Ethanol-Blended Fuels

A Study Guide and Overview of:

- Ethanol's History in the U.S. and Worldwide
- Ethanol Science and Technology
- Engine Performance
- Environmental Effects
- Economics and Energy Security

The Curriculum

This curriculum on ethanol and its use as a fuel was developed by the Clean Fuels Development Coalition in cooperation with the Nebraska Ethanol Board. This material was developed in response to the need for instructional materials on ethanol and its effects on vehicle performance, the environment, and the economy.

As a renewable alternative energy source made from grain and other biomass resources, ethanol study serves as an excellent learning opportunity for students to use in issue clarification and problem-solving activities. Ethanol illustrates that science and technology can provide us with new products and new uses for products. This curriculum provides teachers and students with the basics needed to understand the use and production of ethanol. After sorting out the facts, students can reach their own conclusions about using ethanol as a fuel in their vehicles–and if it is in the interests of the state and nation to do so.

The curriculum begins with "Module 1: Introduction to Ethanol." This module contains basic challenges, history, and reasons for alternative fuels, especially ethanol. This curriculum may be taught as a unit or topics may be integrated into other units of instruction. It is suggested that Module 1 be used to lay the groundwork for any number of the remaining modules.

Goals and Objectives

This curriculum was written to assist those teaching in grades nine and up. It is applicable for use in science, social studies, mathematics, statistics, vocational agriculture, driver education, tech prep, industrial education, automotive technology, and language arts courses. After completion of this curriculum, students will be able to:

a. Identify the process of converting grain to ethanol
b. Identify the variety of biomass/cellulose sources from which ethanol can be produced
c. Identify the energy relationships between science, society, and agriculture
d. Determine benefits and concerns of using ethanol in motor fuel
e. Develop skills in problem solving and personal decision making

Additional Copies

Additional copies are available by contacting the Nebraska Ethanol Board: P.O. 94922, Lincoln, NE 68509-4922, (402) 471-2941, or by downloading an Adobe Acrobat PDF file at: **www.ne-ethanol.org** or at **www.cleanfuelsdc.org**.

Acknowledgements
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Nebraska Ethanol Board

CFDC CLEAN FUELS DEVELOPMENT COALITION

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

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Module 1 Introduction to Ethanol

The Challenges

The world in the 21st century presents many critical challenges. One of the most important challenges is the environment. As population increases and the standard of living improves, there is a growing concern that there will be a shortage of energy to heat our homes and power the vehicles on which we so heavily depend. We must also remember the need for clean air, clean water, cleaner burning fuels, and biodegradable, renewable materials.

Advances in technology have allowed development of alternative energy sources. Alternative energy sources are renewable, cleaner, and more dependable than traditional fuels.

What is Ethanol?

Ethanol is an alternative energy source. It is an alcohol made by fermenting corn or other similar biomass material. There are three primary ways that ethanol can be used as a transportation fuel:

1. As a blend of 10 percent ethanol with 90 percent unleaded gasoline called "E-10 Unleaded";
2. As a component of reformulated gasoline,both directly and/or as ethyl tertiary butyl ether (ETBE); or
3. As a primary fuel with 85 parts of ethanol blended with 15 parts of unleaded gasoline called "E-85."

When mixed with unleaded gasoline, ethanol increases octane levels, decreases exhaust emissions, and extends the supply of gasoline.

Ethanol in its liquid form, called *ethyl alcohol*, can be used as a fuel when blended with gasoline or in its original state. It can also be used as a raw material in various industrial processes. Ethanol is made by fermenting almost any material that contains *starch or sugar*. Grains such as corn and sorghum are good sources; but potatoes, sugar cane, Jerusalem artichokes, and other farm plants and plant wastes are also suitable.

About 2 billion gallons of ethanol are produced annually in the United States. Each bushel of corn processed yields 2.5 to 2.7 gallons of ethanol along with several valuable co-products. The first ethanol-blended gasoline in the 1970s was 10 percent ethanol by volume (E-10), while a blend of 85 percent by volume (E-85) was introduced in the mid 1990s.

History

In ancient times ethanol was known as an intoxicating drink. In the United States, ethanol is produced mainly by the fermentation of corn. It is the same alcohol used in beverage alcohol but meets fuel-grade standards. Ethanol that is to be used as a fuel is "denatured" by adding a small amount of gasoline to it. This makes it unfit for drinking.

During the late 1800s, ethanol was used in the United States for lamp fuel and sales exceeded

25 million gallons per year. At the request of large oil companies, the government placed a tax on ethanol during the Civil War. This tax almost destroyed the ethanol industry. In 1906 the tax was lifted and alcohol fuel did well until competition from oil companies greatly reduced its use.

The first large scale use of ethanol as a fuel occurred during the early 1900s when petroleum supplies in Europe were short. In America, Henry Ford's Model T and other early 1920s automobiles were originally designed to run on alcohol fuels. Germany and the U.S. both relied on ethanol to power vehicles for their armies during World War II. After World War II, oil prices decreased which caused the use of ethanol to decrease as well. The limited use of ethanol continued until the oil crisis in the early 1970s.

The Oil Crisis of the 1970s

The use of ethanol as a fuel has grown since the late 1970s. It was first used as a gasoline extender because of oil shortages. In 1973, the Organization of Petroleum Exporting Countries (OPEC) caused gasoline shortages by increasing prices and blocking shipments of crude oil to the United States. The OPEC action called attention to the fact that the United States was extremely dependent on foreign oil. The focus shifted once again to alternative fuels such as ethanol. At that time gasoline containing ethanol was called "gasohol". Later, when gasoline was more plentiful, ethanol-blended gasoline was introduced to increase the octane rating and the name "gasohol" was dropped in favor of names reflecting the higher octane levels. "E-10 Unleaded" and "super unleaded" are examples of names used today.

Clean Air Benefits

Ethanol, when used as a gasoline component, improves combustion–helping the fuel burn more completely. Ethanol blends also reduce carbon monoxide emissions. Use of ethanol is beneficial in areas of the U.S. that are considered to exceed Environmental Protection Agency air quality standards during the winter months. Some studies have indicated that, when used in a correctly formulated fuel, ethanol can also reduce vehicle emissions which contribute to the formation of smog.

The Advantages of Ethanol

More recently, the country has focused attention on other advantages of ethanol. One of these advantages is ethanol's ability to provide octane while replacing other environmentally harmful components in gasoline. Other studies suggest that using ethanol can slow global warming. And because ethanol is produced here in the United States, it reduces imports by replacing imported gasoline and crude oil. Reducing gasoline and crude oil imports reduces American dependence on foreign oil. According to a recent poll conducted by Research Strategy Management, 75 percent of American voters believe the country needs to do something to reduce its dependence on foreign oil.

Today, ethanol is widely used and available in most areas of the United States. Ethanol is contained in over 15 percent of all gasoline sold in the United States. Ethanol-blended gasoline is, or has been, marketed by such companies as Exxon, Sunoco, Texaco, BP-Amoco, Mobil, ARCO, Super-America, Getty, Chevron, Union, Shell, and Phillips, as well as numerous independent marketers. Since 1978, American consumers have driven more than two trillion miles (80,000 trips around the world) on ethanol-blended gasoline.

New Vehicle Technology

The 1990s saw the introduction and operation of *variable fuel vehicles*. These vehicles are capable of operating on unleaded fuel with ethanol mixtures up to 85 percent without having to make any engine adjustments. These vehicles were introduced in 1992 and have been used extensively in federal and state fleets and in some city governments. They became commercially available shortly thereafter.

E-85 vehicles have been designed for versatility. The key component in a variable fuel vehicle is a sensor that determines the percentage of ethanol in the fuel. With the help of a computer, the vehicle automatically adjusts for best performance and emissions. Chrysler began offering E-85 minivans in the 1998 model year and Ford continues to offer the Taurus and added Windstar and Ranger to the E-85 flexible fuel vehicles in the 1999 model year. Ford, GMC, Chevrolet and Daimler-Chrysler are now offering E-85 variable fuel vehicles.

Why Ethanol Now?

Ethanol use and production has increased considerably during the 1980s and 1990s. Growth in use of "E-10 Unleaded" gasoline has taken place because the fuel performs well in automotive engines and is competitively priced with "conventional" gasoline. Other reasons for increased production and use of ethanol, especially in the Midwest include:

1. Ethanol reduces the country's dependence on imported oil, lowering the trade deficit and ensuring a dependable source of fuel should foreign supplies be interrupted.

2. Farmers see an increased demand for grain which helps to stabilize prices.

3. The quality of the environment improves. Carbon monoxide emissions are reduced, and lead and other carcinogens (cancer causing agents) are removed from gasoline.

4. Car owners benefit from increased octane in gasoline, which reduces engine "knock" or "pinging." Ethanol-blended fuels also absorb moisture and clean the fuel system.

Some have questioned the role of ethanol as an alternate fuel and the use of government incentives to help ethanol gain a toehold in an industry dominated by large petroleum interests. These and other pertinent issues, such as those related to engine performance, are discussed elsewhere in this curriculum.

Ethanol Around the World

Other countries are either producing and using ethanol in large quantities or are providing incentives to expand ethanol production and use. Brazil and Sweden are using large quantities of ethanol as a fuel. Some Canadian provinces promote ethanol use as a fuel by offering subsidies of up to 45 cents per gallon of ethanol.

India is initiating the use of ethanol as an automotive fuel. A move has been made by distilleries in India to use surplus alcohol as a blending agent or an oxygenate in gasoline. Based on experiments by the Indian Institute of Petroleum, a 10 percent ethanol blend with gasoline and a 15 percent ethanol blend with diesel are being considered for use in vehicles in at least one state.

In France, ethanol is produced from grapes that are of insufficient quality for wine production.

Prompted by the increase in oil prices in the 1970s, Brazil introduced a program to produce ethanol for use in automobiles in order to reduce oil imports. Brazilian ethanol is made mainly from sugar cane. Pure ethanol (100% ethanol) is used in approximately 40 percent of the cars in Brazil. The remaining vehicles use blends of 24 percent ethanol with 76 percent gasoline. Brazil consumes nearly 4 billion gallons of ethanol annually. In addition to consumption, Brazil also exports ethanol to other countries.

Sweden has used ethanol in chemical production for many years. As a result, Sweden's crude oil consumption has been cut in half since 1980. During the same time period, the use of gasoline and diesel for transportation has also increased. Emissions have been reduced by placing catalytic converters in vehicle exhaust systems which decrease carbon monoxide, hydrocarbon, and nitrogen oxide emissions.

To address global warming concerns, the amount of carbon dioxide produced while burning fossil fuels must be reduced. Ethanol-blended gasoline and ethanol-blended diesel are being considered as viable alternatives to further lower emission levels.

The Future of Ethanol

Two specific pieces of federal legislation – the Clean Air Act Amendments of 1990 and the Energy Policy Act of 1992 – mandated the phased-in adoption of cleaner-burning fuels and vehicles. These federal laws required that state, municipal, and private fleets meet stricter emission guidelines. This is being accomplished by replacing existing vehicles with new technology such as like the E-85 vehicles. The Energy Policy Act required that 70 percent of all new fleet vehicle purchases meet the new standards by 2000.

Auto manufacturers are responding to the technical challenges of meeting the new standards. Since 1996, new model vehicles have on-board diagnostic monitoring systems capable of monitoring tailpipe and evaporative emissions. New computer technology makes this possible. New E-85 vehicle models are being produced each year.

Programs are also in place to reduce emission levels by updating engine technology in mass transit city buses and over-the-road trucks. Buses in several cities are powered by converted diesel engines that burn 100 percent ethanol. If half of the nation's buses switched to ethanol fuels, it would create a new market for 100 million bushels of corn per year. "E-Diesel," a blend of ethanol and diesel fuel, is being introduced for use in large trucks, tractors and construction equipment.

Ethyl tertiary butyl ether (ETBE) is being tested and used as a motor fuel additive in reformulated gasoline. Ethanol and ETBE blends in gasoline are approved by the Environmental Protection Agency (EPA) for mandated winter-time oxygenated fuel programs where the objective is to lower vehicle carbon monoxide emissions from vehicles. Expanded use of ETBE could provide another 200 million bushel market for U.S. corn growers.

The U.S. Congress is also considering a national renewable fuels requirement that would increase the use of ethanol to five billion gallons per year by the end of the decade. This Renewable Fuel Standard would serve to expand the production and use of ethanol nationally and would provide the impetus for producing ethanol from a wide variety of renewable feed stocks.

Module 1

Study Questions

True / False:

Place a "T" in the blank for each true statement. If the statement is false, write the correct word in the blank that replaces the underlined word to make the statement true.

