles, and even airplanes.





In 1974, two brothers, Robert and Roland Boucher, flew an extremely lightweight, remote-controlled, pilotless aircraft to a height of 300 feet. It was powered by a PV array on the wings. In 1975 an improved version flew to 17,000 feet. (The U.S. Air Force funded the development of these aircraft with the hope of using them as spy planes.) In the early 1980s, Paul MacCready and his son developed a sun-powered plane, which crossed the English Channel at an average speed of 50 mph and a height of 12,000 feet. NASA supported the development of the "Pathfinder," a remote-controlled, 100-foot-long "flying wing" weighing less than 600 pounds. It is almost completely covered by a thin-film PV array. This PV system produces electricity to operate small motors, propellers, and flight control devices that move and steer the craft. The Pathfinder, with its ability to fly to altitudes as high as 80,000 feet, could be the precursor to solar-powered aircraft that can stay aloft for months as alternatives to space-based remote sensing satellites.

Perhaps the first totally solar-powered car was built by Ed Passerini, in 1977. It was small, lightweight, and cost relatively little. Solar cars equipped with advanced technology have been built with the backing of large automobile manufacturers, including General Motors (GM), Ford, and Honda.

CURRENT USES

Because solar cells produce electricity only when the sun is shining, SPVs are not practical for daily use. Most SPVs with built-on PV arrays are used only as research, development, and educational tools, and/or to participate in the various SPV races held around the world. These races, such as the World Solar Challenge (Australia), the Tour de Sol (Switzerland), the American Tour de Sol, and the American Solar Cup, serve as proving grounds for new solar vehicle technologies, and help expose the public to the idea of solar energy as a power source. Students, engineers, and other inventors throughout the world compete in these races, often setting new records for distance, speed, or fuel efficiency.

PV cells are being used in some prototype EVs to extend their driving range. These are often referred to as solar-assist electric vehicles. In this case, the vehicle receives only a small amount of their electricity from solar energy, and uses conventional methods of recharging batteries.

SOURCES

Although solar energy is an unlimited resource, it is not always available when it's needed. To convert and store solar energy, an array of PV cells can be built onto the vehicle body itself, or fixed on a building or a vehicle shelter to charge the electric vehicle's battery while it is parked.

VEHICLE ALTERATIONS

SPVs that have a built-on PV array differ from conventional vehicles (and most EVs) in size, weight, and shape. The car must be extremely efficient. Lightweight structural materials, such as aluminum or lightweight composites, improve performance. They are usually built to carry very little — one or two people. Some use no batteries; others use lightweight silver-zinc batteries. The chassis of GM's Sunraycer, a prototype SPV that has won many solar car races, weighs only 14 pounds; the entire shell weighs less than 100 pounds; and the total weight of the vehicle, without the driver, is 390 pounds. While most developers use crystalline silicon PV cells, GM has used more efficient and more costly gallium arsenide cells.

A large amount of surface area is needed on the car to rely one hundred percent on solar power. The Sunraycer has a 90-square-foot curved solar array integrated into the teardrop-shaped body of the car. John Mitchell Systems designed an SPV with a PV array integrated into two vertical airfoils. These act as a sail to provide aerodynamic thrusts. (In tests, the vehicle achieved 30 miles per hour using wind power alone.) Ford and other auto companies have designed tiltable arrays that track the sun.

MAINTENANCE

Because an SPV has few moving parts, service requirements are less than for conventional cars. An SPV does not have an internal combustion engine, liquid fuel tank, fuel lines, carburetor, spark system, muffler, or pollution-control equipment. No timing belts, water pumps, radiators, fuel injectors, or tailpipes are required. No tune-ups, emissions-control adjustments, oil changes, or oil filter replacements are needed.

Lightweight silver-zinc batteries are expensive and need to be recycled after only a few charging cycles. Nickel-metal-hydride batteries may last up to 100,000 miles.

SAFETY

The primary safety concern with the development of a prototype vehicle or vehicle altered by hobbyists — as the majority of SPVs are — is that of design and an ability to adequately test the vehicle. If meant for road use, the final design must be road worthy. Proper attention must be paid to all aspects of vehicle design, including steering, suspension, breaks, rollover protection for the driver, proper seatbelts and seating, properly secured motors and batteries, and adequate chassis strength and durability. All prototypes and modified vehicles must be properly tested before operating on-road.

