# TRANSPORTATION FUELS: ETHANOL

TRANSPORTATION FUELS

Information and activities to teach students about ethanol as a transportation fuel.

GRADE LEVEL
4–12

SUBJECT AREAS
Science
Social Studies
Math
Language Arts
Technology


NEED
2008-2009
Putting Energy into Education

NEED Project PO Box 10101 Manassas, VA 20108 1-800-875-5029 www.NEED.org

# Teacher Advisory Board



## NEED Mission Statement

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

## Teacher Advisory Board Vision Statement

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

## Permission to Copy

*NEED materials may be reproduced for non-commercial educational purposes.*

***Printed on Recycled Paper with Soy-Based Ink***

# TABLE OF CONTENTS


Correlations to National Science Standards . . . . . 4
Resources for Ethanol Information . . . . . 5
Teacher Guide with Suggested Activities . . . . . 6
Elementary Factsheet: Corn . . . . . 8
Elementary Factsheet: Ethanol . . . . . 9
Intermediate Factsheet: Ethanol . . . . . 10
Secondary Factsheet: Ethanol . . . . . 13
Elementary Ethanol Math . . . . . 16
Intermediate Ethanol Math . . . . . 17
Secondary Ethanol Math . . . . . 18
Elementary Ethanol Crossword . . . . . 19
Intermediate Ethanol Crossword . . . . . 20
Secondary Ethanol Crossword . . . . . 21
Answer Key . . . . . 22
Evaluation Form . . . . . 23



This booklet was developed with funding and technical support from the Governors' Ethanol Coalition and the Illinois Sustainable Education Project (ISTEP).


Governors' Ethanol Coalition

ISTEP Illinois Sustainable Education Project

NEED Putting Energy into Education

# Correlations to National Science Standards

*(Bolded standards are emphasized in the unit.)*

## PRIMARY (K–4) STANDARD D: EARTH AND SPACE SCIENCE

### 1. Properties of Earth Materials

**a. Earth materials are solid rocks and soils, water, and the gases of the atmosphere. The varied materials have different physical and chemical properties, which make them useful in different ways; for example, as building materials, as sources of fuel, or for growing the plants we use as food.**

**b. Earth materials provide many of the resources that humans use.**

## PRIMARY–F: SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES

### 3. Types of Resources

**a. Resources are things that we get from the living and nonliving environment to meet the needs and wants of a population.**

**b. Some resources are basic materials, such as air, water, and soil; some are produced from basic resources, such as food, fuel, and building materials; and some resources are nonmaterial, such as quiet places, beauty, security, and safety.**

**c. The supply of many resources is limited. If used, resources can be extended through recycling and decreased use.**

### 4. Changes in Environments

a. Environments are the space, conditions, and factors that affect an individual's and a population's ability to survive and their quality of life.

b. Changes in environments can be natural or influenced by humans. Some changes are good, some are bad, and some are neither good nor bad.

c. Pollution is a change in the environment that can influence the health, survival, or activities of organisms, including humans.

### 5. Science and Technology in Local Challenges

a. People keep inventing new ways of doing things, solving problems, and getting work done. New ideas and inventions often affect other people; sometimes the effects are good and sometimes they are bad. It is helpful to try to determine in advance how ideas and inventions will affect other people.

b. Science and technology have greatly improved food quality and quantity, transportation, health, sanitation, and communication. These benefits of science and technology are not available to all of the people in the world.

## INTERMEDIATE (5–8) STANDARD E: SCIENCE AND TECHNOLOGY

### 2. Understandings about Science and Technology

c. Technological solutions are temporary and have side effects. Technologies cost, carry risks, and have benefits.

f. Perfectly designed solutions do not exist. All technological solutions have trade-offs, such as safety, cost, efficiency, and appearance. Risk is part of living in a highly technological world. Reducing risk often results in new technology.

## INTERMEDIATE–F: SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES

### 3. Natural Hazards

**b. Human activities can induce hazards through resource acquisition, urban growth, land-use decisions, and waste disposal.**

c. Hazards can present personal and societal challenges because misidentifying the change or incorrectly estimating the rate and scale of change may result in either too little attention and significant human costs or too much cost for unneeded preventive measures.

## INTERMEDIATE–F: SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES

### 4. Risks and Benefits

b. Students should understand the risks associated with natural hazards, chemical hazards, biological hazards, social hazards, and personal hazards.

c. Students can use a systematic approach to thinking critically about risks and benefits.

d. Important personal and social decisions are made based on perceptions of benefits and risks.

### 5. Science and Technology in Society

c. Technology influences society through its products and processes. Technological changes are often accompanied by social, political, and economic changes that can be beneficial or detrimental to individuals and to society. Social needs, attitudes, and values influence the direction of technological development.

d. Science and technology have contributed enormously to economic growth and productivity among societies and groups within societies.

e. Science cannot answer all questions and technology cannot solve all human problems or meet all human needs. Students should appreciate what science and technology can reasonably contribute to society and what they cannot do. For example, new technologies often will decrease some risks and increase others.

## SECONDARY (9–12) STANDARD F: SCIENCE IN PERSONAL & SOCIAL PERSPECTIVES

### 3. Natural Resources

**a. Human populations use resources in the environment to maintain and improve their existence.**

**b. The earth does not have infinite resources; increasing human consumption places severe stress on the natural processes that renew some resources, and depletes those resources that cannot be renewed.**

**c. Humans use many natural systems as resources. Natural systems have the capacity to reuse waste but that capacity is limited. Natural systems can change to an extent that exceeds the limits of organisms to adapt naturally or humans to adapt technologically.**

### 4. Environmental Quality

c. Many factors influence environmental quality. Factors that students might investigate include population growth, resource use, population distribution, overconsumption, the capacity of technology to solve problems, poverty, the role of economic, political, and religious views, and different ways humans view the earth.

### 5. Natural and Human-induced Hazards

b. Human activities can enhance potential for hazards. Acquisition of resources, urban growth, and waste disposal can accelerate rates of natural change.

d. Natural and human-induced hazards present the need for humans to assess potential danger and risk. Many changes in the environment designed by humans bring benefits to society, as well as cause risks. Students should understand the costs and trade-offs of various hazards—ranging from those with minor risk to a few people to major catastrophes with major risk to many people.

### 6. Science and Technology in Local, National, and Global Challenges

b. Understanding basic concepts and principles of science and technology should precede active debate about the economics, policies, politics, and ethics of various science and technology related challenges. However, understanding science alone will not resolve local, national, and global challenges.

# Resources for Ethanol Information

| | |
|---|---|
| Alternative Fuels Data Center | www.eere.energy.gov/afdc/ |
| Department of Energy | www.energy.gov |
| National Renewable Energy Laboratory | www.nrel.gov |
| Energy Information Administration | www.eia.doe.gov |
| Environmental Protection Agency | www.epa.gov |
| U.S. Department of Agriculture | www.usda.gov |
| Governors' Ethanol Coalition | www.ethanol-gec.org |
| National Corn to Ethanol Research Center | www.siue.edu/ETHANOL |
| Renewable Fuels Association | www.EthanolRFA.org |
| American Coalition for Ethanol | www.ethanol.org |
| Ethanol Across America | www.ethanolacrossamerica.net |
| National Ethanol Vehicle Coalition | www.e85fuel.com |
| Ethanol Producers and Consumers | www.ethanolmt.org |
| E10 Unleaded | www.e10unleaded.com |
| National Corn Growers Association | www.ncga.com |
| IL-DCEO | www.illinoisbiz.biz/com/energy/alternate.html |
| Illinois Corn Growers | www.ilcorn.org |
| Minnesota Corn Growers | www.mncorn.org |

# Teacher Guide

**TO TEACH STUDENTS ABOUT ETHANOL AND ENCOURAGE THEM TO EVALUATE ITS ECONOMIC AND ENVIRONMENTAL ADVANTAGES AND DISADVANTAGES AS A TRANSPORTATION FUEL.**

## BACKGROUND

This booklet provides background information on ethanol as a renewable transportation fuel at three reading levels—elementary, intermediate, and secondary—with activities to reinforce knowledge and develop critical thinking and research skills.

## CONCEPTS

- All transportation fuels have economic and environmental advantages and disadvantages.
- Economic and environmental impacts, as well as availability, are determining factors in the transportation fuels used by fleets and consumers.

## TIME

- Two to five class periods.

## SKILL REINFORCEMENT

- Critical thinking
- Math & graph analysis
- Cooperative learning
- Cost/benefit analysis
- Comparison and contrast
- Evaluation of multiple factors
- Research and writing
- Presentation

## MATERIALS & PREPARATION

- Familiarize yourself with the booklet and decide which grade level factsheet and activities you will use.
- Make copies of the appropriate factsheet(s) and worksheets for the students.
- If possible, arrange for an expert (someone who produces or uses ethanol) to make a presentation to the class.
- Procure any additional materials the students will need to conduct the activities.
- Call NEED at 1-800-875-5029 for additional transportation fuels activity booklets if you need them: *The Future is Today* (Secondary), *What Car Will You Drive?* (Intermediate), *Alternative Fuels Debate Game* (5-12), *Alternative Fuels Expo* (4-12), and *Alternative Fuel Rock Performances* (4-12).

# PROCEDURE

## DAY ONE: Introduction and Learning

- Introduce ethanol to the class using the concepts on page 4. Distribute the factsheets and have the students read them and make a list of the important facts and any new vocabulary words. Discuss the main facts and the new words.

- Have the students compare and contrast the properties of gasoline and ethanol, as well as the advantages and disadvantages of both. Discuss.

- Have the students complete the crossword puzzles and math worksheets to reinforce the new vocabulary and the information presented. Review as a group.

## DAYS TWO-FIVE: Synthesis and Reinforcement

Use activities from the list below to reinforce ethanol information.

# SUGGESTED ACTIVITIES

**ELEMENTARY**

1. Ethanol Presentation Day

   Group 1: Corn Song–write and perform a song about the energy in corn.