_______________1. Ethanol is produced by a process called <u>fermentation</u>.
_______________2. Ethanol is made from any <u>starch</u> or <u>sugar</u> based material.
_______________3. <u>Sorghum</u> is the main product used to make ethanol in the U.S.
_______________4. Each bushel of corn produces up to <u>1</u> gallon of ethanol.
_______________5. Ethanol is used to <u>reduce</u> automobile emission levels.
_______________6. Ethanol is used to <u>reduce</u> the octane level of gasoline which reduces engine pinging.
_______________7. Ethanol that is to be used as a fuel is <u>denatured</u> to make it unfit for human consumption.
_______________8. During the gas crisis in the 1970s, <u>ethanol</u> was used to increase fuel supplies.
_______________9. Currently, ethanol blended with gasoline makes up over <u>15 percent</u> of all gasoline sold in the United States.
______________10. Variable fuel vehicles will operate properly on as much as <u>100 percent</u> ethanol.

Short Answer:

Answer each of the following questions.

1. State four advantages of using ethanol as a fuel.

____
____
____
____

2. Name two foreign countries that use ethanol in large quantities.

____
____
____

3. List the three main ways ethanol is used as a fuel.

____
____
____
____

Projects

1. Using a map of your community:
   a. Mark the location of gasoline service stations.
   b. Circle service stations that sell E-10 Unleaded blends.
   c. Underline those stations that do not.
   d. Place a star by any service stations that sell the E-85 blend.
   e. Record the prices and octane ratings of fuel at each service station. Determine the average price.
   f. Determine the reason for price differences if a difference exists.

2. Develop a science fair project on some aspect of alternative energy, ethanol, or air quality.

3. Construct a line graph showing the amount of ethanol produced in your state.

4. Make a list of objects at home or at school that use energy that is purchased. How is each object powered? What fuel is burned to produce the power?

5. Conduct an ethanol survey in your community. The users' perceptions of a new product determines its success or failure. Often a new product fails because it is misunderstood or because very few people learn about it. Sometimes inaccurate information is spread by those wanting to keep new products from replacing what is currently in use. For many other reasons, some products become popular very quickly. In this activity, you will use language and interviewing skills, record and analyze data, and report results to determine the perceptions of ethanol by asking family, friends, and neighbors and to learn about the use of ethanol blends in their vehicles.

   Procedure:
   Design a questionnaire similar to the one on the next page and make enough copies so one can be used for each interview. Once you have collected and tabulated the data, compute the statistics (averages, percentages, etc.), and report the results. Identify similarities and differences from the survey results with information presented in this material.

Sample Questionnaire

Read these questions aloud to family, friends, and neighbors and record their responses. Use a separate sheet for each interview.

Do you buy gasoline? Yes_____ No_____
If yes, does it contain ethanol? Yes_____ No_____ Don't Know_____
If yes, why do you buy gas containing ethanol? (Check all that apply)
____Availability
____Price
____Performance in my car
____Helps farmers
____Reduces America's dependence on imported oil
____Other ____

What is used to make ethanol? (Check all that apply)
_____Coal
_____Forest products
_____Corn
_____Sugar cane
_____Other ___________________________________
(If a person doesn't answer "corn," be sure to mention that most ethanol we use is made from corn.)

Do you agree or disagree with these statements? (Circle the appropriate answer.)

Agree	Disagree	An engine using ethanol blended with gasoline decreases spark knock/pinging.
Agree	Disagree	An engine using ethanol blends causes less air pollution.
Agree	Disagree	An engine using ethanol blends decreases engine deposits as compared to using straight gasoline.
Agree	Disagree	Using ethanol blends for a long time will harm an automotive engine.
Agree	Disagree	An engine using ethanol blends starts easier.
Agree	Disagree	An engine using ethanol blends has better acceleration.

Module 2 Ethanol Science & Technology

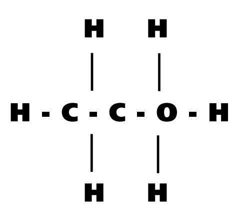
Chemistry

Ethanol is a colorless, volatile, flammable liquid that is the intoxicating agent in liquors and is also used as a fuel or solvent. Ethanol is also called *ethyl alcohol* or *grain alcohol*.

Ethanol is the most important member of a large group of organic compounds that are called alcohols. Alcohol is an organic compound that has one or more hydroxyl (OH) groups attached to a carbon atom. Alcohol is shown as: C-O-H or C-OH.

What is attached to the carbon at the three remaining bonds or locations determines the particular kind of alcohol. Ethanol has hydrogen present at two sites while the remaining site holds another carbon atom. This carbon atom, in turn, holds three more hydrogen atoms.

It may be shown as:



or CH_3CH_2OH

In its pure form, ethanol is a colorless clear liquid with a mild characteristic odor which boils at 78º C (172º F) and freezes at -112º C (-170º F). Ethanol has no basic or acidic properties. When burned, ethanol produces a pale blue flame with no residue and considerable energy, making it an ideal fuel.

Ethanol mixes readily with water and with most organic solvents. It is also useful as a solvent and as an ingredient when making many other substances including perfumes, paints, lacquers, and explosives.

How is Ethanol Made?

Ethanol is a product of fermentation. Fermentation is a sequence of reactions which release energy from organic molecules in the absence of oxygen. In this application of fermentation, energy is obtained when sugar is changed to ethanol and carbon dioxide.

Changing corn to ethanol by fermentation takes many steps. Starch in corn must be broken down into simple sugars before fermentation can occur. In earlier times, this was done by chewing the corn. This allowed the salivary enzymes to naturally break down the starch. Today, this is achieved by cooking the corn and adding the enzymes alpha amylase and gluco amylase. These enzymes function as catalysts to speed up the chemical changes.

Once a simple sugar is obtained, yeast is added. Yeast is a single-celled fungus that feeds on the sugar and causes the fermentation. As the fungus feeds on the sugar, it produces alcohol (ethanol) and carbon dioxide. In fermentation, the ethanol retains much of the energy that was originally in the sugar, which explains why ethanol is an excellent fuel.

Commercial Production

Most of the ethanol production in the United States is made in 60 production facilities in 20 different states. Most of these plants are located in the Midwest due to the ready availability of corn.

Changing the starch in kernels of corn to sugar and changing sugar to ethanol is a complex process requiring a mix of technologies that include microbiology, chemistry and engineering.

Ethanol is produced from corn by using one of two standard processes: wet milling or dry milling. Dry milling plants cost less to build and produce higher yields of ethanol (2.7 gallons per bushel of corn), but the value of the co-products is less.

Dry Milling

Most of the ethanol plants in the country utilize a dry milling process. The major steps of dry milling are outlined below:

1. **Milling:** After the corn (or other grain or biomass) is cleaned, it passes first through hammer mills which grind it into a fine powder.

2. **Liquefaction:** The meal is then mixed with water and an enzyme (alpha amylase), and passes through cookers where the starch is liquefied. A pH of 7 is maintained by adding sulfuric acid or sodium hydroxide. Heat is applied to enable liquefaction. Cookers with a high temperature stage (120º-150º C) and a lower temperature holding period (95º C) are used. The high temperatures reduce bacteria levels in the mash.

3. **Saccharification:** The mash from the cookers is cooled and the enzyme gluco amylase is added to convert starch molecules to fermentable sugars (dextrose).

4. **Fermentation:** Yeast is added to the mash to ferment the sugars to ethanol and carbon dioxide. Using a continuous process, the fermenting mash flows through several fermenters until the mash is fully fermented and leaves the tank. In a batch fermentation process, the mash stays in one fermenter for about 48 hours.

5. **Distillation:** The fermented mash, now called "beer," contains about 10 percent alcohol, as well as all the non-fermentable solids from the corn and the yeast cells. The mash is then pumped to the continuous flow, multi-column distillation system where the alcohol is removed from the solids and water. The alcohol leaves the top of the final column at about 96 percent strength, and the residue mash, called *stillage*, is transferred from the base of the column to the co-product processing area.

6. **Dehydration:** The alcohol then passes through a dehydration system where the remaining water is removed. Most plants use a molecular sieve to capture the last bit of water in the ethanol. The alcohol at this stage is called *anhydrous* (pure, without water) ethanol and is approximately 200 proof.

7. **Denaturing:** Ethanol that is used for fuel is then denatured with a small amount (2-5%) of some product, like gasoline, to make it unfit for human consumption.

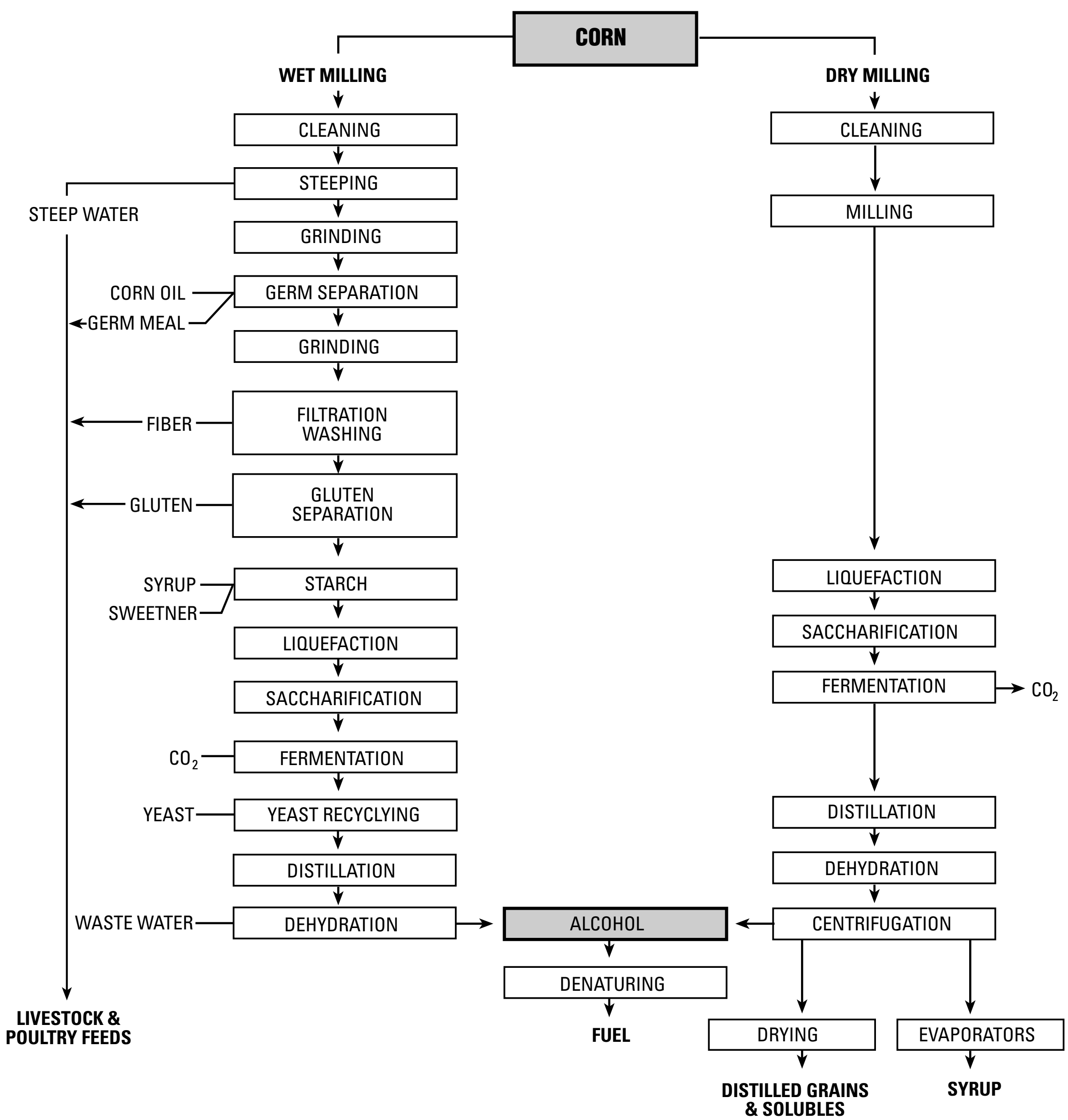
Wet Milling

The wet-milling operation is more elaborate because the grain must be separated into its components. After milling, the corn is heated in a solution of water and sulfur dioxide for 24 to 48 hours to loosen the germ and the hull fiber. The germ is then removed from the kernel, and corn oil is extracted from the germ. The remaining germ meal is added to the hulls and fiber to form corn gluten feed. A high-protein portion of the kernel called gluten is separated and becomes corn gluten meal which is used for animal feed. In wet milling, only the starch is fermented, unlike dry milling, when the entire mash is fermented.