As with all electric vehicles, lethal levels of electricity may be present in the battery pack, so it should be treated with the same caution and respect as a full fuel tank in an internal combustion vehicle.

PERFORMANCE

The first American Solar Cup was held in September 1988 in Visalia, California, with the winning car clocking speeds up to 85 mph. Electric vehicles are very quiet.

RANGE AND RECHARGING

A vehicle completely covered with solar cells receives only a small amount of solar energy each day, and converts an even smaller amount of that to useful energy. State-of-the-art PV cells are only about 20 percent efficient.

The efficiency of solar cars is measured in watt-hours per mile, instead of miles per gallon. Efficient vehicles have traveled a mile on less energy than a 100-watt light bulb consumes in one hour. (For a gasoline-powered car to achieve comparable efficiency, it would need to get 500 miles per gallon.)

To store solar-generated electricity, some SPVs use silver-zinc batteries, which have both advantages and disadvantages when compared with lead-acid batteries. Silver-zinc batteries are lighter, are more efficient, and accept higher rates of charging. They are very expensive, however, and may be charged and discharged (cycled) only a few times before they become unusable and require recycling.

EMISSIONS

Of all the vehicle types, those relying on solar energy have the least impact on the environment. Since there is no internal combustion engine and no combustion takes place, there are no emissions. Added emissions are not produced by power plants, since SPVs do not rely on utility-generated electricity.

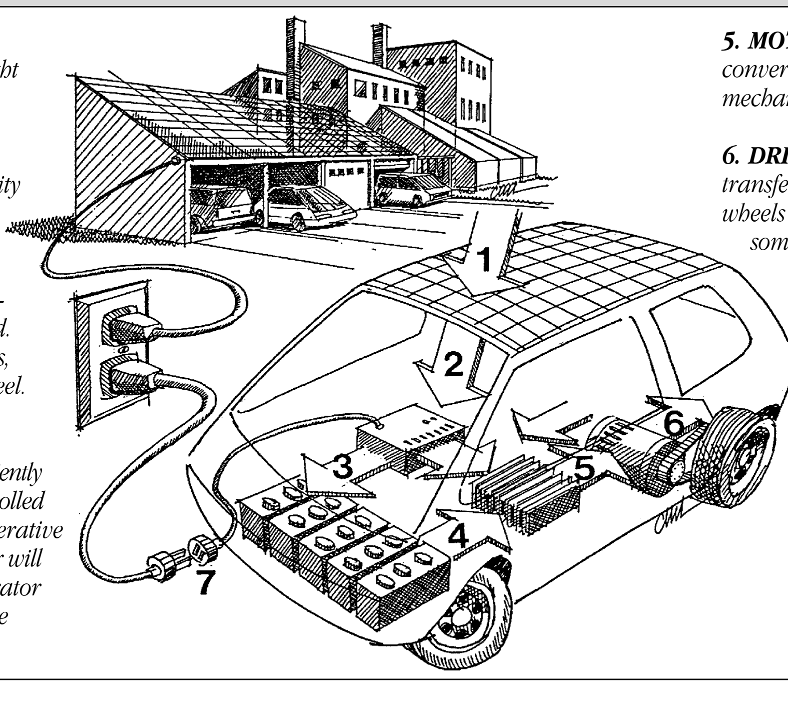
HOW A SOLAR-ASSIST ELECTRIC CAR WORKS

1. SOLAR PANELS - *(photovoltaic cells) convert sunlight to electricity.*

2. COMPUTER - *decides whether to store electricity in the battery or send it directly to the motor.*

3. ENERGY-STORAGE SYSTEM - *stores electricity until it is needed. The system may include batteries, supercapacitors, and/or a flywheel.*

4. MOTOR CONTROLLER - *sends electricity smoothly and efficiently to the motor as needed. It is controlled by an accelerator pedal. If regenerative braking is installed, the controller will allow the motor to act as a generator and return braking energy to the energy-storage system.*



5. MOTOR - *converts electrical energy to mechanical energy and vice versa.*

6. DRIVETRAIN - *transfers mechanical energy to wheels through a differential and sometimes a transmission.*

7. GRID CONNECTION - *enables the energy-storage system to be charged by plugging into the grid or by home-mounted solar collectors. The charger may be on or off the vehicle.*

RESOURCE GUIDE

RESOURCE GUIDE

This Resource Guide includes sources of information used in this unit and additional resources found on the web which may be useful to students and teachers doing research about alternative fuels. (This list is not comprehensive. Much information may be found on other sites and in periodicals, encyclopedias, and other publications in your library.) To save time for students who have limited access to the Internet, specific pages of web sites have been identified where information useful to this project can be found. (Please note that the Internet and website addresses are constantly changing.)