   Group 2: Ethanol Song–write and perform a song about ethanol.

   Group 3: Ethanol Newscast–write and conduct interviews of a farmer, an ethanol manufacturer, and a person who uses ethanol fuel in his/her vehicle.

   Group 4: Make a poster of corn products or states that produce the most corn or ethanol.

   Group 5: Write a commercial to convince people to use ethanol fuels.

2. Have the students design brochures to teach their peers and parents about ethanol fuels.

3. Have the students explore the Department of Energy—Energy Information Agency's Kid Page website at ***www.eia.doe.gov/kids/history/timelines/ethanol.html*** to learn two interesting facts about ethanol.

**INTERMEDIATE/SECONDARY**

1. Have the students conduct research to answer the following questions:

   How many vehicles does your school district have, what kind of vehicles are they, what fuels do they use? Are there plans to change fuels?

   How many vehicles does your community (town, city, county) have, what kind of vehicles are they, what fuels do they use? Are there plans to change fuels?

   What are the effects on the environment of gasoline and ethanol emissions?

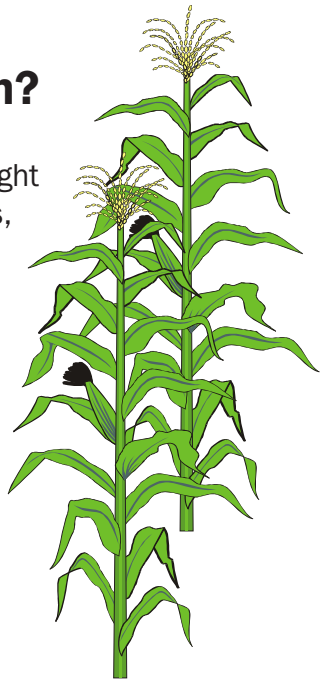
   Where is ethanol being used today? By how many fleets/vehicles?

   How is corn turned into ethanol? What other feedstocks can be used to make ethanol?

   Which states grow the most corn?

2. Have the students produce Power Point presentations on the results of their research.
3. Have the students produce Power Point presentations to convince someone to use ethanol.
4. Have the students design brochures to inform their peers and community about ethanol.
5. Have the students design a procedure to make ethanol.

# ELEMENTARY: What Can You Do With a Field of Corn?



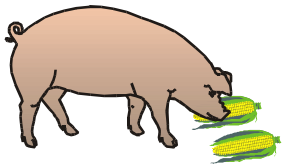
Corn, like all plants, is full of energy. It gets its energy from the sun. Plants take in light from the sun and turn it into sugars. They store the sugars in their roots, leaves, stems, flowers, and seeds. The energy in the sugars makes them grow. When people or animals eat corn, the stored sugars give them energy.

Corn is a member of the grass family. Unlike many grasses, corn is an **annual** plant. It cannot survive over the winter and must be planted again every year. One stalk of corn produces one or two ears of corn. Each ear has about 300–500 seeds or kernels.

There are several kinds of corn and they are used for different things. Sweet corn is the corn we eat off the cob. Popcorn is another kind of corn humans eat. Field corn is the kind of corn used to make animal feed, vehicle fuel, and sweeteners.

Corn is a native grain of the Americas. Corn was first grown by Mayan, Aztec, and Inca Indians more than 5,600 years ago. The Indians chewed the sugar-filled leaves of the corn plant like we chew gum, ate the fresh ears of corn, and ground dried corn into flour for bread.

The Pilgrims might have died during their first winter in the new country if Native Americans had not given them corn. The Native Americans showed the Pilgrims how to grow corn and make it into bread, soup, fried corn cakes, and pudding. Corn was so valuable that early settlers used corn to trade with the Native Americans for food and furs.



Today, the United States and the rest of the world use corn primarily as food for livestock. More than half of the corn in the United States is eaten by animals. Much of the food we eat is from corn. We use corn to make breads, cereals, and many other foods; we also eat fresh corn on the cob.

Corn has been used for a long time for more than animal or human food. The British Parliament tried to get American colonists to turn corn into sugar with the Molasses Act in 1733. Today, we use corn syrup and other sweeteners in many foods such as soda, ice cream, and cookies.

Corn has also been used to make alcohol for many years. Native Americans used corn to make beer before the colonists arrived in America. The 1792 Whiskey Rebellion came about when England tried to tax corn whiskey.


Long before the automobile, corn was being turned into an alcohol fuel called **ethanol**. In 1908, Henry Ford designed his first Model T to run on ethanol. He called it the fuel of the future. Ethanol is now being used as a clean-burning fuel for many vehicles. It is usually mixed with gasoline to help reduce air pollution. Today, about ten percent of the corn grown in the United States is used to make ethanol.

Corn plants and other farm waste can be made into a gas called **biogas**. Biogas is full of energy and can be used to cook food, power lights, and heat homes. We can also compost the plants to make fertilizer for our gardens.

Corn is the biggest crop in the United States and is grown all over the world. Corn can grow at altitudes as high as 12,000 feet and as low as sea level. It can grow in tropical climates that get 400 inches of rainfall a year or in areas that get only 12 inches of rain a year.

The next time you see a field of corn, think about all of the ways we can use its energy. We can feed animals and feed ourselves. We can make ethanol to power vehicles. We can turn it into biogas to make heat and electricity. Corn is an amazing plant, full of energy we can use.

# ELEMENTARY: **What is Ethanol?**

**Ethanol** is a fuel made from sugars found in plants. In the U.S., it is usually made from corn or grain sorghum. Ethanol can also be made from many other plants or parts of plants, such as wheat, sugar cane, sawdust, and yard clippings. Ethanol is usually mixed with gasoline when it is used as a fuel.

Most cars in the U.S. run on gasoline. Gasoline is made from **petroleum**, a **nonrenewable** energy source. Petroleum is a **fossil fuel**; it takes millions of years to form underground. We use so much petroleum in the United States that we must import two-thirds of it from other countries.

There are many good reasons to use ethanol instead of gasoline, or to mix it with gasoline. One reason is that petroleum fuels can pollute the air when they are used in vehicle engines. Ethanol is cleaner than gasoline. This means the air is healthier and cleaner to breathe when cars use ethanol.

Petroleum fuels, like gasoline, are not safe for people to handle; they are **toxic**. Ethanol is **nontoxic** and is also **biodegradable**—it breaks down quickly into harmless substances if it is spilled.

When we use gasoline, we are using a nonrenewable energy source. We cannot replace what we use in a short period of time. Since ethanol is made from plants, it comes from a **renewable** energy source. We can grow more plants to make more ethanol in a short period of time.

Most of the ethanol fuel used today is E10. The letter E stands for ethanol and the number stands for the percent of ethanol that is mixed with gasoline. **E10** is 10 percent ethanol and 90 percent gasoline. There are fueling stations all over the country that offer E10 in their pumps. All vehicles that run on gasoline can use E10 without making any changes to their engines.

When we add small amounts of ethanol to gasoline (up to 10 percent) there are many advantages. It reduces the pollution from the tailpipes of vehicles, making the air cleaner. It keeps engines running smoothly without the need for lead or other dangerous chemicals. Ethanol is produced from crops grown in the United States; it is a domestic fuel. Over ninety percent (90%) of the ethanol produced in the United States today is mixed with gasoline to make E10.

There are also cars that are designed to run on higher ethanol blends. These cars are called **flexible fuel vehicles (FFVs)**. They can use any blend of ethanol fuel from E10 to E85. There are over four million FFVs in the United States today. This number is expected to double in the next few years. The U.S. Postal Service has 23,000 FFVs on the road almost every day. There are fueling stations with E85 pumps in half of the states.

*An E85 fueling station in Illinois.*

Ethanol can be mixed with diesel as a fuel for trucks and buses that usually run on diesel. It can also be used instead of leaded gasoline in small planes. In addition, ethanol is being tested as a fuel to produce hydrogen for fuel cell vehicles.

Using ethanol as a fuel helps farmers by providing additional uses for their crops. Ethanol is a cleaner fuel than gasoline; it makes the air healthier to breathe. Using ethanol also means we don't have to import as much petroleum from other countries. Ethanol is good for the economy, the environment, and the country.

# INTERMEDIATE: ETHANOL—A Domestic, Renewable Fuel

## What is Ethanol?

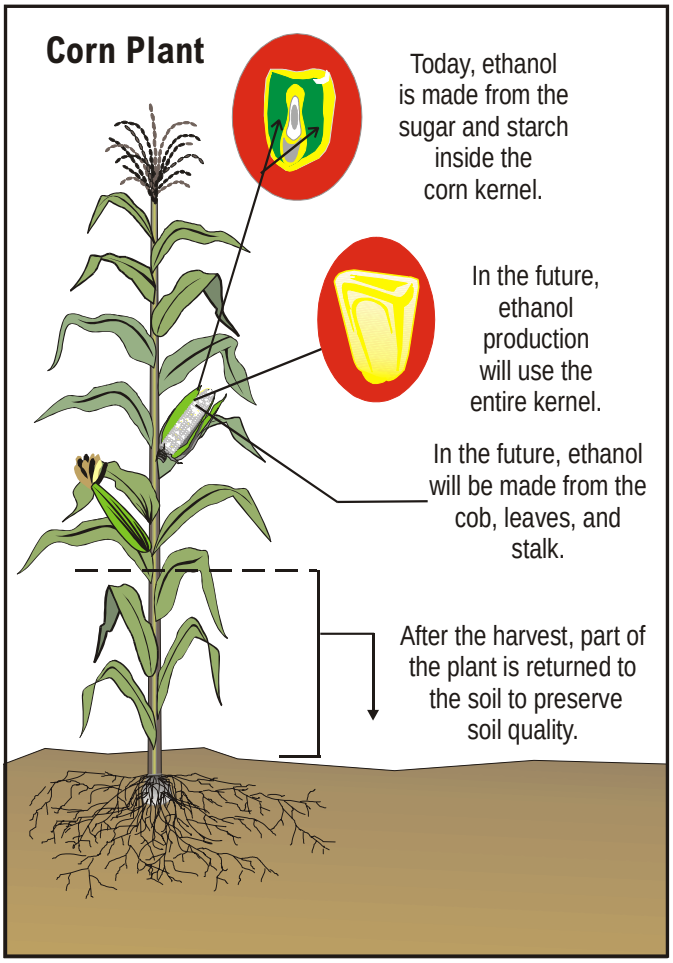
Ethanol is an alcohol fuel (ethyl alcohol) made from sugars and starch found in plants. In the United States, we produce more than 90 percent of our ethanol from corn, but sorghum, wheat, sugar cane, potatoes, rice, sawdust, and yard clippings can also be used. Ethanol is usually blended with gasoline when it is used as a transportation fuel.