Technology

The production of ethanol is an example of how science, technology, agriculture, and allied industries must work in harmony to change a farm product into a fuel. Ethanol plants receive the large quantities of corn they need by truck, rail, or barge. The corn is cleaned, ground, and blown into large tanks where it is mixed into a

WET & DRY MILLING EXPLAINED



slurry of cornmeal and water. Enzymes are added and exact acidity levels and temperatures are maintained, causing the starch in the corn to break down–first into complex sugars and then into simple sugars.

New technologies have changed the fermentation process. In the beginning it took several days for the yeast to work in each batch. A new, faster and less costly method of continuous fermentation has been developed.

Plant scientists and geneticists are also involved. They have been successful in developing strains of yeast that can convert greater percentages of starch to ethanol. Scientists are also developing enzymes that will convert the complex sugars in biomass materials to ethanol. Cornstalks, wheat and rice straw, forestry wastes and switchgrass all show promise as future sources of ethanol.

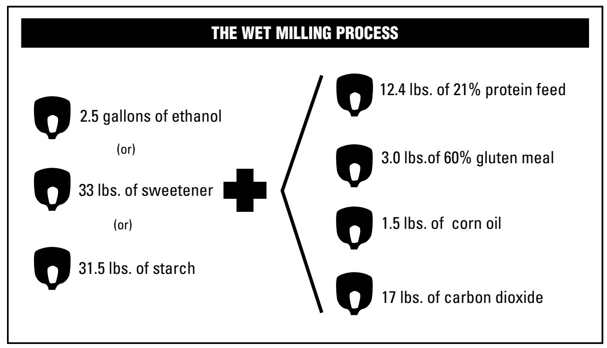
After fermentation, the ethanol is removed from the mix of ethanol, water, yeast, and residue. It is then purified through distillation. The distilling process takes advantage of the low boiling point of ethanol (78° C). When the temperature of the mix is increased slightly beyond the boiling point, the ethanol evaporates. It is then captured as a gas vapor and condensed back to a liquid. Other chemicals are added and molecular sieves are used to purify the ethanol.

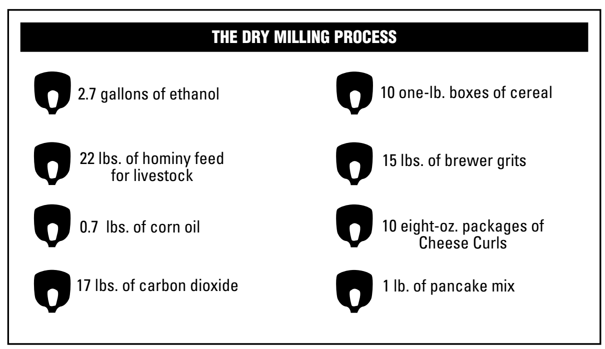
Advances in technology are being made to further reduce the amount of energy needed for distillation. Technologies expected to be adopted include: steeping with gas injection of sulfur dioxide, membrane saccharification, high-tolerance yeast, yeast immobilization, bacterial fermentation, and pervaporation. These advances are helping to reduce the costs and make ethanol production even more economical.

What's in a Bushel of Corn?

Each bushel of corn can produce 2.5 to 2.7 gallons of ethanol, depending on which milling process is used. Only the starch from the corn is used to make ethanol. Most of the substance of the corn kernel remains, leaving the protein and valuable co-products to be used in the production of food for people, livestock feed, and various chemicals. That same bushel of

WHAT'S IN A BUSHEL OF CORN?





corn (56 lbs.) used in ethanol manufacturing can also produce the products shown in the accompanying charts. The corn oil is used in producing food for human consumption. For example, 1.5 lbs. of corn oil from a bushel of corn is equivalent to 2 lbs. of margarine. The 21 percent protein feed is used in making high protein livestock feed. The carbon dioxide is used as a refrigerant in carbonated beverages, to help vegetable crops grow more rapidly in greenhouses, and to flush oil wells. Only the starch of the corn (carbon, hydrogen, and oxygen) is used to make ethanol.

Net Energy

One of the most controversial issues relating to ethanol is the question of "net energy" of ethanol production. According to the Institute for Local Self Reliance research in 1995 and studies made by the U.S. Department of Agriculture in 1997 and Michigan State University in 2002, the production of ethanol from corn is a *positive net energy generator*. If corn farmers use state-of-the-art, energy efficient farming techniques, and ethanol plants use state-of-the-art production processes, then the amount of energy contained in a gallon of ethanol and the other co-products is more than twice the energy used to grow the corn and convert it into ethanol. These studies indicated an industry average net energy gain of 1.38 to 1. The industry-best existing production net energy ratio was 2.09 to 1. If farmers and industry were to use all the best technologies and practices the net energy ratio would be 2.51 to 1. In other words, the production of ethanol would result in more than 2-1/2 times the available energy than it took to produce it. The accompanying chart indicates the percentage gains and the actual gains in BTUs (British Thermal Units).

ENERGY GAIN IN MAKING ETHANOL FROM CORN

	BTUs	PERCENTAGE	RATIO
Industry average	30,589	38%	1.38:1
Industry best	62,857	109%	2.09:1
State-of-the-art	72,413	151%	2.51:1

According to research by the United States Department of Agriculture, each BTU used to produce 1 BTU of gasoline could be used to produce 8 BTUs of ethanol.

True / False:

Circle T for each true statement or F for each false statement.

T F 1. Ethyl alcohol is another name for ethanol.
T F 2. Ethanol is used as a fuel or solvent.
T F 3. One disadvantage of ethanol is that it is hard to mix with other chemicals.
T F 4. Ethanol burns with a yellow-red flame.
T F 5. Ethanol is made using a fermentation process.
T F 6. Fermentation releases energy by changing sugar into carbon dioxide and ethanol.
T F 7. Starch in corn must be changed to sugar before fermentation can take place.
T F 8. Yeast feeds on sugar which produces carbon dioxide and water.
T F 9. Most ethanol is produced in the southern United States.
T F 10. It takes more energy to produce one gallon of ethanol than the energy in one gallon of ethanol.
T F 11. In the wet-milling process, all of the mash is fermented.
T F 12. Ethanol can also be produced from wheat straw, grapes, and other biomass sources.

Short Answer:

Fill in the blanks with the best answer to complete each statement below.

1. One bushel of corn produces up to ________ gallons of ethanol.

2. List 4 other products that are produced during the manufacturing of ethanol.
   a. ______________________________________
   b. ______________________________________
   c. ______________________________________
   d. ______________________________________

3. The part of a kernel of corn that is used to make ethanol is called ____________.

4. The ethanol manufacturing industry's average net energy gain is ________ to one.

5. Each BTU used to produce 1 BTU of gasoline could be used to produce ________ BTUs of ethanol.

6. The boiling point of ethanol is _______ ° Celsius.

Sequence:

Indicate the major steps used in a **dry milling process** by placing a number in the blank provided to indicate the proper steps in order. (The first step is number 1, etc.)

__________________ a. Liquefaction

__________________ b. Fermentation

__________________ c. Milling

__________________ d. Dehydration

__________________ e. Saccharification

__________________ f. Distillation

__________________ g. Denaturing

Complete an experiment in fermentation. This experiment will test different foods and determine how heat affects fermentation.

Fermentation Experiment

Ethanol is made from a variety of plant substances including corn, sorghum, sugar cane and wood. The process used to make ethanol is fermentation. Fermentation was discovered many years ago when bubbles were formed while making wine and beer. Studies by Louis Pasteur described fermentation as changes caused by yeast growing in the absence of air. Fermentation is an energy yielding process caused by enzymes (provided by yeast) in which fuel molecules such as glucose (sugar) are broken down in the absence of oxygen.

You will test different substances while observing for fermentation (bubbling). State your findings in the space provided.

Materials:

• 8 or more packages of yeast • ice • measuring spoons • flour • salt • sugar • vinegar • stirrers • heating element • 4 clear glasses, or half-liter beakers

Fermenting Foods

1. Empty a pkg. of yeast into each half-liter (1 pint) beaker of warm water. Stir for 1 minute.
2. Add 10 ml (2 tsp.) of flour to each beaker and stir again.
3. Add 5 ml (1 tsp.) of salt to the first beaker, 5 ml of sugar to the second beaker, 5 ml of vinegar to the third, and do nothing to the fourth. Stir again.

4. Wait 5 minutes. Record your observations.
   Beaker 1 ______________________________
   Beaker 2 ______________________________
   Beaker 3 ______________________________
   Beaker 4 ______________________________

5. Wait 15 more minutes and record your observations.
   Beaker 1 ______________________________
   Beaker 2 ______________________________
   Beaker 3 ______________________________
   Beaker 4 ______________________________

6. Let the solutions sit overnight and record your observations.
   Beaker 1______________________________
   Beaker 2______________________________
   Beaker 3______________________________
   Beaker 4______________________________

Questions:

1. What is the evidence that reactions are going on in any of the containers?
   ____
   ____
2. How are these observations related to fermentation?
   ____
   ____
3. State any conclusions about which of the substances tested was most helpful to yeast fermentation:
   ____
   ____

Changing Temperatures

1. In this exercise you will observe the effect of different temperatures of water on fermentation. The teacher will prepare boiling water for the first beaker. Fill the second beaker with warm water (just slightly warmer than skin temperature). Fill the third beaker with cold tap water. Fill the fourth beaker with ice water.

2. Empty one packet of yeast into each beaker and stir to dissolve. Add 10 ml of flour and 5 ml of sugar to each jar and stir again.

3. Wait 5 minutes. Record your observations.
   Beaker 1______________________________
   Beaker 2______________________________
   Beaker 3______________________________
   Beaker 4______________________________

4. Wait 15 more minutes. Record your observations.
   Beaker 1______________________________
   Beaker 2______________________________
   Beaker 3______________________________
   Beaker 4______________________________

Questions:

1. Were there any conditions under which fermentation did not proceed, or went very slowly? What were they? Explain each one.

2. State any conclusions about what temperature is best for yeast-flour-sugar fermentation.

Module 3 Ethanol: Fuel Characteristics

Millions of cars powered by ethanol-blended gasoline are on America's roads, and the number continues to grow. American motorists have driven more than one trillion trouble-free miles on ethanol-blended gasoline.

Ethanol's original use was as a gas extender when foreign oil prices skyrocketed in the 1970s. As a result of the phasing out of leaded fuel, ethanol became popular as a high-quality octane booster. Because of environmental concerns, ethanol was used as an emission-reducing oxygenate. As an oxygenate, ethanol has a high oxygen content and burns more completely and pollutes less.

Ethanol-blended gasoline sales represent over 15 percent of all automotive fuels sold in the United States. The U.S. produces approximately 2 billion gallons of ethanol each year from nearly 60 ethanol-producing facilities operating in 20 different states. The top three ethanol-producing states are Illinois, Iowa and Nebraska.

The Clean Air Act of 1990 and the National Energy Policy Act of 1992 created new market opportunities for alternative fuels by phasing in requirements for fleet vehicles to operate on cleaner fuels. Congress is also considering a national renewable fuels standard as a means of helping to reduce oil imports. State governments are recognizing the economic, energy, and environmental benefits of ethanol. Many Midwestern states and the federal government operate variable fuel vehicles in their fleets. These vehicles are capable of operating on E-85, a blend of 85 percent ethanol and 15 pecent unleaded gasoline. The small percentage of unleaded gasoline in E-85 fuels enhances starting in extremely cold weather.

Brazil has used ethanol blends since 1939. High oil prices in the 1970s prompted a government mandate in Brazil to produce vehicles fueled by pure ethanol in order to reduce dependence on foreign oil and provide value-added markets for its sugar cane producers. Today, there are more than 4.2 million ethanol-powered vehicles in Brazil (about 40 percent are passenger vehicles) that consume nearly 4 billion gallons of ethanol annually. Brazil is the largest transportation fuels market in the world for ethanol.

Requirements in the Clean Air Act to make cleaner burning reformulated gasoline (RFG) with lower volatility and fewer toxic components have increased interest in ethanol-based ethers such as ethyl tertiary butyl ether (ETBE). ETBE is a chemical compound produced by reacting ethanol and isobutylene (a petroleum-derived byproduct of the refining process).

ETBE has superior physical and combustion characteristics to other ethers. They include: low volatility, high octane value, lower carbon monoxide and hydrocarbon emissions, and superior driveability. Ethanol and ETBE are among the oxygenates used in reformulated gasoline that is required in certain ozone non-attainment areas in the U.S.

What is Fuel Ethanol?