CONTENTS

ENERGY INFORMATION

National Energy Information Center, U.S. Department of Energy
Energy Information Administration, EI 30
1000 Independence Avenue, SW, Washington, DC 20585
tel: (202) 586-8800
e-mail: infoetr@eia.doe.gov
URL: http://www.eia.doe.gov
Oil Consumption and Supplies
URL: http://www.eia.doe.gov/emeu/iea/table12.html
URL: http://www.eia.doe.gov/emeu/iea/table81.html

TRANSPORTATION IN THE UNITED STATES

Oak Ridge National Laboratory, U.S. Department of Energy
Center for Transportation Analysis, Oak Ridge, Tenn.
Publication: *Transportation Energy Data Book*
URL: http://www-cta.ornl.gov/publications/tedb.html

U.S. Department of Transportation
National Center for Statistics and Analysis, Washington, D.C.
tel: (202) 366-1503

AIR QUALITY AND HEALTH

American Lung Association
1726 M Street, N.W. Suite 902, Washington, DC 20036
(Also see your local ALA chapter.)
Publication: *State of the Air 2002 Report*
URL: http://www.lungusa.org/air/

California Air Resources Board: Public Information Office
2020 L Street, Sacramento, CA 95814
tel: (916) 322-2990
URL: http://www.arb.ca.gov

Offices of Air and Radiation, and Air Quality Planning and Standards, U.S. Environmental Protection Agency
Annual publication: *National Air Quality and Emissions Trends Report*, 1998 (Ch. 4: Criteria Pollutants–Nonattainment Areas)
URL: http://www.epa.gov/air/urbanair/

Publication: *Greenbook: Nonattainment Areas for Criteria Pollutants*
URL: http://www.epa.gov/oar/oaqps/greenbk/

Also see:
URL: http://www.epa.gov/oar/aqtrnd97/brochure/
URL: http://www.epa.gov/oar/topics/comeap.html
URL: http://www.epa.gov/oar/oaqps/cleanair.html
URL: http://www.epa.gov/airs/criteria.html
URL: http://www.epa.gov/airnow/

Office of Transportation and Air Quality, U.S. Environmental Protection Agency
2565 Plymouth Road, Ann Arbor, MI 48105
tel: (734) 214-4333
URL: http://www.epa.gov/otaq/consumer.htm

GREENHOUSE GASES AND GLOBAL WARMING

National Energy Information Center, U.S. Department of Energy
see Energy Information above
Report: *Carbon Dioxide Emissions from the Generation of Electric Power in the United States*, July 2000
URL: http://www.eia.doe.gov/cneaf/electricity/page/co2_report/co2report.html

U.S. Environmental Protection Agency
URL: http://www.epa.gov/globalwarming/actions/transport/index.html
URL: http://www.epa.gov/oppeoee1/globalwarming/
URL: http://www.epa.gov/oar/topics/comeap.html

ALTERNATIVE FUELS, MISCELLANEOUS

California Energy Commission: Transportation Technology Office
1516 Ninth Street, MS-41, Sacramento, CA 95814-5504
tel: (916) 654-4989
Publications: (916) 654-5200
fax: (916) 654-4420
e-mail: energia@energy.ca.gov
URL: http://www.energy.ca.gov/afvs/

Publication: *ABCs of AFVs: A Guide to Alternative Fuel Vehicles*, November 1999 (# 500-99-013. Cost: $8.00)
URL: http://www.energy.ca.gov/afvs/reports/ABCsintro.html

Clean Cities, U.S. Department of Energy
P.O. Box 12316, Arlington, VA 22209
hotline: 800-C-CITIES
e-mail: ccities@nrel.gov
URL: http://www.ccities.doe.gov
URL: http://www.ccities.doe.gov/success.shtml

Publications:
Greening the Fleet: A Local Government Guide to Alternative Fuels and Vehicles, 1997
Guide to Alternative Fuel Vehicle Incentives & Laws, November 1996
Taking an Alternative Route: Fueling the Future

Clean Fuels Development Coalition
4641 Montgomery Avenue, Suite 350, Bethesda, MD 20814
tel: (301) 718-0077
fax: (301) 718-0606
e-mail: cfdcinc@aol.com
URL: http://www.cleanfuelsdc.org