## History of Ethanol

Ethanol is not a new fuel. In the 1850s, almost 90 million gallons were produced each year to light homes and businesses. During the Civil War, a liquor tax was placed on ethanol to raise money for the war. The tax increased the price of ethanol so much that it could not compete with other fuels such as kerosene for lighting. Ethanol production declined sharply because of this tax and production levels did not begin to recover until the tax was repealed in 1906.

In 1908, Henry Ford designed his original Model T Ford to run on a mixture of gasoline and alcohol. He called ethanol the fuel of the future. During World War I, the use of ethanol increased rapidly and, by the end of the war, production had risen to 50 million gallons a year. It was used not only as a fuel, but in the manufacture of war materials, as well.

In 1919, the ethanol industry received another setback with Prohibition. Ethanol production declined sharply because only a few companies could produce it under strict government regulations. With the end of Prohibition in 1933, ethanol production and use began to increase again.




During World War II, production of ethanol rose to 600 million gallons a year. Some ethanol was used as fuel, but most was used in the production of synthetic rubber, since supplies of natural rubber had been cut off by the war in Asia. After World War II, ethanol production again declined. Farmers were exporting much of their corn and large supplies of cheap foreign oil made gasoline less expensive. In the 1970s, embargoes by major oil producing countries cut gasoline supplies, reviving interest in ethanol as a transportation fuel.

## Producing Ethanol

There are several processes that are used to make ethanol from plants. The two most common methods use yeast to ferment the sugars and starch in the plants. Only part of the plant is used; the remainder is made into animal feed. Nothing is wasted. Cider, for example, is made by fermenting apple juice.

A new process uses enzymes to break down the cellulose in woody fibers, so that more of the plant can be used to make ethanol. This technology makes it possible to make ethanol from trees, grasses, and crop wastes, but it is not yet cost-effective.

Trees and grasses require less energy to produce than corn, which must be replanted and tended every year. Scientists have developed fast-growing trees that can be harvested in ten years or less. Many grasses can be established in one year and can produce two harvests a year for many years. These new energy crops will require less energy and tending than corn, and their root systems will rebuild the soil. They will also prevent erosion and offer habitats for wild animals.

In the future, you may be driving by huge farms that are not producing food or animal feed, but fuel for ethanol and power plants. These energy crops will help support U.S. farmers. In recent years, advances in farming have allowed farmers to produce enough food for the country on much less land. In fact, American farmers export forty percent of the food they grow. Energy crops will allow farmers to use their land more productively.

## Ethanol Use

Twenty percent of the vehicle fuels sold in the United States today are ethanol blends. **E10** is a mixture of ten percent ethanol and 90 percent gasoline and is used by millions of consumers across the nation. More than 90 percent of the ethanol produced in the United States is used to make E10. Any gasoline-powered vehicle can run on E10 without any change to its engine. Ethanol in low percentage blends such as E10 is considered a fuel additive, not an alternative fuel.

There are also some vehicles that are specially manufactured with changes to their engines and fuel delivery systems to run on higher percentages of ethanol. **Flexible fuel vehicles (FFVs)** are designed to use any combination of ethanol and gasoline up to 85 percent ethanol. E85 is considered an alternative fuel.

**E85**, a fuel that is 85 percent ethanol and 15 percent gasoline, is used mainly in the Midwest and South. There are more than four million FFVs in the U.S today. Forty percent are private vehicles; the remaining 60 percent are federal, state, and local government fleet vehicles. The U.S. Postal Service has more than 23,000 FFVs in its fleet.

*An E85 fueling station in Illinois.*

## Characteristics of Ethanol

Vehicles using ethanol blends have similar horsepower, acceleration, payload capacity, and cruise speed as those using gasoline. Because ethanol contains less energy per gallon than gasoline, vehicle range (the distance a vehicle can travel on a tank of fuel) can be slightly less. Maintenance of vehicles using ethanol is similar. Oil changes are needed less frequently for cars using ethanol blends. Ethanol keeps fuel lines and injectors cleaner than gasoline. Since ethanol absorbs moisture, it can help reduce fuel-line-freeze-up during the winter. Ethanol is also less flammable than gasoline. It is safer to store, transport, and refuel.

## Distribution of Ethanol

In 2005, 95 ethanol plants were producing more than four billion gallons of ethanol annually. These plants are located mostly in the Midwest. Many new plants are in the planning stages throughout the United States. In many states, E10 is available at most fueling stations. In Minnesota, E10 is available at every station. In addition, there are currently more than 550 E85 fueling stations across the nation. One hundred of these stations are located in Minnesota. Ethanol fuels for trucks and buses, such as E95, are available only through bulk suppliers.

## Economics of Ethanol

Today, it costs more to produce ethanol than gasoline because of different tax and government support structures. Federal and state tax advantages make ethanol competitive in the marketplace. If the tax and support structures were the same, the cost of ethanol would be cheaper than gasoline.

The United States imports nearly two-thirds of the petroleum it uses. Ethanol is made from renewable crops grown in the U.S. Using ethanol can reduce the need to import foreign oil, promote energy security, and reduce the trade deficit.

An additional benefit of ethanol is that it adds value to crops for farmers. Overall, ethanol accounts for $4.5 billion of U.S. farmer income each year. As new technologies for making ethanol from all parts of plants and trees become cost-effective, new crops will be available to farmers.

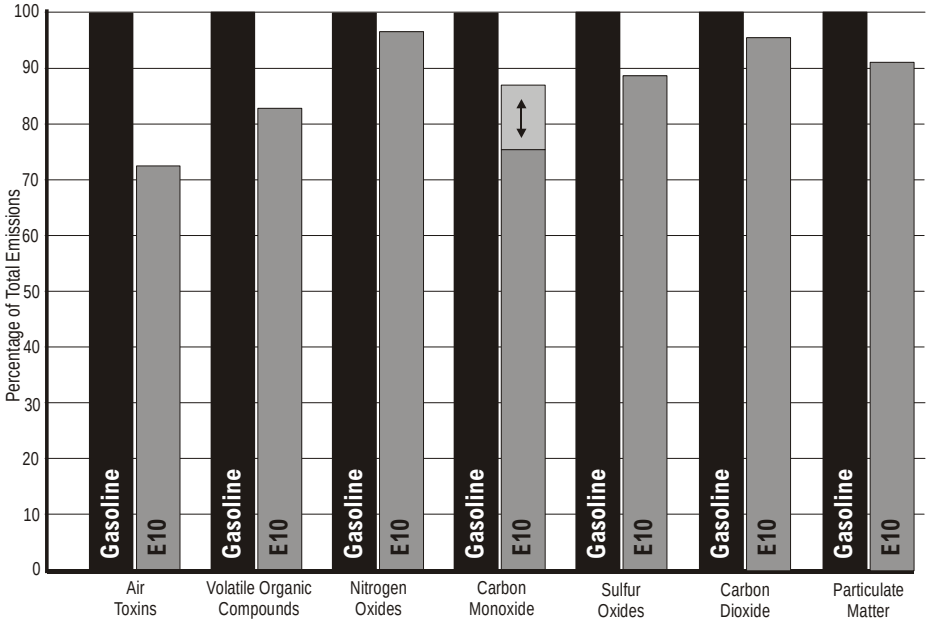
Another consideration is the energy balance of producing ethanol compared to producing gasoline. According to the latest studies from the U.S. Department of Agriculture, there is a net energy gain of 67 percent in ethanol production. There is a net energy deficit of 15 percent in gasoline production. This means that we use more energy to produce gasoline than the energy we get from using it as a fuel. We get much more energy using ethanol as a fuel than it takes to produce the ethanol.

## Environmental Impacts

Ethanol is renewable, biodegradable, and water soluble. If an ethanol spill occurs, it is less damaging to the environment than a gasoline spill.

Compared to gasoline, it is cleaner burning, producing fewer air pollutants. Using ethanol can also reduce total carbon dioxide emissions. Ethanol is made from crops that absorb carbon dioxide and give off oxygen. This carbon cycle maintains the balance of carbon dioxide in the atmosphere when using ethanol as a fuel.