Ethanol is a high octane, water-free alcohol produced from the fermentation of sugar or converted starch. It is used as a blending ingredient in gasoline or as a raw material to produce high-octane fuel-ether additives. Ethanol is made from grains (mainly corn) or other renewable agricultural or forestry products such as wood, brewery waste, potatoes, cheese whey, paper waste, beets, or vegetable waste.

Engine Performance & Ethanol

Auto manufacturers today are recommending ethanol-blended gasoline for the vehicles they sell. A recent survey revealed that nine out of ten auto dealers use ethanol-blended gasoline in their personal vehicles. Over half of the dealerships surveyed indicated their customers reported benefits that included: reduced knocking and pinging, improved gas mileage, better acceleration, and improved starting qualities.

Independent automotive technicians also trust their family cars to ethanol blends. A 1997 Iowa survey indicated that nine out of ten technicians used ethanol in their personal vehicles and reported the same benefits as the auto dealers.

E-10 Unleaded (10% ethanol / 90% gasoline) is approved under the warranties of all domestic and foreign automobile manufacturers marketing vehicles in the United States. In fact, the nation's top three automakers, Daimler-Chrysler, Ford and General Motors, recommend the use of oxygenated fuels such as ethanol blends because of their clean air benefits and performance qualities.

Ethanol is a good cleaning agent. In newer vehicles it helps keep the engine clean. In older vehicles it can sometimes loosen contaminants and residues that have already been deposited in a vehicle's fuel delivery system. Occasionally, these loosened materials collect in the fuel filter, and can then be removed simply by changing the fuel filter.

All alcohols have the ability to absorb water. Condensation of water in the fuel system is absorbed and does not have the opportunity to collect and freeze. Since ethanol blends contain at least 10 percent ethanol, they are able to absorb water and eliminate the need for adding a gas-line antifreeze in winter.

Ethanol is a fuel for old and new engine technology. Automotive engines older than 1969 with non-hardened valve seats may need a lead substitute added to gasoline or ethanol blends to prevent premature valve seat wear. Valve burning is decreased when ethanol blends are used because ethanol burns cooler than ordinary unleaded gasoline. Many high performance racing engines use pure alcohol for that reason.

Modern computerized vehicles of today, when operating correctly, will perform better than non-computer equipped vehicles. Improved performance is due to the vehicle's computerized fuel system being able to make adjustments with changes in operating conditions or fuel type. Some of the chemicals used to manufacture gasoline, such as olefins, have been identified as a cause of deposits on port fuel injectors. Today's gasolines contain detergent additives that are designed to prevent fuel injector and valve deposits.

Car owners should review their vehicle owner's manual. This will help to answer many questions. The owner/driver should note the octane requirement or Antiknock Index (AKI) number of gasoline required for proper engine performance for the vehicle. Then note the

User Guidelines

To help ensure proper engine operation and keep fuel costs to a minimum, follow these guidelines:

- Purchase fuel from a busy station to be sure fuel is fresh and less likely to be contaminated with moisture.
- Keep the fuel tank above one-quarter full, especially during cold weather, to help reduce condensed moisture and gas line freeze-up.
- Do not purchase a fuel with a higher octane rating than is necessary.
- Do not purchase fuel from a retail outlet when a tanker truck is filling the storage tanks. Dirt, rust, and water may be stirred up.
- Do not overfill the gas tank. After the nozzle clicks off, add just enough fuel to round up to the next dime. This will prevent damage to the vehicle's fuel evaporative system.

octane number on the sticker on the gas pump to make sure it is not less than the required number. Using a higher octane number will not realize better economy unless engine knock or ping already exists.

The performance of ethanol-blended gasoline has been proven by years of use. The Nebraska State Highway Patrol has been using ethanol-blended gasoline more than 20 years. In several states, state vehicles have been successfully using ethanol-blended gasoline since 1979. Three-time IHRA world champion funny car driver Mark Thomas also used ethanol to fuel his winning Dodge Avenger.

Fuel Quality

The quality of fuel used in any motor vehicle engine is very important to its long life and proper operation. If the fuel is not right for the air temperature or if fuel changes to a vapor incorrectly, driveability will suffer.

Gasoline is a complex mixture of approximately 300 various ingredients, mainly hydrocarbons, refined from crude petroleum oil for use as fuel in engines. Refiners must meet gasoline standards set by the American Society for Testing and Materials (ASTM), the Environmental Protection Agency (EPA), state regulatory agencies and their own company standards.

Antiknock Index (AKI) and Octane Ratings

Gasolines are most commonly rated based on their Antiknock Index (AKI), a measure of octane quality. The AKI is a measure of a fuel's ability to resist engine knock (ping). The AKI of a motor fuel is the average of the research octane number and the motor octane number: (R+M)/2. This is also the number displayed on the octane decal posted on a gasoline pump. In general, a low research octane could cause a low to medium speed knock and run-on (or dieseling) after the engine is shut off. A low motor octane could cause engine knock when power is needed during acceleration, such as passing or climbing hills.

A typical average octane number of 87 would contain a research octane of 92 and a motor octane of 82. However, it could also be the average of 94 and 80, depending on the availability of blending products on hand at the refinery. These different blends can affect engines differently, depending on the octane requirement of that particular engine, and explains why engines can perform differently with a change of fuel.

Factors affecting the octane number requirement include:

- Compression ratio
- Barometric pressure/altitude
- Ignition timing
- Temperature
- Air/fuel ratio
- Humidity
- Combustion temperature (intake manifold heat, inlet air temperature, coolant temperature)
- Exhaust gas re-circulation rate
- Combustion chamber deposits
- Combustion chamber design

Using a higher octane or AKI fuel will not increase gas mileage unless the engine is knocking or pinging with the lower octane fuel.

Volatility and Vapor Pressure

Gasoline is metered in liquid form through the fuel injectors or the carburetor and is atomized (mixed with air) and vaporized before entering the cylinders. It is very important to control a fuel's tendency to evaporate. This tendency to vaporize or change from a liquid to a vapor is referred to as the fuel's *volatility*.

If volatility is too low (not volatile enough), symptoms could include: poor cold start, poor warm up performance, poor cool weather driveability, unequal fuel distribution, or increased deposits in the crankcase, combustion chamber, and spark plug.

If volatility is too high and too much vapor is formed, it could cause a decrease of fuel flow resulting in vapor lock, loss of power, rough running or stalling, decreased fuel mileage, or increased evaporative emissions leading to overloading the fuel evaporative canister. Refiners are required to deliver the correct volatility of fuel for winter, summer, and fall/spring. A vapor pressure test to determine volatility of a fuel sample can be performed by a technician using special test equipment and following a specific procedure. It is referred to as a Reid Vapor Pressure (RVP) test and is recorded in pounds per square inch (psi). Ethanol blends, such as E-10 Unleaded, are allowed an increase in the RVP of 1.0 psi.

During the mid-1980s, the RVP of summer fuels was found to be as high as 10.5 psi due to additives used to increase octane ratings. This caused a drastic increase in driveability problems. Many of these problems were blamed on ethanol, when the problem was actually caused by the base gasoline used for blending.

Other Fuel Additives

In addition to AKI and volatility, other fuel standards exist for copper corrosivity, stability in storage, sulfur content, metallic additives, and temperature for phase separation. It is important to note that gasoline retains its original "fresh" state for 90 days. It is usually 30 days old when it becomes available for consumer use. If gasoline is to be stored for longer than 60 days, a good gas stabilizer additive should be used by following the product directions. Other additives found in gasoline are detergents and deposit-control additives, anti-icers, fluidizer oils, corrosion inhibitors, anti-oxidants, metal deactivators, and lead substitute additives.

Detergents play an important role in preventing deposit buildup of port fuel injectors, intake valves, and combustion chamber deposits.

Gasoline Additives

ADDITIVE	PURPOSE
Detergents/deposit control additives*	To eliminate or remove fuel system deposits
Anti-icers	To prevent fuel-line freeze up
Fluidizer oils	Used with deposit control additives to control intake valve deposits
Corrosion inhibitors	To minimize fuel system corrosion
Anti-oxidants	To minimize gum formation of stored gasoline
Metal deactivators	To minimize the effect of metal-based components that may occur in gasoline.
Lead replacement additives	To minimize exhaust valve seat recession

*Deposit control additives can also control/reduce intake valve deposits.

Deposits on injectors and intake valves have been corrected by changes in detergents; however, some engines experience a buildup of deposits in the combustion chamber. Gas tank additives for injectors are designed to keep deposits from collecting. Special equipment and cleaning agents must be used to remove deposits. These special cleaning chemicals must not be used in the gas tank.

Compatibility of materials is an issue, especially with certain brands of port fuel injectors. Causes of failure have not been verified, but a newly designed replacement injector prevents the problem from reoccurring.

Fuel Testing

A simple test a technician might use is to determine the amount of alcohol present in gasoline. This can be done using a water extraction method. A graduated glass cylinder, usually 100 milliliters (ml), is used for the test. Place 100 ml of the gasoline sample in the graduated cylinder. Add 10 ml of water into the cylinder, stopper the top, and shake thoroughly for one minute. Set aside for two minutes. If no alcohol is present, the 10 ml of water will settle to the bottom of the cylinder. If alcohol is present, the alcohol will drop to the bottom along with the water, increasing the bottom layer to greater than 10 ml. Subtract 10 from total bottom layer and remainder will be the percentage of alcohol in the gasoline. Over-blends of ethanol were found during the early (1970s) use of gasohol due to the methods used to obtain the products and deliver them. Today both gasoline and ethanol are located at a pipeline terminal and are monitored closely for proper blending.

Ethanol vs. Methanol

While ethanol is the preferred alternative as an oxygenate, methanol has also been considered. Methanol is made from natural gas or coal, and is also known as wood alcohol. It is highly corrosive, more volatile than ethanol, and more damaging to plastic and rubber fuel system components known as elastomers.

Ethyl tertiary butyl ether (ETBE) and methyl tertiary butyl ether (MTBE) are both high octane, low volatility, oxygenated fuel components made by combining alcohol with isobutylene. MTBE is permitted in unleaded gasoline up to a level of 15 percent. ETBE can be added to gasoline up to a level of approximately 17 percent. ETBE is made by using ethanol while MTBE is made using methanol. Many car company warranties do not cover the use of methanol-based fuels, while all auto makers approve of the use of ethanol-blended gasoline. More than a dozen states currently restrict the use of MTBE due to concerns about MTBE contamination of water supplies in areas of the country where MTBE spills and tank leaks have occurred.

Non-Automotive Use

In the past, there has been a great deal of confusion about the use of oxygenated fuels in non-automotive applications such as motorcycles, lawn mowers and small engines. Initially, this confusion centered primarily around ethanol-blended fuel. The expanded use of oxygenated fuels in recent years has also prompted concerns about gasoline containing MTBE.

Past concerns identified by equipment manufacturers fall into five categories. These include: materials compatibility (metals, plastics, elastomers), lubricity, enleanment, storage considerations, and overblends. Some manufacturers found it necessary to upgrade materials used in fuel systems.

As mentioned earlier, base gasoline composition changes also took place and caused some of the compatibility problems. Remember also that gasoline standards are set for automotive use. Gasoline must operate properly in a Dodge Viper as well as a lawn mower. The limited data available indicate that ethanol blends may improve lubricity slightly. It may be necessary to reset or "rejet" carbureted engines to allow increased fuel mixtures because of the increased oxygen content in ethanol. Computerized systems will automatically compensate for the extra oxygen. Since many of these non-automotive applications are for seasonal use, the "life" of gasoline in storage being limited to 90 days requires special attention. Draining fuel systems and refilling them with fresh fuel or using a gas stabilizer is recommended.

Consumers and technicians should focus on the recommendations by the equipment manufacturers when it comes to fuel usage. They are the most familiar with the characteristics of their products and whether or not they will operate satisfactorily on specific fuels. In 1994, Downstream Alternatives, Inc. reviewed each company's owner's manuals and found that all manufacturers of non-automotive equipment/engines either approve or make no mention of using 10 percent ethanol blends (E-10 Unleaded).

E-85 Fuel

Several state governments operate large fleets of variable fuel vehicles. The driving forces for this type of automotive fuel technology are: air pollution from fossil fuels such as gasoline, dependence on foreign suppliers, and the dim prospects for gasoline as the world's oil supply dwindles.

The National Ethanol Vehicle Coalition (www.e85fuel.com) helped introduce E-85, an ethanol-based fuel comprised of 85 percent ethanol and 15 percent unleaded gasoline. E-85 is environmentally friendly. It has the highest oxygen content of any fuel available today, making it burn cleaner than ordinary gasoline. The use of E-85 reduces pollutants such as ozone and carbon monoxide and air toxins like benzene. For years, hundreds of state vehicles in the Midwest have operated on E-85 fuel.