National Renewable Energy Laboratory (NREL), U.S. Department of Energy
1617 Cole Blvd., Golden, CO 80401-3393
The Alternative Fuels Data Center
tel: (800) 423-1363
URL: http://www.afdc.nrel.gov/
e-mail: hotline@afdc.nrel.gov
URL: http://www.afdc.nrel.gov/questions.html
URL: http://www.afdc.nrel.gov/refueling.html
Photographic Information Exchange
URL: http://www.nrel.gov/data/pix/

Office of Transportation Technologies, U.S. Department of Energy
1000 Independence Avenue, SW, Washington, DC 20585
tel: (202) 586-8072
URL: http://www.ott.doe.gov/technologies.shtml
URL: http://www.afdc.doe.gov/

Oak Ridge National Laboratory, U.S. Department of Energy
Publications Office (c/o Stacy C. Davis)
P.O. Box 2008, Building 3156, MS-6073
Oak Ridge, TN 37831-6073
tel: (423) 574-5957
fax: (423) 574-3851
e-mail: DAVISSC@ornl.gov
URL: http://www-cta.ornl.gov
Annual publication: *Transportation Energy Data Book*
URL: http://www-cta.ornl.gov/Publications/Tedb.html

Office of Transportation and Air Quality, U.S. Environmental Protection Agency
2565 Plymouth Road, Ann Arbor, MI 48105
tel: (734) 214-4333
URL: http://www.epa.gov/otaq/fuels.htm

BATTERY ELECTRIC

Argonne National Laboratory, U.S. Department of Energy
9700 S. Cass Avenue, Argonne, IL 60439
tel: (630) 252-2000
URL: http://www.transportation.anl.gov/ttrdc/batteries/index.html (brochure)
URL: http://www.transportation.anl.gov/ttrdc/publications/
URL: http://www.transportation.anl.gov/ttrdc/publications/papers/saricks/sld009.html (slide)

United States Council for Automotive Research, U.S. Advanced Battery Consortium(USABC)
330 Town Center Drive, Fairlane Plaza South, Dearborn, MI 48126
tel: (313) 248-4298
URL: http://www.uscar.org/consortia&teams/consortiahomepages/con-usabc.htm

National Station Car Association
tel: (510) 839-6054
e-mail: stncar@ix.netcom.com
URL: http://www.stncar.com
URL: http://www.stncar.com/toc.html
URL: http://www.stncar.com/conc.html

Southern California Edison Company
Electric Transportation Department
2244 Walnut Grove Avenue, Rosemead, CA 91770
tel: (800) 483-4636 or (800) 4-EVINFO

BIODIESEL

Biodiesel Information Centre, Canadian Renewable Fuels Association
90 Woodlawn Road W., Guelph, Ontario. N1H 1B2
tel: (519) 767-0431
fax: (519) 837-1674
URL: http://www.greenfuels.org/bioindex.html

Energy Efficiency and Renewable Energy Clearinghouse (EREC)
P.O. Box 3048, Merrifield, VA 22116
tel: (800) DOE-EREC or (800) 363-3732
e-mail: doe.erec@nciinc.com
URL: http://www.eren.doe.gov/consumerinfo/refbriefs/ta2.html
URL: http://www.eren.doe.gov/consumerinfo/afv.html

National Biodiesel Board
P.O. Box 104898, 1907 Williams Street, Jefferson City, MO 65110
tel: (573) 635-3893 or (800) 841-5849
e-mail: info@nbb.org
URL: http://www.biodiesel.org

National Biofuels Program, U.S. Department of Energy
URL: http://www.biofuels.doe.gov/biofuels.html
URL: http://www.ott.doe.gov/biofuels/
URL: http://www.eren.doe.gov/RE/bioenergy.html

Office of Transportation Technologies, U.S. Department of Energy
1000 Independence Avenue, SW, Washington, DC 20585
tel: (202) 586-8072
URL: http://www.afdc.doe.gov/altfuel/biodiesel.html

ELECTRIC VEHICLES, INCLUDING SOLAR

Bay Area Action
265 Moffett Boulevard, Mountain View CA 94043-4723
tel: (650) 625-1994
URL: www.baaction.org/ev_project

Electric Vehicle Association of Canada
Suite 11, 21 Concourse Gate, Nepean, ON, Canada, K2E 7S4
fax: (613) 723-8275
e-mail: information@evac.ca
URL: http://www.evac.ca