### COMPARISON OF EMISSIONS OF GASOLINE AND E10




*U.S. Environmental Protection Agency*

*Vehicles that run on ethanol and ethanol blends.*

# SECONDARY: ETHANOL—A Domestic, Renewable Fuel

## What is Ethanol?

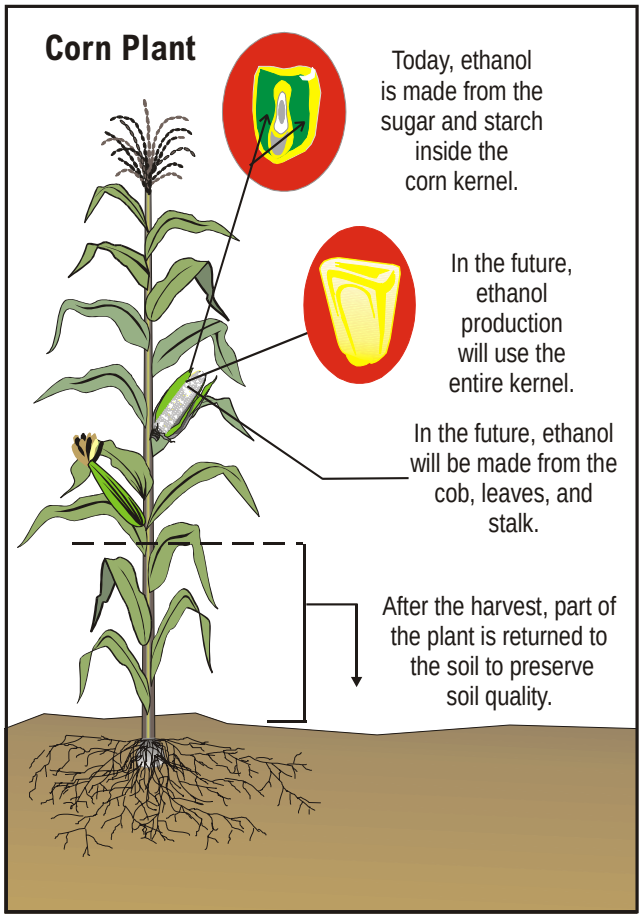
Ethanol is an alcohol fuel (ethyl alcohol) made by fermenting the sugars and starches found in plants. Any organic material containing cellulose, starch, or sugar can be made into ethanol. More than 90 percent of the ethanol produced in the United States comes from corn, but sorghum, wheat, sugar cane, potato wastes, cheese whey, corn fiber, rice straw, sawdust, urban wastes, and yard clippings can also be used. Ethanol is usually blended with gasoline when it is used as a transportation fuel.

## History of Ethanol

Ethanol is not a new fuel. In the 1850s, nearly 90 million gallons were produced every year to fuel lights, not vehicles. At the beginning of the Civil War, a $2.08 per gallon tax was imposed on liquor to finance the war. Ethanol, a product of fermentation, was taxed as liquor. At the same time, other fuels such as kerosene and methanol were taxed at only 10 cents a gallon. As a result, ethanol could not compete as a fuel and disappeared from the market.

In 1906, the federal liquor tax was repealed and ethanol once again became competitive as a fuel. In fact, in 1908 Henry Ford designed his Model T Ford to run on either gasoline or alcohol, calling ethanol the fuel of the future. During World War I, the use of ethanol increased rapidly and, by the end of the war, production had risen to 50 million gallons a year. It was used not only as a transportation fuel, but also in the manufacture of war materials.

In 1919, the ethanol industry received another blow when the era of Prohibition began. Since ethanol can be used as a liquor as well as a fuel, production decreased sharply. By the 1920s, ethanol was no longer thought of as an alternative to gasoline; it was considered a gasoline extender or octane enhancer that boosts the power of a car's engine. However, with the production of ethanol effectively banned by Prohibition, other products were used for that purpose.




With the end of Prohibition in 1933, interest in using ethanol fuel was revived. During World War II, production of ethanol rose dramatically, to 600 million gallons a year. While some ethanol was used as fuel, most was used in the production of synthetic rubber, since supplies of natural rubber had been cut off by the war in Asia.

After World War II, ethanol production again declined sharply. Not only were there no more government contracts to produce ethanol, but farmers were exporting much of their grain to European countries devastated by the war. At the same time, large supplies of cheap foreign oil made gasoline less expensive.

In the 1970s, embargoes by major oil producing countries curtailed gasoline supplies, once again reviving interest in ethanol as a transportation fuel.

## Ethanol Production Processes

There are several processes that can produce alcohol (ethanol) from various plant forms of biomass. The two most common processes involve using yeast to ferment the sugars and starches in the feedstock. Only part of the plant is fermented into alcohol; the remainder of the plant is turned into animal feed. No part of the plant is wasted. Apple cider, for example, is a product of the fermentation process.

A new process uses enzymes to break down the cellulose in woody fibers so that more of the plant waste can be used to make ethanol. This technology makes it possible to make ethanol from trees, grasses, and crop residues, but at the present time it is not cost-effective. Trees and grasses require less energy to produce than corn, which must be replanted and tended every year. Scientists have developed fast-growing, hybrid trees that can be harvested in ten years or less. Many perennial grasses can be established in one year and can produce two harvests a year for many years. These new energy crops will not require constant tending or fertilizers, and their root systems will rebuild the soil. They will also prevent erosion and offer habitats for wild animals.

In the future, you may drive by huge farms that are not producing food or animal feed, but fuel for ethanol and power plants. These energy crops will be a boon to the American farmer. In recent years, advances in farming have allowed farmers to produce enough food for the country on much less land. In fact, American farmers export forty percent of the food they grow. Energy crops will allow farmers to use their land more productively.

## Ethanol Use

Today, 20 percent of the transportation fuels sold in the United States are ethanol blends. E10, named for its mixture of ten percent ethanol and 90 percent gasoline, is widely used by millions of consumers across the country. More than 99 percent of the ethanol produced today is used in E10 blends. Any vehicle can use E10 without any changes to its engine or fuel delivery system. Ethanol in low percentage blends is considered a fuel additive, not an alternative fuel.

Some vehicles are manufactured with engine and fuel delivery systems that resist the corrosive properties of ethanol to run on higher percentage blends. Flexible fuel vehicles (FFVs) are designed to use any combination of ethanol and gasoline. E85, a fuel that is 85 percent ethanol and 15 percent gasoline, is used in FFVs mainly in the Midwest and South. E85 is considered an alternative fuel.

Today, more than four million FFVs are in use in the U.S. and that number is expected to double in the next few years. Forty percent of these are private vehicles; the remaining 60 percent are federal, state, and local government fleet vehicles. The U.S. Postal Service has over 23,000 FFVs in its fleet.

*An E85 fueling station in Illinois.*

## Characteristics of Ethanol

With one of the highest octane ratings of any transportation fuel, ethanol increases the energy efficiency of an engine. When using ethanol blends, vehicles have comparable power, acceleration, payload capacity, and cruise speed to those using gasoline. However, because ethanol contains less energy per gallon than gasoline, vehicle range (the distance a vehicle can travel on a tank of fuel) can be slightly less. Ethanol is also less flammable than gasoline; it is safer to store, transport, and refuel.

Vehicle maintenance for ethanol-powered vehicles is similar to those using gasoline. Oil changes, in fact, are needed less frequently. Due to its detergent properties, ethanol tends to keep fuel lines and injectors cleaner than gasoline. Because ethanol has a tendency to absorb moisture, using ethanol fuel can help reduce the possibility of fuel-line-freeze-up during the winter.

## Distribution of Ethanol

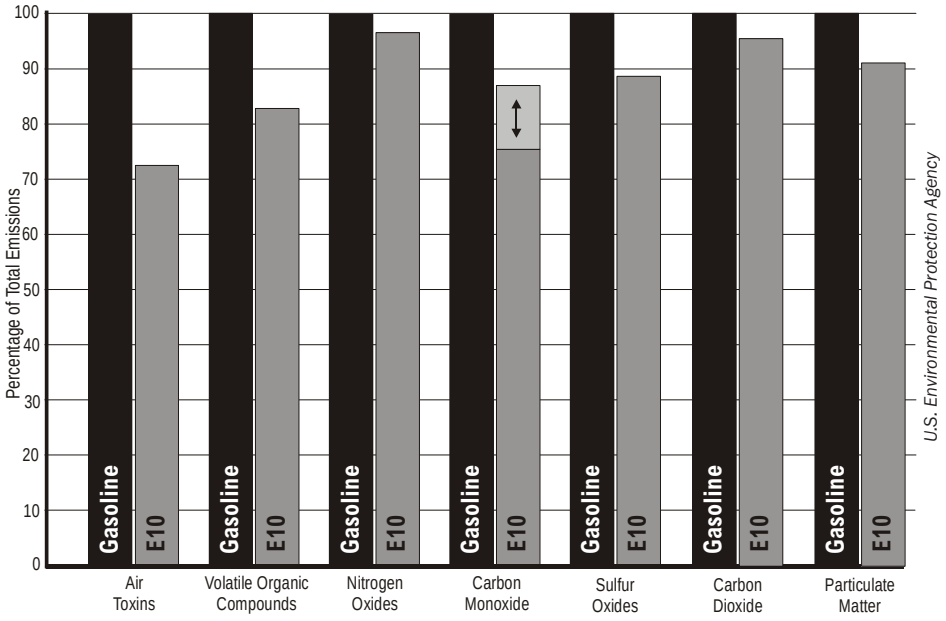
In 2005, 95 ethanol plants in the U.S. were producing more than four billion gallons of ethanol annually. These plants are located mostly in the Midwest. Many new plants are in the planning stages. In many states, E10 is available at most gasoline stations. In Minnesota, E10 is available at every station. In addition, there are currently more than 550 E85 fueling stations across the nation. Almost half of these stations are located in Minnesota. Ethanol fuels for heavy-duty applications are available only through bulk suppliers.

## Economics of Ethanol

Today, it costs more to produce ethanol than gasoline, because of different tax and government support structures. Federal and state tax advantages make ethanol competitive in the marketplace. If the tax and support structures were the same, the cost of ethanol would be cheaper than gasoline.

The U.S. imports nearly two-thirds of the petroleum it uses. Ethanol is made from renewable crops grown in the U.S. and its use can reduce the need to import oil, promote energy security, and reduce the trade deficit.