Testing shows the E-85 cars perform well with significant reductions in emissions when compared to vehicles using ordinary unleaded gasoline. Reductions in carbon monoxide and hydrocarbons, two particularly troublesome pollutants, are reduced significantly. Ethanol is one of only two liquid fuels available that combats global warming because of its raw material source. As corn grows, it converts carbon dioxide into oxygen.

As was mentioned in “Module 1: Introduction to Ethanol,” auto makers are offering more flexible fuel vehicles. Purchase price of these vehicles has been comparable to the base price of gasoline models. Since E-85 is a cleaner burning fuel, it is expected that the life of a flexible fuel vehicle will be somewhat longer than that of a comparable gasoline vehicle.

A gallon of E-85 blended gasoline contains about 2/3 the energy of a gallon of gasoline. Based on ethanol’s energy content (BTU), you might assume the mileage would be 2/3 less. Fleet experience to date, however, has found miles per gallon on ethanol blends to be 5-10 percent higher than a direct BTU comparison. Using the federal blender’s tax credit, the price of E-85 ethanol fuel is about the same as the price of gasoline.

Module 3 Study Questions

True / False:

Place a T in the blank provided for each true statement. If the statement is false, replace the underlined word(s) to make the statement true. Use the blank provided.

_______________ 1. Ethanol's original automotive use was as an <u>octane booster.</u>
_______________ 2. When lead was removed from gasoline, ethanol was used as a <u>product extender.</u>
_______________ 3. Concerns about air quality have caused ethanol to be used as an <u>oxygenate.</u>
_______________ 4. Automakers are introducing more flexible fuel vehicles capable of operating on <u>E-85</u> fuel.
_______________ 5. Clean air laws passed in the early '90s require <u>fleet</u> vehicles to operate on cleaner fuels.
_______________ 6. Vehicle fleets in several Midwestern states are using vehicles operating on <u>100 percent</u> ethanol.
_______________ 7. <u>The United States</u> is the largest user of ethanol in the world.
_______________ 8. Reformulated gasoline has lower volatility and fewer toxic byproducts, which helps to meet the <u>Clean Air Act requirements</u>.
_______________ 9. <u>Reformulated gasoline</u> is a high-octane, water-free alcohol made by fermenting sugar.
______________ 10. <u>Ethanol</u> is used as a blend with gasoline or as a raw material to make high-octane additives.

Multiple Choice:

Place the letter that best answers the question in the blank provided at the left of each question.

__________ 1. Which of the following statements are true?

I. A majority of auto dealers use ethanol-blended gasoline.
II. A majority of independent automotive technicians use ethanol-blended gasoline.

A. Only statement I is true.
B. Only statement II is true.
C. Both statements are true.
D. Neither statement is true.

__________ 2. E-10 Unleaded gasoline is approved under the warranties of:

A. Chrysler
B. Ford
C. General Motors
D. Toyota
E. All domestic & foreign car manufacturers

_________ 3. Ethanol has the ability to absorb water which eliminates:
A. Carburetor icing
B. The need to use a gas line antifreeze
C. Engine ping
D. Changing fuel filters

_________ 4. Which of the following statements are true?
I. Ethanol burns hotter than gasoline.
II. Computer-equipped vehicles recognize the amount of ethanol in gasoline and automatically make the necessary adjustments for normal operaton.

A. Only statement I is true.
B. Only statement II is true.
C. Both statements are true.
D. Neither statement is true.

_________ 5. The use of a higher octane gasoline:
A. Will result in increased fuel economy and performance only if engine knock or ping was previously present.
B. Will decrease fuel economy and performance.
C. Decreases deposits on intake valves and fuel injectors.
D. Will decrease vapor lock.

Fill in the blank:

Write the word or words which best completes each statement.

1. ____________________ is a mixture of 300 chemicals, most of which are refined from crude oil.

2. The ____________________ is the measure of a fuel's ability to resist engine ping or knock.

3. If an engine's octane requirement is higher than the fuel octane number, ____________________ results.

4. A fuel's ability to change to a vapor is called ____________________.

5. Gasoline is "fresh" for _________ days after it is manufactured.

6. Wood alcohol or ____________________ is very corrosive and volatile and will damage certain fuel system components.

7. ETBE can be blended with gasoline up to ____________percent.

8. _________ percent of small or non-automotive engine manufacturers either approve of or make no mention of the use of E-10 Unleaded gasoline in their respective owners' manuals.

9. Vehicles that will operate on ordinary unleaded gasoline, or any blend of gasoline with up to 85 percent ethanol, are called ____________________ fuel vehicles.

Short Answer:

Answer each of the following questions.

1. Engine design and compression ratio determine the fuel octane requirement of an engine. List six other causes of increased octane requirement of an engine.

____

____

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2. State how the improper volatility of fuel can affect engine operation.

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3. What effects do E-85 vehicles have on the atmosphere?

____

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1. Prepare a Report About Your Family Car:

What kind of gasoline does your family put in its car? Does it contain additives? Do the additives make a difference in how the car runs? Do they make a difference in the amount of pollution the car produces?

2. Collect Five New Car Brochures:

Compare the EPA mileage figures and prices for each car make and model. Use the price of gasoline to figure out which car will cost more over a five-year period, based only on the purchase price of the car and the cost of gasoline to drive it 12,000 miles per year. Make it more interesting by using one flexible fuel vehicle in your example.

3. Test Your Math:

Assume that a Ford Taurus gets 30.9 miles per gallon on a mixture of 10 percent ethanol and 90 percent gasoline (E-10 Unleaded), and only 23.1 miles per gallon with a mix of 85 percent ethanol and 15 percent gasoline. If pure gasoline costs $1.25 per gallon, what price must ethanol be to make the cost per mile the same for both mixtures?

Module 4
Ethanol & The Environment

In 1990, the federal government passed amendments to the Clean Air Act that set minimum standards for air quality in America's cities. These amendments included provisions that required the use of oxygenated fuels by 1992 in nearly all areas where excessive amounts of carbon monoxide (CO) existed. Since the majority of air pollution is caused by vehicle exhaust, using cleaner burning fuels is one alternative that provides nearly immediate results. Ethanol-blended gasoline is one oxygenated fuel being offered as a solution.

Emissions from Vehicle Exhaust

Hydrocarbons (HCs) are formed from products made from crude oil. Petroleum and gasoline consist of blends of over 250 diverse hydrocarbons. Many of these are toxic; some, such as benzene, are carcinogens (cancer causing agents). Hydrocarbons escape into the air when refilling the gas tank, from the gas tank and carburetor during normal operation, and from engine exhaust. Hydrocarbons that evaporate from gasoline are sometimes called *volatile organic compounds (VOCs)*. If uncontrolled, transportation sources would make up 30-50 percent of the total hydrocarbon emissions in the atmosphere. The automotive industry has developed and is using various vehicle emission control systems that control hydrocarbon emissions. Hydrocarbons also contribute to the formation of ground level ozone. Since ethanol is an alcohol, it does not produce hydrocarbons when being burned or during evaporation.

Ozone, sometimes referred to as photochemical smog, is formed in the air when hydrocarbons and nitrogen oxides react in the presence of sunlight. It is more of a concern on warm, quiet, summer-like days when smog fills the air, creating a brownish haze in the lower atmosphere. This ground level ozone causes human respiratory stress and can cause plant damage, sometimes reducing crop yields. This ground level ozone does not increase the ozone that is in the stratosphere and does not block the sun's harmful ultraviolet rays. Several U.S.-based studies conclude that, overall, the ozone forming potential of ethanol blends, which vaporize at lower temperatures due to higher volatility, is about the same as gasoline. In Canada, however, the volatility of ethanol blends must match normal gasoline.

Aldehyde emissions from the combustion of ethanol blends are slightly higher than when burning gasoline alone. The concentrations are extremely small and are sufficiently reduced by the vehicle's three-way catalytic converter found on all recent cars. The Royal Society of Canada termed the possibility of negative health effects caused by aldehyde emissions from the use of ethanol blends as being "remote."

Carbon monoxide (CO) is a poisonous gas formed by incomplete combustion. It is readily produced from burning petroleum fuels which contain no oxygen in their molecular structure. It is especially produced when excessive fuel-to-air mixtures are delivered and burned in the engine. More fuel and less air are necessary to start a cold engine and to keep it running until reaching normal operating temperature. Vehicles operating at colder temperatures (in winter months, during engine warm up, or in stop-and-go traffic) produce significant quantities of this toxic gas.

By adding ethanol, which contains oxygen, combustion in the engine is more complete and CO is reduced. Research shows that reductions may reach as high as 30 percent depending on the type and age of the automobile, the emission system used, and the atmospheric conditions. Because of health concerns over carbon monoxide, the 1990 amendments to the Clean Air Act mandate the use of oxygenated fuels in many major urban areas (CO non-attainment areas) during the winter months.

Carbon dioxide (CO_2) is a normal non-toxic product of burning fuel, but it contributes to the greenhouse effect (global warming). All petroleum-based fuels cause increased atmospheric carbon dioxide levels. Using renewable fuels, such as ethanol, does not increase atmospheric carbon dioxide levels. The carbon dioxide formed during combustion is balanced by that absorbed during the annual growth of plants used to produce ethanol. Plants "breathe" carbon dioxide and give off oxygen. Therefore, increased use of renewable fuels made from plants will partially offset the global warming effect of burning gasoline. It is also worth noting that renewable fuel technology can result in a net reduction in atmospheric carbon dioxide levels. This is accomplished by transforming carbon dioxide into organic matter that is returned to the soil, thereby increasing soil fertility and reducing erosion. Ethanol use in gasoline has tremendous potential for a net reduction in atmospheric carbon dioxide levels.

Nitrogen oxides (NOx) are produced when high combustion temperatures exist. NOx contributes to ground level ozone (photochemical smog). Several components of gasoline that impact NOx emissions, including olefins and aromatics, are reduced by adding ethanol to gasoline. EPA studies indicate the use of ethanol blends may slightly increase NOx emissions under some conditions, but the extent and effects are uncertain.

Results with Oxygenates

The oxygenated fuel programs resulted in excellent program compliance during the first year. In the winter of 1992-93, seven programs in the western states realized 50 percent fewer CO violations compared to the previous year. Eight new California programs experienced 80 percent reductions in violations. Use of oxygenated fuels is a quicker and more economical way of achieving reductions than implementing a vehicle emission maintenance program that requires every vehicle to be tested or repaired.

Ethanol is one of the best tools we have to fight air pollution. Ethanol reduces pollution through the volumetric displacement of gasoline and by adding oxygen to the combustion process which reduces exhaust emissions. The use of ethanol results in reductions in every pollutant regulated by the Environmental Protection Agency (EPA), including ozone, air toxins, carbon monoxide, particulate matter, and nitrogen oxides. New model cars of the late 1990s and beyond include on-board diagnostic monitoring systems capable of monitoring tailpipe and evaporative emissions. Advances in computer technology not only improve monitoring and control of emissions, but also make it possible to use blends of up to 85 percent ethanol. These flexible fuel vehicles are able to sense the volume of ethanol in gasoline and make the necessary engine adjustments for best efficiency, performance, and emission levels.

Module 4 Study Questions

Matching:

Place the number of the statement which best matches each term in the blank provided.

________ A. carbon dioxide	1. Unburned fuel from evaporation of gasoline and incomplete combustion.
________ B. carbon monoxide	2. Non-toxic vapor produced by complete combustion.
________ C. hydrocarbons	3. Produced during high combustion temperatures.
________ D. nitrogen oxides	4. A toxic vapor produced when burning excessively rich air/fuel mixtures.
________ E. ozone	5. Created when unburned fuel vapors and nitrogen oxides react when sunlight is present.

Essay:

Answer the following question:

1. In 1992, use of oxygenated fuel was required in certain geographical areas where carbon monoxide levels were excessive. How does burning ethanol-blended gasoline in a vehicle lower carbon monoxide levels?

Module 4 Study Questions

Unscramble the following words that relate to ethanol fuels:

_______________ 1. THLANOE
_______________ 2. NOTCAE
_______________ 3. OSALINGE
_______________ 4. BRANCO XOMNOIDE
_______________ 5. SIMENOSIS
_______________ 6. RAING
_______________ 7. NORC
_______________ 8. HOLACOL
_______________ 9. NOZEO
_______________ 10. GYERNE
_______________ 11. HANNECER
_______________ 12. GENYXO
_______________ 13. BUYSIDS
_______________ 14. LOI
_______________ 15. RATDYEHDE
_______________ 16. ZRIBAL
_______________ 17. RAMEFR
_______________ 18. EUFL
_______________ 19. DRYHOBORCANS
_______________ 20. DEALUNED
_______________ 21. TEVINICEN

Module 5 Ethanol Economics

The production and use of ethanol, a renewable fuel made from agricultural and biomass products, increases economic activity, creates jobs to stabilize farm commodity prices, and boosts farm income. It can help us become less dependent on imported oil and improve our balance of trade.

