CHAPTER 13
Ethanol

INTRODUCTION

Ethanol (ethyl or grain alcohol) is a renewable fuel used to power vehicles and other internal combustion engines. Ethanol is currently made from feedstock crops such as corn, barley and sugarcane that contain significant amounts of sugar, or materials that can be converted into sugar, such as starch.

About 90 percent of ethanol in the U.S. is made from corn, due in large part to federal subsidies to encourage the production and consumption of corn-based ethanol.[1] Cellulosic ethanol, by contrast, is produced from wheat straw, corn stalks (called stover), sawdust, rice hulls, paper pulp, wood chips, energy cane, sorghum, miscanthus grass and switchgrass, all of which contain cellulose and hemicellulose, which can be converted into sugars and then fermented into ethanol.

At present, corn is much easier and cheaper to process into ethanol than cellulosic biomass. However, compared to corn, cellulosic biomass crops require less energy, fertilizer, pesticide and herbicide to grow.[2] Cellulosic ethanol production may not become economically feasible for a number of years, although the basic technology has existed for more than a hundred years.

Ethanol can be used as an alternative to gasoline and could help reduce America's dependence on imported oil. In early 2007, President George W. Bush announced his goal to reduce U.S. gasoline consumption by 20 percent in 10 years. Furthermore, the 2007 federal energy bill sets a goal that the U.S. will produce 15.2 billion gallons of renewable fuels annually by 2012 and 36 billion gallons by 2022.[3] In addition to the Renewable Fuel Standard (RFS), ethanol production also benefits from federal tax credits.

In addition to federal policies encouraging ethanol production, relatively low grain prices and high crude oil prices contributed to the industry's growth. In January 2007, corn sold for $3.05 a bushel, although by March 2008 increased demand for corn to produce ethanol had driven the price up to $4.83 a bushel, a 58 percent increase in just over a year.[4]

Like all industries, ethanol production can spur job growth and increase local tax revenues. Ethanol production can contribute to local economies.

History

Ethanol has been used as a source of energy for almost 200 years. The 1908 Ford Model T was designed to run on a mixture of gasoline and alcohol. Ethanol use increased during the 1970s and 1980s when gasoline supplies decreased and became more expensive.[5] Currently, ethanol is used as a gasoline additive in mixes of up to 85 percent ethanol.[6]

Uses

Ethanol can be used as an engine fuel by motor vehicles as well as some lightweight aircraft.

It can be blended with gasoline to produce a fuel called E85 — 85 percent ethanol and 15 percent gasoline. This fuel has a high oxygen content, and burns cleaner than other motor vehicle fuel. But ethanol has a lower energy content than gasoline and thus is less efficient; vehicles running on ethanol get fewer miles per gallon. On average, a vehicle consumes 1.4 gallons of E85 for every gallon of regular gasoline.[7]

E85 is used in flexible fuel vehicles (FFVs) that are specifically designed to use it. (All cars built after 1970 can run on E10, a fuel that is 90 percent gasoline and 10 percent ethanol.) Except for minor engine and fuel system modifications, FFVs are identical to gasoline models. FFVs have been produced since the 1980s, and many models are available, though there remain few filling stations that sell E85.

Ethanol also can replace Methyl Tertiary Butyl Ether (MTBE), a fuel additive derived from natural gas used to increase gasoline's octane rating and prevent

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engine knocking. In 2006, several major oil companies announced that they would replace MTBE with ethanol in all of Texas' "non-attainment" cities — areas that have failed to meet federal standards for ambient air quality. These include Dallas-Fort Worth, Houston-Galveston-Brazoria, Beaumont-Port Arthur, San Antonio and El Paso.[8] MTBE replacement alone will create a demand in the state for 400 to 500 million gallons of ethanol per year.[9]

MTBE is being replaced with ethanol because MTBE is water-soluble, is not biodegradable and has been found leaking into some groundwater supplies.[10]

Ethanol in Texas

At this writing, Texas has two operational ethanol plants, and two more under construction with others planned. Texas has a limited number of fueling stations for E85. Ethanol thus has only a limited impact on Texas and much of the discussion that follows focuses on ethanol's impact nationally, with some discussion of the existing or potential impact on Texas.