### COMPARISON OF EMISSIONS OF GASOLINE AND E10



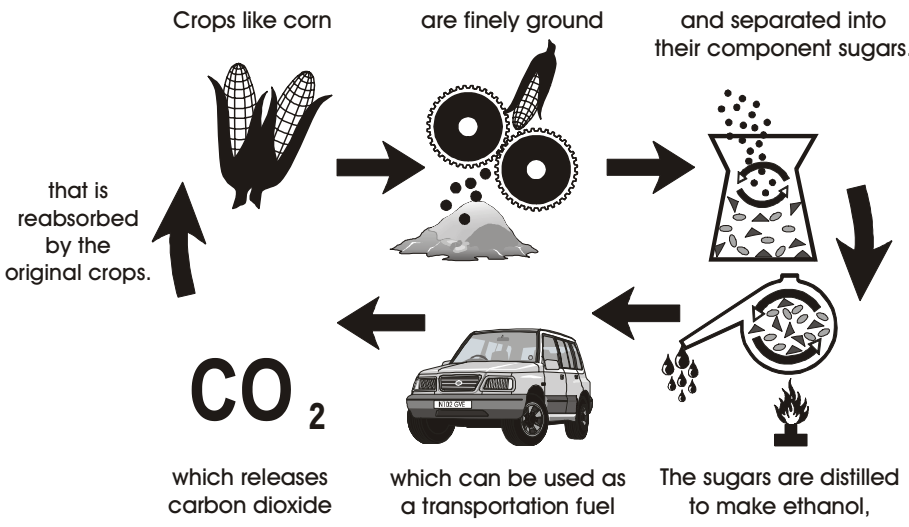

Since it is the third largest use of corn, ethanol production adds value to crops for farmers. With current rates of production, ethanol adds 20-40 cents to each bushel of corn. Overall, ethanol production annually accounts for $4.5 billion of U.S. farmer income. As new technologies for producing ethanol from all parts of plants and trees become cost-effective, the production and use of ethanol will increase dramatically.

An additional consideration is the energy balance of producing ethanol compared to producing gasoline. According to the latest studies from the U.S. Department of Agriculture, there is a net energy gain of 67 percent in ethanol production. There is a net energy deficit of 15 percent in gasoline production. This means that we use more energy to produce gasoline than the energy we get from using it as a fuel. We get much more energy using ethanol as a fuel than it takes to produce the ethanol.

## Environmental Impacts

Ethanol is both water soluble and biodegradable. If a fuel spill occurs, the effects are less environmentally severe than with gasoline. Because ethanol contains oxygen, using it as a fuel additive results in lower carbon monoxide emissions. E10 is widely used in areas that fail to meet the EPA's air quality standards for carbon monoxide and ozone. This E10 blend results in 12–25 percent less carbon monoxide emissions than conventional gasoline.

### THE CARBON CYCLE



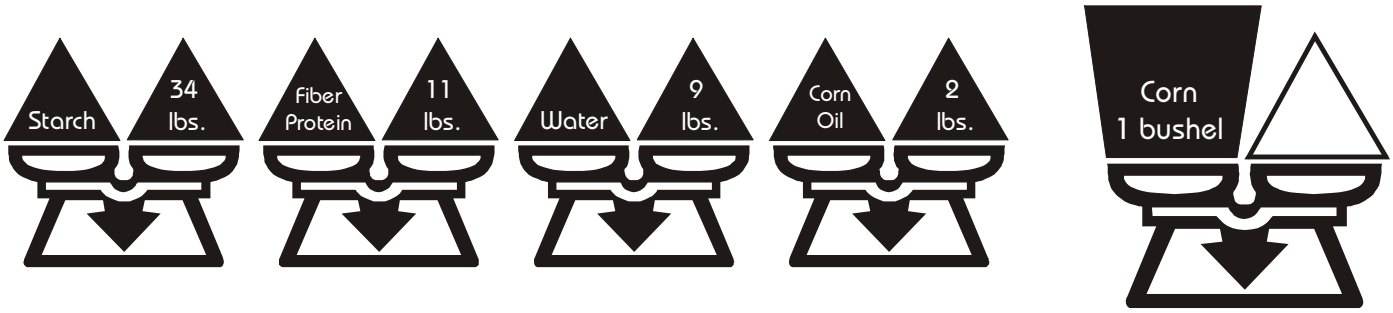

Compared to gasoline, using E85 reduces ozone-forming volatile organic compounds by 15 percent, carbon monoxide by 40 percent, particulate matter by 20 percent, nitrous oxides by 10 percent, and sulfate emissions by 80 percent.

Using ethanol can also reduce total carbon dioxide emissions. Ethanol is made from crops that absorb carbon dioxide and give off oxygen. This cycle maintains the balance of $CO_2$ in the atmosphere when using ethanol as a fuel.

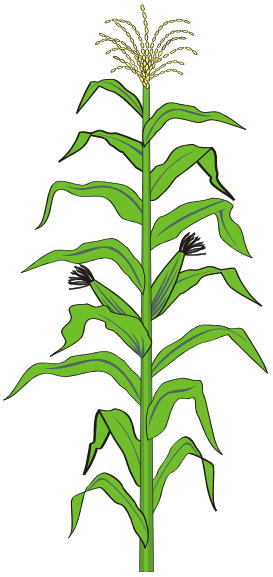
There are millions of vehicles on the road today. Reducing the emissions from those vehicles provides a significant benefit to our public health and the environment. Using ethanol as a transportation fuel can help accomplish that goal.

# ELEMENTARY Ethanol **MATH: Count the Corn**

1. **A bushel of corn produces the products shown below. How much does the bushel of corn weigh? Write your answer in the white triangle.**

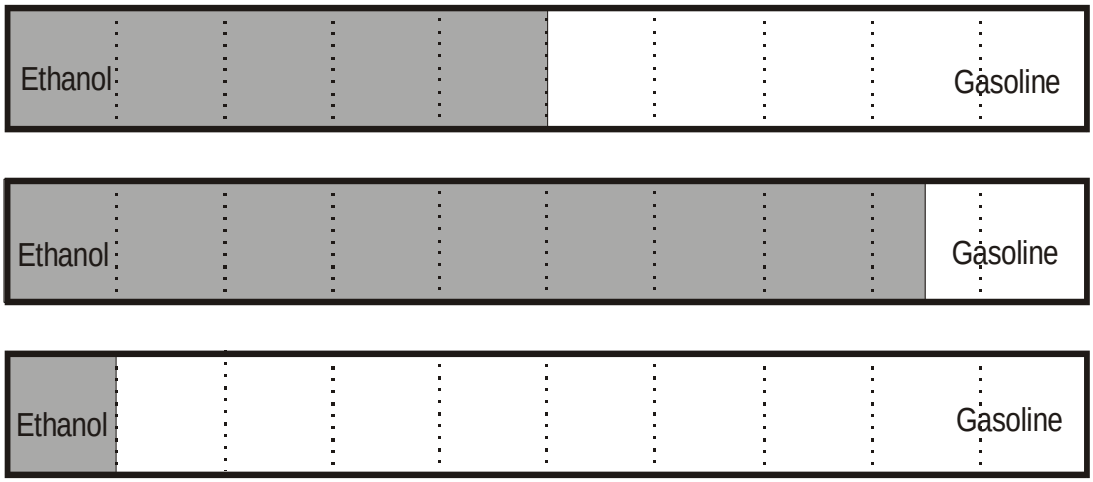



2. **If the average corn plant has two ears of corn, how many ears would there be on 18 corn plants?**



3. **If each ear of corn in the picture has 600 kernels, how many kernels are on the plant?**

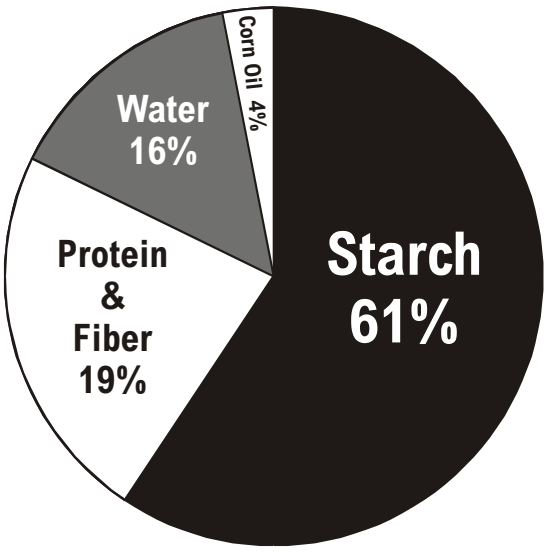
4. **E10 is a mixture of 10 percent ethanol and 90 percent gasoline. Circle the bar below that represents the E10 blend. Make an X on the bar that represents the E85 blend.**



# INTERMEDIATE Ethanol **MATH: Count the Corn**

1. **Today, ethanol is made from the starch in corn. If a bushel of corn weighs 56 pounds, how many pounds could be used to produce ethanol?**

2. **If technology and economics allow ethanol to be produced from the protein and fiber in corn, as well as the starch, what percentage of a corn plant will be used to produce ethanol?**



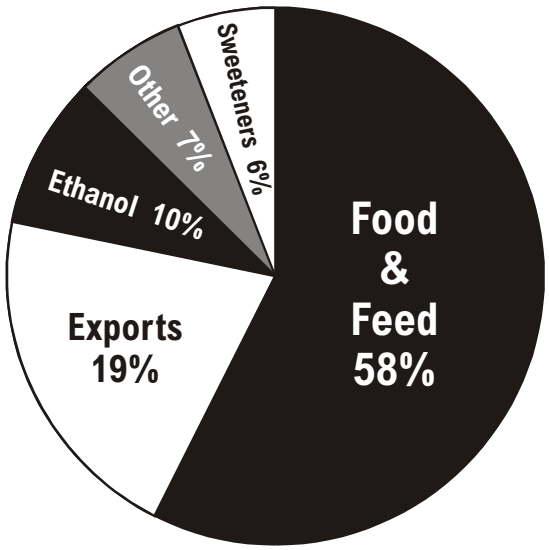

**Components of Corn**

3. **If the U.S. produced 9 million bushels of corn last year on 69,000 acres of land, what was the average yield per acre?**

4. **If the U.S. produced 9 million bushels of corn last year and the average bushel of corn weighs 56 pounds, what is the total weight of the corn produced?**

5. **If 10 percent of total corn production is for ethanol, how many pounds of a 56-pound bushel is made into ethanol today?**