The National Scene

The ethanol industry contributes to the U.S. economy in a positive way, particularly in rural communities where ethanol production is based. The economy is expanded by providing direct and indirect jobs and increasing corn prices and rural income. The U.S. Department of Agriculture has concluded that an ethanol facility with a 100-million-gallon capacity could create 2,250 direct and indirect jobs in some instances.

As the ethanol industry grows, so will its impact on the U.S. economy. A report by economists at Northwestern University's Kellogg School of Business on the economic outlook of the U.S. ethanol industry over a seven-year period (1996 to 2002) concluded:

- Ethanol will add $51 billion (1996 dollars) to the U.S. economy. The goods and services purchased by ethanol producers represent increased demand for other industries. These include purchases of grain, natural gas, electricity, water, communications, accounting and legal services.

- Annual farm income for crop producers will increase $4.5 billion because of ethanol production. Increased demand for grain grown by American farmers provides market support for prices and incomes.

- The ethanol industry supports nearly 55,000 jobs. Ethanol production directly accounts for over 5,800 jobs in the food/fuel processing industry in 20 states. Additionally, the spending by ethanol manufacturers on goods and services indirectly supports an average of 48,900 jobs. Increases in ethanol production offer enormous potential for overall economic growth and additional employment in rural communities where ethanol production is often based.

- Ethanol production will increase total household income by $12.5 billion over the next seven years. The ethanol industry directly pays $277 million in wages to employees. These employees and their families spend this income, thereby creating demand for other goods and services. The indirect impact of ethanol production adds another $1.8 billion to household income annually.

- Ethanol generates $555 million of net tax revenue for the federal treasury annually through personal and business income tax collections. Additional revenues, provided by taxes on household and farm income that are generated and supported by the ethanol industry, offset the cost of the partial ethanol excise tax exemption for ethanol-blended gasoline.

- Ethanol contributes over $2 billion annually to the U.S. trade balance. The U.S. currently imports 54 percent of its petroleum demand. Use of ethanol reduces the trade deficit by about $1.3 billion annually by replacing imported MTBE. Another $800 million is gained annually due to export of the byproducts of ethanol, such as corn gluten feed and gluten meal for livestock consumption.

According to a more recent study, "Ethanol and the Local Community," conducted by John Urbanchuk of AUS Consultants and Jeff Kapell of SJH & Co, building a new ethanol plant will have a significant positive impact on the local economy. The study, based on a new 40 million gallon per year dry mill ethanol facility, concluded:

- With an approximate cost of $60 million and one year of construction, the facility will expand the economic base for the local economy by $110.2 million.

- Ethanol production will generate an additional $19.6 million in household income.

- Tax revenue for the state and local governments will increase by a minimum of $1.2 million.

- Approximately 694 permanent new jobs will be created.

According to the American Coalition for Ethanol, more than $3 billion has been invested in 60 ethanol production facilities in 20 different states across the country in 2002. Additional plant construction since then has boosted investment and increased the number of plants.

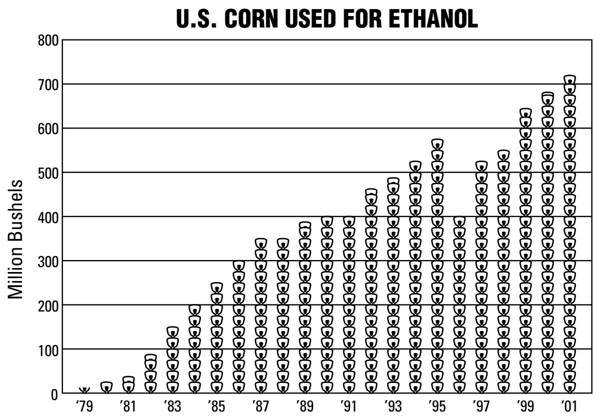
Agriculture

Ethanol is made from farm-produced raw products which are usually in surplus. Corn is the primary grain used in ethanol production, and it supplies most of the raw material needed. Ethanol production creates domestic markets for corn and adds 4 to 6 cents a bushel for each 100 million bushels used. Better prices mean less reliance on government subsidy programs and more income and independence for farmers. Ethanol production consumed 535 million bushels of corn in 1994 (5.3 percent of the record 10 billion bushel corn crop). Today more than 700 million bushels of corn are used by ethanol producers annually.

A report by the Midwestern Governors' Conference notes that the ethanol industry has become an important value-added market for agriculture. Ethanol production is the third largest user of corn, behind domestic livestock feed and export uses. Ethanol production uses about 7 percent of the nation's corn crop. The conclusions of the report verify that the federal ethanol program is cost effective. The partial excise tax exemption for ethanol blends creates jobs, stimulates economic activity, and reduces the U.S. trade imbalance. The February 1997 report concluded that the ethanol industry:

- Will increase net farm income more than $6.6 billion over the next 15 years;
- Improves the balance of trade by more than $2 billion;
- Adds more than $450 million to state tax receipts, and
- Results in net federal budget savings of more than $3.5 billion.

EVERY BUSHEL OF CORN CAN PRODUCE UP TO 2.7 GALLONS OF ETHANOL



Source: U.S. Department of Agriculture

The report also stated that the impact of the demand for ethanol can have other effects. The projected 1997 demand for ethanol was estimated at 1.52 billion gallons, or 550 million bushels. Corn production would increase by 420 million bushels and raise the corn price by 45 cents per bushel. The increase in production and price would raise gross farm income by $5.0 billion and net farm income by $4.5 billion in 1997. The increase in farm expenditures and employment opportunities in the ethanol industry is projected to increase annually in relationship to additional ethanol production and use.

As the domestic ethanol industry continues to grow, it is witnessing a surge in the construction of farmer-owned ethanol production facilities. Farmers are realizing the added benefits to the ethanol industry through ownership of manufacturing plants. Over the past 15 years, more than 12 billion gallons of high-quality, high-performance ethanol fuel have been produced using about 5 billion bushels of corn.

Ethanol's importance to agriculture is evident:

- Ethanol creates value-added markets for America's farmers, stimulating rural economies by increasing corn prices and rural income.

- Each 100 million bushel increase in the demand for corn results in a corn price increase of 4 to 6 cents per bushel.

- Ethanol accounts for 14 cents of the value of every bushel of corn marketed by American farmers. This will vary according to crop prospects, carryover levels, and global supply and demand.

- Ethanol accounts for 7 percent of the total corn utilization in the U.S. and is the third largest individual use of corn, behind only domestic livestock feed and exports.

- Each 100 million bushels of corn used in ethanol production affects the price of other commodities, adding 2 cents per bushel to the wheat price and 10 to 13 cents to the price of soybeans, depending on market conditions.

The production of ethanol does not mean less corn is available for food. Instead, ethanol production creates many valuable high-protein food and feed co-products. An acre of corn (125 bushels) produces 313 gallons of ethanol, 1,362 pounds of distillers grains, 325 pounds of 60 percent gluten meal, and 189 pounds of corn oil. Distillers grain can be used for feed in most every type of animal ration and is used as a cost-effective, nutritional, digestible, and palatable protein feed for cattle, swine, and sheep. Approximately 1.4 billion tons of distillers grain are produced annually.

Production Costs & Price

Advances in ethanol production technology have substantially reduced costs. A shift to larger production plants along with improved yeast strains and enzymes have significantly reduced ethanol production costs. These innovations have lowered production costs from $1.40 per gallon in 1980 to less than $1.19 in 2000. Still newer plants and improved technologies have further reduced costs to an approximate current average of $1.10 to produce one gallon of ethanol. This trend is expected to continue. The cost of producing ethanol will also be affected by corn yields, corn costs, and markets for co-products.

Consumer prices at the service station pump for E-10 Unleaded gasoline are usually near the same price per gallon as unblended fuel. This is also true for E-85 blends. These prices generally reflect applicable state or federal fuel tax incentives which are intended to make ethanol blends competitive with petroleum products.

Offsetting the cost of federal tax incentives is a reduction in farm subsidies and an increase in tax revenues. According to the U.S. Department of Agriculture, if ethanol use does not continue to grow, “deficiency payments for corn and other program crops will increase by $580 million for crop year 1998 and $740 million by the year 2000”—more than the cost of the tax incentives. The economic activity attributable to the ethanol industry will generate $3.5 billion in additional income tax revenue over the next five years – $1 billion more than the cost of tax exemptions. The U.S. ethanol industry will create a net gain to the taxpayers of almost $4 billion over the next five years.

The oil industry began receiving federal subsidies as early as 1916 to promote development of an energy industry. As the oil industry became more profitable, the subsidy payments continued. A recent study by the U.S. General Accounting Office found that since 1968, the oil industry has received approximately $150 billion in tax incentives. By contrast, the ethanol industry has received $11.2 billion through a partial exemption of the federal excise tax and $200 million in income tax credits.

Check ☑ each phrase that correctly finishes the following statement:

The production and use of ethanol:

- ☐ 1. Increases the U.S. economy.
- ☐ 2. Increases the economy in states that produce ethanol.
- ☐ 3. Is the largest market for America's corn farmers.
- ☐ 4. Creates jobs.
- ☐ 5. Creates a shortage of corn available for food.
- ☐ 6. Creates thousands of jobs in rural America.
- ☐ 7. Uses about 7 percent of the nation's corn crop.
- ☐ 8. Increases farm income.
- ☐ 9. Increases government tax receipts.
- ☐ 10. Saves money for the federal government.
- ☐ 11. Reduces the balance of trade.
- ☐ 12. Increases national dependence on imported oil.
- ☐ 13. Uses about 150 million bushels of American corn and milo each year.
- ☐ 14. Has become less efficient and more costly in recent years.
- ☐ 15. Decreases soybean prices.

Essay:

Answer each of the following questions:

1. Half of the oil used in the U.S. comes from foreign countries. The raw materials used to make ethanol are all grown in the U.S. How would producing more ethanol affect the U.S. economy?

   ____

   ____

   ____

2. Large quantities of corn are used to feed cattle. What might happen to meat and milk prices if more corn is used to make ethanol?

   ____

   ____

   ____

Module 5 Projects

1. Construct a bar graph showing the amount of corn used for U.S. ethanol production. Use the following USDA information. **Amounts are in millions of bushels.**

Year	Bushels	Year	Bushels	Year	Bushels	Year	Bushels	Year	Bushels
1979	7	1984	205	1989	365	1994	515	1999	640
1980	12	1985	247	1990	395	1995	570	2000	680
1981	25	1986	305	1991	400	1996	400	2001	720
1982	90	1987	340	1992	460	1997	520		
1983	150	1988	350	1993	480	1998	550		

2. Interview a farmer about ethanol and its use as a fuel. Does he/she use it in his/her own vehicles? What does the use of ethanol mean to him/her? Prepare a report of your findings.

3. Calculate the miles that an automobile can be driven using ethanol produced from 750 acres of corn. Assume the car is using E-10 Unleaded gas and gets an average of 26.3 average miles per gallon. One acre of corn produces an average of 127 bushels.

Glossary

Aldehyde: Created from the combustion of alcohols (ethanol/methanol).

American Society for Testing and Materials (ASTM): A non-profit organization that provides specifications and procedures that are recognized as guidelines for gasoline quality.

Anti-Icer: Typically an alcohol (ethanol, isopropyl alcohol, or methanol) added to gasoline in small amounts to eliminate water; thereby, reducing the chance for fuel line freeze-up.

Antiknock Index (AKI): Measures the ability of a gasoline to resist engine knock/ping. AKI is the average of research octane and motor octane or (R+M)/2. Commonly referred to as pump octane.

Anti-Oxidant: A stabilizing compound used to inhibit gum formation from oxidation of gasoline.

Aromatic: High octane blending components that have a benzene ring in their molecular structure (benzene, toluene, xylene).

Benzene: Basic aromatic usually of higher value as a chemical feedstock. A known cancer causing agent.

British Thermal Unit (BTU): One British Thermal Unit represents the amount of heat required to raise one pound of water one degree Fahrenheit.

Butane: A light hydrocarbon used to raise octane and increase fuel volatility.

Carbon Dioxide: A normal byproduct of combustion. A food for plants.

Carbon Monoxide (CO): A deadly toxic gas produced from the tail pipe when cars burn fuel.