Electric Vehicle Association of the Americas
601 California St., Suite 502, San Francisco, CA 94108
tel: (415) 249-2690 or (800) 4EV-FACT
e-mail: ev@evaa.org
URL: http://www.evaa.org/evaa/pages/qfacts.html

Electric Transit Vehicle Institute
1617-b Wilcox Boulevard, Chattanooga, TN 37404
fax: (423) 622-0744
email: etvi@vol.com
URL: http://www.etvi.org/

CALSTART/WESTART
3360 E. Foothill Blvd., Pasadena, CA 91107
tel: (626) 744-5600
URL: http://www.calstart.org

Northeast Sustainable Energy Association (NESEA)
50 Miles Street, Greenfield, MA 01301
tel: (413) 774-6051
URL: http://www.nesea.org/

Pacific Gas and Electric (PG&E)
San Francisco, California
tel: (800) 684-4648
URL: http://www.pge.com/cleanair/
URL: http://www.pge.com/003_save_energy/003b_bus/pdf/ev8pt6.pdf

Southern California Edison Company
Electric Transportation Department
2244 Walnut Grove Avenue, Rosemead, CA 91770
tel: (800) 438-4636

ETHANOL

Argonne National Laboratory, U.S. Department of Energy
see Battery Electric above
URL: http://www.transportation.anl.gov/ttrdc/fuels/index.html (see Guidebook for Handling)
URL: http://www.transportation.anl.gov/ttrdc/publications/papers/saricks/sld009.html (slide)

American Coalition for Ethanol
P.O. Box 85102, Sioux Falls, SD 57104
tel: (605) 334-3381
fax: (605) 334-3389
URL: http://www.ethanol.org/
URL: http://www.ethanol.org/information/ethanol_information.htm

Ethanol Information Center, Canadian Renewable Fuels Association
90 Woodlawn Road W., Guelph, Ontario. N1H 1B2
tel: (519) 767-0431
fax: (519) 837-1674
URL: http://www.greenfuels.org/ethindex.html

National Biofuels Program, U.S. Department of Energy
URL: http://www.biofuels.doe.gov/biofuels.html
URL: http://www.ott.doe.gov/biofuels/

Renewable Fuels Association
One Massachusetts Ave., NW, Suite 820, Washington, DC 20001
tel: (202) 289-3835
fax: (202) 289-7519
e-mail: info@ethanolrfa.org
URL: http://www.ethanolrfa.org
URL: http://www.ethanolrfa.org/outlook99/99industryoutlook.html

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FUEL CELLS

American Methanol Institute
800 Connecticut Ave., NW, Suite 620, Washington, DC 20006
fax: (202) 331-9055
e-mail: AMI@methanol.org
URL: http://www.methanol.org/fuelcell/

Argonne National Laboratory, U.S. Department of Energy
see Battery Electric above
URL: http://www.transportation.anl.gov/ttrdc/fuelcell/index.html (brochure)

Ballard Power Systems, Inc.
9000 Glenlyon Parkway, Burnaby, BC V5J 5J9
tel: (604) 454-0900
fax: (604) 412-4700
URL: http://www.ballard.com/pem_intro.asp

Breakthrough Technologies Institute/Fuel Cells 2000
1625 K Street, NW, Suite 725, Washington, DC 20006
tel: (202) 785-4222
fax: (202) 785-4313
URL: http://www.fuelcells.org

Fuel Cell Institute
P.O. Box 65481, Washington, DC 20035-5481
tel: (301) 681-3532

Gas Technology Institute (GTI)
1700 South Mount Prospect Road, Des Plaines, IL 60018-1804
URL: http://www.gri.org/

Los Alamos National Laboratory, U.S. Department of Energy
"Fuel Cells at Los Alamos"
URL: http://www.lanl.gov/worldview/science/features/fuelcell.html
Publication: *Fuel Cells: Green Power* by Sharon Thomas and Marcia Zalbowitz
URL: http://education.lanl.gov/resources/fuelcells/

Union of Concerned Scientists
2 Brattle Square, Cambridge, MA 02238
tel: (617) 547-5552
e-mail: ucs@ucsusa.org
URL: http://www.ucsusa.org

HYBRID ELECTRIC

Argonne National Laboratory, U.S. Department of Energy
see Battery Electric above
URL: http://www.transportation.anl.gov/ttrdc/publications/

Office of Transportation Technologies, U.S. Department of Energy
URL: http://www.ott.doe.gov/hev/