6. **If the percentage of ethanol production doubles in the next five years and exports, sweeteners and other uses remain the same, what will the percentage be for food and feed production?**

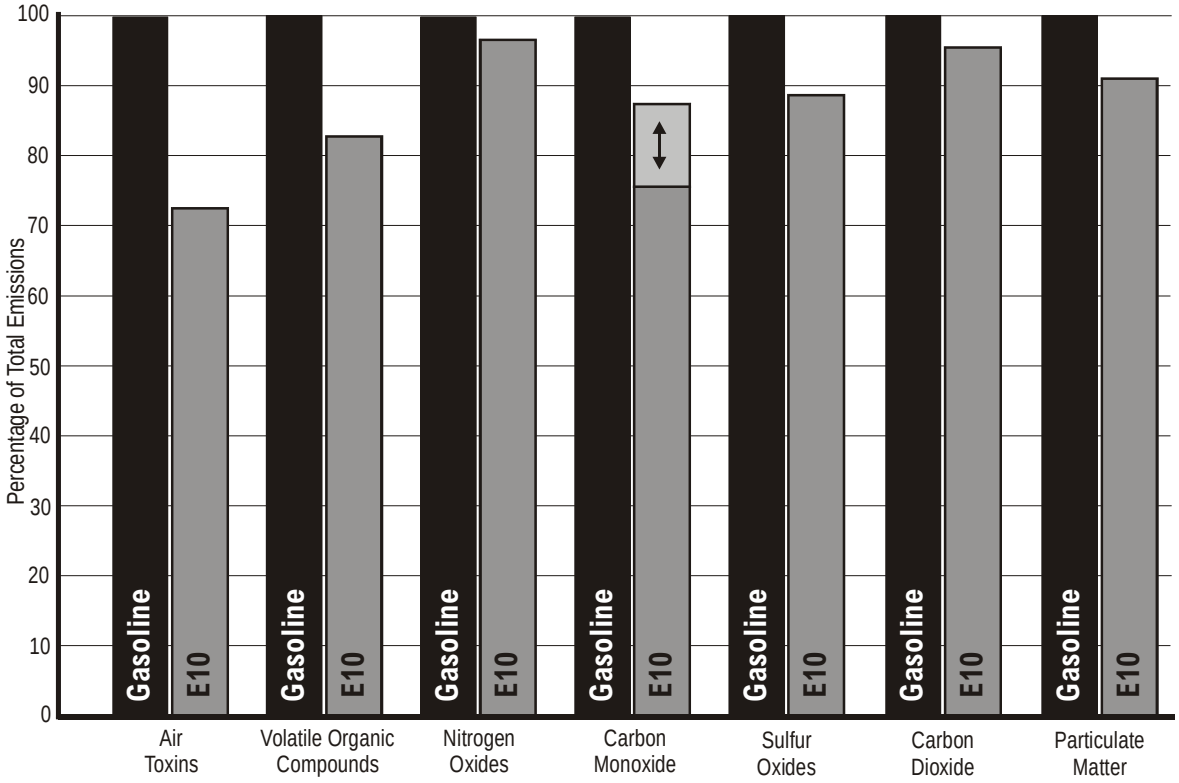



**Corn Production**

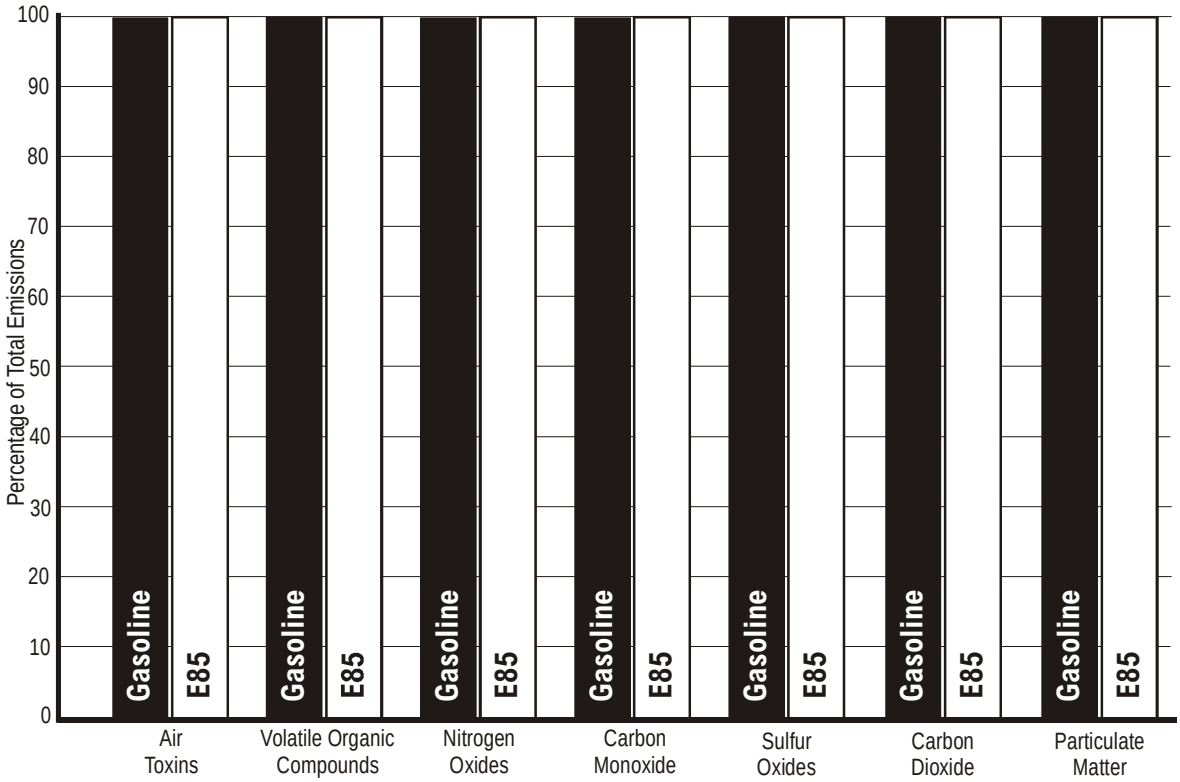
# SECONDARY Ethanol **MATH: Graphing Emissions**

**DIRECTIONS:** The emission comparisons for gasoline and E10 are provided in the first graph. Research the emission comparisons for gasoline and E85 and complete the second graph, then write a paragraph on the back of the page comparing E10 and E85 emissions.

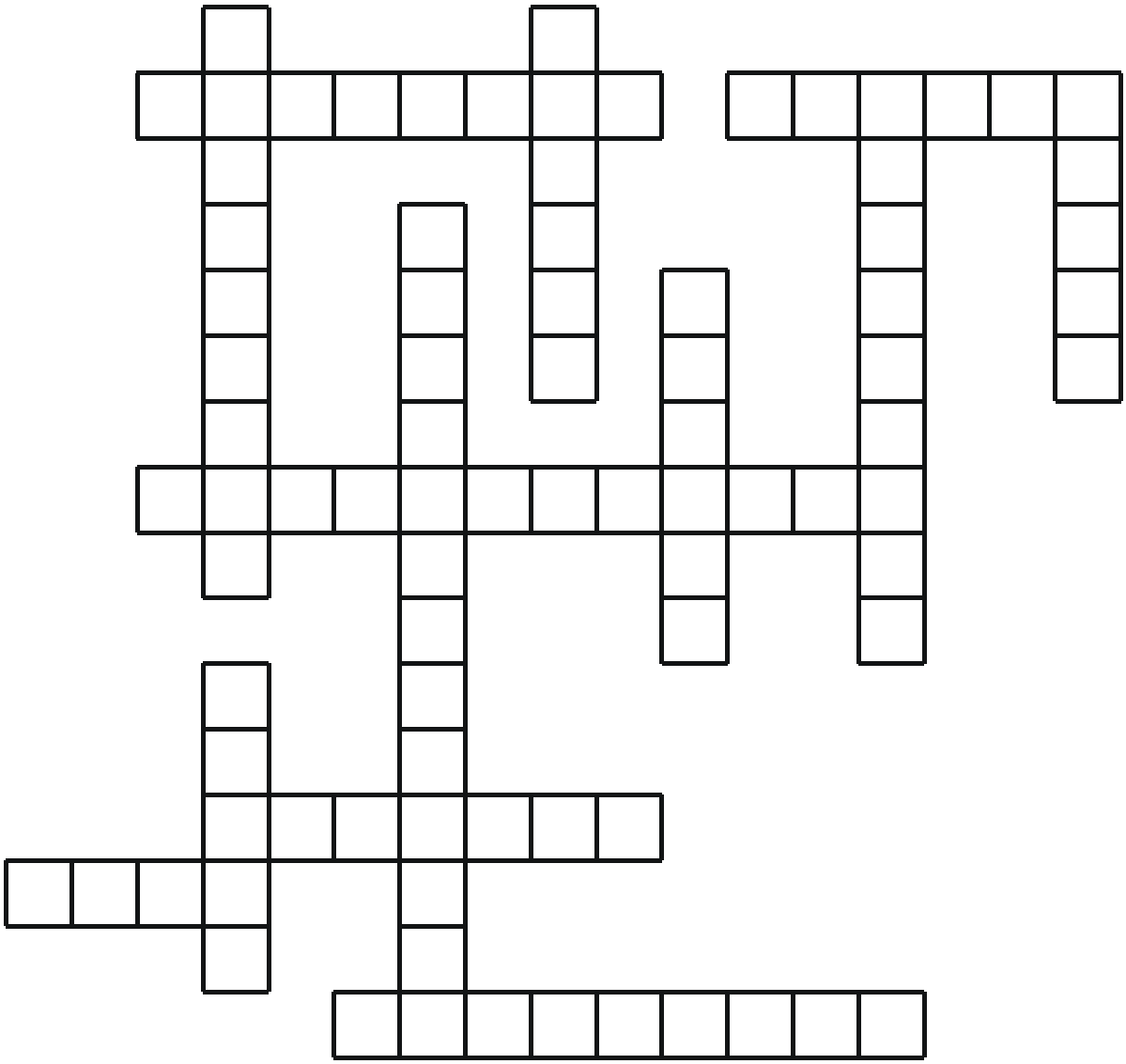
## COMPARISON OF EMISSIONS OF GASOLINE AND E10