Clean Air Act Amendments of 1990: A series of amendments to the original Clean Air Act which includes requirements for oxygenated fuel programs in CO (carbon monoxide) non-attainment areas and reformulated gasoline programs in certain ozone non-attainment areas.

Corrosion Inhibitors: An additive used to reduce the corrosion properties of gasoline.

Deposit Control Additive: Performs same functions as detergent and minimizes deposit buildup in intake manifold, intake ports, and underside of intake valves.

Detergent: Additive used to prevent and/or clean up carburetor and fuel injector deposits.

E-10 Unleaded: A mixture of 10 percent ethanol and 90 percent gasoline based on volume.

E-85: A mixture of 85 percent ethanol and 15 percent gasoline based on volume.

Elastomer: The rubber-like compounds used in fuel lines, evaporative canister lines, and carburetor parts.

Environmental Protection Agency (EPA): A federal agency charged with monitoring and creating standards for air and water quality. Determines standards for vehicle emissions and testing procedures.

Ethanol (ethyl alcohol, grain alcohol): An alcohol typically fermented from grain. An octane enhancer added to gasoline at a rate of up to 85 percent. Increases octane 2.5 to 3.0 numbers at 10 percent concentration (E-10 Unleaded). Ethanol is a fuel oxygenate, which improves combustion and reduces emissions. Also can be used "neat" (pure) as a fuel in specially designed vehicles.

ETBE (ethyl tertiary butyl ether): An ether similar to MTBE. This fuel oxygenate is manufactured by reacting isobutylene with ethanol. The resulting ether is of high octane and low volatility. Can be added to gasoline up to a level of approximately 17 percent to improve combustion and reduce emissions.

Fermentation: A chemical decomposition which takes place in an organic substance exposed to the air due to the action of microscopic organisms.

Fluidizer Oils: Oils typically used with deposit control additives to control deposit formation on intake valves.

Gasohol: In the U.S., the term "gasohol" refers to gasoline which contains 10 percent ethanol. This term was used in the late 1970s and early 1980s but has been replaced by terms such as E-10 Unleaded, Super Unleaded Plus Ethanol or Unleaded Plus.

Ground Level Ozone: A reaction of hydrocarbons, nitrogen oxides, and sunlight creating a brown haze in the lower atmosphere. Also referred to as photochemical smog.

Hydrocarbons (HCs): Vapors formed from products made from crude oil. Usually vapors created from incomplete combustion or from vaporization of liquid gasoline. A pollutant that contributes to ground level ozone.

Isobutylene: A chemical that is reacted with methanol to form MTBE or with ethanol to form ETBE.

Lead (tetraethyl lead): A metallic octane enhancer. One gram of lead increases the octane of one gallon of gasoline about six numbers. Not permitted in U.S. gasoline after 1995, except for certain racing or aviation uses.

Metal Deactivator: Gasoline additive used to neutralize the effects of copper compounds.

Methanol (methyl alcohol, wood alcohol): Typically manufactured from natural gas. In the 1980s, methanol was used in combination with heavier alcohols as an octane enhancer in gasoline. Also is being considered for use as a "neat" (pure) fuel in specially designed vehicles. Typically not blended with today's gasoline.

MTBE (methyl tertiary butyl ether): An ether manufactured by reacting methanol and isobutylene. The resulting ether is of high octane and low volatility. A fuel oxygenate permitted in unleaded gasoline up to 15 percent. MTBE has been shown to pollute groundwater supplies, so it is being phased out of the U.S. fuel supply.

National Energy Policy Act of 1992: Legislation requiring the phasing in of alternative fuel vehicles in fleets.

Nitrogen Oxides (NOx): Produced when high combustion temperatures (2300°-2500° F) exist. Contributes to ground level ozone.

Non-Attainment Areas: Those areas of the country which have excessive levels of carbon monoxide and/or ozone in their air.

Octane: General term for a gasoline's ability to resist engine knock.

Pump Octane: A term used to describe the octane as posted on the retail gasoline dispenser as (R+M)/2 and is the same as the Antiknock Index number.

Motor Octane: The octane as tested in a single-cylinder octane test engine at more severe operating conditions. Affects high speed and part throttle knock and performance under load, passing, etc. Abbreviated "M" and is the lower number in (R+M)/2.

Research Octane: The octane as tested in a single-cylinder octane test engine operated under less severe operating conditions. Affects low to medium speed knock and engine run-on. Abbreviated "R" and is the higher number in (R+M)/2.

Octane Enhancer: Common term designating components that are added to gasoline to increase octane and reduce engine knock. Toluene, ethanol, ETBE and MTBE are octane enhancers.

Octane Number Requirement (ONR): The octane level required to provide knock-free operation in a given engine.

Olefins: A gasoline component resulting from several refining processes. Ethylene and butylene are examples. Often contribute to the formation of gum and deposits in engines.

Oxygenate: A term used to denote octane components containing hydrogen, carbon, and oxygen in their molecular structure. Includes ethers such as MTBE and ETBE and alcohols such as ethanol and methanol.

Oxygenated Gasoline: Gasoline containing an oxygenate such as ethanol or MTBE. Provides chemical enleanment of the air/fuel charge, thereby improving combustion and reducing tailpipe emissions of carbon monoxide (CO).

Ozone: Is formed when oxygen and other compounds react in sunlight. In the upper atmosphere, ozone protects the earth from the sun's ultraviolet rays. Though beneficial in the upper atmosphere, at ground level, ozone is a respiratory irritant and considered a pollutant.

Photochemical Smog (ground level ozone): A reaction of hydrocarbons, nitrogen oxides, and sunlight, creating a brown haze in the lower atmosphere.

Reformulated Gasoline (RFG): Gasolines which have had ether composition and/or characteristics altered to reduce vehicular emissions of pollutants. Specifically, those gasolines which meet RFG requirements of the 1990 Clean Air Act Amendments.

Reid Vapor Pressure (RVP): A method of determining vapor pressure of gasoline. Used as an indicator of volatility (vaporization characteristics) of gasoline.

Toxics: As defined in the 1990 Clean Air Act Amendments, toxics include benzene, 1,3 butadiene, formaldehyde, acetaldehyde, and polycyclic organic matter.

Vapor Liquid Ratio: A measurement of the ratio of vapor to liquid at a given temperature used to determine a gasoline's tendency to contribute to vapor lock in an automotive fuel system.

Volatility: A term used to describe a gasoline's tendency to change from liquid to a vapor.

Volume Percent: A percentage measurement based solely on volume without regard to differences in weight or density. Typically used to measure the concentration of alcohols and ethers in gasoline.

Weight Percent: A percentage measurement based on weight. Typically used to measure the oxygen content of gasoline.

Additional Projects & Activities for Students

1. Construct a line graph showing the amount of ethanol produced in the U.S. Use the following IBIS (Branch office of Gist Brocades International) information. **Amounts are in millions of gallons.**

Year	Gallons
1981	90
1982	200
1983	400
1984	450

Year	Gallons
1985	600
1986	700
1987	800
1988	800

Year	Gallons
1989	850
1990	962
1991	1000
1992	1200

Year	Gallons
1993	1300
1994	1350
1995	1450
1996	1000

Year	Gallons
1997	1300
1998	1800
1999	1600
2000	1700
2001	1800

2. Write a one page essay on one of the following topics/questions:

   a. What are the differences between renewable and non-renewable energy?
   b. What is alternative energy?
   c. Why is the quality of air important to you?
   d. How does the use of ethanol affect you? Your state? The United States?
   e. Who or what groups stand to gain the most from greater use of ethanol?
   f. Who or what groups stand to gain the most from less use of ethanol?
   g. What are the effects of using ethanol-blended gasoline on national security?
   h. Why should a driver who lives in an urban area use or not use ethanol-blended gasoline?
   i. What reasons might a farmer use to convince another farmer to use or not use ethanol-blended gasoline?
   j. Besides ethanol, what other products are made during its production and how are they used?
   k. What might happen to meat and milk prices if more corn is used to make ethanol?
   l. Compare the efficiency of a school bus to personal cars being used to transport 31 students to and from school.

3. Write a research paper on one of the following topics
   - The effects of large scale use of ethanol as a fuel
   - The effects of using ethanol-blended gasoline in automobiles
   - Economic impacts of increased use of ethanol in gasoline
   - The rationale for government support for ethanol
   - The need for alternative fuels

4. Determine how many acres or square miles in your state are used to produce grain. Outline this area on a state map. Shade the portion going to the production of:
    a. ethanol
    b. livestock feed
    c. food for people

5. Organize a debate on the following: The national government should act to encourage the use of ethanol-blended gasoline in motor vehicles. Designate teams of 2 or 3 students to research and argue both sides of the issue. Let the class judge which team did the best job and which side had the best case.

6. Develop a promotional campaign to encourage ethanol use. Design a display advertisement, bumper sticker, poster, slogan, jingle, character, song, and/or logo.

7. Write a short story or essay using as many vocabulary words related to corn or ethanol as possible. For example: Kernel Korn spent many hours in the corn field with his wife Ethyl and son Cornelius during the planting season. The Kernel was affectionately known as "pop" to his neighbors.

8. Organize a debate about energy used in transportation.

9. Divide the class into transportation groups such as: fossil (gasoline, diesel), renewable, electric, solar, nuclear vehicles, wind powered vehicles. Allow one class period for groups to research and list advantages and disadvantages of their fuel source. Assign each group a number. Roll dice or a spinner to identify which group gets to speak first. A spokesperson identifies the group and its intention, and states a fact. (Example: I'm from fossil fuels. I'd like to move up a step as there is no harmful radiation released when using gasoline.) The group moves up a step. Determine the next group to speak. (Example: I'm from the nuclear vehicles. I wish to move fossil fuels back because the NOx emissions from fossil fuels contribute to photochemical smog.) Continue until a group reaches the goal. Penalize a group a step for repeating or giving wrong information. Decisions by the judge (teacher) are final! Lead a follow-up discussion. Did any fuel make it to the top or to the bottom? Where did each group finish? Do the final positions reflect the nation's energy mix?

10. Organize a field trip. All aspects of production or use related to ethanol or other alternative fuels are useful reinforcement to students whether they deal with technology on local farms, in research labs, manufacturing plants, distribution centers, fuel pipeline terminals, or where products and co-products are used.

11. Demonstrate or test for the amount of alcohol present in gasoline. This can be done using a water extraction method. A graduated glass cylinder, usually 100 milliliters (ml), is used for the test. Place 100 ml of the gasoline sample in the graduated cylinder. Add 10 ml of water into the cylinder, stopper the top, and shake thoroughly for one minute. Set aside for two minutes. If no alcohol is present, the 10 ml of water will settle to the bottom of the cylinder. If alcohol is present, the alcohol will drop to the bottom along with the water, increasing the bottom layer to greater than 10 ml. Subtract 10 from total bottom layer and the remainder will be the percentage of alcohol in the gasoline.

Additional Resources

Ethanol Information Overview

The facts below are reprinted with permission from the American Coalition for Ethanol and will change with market conditions and as the industry evolves.

Consumer Benefits:

- Consumers use more than 18 billion gallons of high performance, cleaner burning ethanol blended gasoline each year.
- Ethanol and ethyl tertiary butyl ether (ETBE) increase oxygenated supplies, reducing the need for methyl tertiary butyl ether (MTBE) imports and helping to reduce consumer costs.
- Ethanol is a high octane blending component used by many independent gasoline marketers – creating competition for the major oil companies.
- ETBE is a low volatility oxygenate which provides refiners a cost-effective means to meet Clean Air Amendment standards.
- Ethanol blends, such as E-10 unleaded, can be used in virtually all gas engines without any engine or mechanical revisions.
- Ethanol guards against gas line freeze by absorbing moisture that may get in the tank during cold weather.

Taxpayer Benefits:

- The partial excise tax exemption for ethanol blends available to gasoline marketers saves money.
- A GAO study has shown that reduced farm program costs and increased income tax revenues offset the cost of the incentive.
- According to the USDA, if ethanol use does not continue to grow, "deficiency payments for corn and other program crops will increase by $580 million for crop year 1998 and $740 million by 2000" – more than the cost of the tax incentive.
- The economic activity caused by the ethanol industry will generate $3.5 billion in additional income tax revenue over the next five years – $1 billion more than the cost of the exemption.
- The U.S. ethanol industry will create a net gain to taxpayers of almost $4 billion over the next five years.

Economic Benefits:

- More than $3 billion has been invested in 60 ethanol production facilities operating in 20 different states across the country.
- The ethanol industry is responsible for more than 40,000 direct and indirect jobs, creating more than $1.3 billion in increased household income annually, and more than $12.6 billion over the next five years.
- The ethanol industry directly and indirectly adds more than $6 billion to the American economy each year.
- As the economic activity created by the ethanol industry ripples through the economy, it will generate $30 billion in final demand between 1996 and 2000.