Electric Transit Vehicle Institute
1617-b Wilcox Boulevard, Chattanooga, TN 37404
fax: (423) 622-0744
email: etvi@vol.com
URL: http://www.etvi.org/

Rocky Mountain Institute: Hypercar Center
1739 Snowmass Creek Road, Snowmass, CO 81654
tel: (303) 927-3851
URL: http://www.hypercarcenter.org/

HYDROGEN

Energy Efficiency and Renewable Energy Network, U.S. Department of Energy
Hydrogen Information Network
URL: http://www.eren.doe.gov/hydrogen/
URL: http://www.eren.doe.gov/consumerinfo/refbriefs/a109.html

National Hydrogen Association
1800 M Street, N.W., Suite 300, Washington, DC 20036-5802
tel: (202) 223-5547
fax: (202) 223-5537
URL: http://www.hydrogenus.com/

LIQUEFIED PETROLEUM GAS (PROPANE)

Argonne National Laboratory, U.S. Department of Energy
see Battery Electric above
URL: http://www.transportation.anl.gov/ttrdc/publications/papers/saricks/sld009.html (slide)

National Propane Gas Association
1600 Eisenhower Lane, Lisle, IL 60532-2167
tel: (630) 515-0600
fax: (630) 515-8774
e-mail: info@npga.org
URL: http://www.npga.org
URL: http://www.npga.org/public/articles/index.html?Cat=7

Ontario Propane Association
11-1155 North Service Road West, Oakville, ON, Canada L6M 3E3
tel: (905) 469-1941
fax: (905) 469-1942
URL: http://www.propane.ca

Propane Education and Research Council
1776 K Street, NW, Suite 204, Washington, DC 20006
tel: (202) 452-8975
fax: (202) 452-9054
URL: http://www.propanecouncil.org

Propane Vehicle Council
1130 Connecticut Ave. N.W., Suite 700, Washington, DC 20036
tel: (202) 530-0479
fax: (202) 223-0479
e-mail: vehicle@propanegas.com
URL: http://www.propanegas.com/index.html
URL: http://www.propanegas.com/consumer/index.html

METHANOL

American Methanol Institute
see Fuel Cells above
e-mail: AMI@methanol.org
URL: http://www.methanol.org

California Energy Commission, Transportation Technology and Fuels Office
see Alternative Fuels above
URL: http://www.energy.ca.gov/afvs/

NATURAL GAS (CNG AND LNG)

American Gas Association
1515 Wilson Blvd., Arlington, VA 22209
tel: (703) 841-8000
URL: http://www.aga.org
URL: http://www.fuelingthefuture.org/contents/NaturalGasVehicles.asp/

Argonne National Laboratory, U.S. Department of Energy
see Battery Electric above
URL: http://www.transportation.anl.gov/ttrdc/publications/papers/saricks/sld009.html (slide)

CALSTART-WESTART
see Electric Vehicles above
URL: http://www.calstart.org/afvscom.html

The EnergySource Network
tel: (480) 377-8800
URL: http://www.energysource.com/energyexperts/natural_gas_facts/index.html

Natural Fuels Company, LLC
5855 Stapleton Drive North, Denver, CO 80216-3312
tel: (303) 322-4600 or (800) 366-4602
fax: (303) 322-4622
e-mail: jgonzales@naturalfuels.com
URL: http://www.naturalfuels.com
URL: http://www.naturalfuels.com/q_and_a.htm

The Natural Gas Vehicle Coalition
1100 Wilson Blvd., Suite 850, Arlington, VA 22209
tel: (703) 527-3022
fax: (703) 527-3025
URL: http://www.ngvc.org
URL: http://www.ngvc.org/qa.html#work
URL: http://www.ngvc.org/ngvs.html

Pacific Gas and Electric Company (PG&E)
see Electric Vehicles above
URL: http://www.pge.com/cleanair/
URL: http://www.pge.com/003_save_energy/003b_bus/003b3a2_gas_veh.shtml

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ALTERNATIVE MODES OF TRANSPORTATION

Bicycle Awareness Program, California Air Resources Board
P.O. Box 2815, Sacramento, CA 95812-2815
tel: (916) 322-7062
fax: (916) 322-3646

Center of Excellence for Sustainable Development, U.S. Department of Energy
Sustainable Transportation Success Stories:
URL: http://www.sustainable.doe.gov/transprt/trsstoc.shtml

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