## COMPARISON OF EMISSIONS OF GASOLINE AND E85



# Elementary Crossword



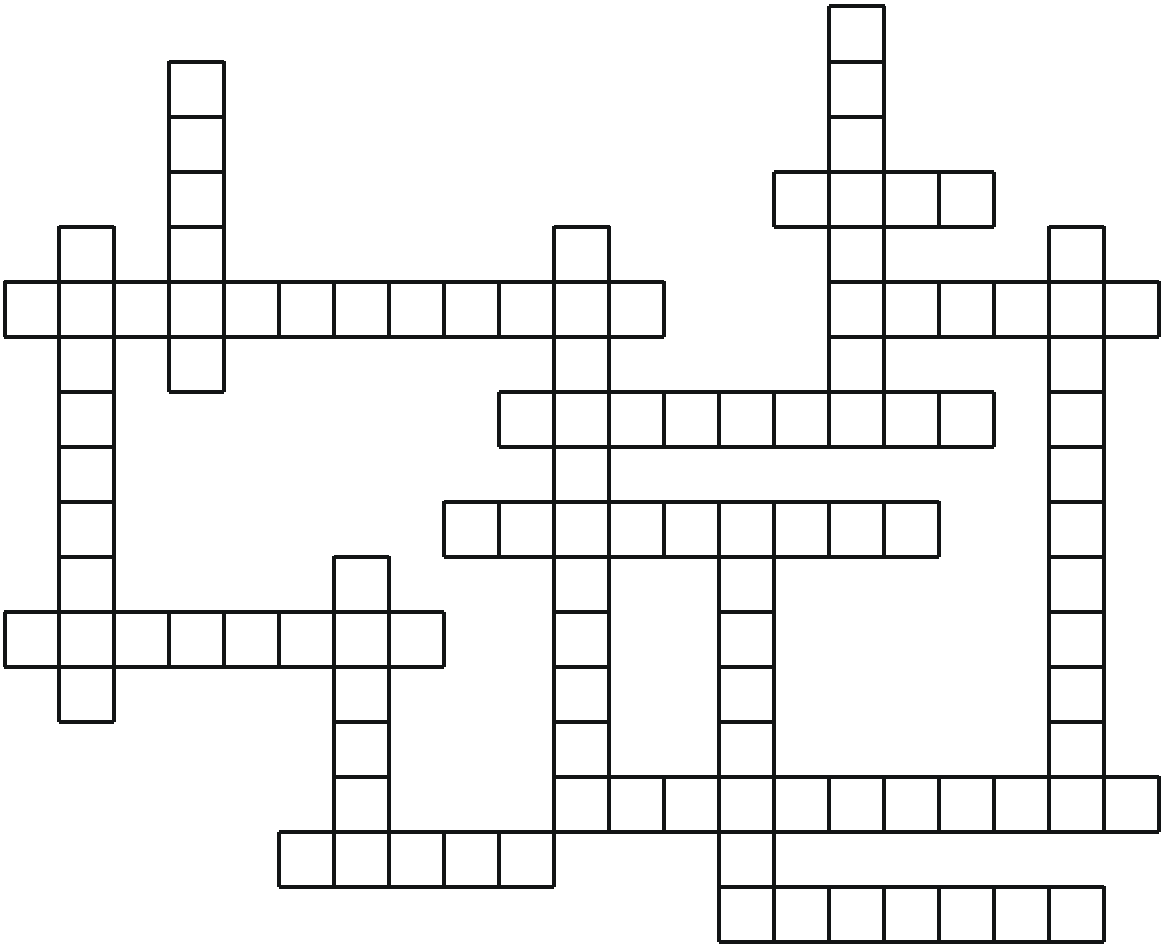
**Across**

3. made in the U.S.
4. buy from another country
9. takes millions of years to form
11. alcohol fuel made from corn
12. an energy-rich grass
13. can be made in a short time

**Down**

1. dirty emissions
2. fuel used by trucks
5. fossil fuel used to make gasoline
6. dangerous to handle
7. breaks down quickly
8. plants turn light into these
10. mixture

# Intermediate Crossword



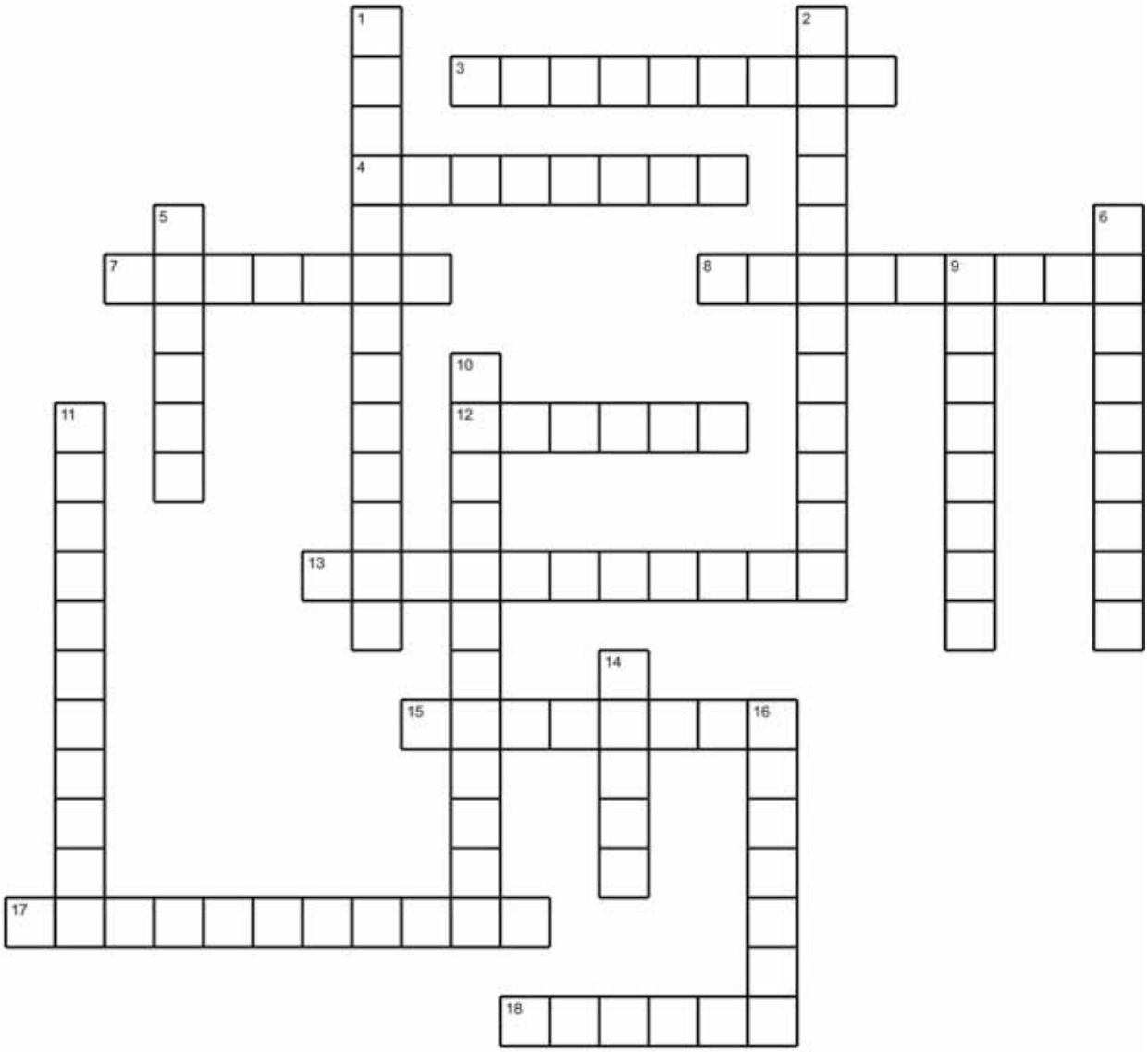
**Across**

3. inventor of Model T
7. takes millions of years to form
8. buy from other countries
9. fossil fuel used to make gasoline
10. can be replenished quickly
13. made in the U.S.
14. the natural world around us
15. mixture
16. alcohol fuel made from plants

**Down**

1. fuel used by most cars
2. sell to other countries
4. emissions that hurt the air or water
5. high ethanol blends are considered this kind of fuel.
6. the era when alcohol was banned
11. ethanol is considered this in low-percentage blends
12. fuel used by most trucks

# Secondary Crossword



**Across**

3. emissions that damage the environment
4. made in the U.S.
7. slow or cut off supplies of a commodity
8. can be replenished quickly
12. sell to other countries
13. high ethanol blends are considered this kind of fuel
15. fuel used by most cars
17. the natural world around us
18. fuel used by most trucks

**Down**

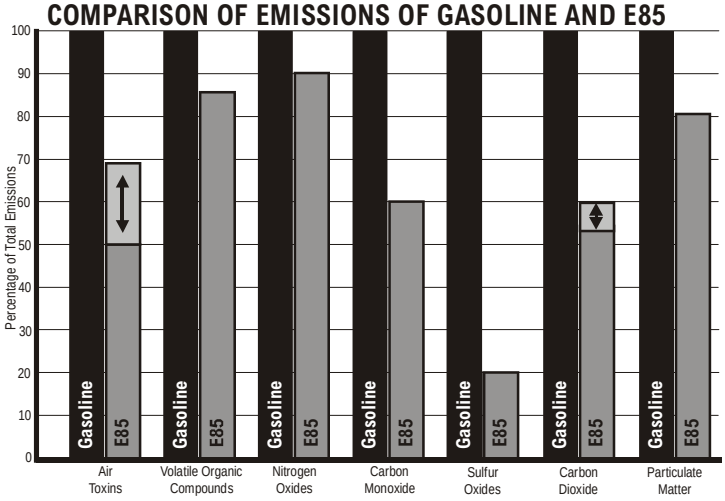
1. broken down quickly in nature
2. takes millions of years to form
5. buy from other countries
6. fossil fuel used to make gasoline
9. ethanol is considered this in low-percentage blends
10. process by which ethanol is made
11. the era when alcohol was banned
14. mixture
16. alcohol fuel made from plants