- Increases in ethanol production offer potential for economic growth in small rural communities. USDA has estimated that a 100 million gallon ethanol plant could create 2,250 local jobs, including grain production.
- Each gallon of ethanol produced domestically displaces seven gallons of imported oil.
- Every 100 BTUs of energy used to produce ethanol (including planting, cultivating, harvesting, and processing) yield 135 BTUs of ethanol. By comparison, the same 100 BTUs of energy yields 85 BTUs of gasoline or 55 BTUs of methanol.

Agricultural Benefits:

- Industrial corn use, which includes ethanol and sweetener production, is now the third largest consumer of corn in America.
- Each $1 of up-stream and on-farm economic activity generates $3.20 in downstream economic stimulus attributable to ethanol processing, compared to just $0.31 when U.S. corn is exported.
- Ethanol production consumed nearly 535 million bushels of corn in 1994 (5.3 percent of the record 10 billion bushel corn crop).
- The demand for corn created by the ethanol industry increases crop values.
- If the market for ethanol did not exist, corn stocks would rise and net income to American corn farmers would be reduced by $6 billion over the next five years, or about 11 percent.
- One acre of corn can produce 300 gallons of ethanol – enough to fuel four cars for one year with a 10 percent ethanol blend.

Energy / Trade Benefits:

- Domestic ethanol and ETBE production reduces demand for imported oil and MTBE which drains our economy – oil and MTBE imports now represent almost 80 percent of the U.S. trade deficit.
- Currently, imported oil accounts for 54 percent of consumption.
- Today, ethanol reduces the demand for gasoline and MTBE imports by 98,000 barrels per day.
- Ethanol production generates exports of feed co-products, such as corn gluten in livestock feed, further decreasing our balance of trade. Corn gluten exports can top $800 million a year.
- Ethanol production is energy efficient, with a positive energy balance of 125 percent compared to 85 percent for gasoline.
- Ethanol production is the most efficient method of producing liquid transportation fuels. According to USDA, each BTU used to produce 1 BTU of gasoline could be used to produce 8 BTUs of ethanol.

Environmental Benefits:

- Ethanol blends reduce carbon monoxide better than any reformulated gasoline blend—more than 25 percent.
- Ethanol is low in reactivity and high in oxygen content, making it an effective tool in reducing ozone pollution.
- Ethanol is a safe replacement for toxic octane enhancers in gasoline such as benzene, toluene, and xylene.
- Because it is produced from renewable agricultural feedstocks, ethanol reduces greenhouse gas emissions.

Agencies and Organizations

Contact the following agencies and organizations for more information about ethanol and other alternative energy sources. If possible, please check the Internet web sites before your inquiry.

If you choose to contact these sources by telephone, you'll need to listen carefully as you access their automated communications systems. Specific questions will yield more complete results and answers.

American Coalition for Ethanol
PO Box 85102
Sioux Falls, SD 57104
(605) 334-3381
www.ethanol.org

Clean Fuels Development Coalition
4641 Montgomery Ave., Suite 350
Bethesda, MD 20814
(301) 718-0077
www.cleanfuelsdc.org

Downstream Alternatives
PO Box 190
Bremen, IN 46506
Auto Technicians Manual: $2.50

Economic Research Service
Room 2132, USDA
1800 M Street
Washington, DC 20036,
(202) 694-5021

Nebraska Ethanol Board
301 Centennial Mall South
P.O. Box 94922
Lincoln, NE 68509-4922,
(402)-471-2941
www.ne-ethanol.org

Iowa Department of Natural Resources
Wallace Bldg. 502 E. 9th St.
Des Moines, IA 50319, (515) 281-8518

Northwest Iowa Community College
Business & Industry Center
603 W. Park
Sheldon, IA 51201
(712) 324-5061
Additional information on ethanol surveys of automotive and non-automotive dealers and technicians in Iowa.

Office of Renewable Fuels:
Iowa Department of Agriculture
and Land Stewardship
Wallace Building
Des Moines, IA 50319
(515) 281-6936
Contact Pat Paustian for booklets and videos on "Adding Value to Iowa's Agriculture Commodities." (An 8-minute video describing the benefits of using ethanol in your car was distributed to all drivers' education instructors in the fall of 1997.)

Renewable Fuels Association
Suite 820, One Massachusetts Ave., N.W.
Washington, DC 20002
(202) 289-3835
E-mail: ethrfa@erols.com
www.ethanolrfa.org
Provides publications on alternative energy sources including ethanol.

The Institute for Local Self-Reliance
1313 Fifth St. SE
Minneapolis, MN 55414
(612) 379-3815
www.ilsr.org

The National Renewable Energy Laboratory
1617 Cole Blvd.
Golden, CO 80401
(303) 275-3080
www.nrel.gov

U.S. Department of Energy Office of Energy Efficiency & Renewable Energy
www.eren.doe.gov

American Coalition for Ethanol: www.ethanol.org

Arkenol, Inc.: www.arkenol.com

American Bioenergy Association: www.biomass.org

Canadian Renewable Fuels Foundation: www.greenfuels.org

Clean Fuels Development Coalition: www.cleanfuelsdc.org

E-10 Unleaded: www.e10unleaded.com

Energy Information Administration: www.eia.doe.gov

Ford: www.ford.com

Governor's Ethanol Coalition: www.ethanol-gec.org

Institute for Local Self-Reliance: www.ilsr.org

Minnesota Corn Growers Association: www.mncorn.org

National Renewable Energy Laboratory: www.nrel.gov

Nebraska Ethanol Board: www.ne-ethanol.org

Renewable Fuels Association: www.ethanolrfa.org

Sustainable Minnesota Biofuels Resources: www.me3.org/issues/ethanol

U.S. Department of Energy/Office of Energy Efficiency & Renewable Energy: www.eren.doe.gov

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TRUE / FALSE:

Circle the letter "T" for each true statement or "F" for each false statement.

T F 1. It is in the interest of the U.S. economy to market grain as ethanol.
T F 2. A molecule of ethanol is composed of more hydrogen atoms than carbon atoms.
T F 3. The technology used to make ethanol involves the use of enzymes.
T F 4. Use of E-10 Unleaded gasoline will greatly affect U.S. food supplies.
T F 5. The EPA is interested in the effect that using E-10 Unleaded has on air quality in large cities.
T F 6. CO_2, a co-product of ethanol production, is growing in importance.
T F 7. Variable fuel vehicles use a sensor to determine the amount of ethanol in gasoline.

MULTIPLE CHOICE:

Place the letter of the best answer in the blank provided at the left of each question.

_________ 1. What country uses the most ethanol in its transportation fuels market?

A. Argentina
B. Brazil
C. China
D. France
E. United States

_________ 2 . How much ethanol is produced in the United States every year?

A. 150 million gallons
B. 900 million gallons
C. Approximately 2 billion gallons
D. 15 billion gallons

_________ 3. Which of these pollutants are reduced by the use of ethanol?

A. Carbon monoxide
B. Oxides of nitrogen (NOx)
C. Particulate matter
D. Volatile organic compounds
E. Greenhouse gas
F. All of the above

_________ 4. The increased use of ethanol in our nation's fuel supply can help:

A. Reduce our dependence on imported oil
B. Improve air quality
C. Create stronger markets for American farmers
D. Strengthen the balance of trade for the U.S.
E. All of the above

_________ 5. Which of the following sources can be used to produce ethanol?

A. Corn
B. Paper sludge
C. Sawdust
D. Yard clippings
E. All of the above

__________ 6. Using the best practices available, the production of ethanol will result in how much more energy than it takes to produce the ethanol?

A. 1.5 times more energy
B. 2.5 times more energy
C. 3.0 times more energy
D. 5.0 times more energy
E. None of the above

__________ 7. Which of the following car manufacturers recommend the use of ethanol blended-gasoline in their vehicles?

A. Daimler-Chrysler
B. Ford
C. General Motors
D. Toyota
E. All of the above

__________ 8. What percentage of Americans are concerned about our foreign oil imports?

A. 15 percent
B. 30 percent
C. 50 percent
D. 75 percent

__________ 9. Distillation refers to:

A. separating substances with different boiling points
B. adding yeast to a mash and allowing it to work
C. diluting substances such as ethanol with other solvents
D. adding enzymes to convert large molecules into smaller ones
E. adding a base or acid to change the pH

__________ 10. Which of these would NOT occur if all gasoline sold contained ethanol?

A. auto repair shops would be very busy
B. corn prices would rise
C. employment in ethanol-producing states would increase
D. food supplies would remain stable
E. the air would be cleaner

__________ 11. Which of these is NOT a key aspect in producing ethanol?

A. grinding corn into a fine powder
B. scrubbing corn to remove pesticides and insect residue
C. processing of co-products for sale
D. converting starch in corn to sugar
E. yeast fermentation

__________ 12. Which of these is NOT a reason for using E-10 Unleaded gasoline?

A. helps to improve air quality
B. makes use of surplus corn crops
C. results in cleaner engine components
D. increases vehicle emission levels
E. improves U.S. trade deficit

Module 1: Introduction to Ethanol

True / False:

1. True
2. True
3. False: Corn
4. False: 2.7 Gallons
5. True
6. False: Increase
7. True
8. True
9. True
10. False: 85 percent

Short Answer:

1. Reduces oil imports/trade deficits; stabilizes corn prices; improves the environment; reduces engine pinging/knock; or absorbs moisture in the fuel system.
2. Brazil and Sweden
3. A blend of 10 percent ethanol and 90 percent gasoline; as a component of reformulated gasoline; directly as a fuel with 15 percent gasoline (E-85).

Module 2: Science and Technology

True / False:

1. True
2. True
3. False
4. False
5. True
6. True
7. True
8. True
9. False
10. False
11. False
12. True

Short Answer:

1. 2.7
2. Starch, sweetener, protein feed, gluten meal, corn oil, or carbon dioxide
3. Starch
4. 1.38
5. 8
6. 78° C (172.4° F)

Sequence:

a. 2
b. 4
c. 1
d. 6
e. 3
f. 5
g. 7

Module 3: The Fuel

True / False:

1. False: Fuel extender
2. False: Octane booster
3. True
4. True
5. True
6. False: 85 percent
7. False: Brazil
8. True
9. False: Ethanol
10. True

Multiple Choice:

1. C 2. E 3. B 4. B 5. A

Fill in the Blank:

1. gasoline
2. octane rating
3. pinging or knocking
4. volatility
5. 90
6. methanol
7. 17 percent
8. 100 percent
9. variable or flexible

Short Answer:

1. Ignition timing, air/fuel ratio, barometric pressure, temperature, humidity, combustion temperature, exhaust gas re-circulation rate, combustion chamber deposits.
2. Volatility too low causes: poor cold starts, poor warm-up performance, poor cool weather driveability, combustion chamber and spark plug deposits, unequal fuel distribution. Volatility too high causes: vapor lock, loss of power, rough running or stalling, decreased fuel mileage, increased evaporative emissions, fuel evaporation canister overload.
3. Reduced emission levels, especially hydrocarbons and carbon monoxide. Use of ethanol made from corn increases amounts of corn grown, which increases the conversion of carbon dioxide into oxygen, which combats global warming.

Module 4: Environment

Matching:

1. C
2. A
3. D
4. B
5. E

Essay:

1. Ethanol and other oxygenates take the place of some of the gasoline and add oxygen to the combustion process which reduces levels of all pollutants controlled by the EPA.

Project Answers:

1. ethanol	12. oxygen
2. octane	13. subsidy
3. gasoline	14. oil
4. carbon monoxide	15. dehydrate
5. emissions	16. brazil
6. grain	17. farmer
7. corn	18. fuel
8. alcohol	19. hydrocarbons
9. ozone	20. unleaded
10. energy	21. incentive
11. enhancer	

Module 5: Economics

Check:

1. √	6. √	11.
2. √	7. √	12.
3.	8. √	13.
4. √	9. √	14.
5.	10. √	15.

Essay:

1. Increases farm income, boosts employment, improves balance of trade, adds to tax receipts, results in a net savings to the federal government, less dependence on foreign oil.

2. The increase in corn prices is offset by the production of cattle feed during the making of ethanol. While it is possible that meat and milk prices might increase slightly, it is doubtful.

Ethanol Evaluation

True / False:

1. True	5. True
2. True	6. True
3. True	7. True
4. False	

Multiple Choice:

1. B	6. B	11. B
2. C	7. E	12. D
3. F	8. D	
4. E	9. A	
5. E	10. A	