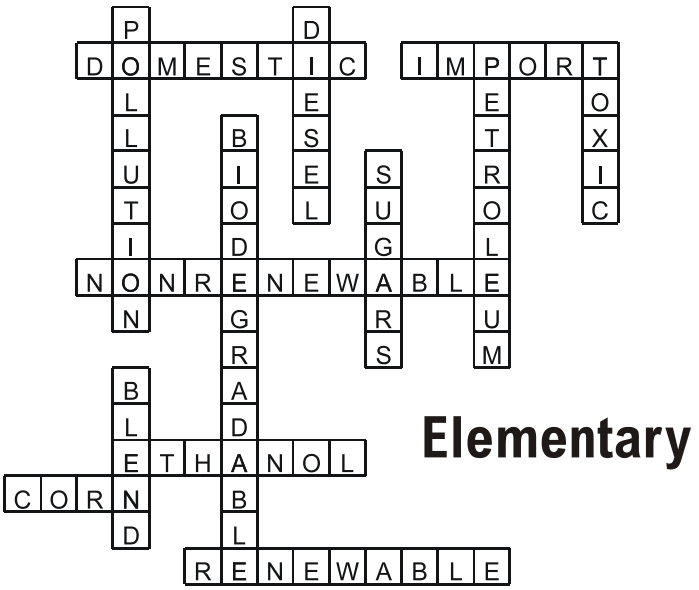
# ANSWER KEY

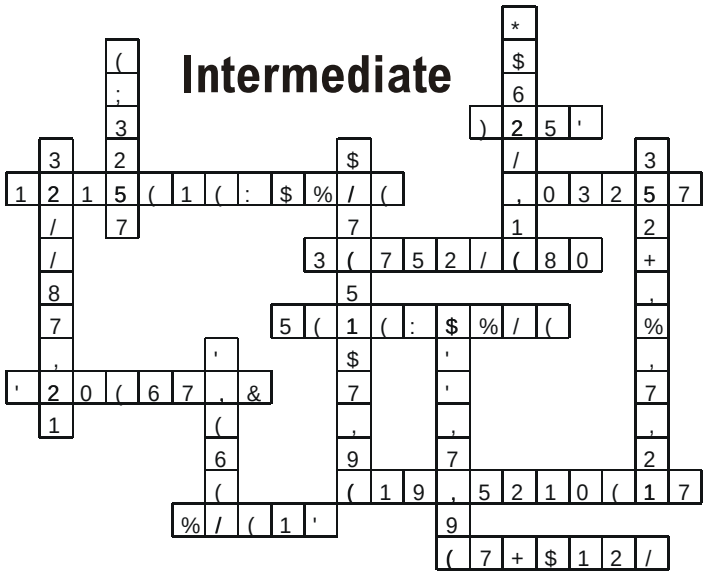
Elementary Math: 1. 56 lbs. 2. 36 ears 3. 1,200 kernels 4. Circle bottom; X middle

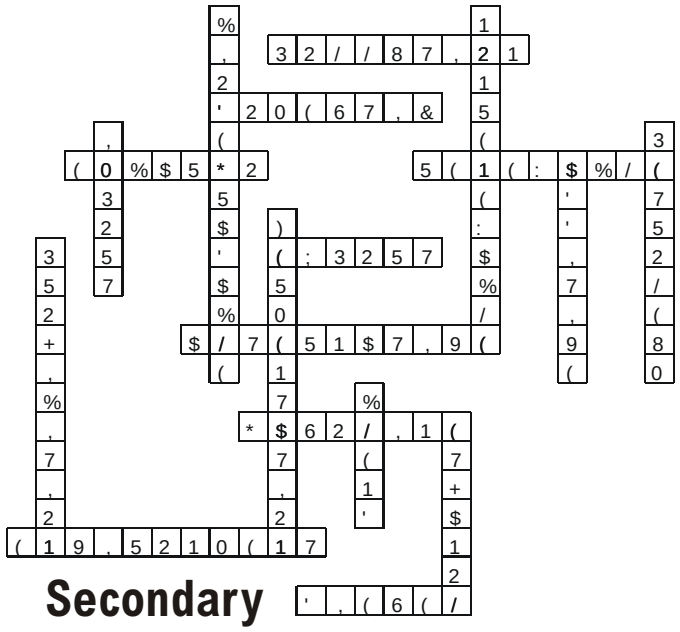
Intermediate Math: 1. 34.16 lbs. 2. 80% 3. 130.4 bushels/acre 4. 504 million lbs.
5. 5.6 lbs. 6. 48%

Secondary Math:



# ETHANOL
## Evaluation Form

**State: _____ Grade Level: _____ Number of Students: _____**

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

How would you rate the activity overall (excellent, good, fair, poor)?

How would your students rate the activity overall (excellent, good, fair, poor)?

What would make the activity more useful to you?

Other Comments:

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

# NEED National Sponsors and Partners

American Association of Blacks in Energy
American Electric Power
American Electric Power Foundation
American Petroleum Institute
American Solar Energy Society
American Wind Energy Association
Aramco Services Company
Armstrong Energy Corporation
Association of Desk & Derrick Clubs
All Wild About Kentucky's Environment
Robert L. Bayless, Producer, LLC
BP Foundation
BP
BP Alaska
BP Solar
Bureau of Land Management–
U.S. Department of the Interior
C&E Operators
Cape and Islands Self Reliance
Cape Cod Cooperative Extension
Cape Light Compact–Massachusetts
L.J. and Wilma Carr
Center for the Advancement of Process
Technology–College of the Mainland–TX
Chesapeake Public Schools–VA
Chesterfield County Public Schools–VA
Chevron
Chevron Energy Solutions
City of Melrose–MA
Colorado Energy Science Center
ComEd
ConEd Solutions
ConocoPhillips
CPS Energy
Cypress-Fairbanks Independent School
District–TX
Dart Foundation
Desk and Derrick of Roswell, NM
Devon Energy
Dominion
Dominion Foundation
Duke Energy Kentucky
Duke Energy Indiana
Duke Energy North Carolina
Duke Energy South Carolina
East Kentucky Power
EnCana
Energy Information Administration–
U.S. Department of Energy
Energy Training Solutions
Energy and Mineral Law Foundation
Energy Training Solutions
Equitable Resources
Escambia County School District–FL
FPL Energy Encounter–FL
First Roswell Company
Florida Department of Environmental
Protection
Foundation for Environmental Education
Robert Gorham
Guam Energy Office
Halliburton Foundation
Gerald Harrington, Geologist
Houston Museum of Natural Science
Hydropower Research Foundation
Illinois Clean Energy Community Foundation
Illinois Department of Commerce and
Economic Opportunity
Independent Petroleum Association of
America
Independent Petroleum Association of New
Mexico
Indiana Office of Energy and Defense
Development
Interstate Renewable Energy Council
Iowa Energy Center
Kentucky Clean Fuels Coalition
Kentucky Office of Energy Policy
Kentucky Oil and Gas Association
Kentucky Propane Education and Research
Council
Kentucky River Properties LLC
Keyspan
KidWind
Llano Land and Exploration
Long Island Power Authority–NY
Maine Energy Education Project
Maine Public Service Company
Marianas Islands Energy Office
Maryland Energy Administration
Massachusetts Division of Energy
Resources
Michigan Energy Office
Michigan Oil and Gas Producers Education
Foundation
Minerals Management Service–
U.S. Department of the Interior
Mississippi Development Authority–Energy
Division
Montana Energy Education Council
Narragansett Electric–
A National Grid Company
NASA Educator Resource Center–WV
National Alternative Fuels Training Center–
West Virginia University
National Association of State Energy
Officials
National Association of State Universities
and Land Grant Colleges
National Hydropower Association
National Ocean Industries Association
National Renewable Energy Laboratory
New Jersey Department of Environmental
Protection
New York Power Authority
North Carolina Department of
Administration–State Energy Office
Nebraska Public Power District
New Mexico Oil Corporation
New Mexico Landman's Association
New York State Energy Research and
Development Authority
Offshore Energy Center/Ocean Star/
OEC Society
Offshore Technology Conference
Ohio Energy Project
Pacific Gas and Electric Company
Petroleum Equipment Suppliers
Association
Poudre School District–CO
Puerto Rico Energy Affairs Administration
Puget Sound Energy
Roswell Desk and Derrick Club
Roswell Geological Society
Rhode Island State Energy Office
Sacramento Municipal Utility District
Saudi Aramco
Schlumberger
Sentech, Inc.
Shell Exploration and Production
Snohomish County Public Utility District–
WA
Society of Petroleum Engineers
David Sorenson
Southwest Gas
Spring Branch Independent School
District–TX
Tennessee Department of Economic and
Community Development–Energy Division
Toyota
TransOptions, Inc.
TXU Energy
University of Nevada–Las Vegas, NV
United Illuminating Company
U.S. Environmental Protection Agency
U.S. Department of Energy
U.S. Department of Energy–Hydrogen,
Fuel Cells and Infrastructure Technologies
Virgin Islands Energy Office
Virginia Department of Mines, Minerals
and Energy
Virginia Department of Education
Virginia General Assembly
Wake County Public Schools–NC
Western Kentucky Science Alliance
W. Plack Carr Company
Yates Petroleum