At this writing, Texas has two operational ethanol plants.

Economic Impact

According to the Renewable Fuels Association, the ethanol industry created 147,000 jobs in all sectors of the U.S. economy in 2004, and provided more than $2 billion in tax revenue to all levels of the government. The U.S. Department of Energy (DOE) estimates that for every 1 billion gallons of ethanol produced, 10,000 to 20,000 jobs will be added.[11]

A Texas ethanol plant producing 100 million gallons per year could create about 1,600 new jobs in all sectors of the economy. These jobs may be created in other states, since feedstocks for producing ethanol could come from outside Texas.[12]

Consumption

In 2006, the U.S. demand for ethanol was about 5.4 billion gallons. U.S. production of ethanol that year was only 4.9 billion gallons, prompting the nation to import 653 million gallons.[13] The U.S. Energy Information Administration has estimated that Texas motorists used 29 million gallons of ethanol in 2005. Leading the nation, Californians used 918 million gallons of ethanol in the same year.[14] Some states are requiring oil companies to replace the MTBE in gasoline with ethanol, and some companies are doing so voluntarily; this is expected to increase national demand for ethanol.

The U.S. Department of Agriculture (USDA) estimates that by 2010, 30 percent of U.S. corn production will be required to meet the increased demand for ethanol. Even at this rate, USDA estimates that only 8 percent of the nation's annual gasoline consumption will be displaced.[15] The long-term survival of the ethanol industry depends upon a continuing supply of low-cost feedstocks such as corn, or a transition to cellulosic ethanol, using sources such as sorghum, switchgrass or wood.

Production

One bushel of corn (56 pounds) can produce up to 2.8 gallons of ethanol.[16]

As of April 2008, the U.S. had 147 operating ethanol plants, 55 plants under construction and 6 existing plants undergoing expansions.[17] The majority of these plants are located in the Midwestern Corn Belt (**Exhibit 13-1**). Texas has two operating ethanol plants. The U.S. has no commercial cellulosic ethanol plants, but DOE has funded six pre-commercial scale plants for demonstration, none of which are in Texas.

U.S. ethanol production has increased rapidly over the past five years. In 2007, U.S. ethanol production reached 6.5 billion gallons (**Exhibit 13-2**).

Exhibit 13-1
Top U.S. Ethanol Producing States, 2007

State	Number of Facilities	Production Capacity (millions of gallons)
Iowa	28	1,862.5
Nebraska	18	1,017.5
Illinois	7	881.0
South Dakota	13	607.0
Minnesota	16	604.6

Source: National Corn Growers Association.

Extraction/Collection

Ethanol can be made from corn by either of two processes: *dry milling* and *wet milling*. Ethanol plants also yield a number of other commercially valuable co-products, such as livestock feed and carbon dioxide.

Dry milling works by grinding the corn into flour and then adding water to create mash. The mash then is mixed with enzymes to convert the starches to sugars. At this point, yeast is added to convert sugar to ethanol and carbon dioxide. Dry mills also produce distillers' dried grain with solubles (DDGS) and carbon dioxide. The livestock industry uses DDGS as a high-value feed, and the carbon dioxide can be sold to beverage makers for carbonation (**Exhibit 13-3**).[18]

In *wet milling*, corn is soaked in water and acid to separate the various grain components. Grinders then separate the corn germ from the fiber, gluten and starches. The starch and water from the mash are converted into ethanol. Other components of the corn can be used to produce corn gluten meal, corn gluten feed, cornstarch, corn syrup and corn oil (**Exhibit 13-4**).

Cellulosic Ethanol

Three primary polymers exist in the walls of plant cells — cellulose, hemicellulose and lignin. To convert cellulose to ethanol, the chains of cellulose molecules must be broken into sugars and then fermented into ethanol using yeasts (**Exhibit 13-5**).

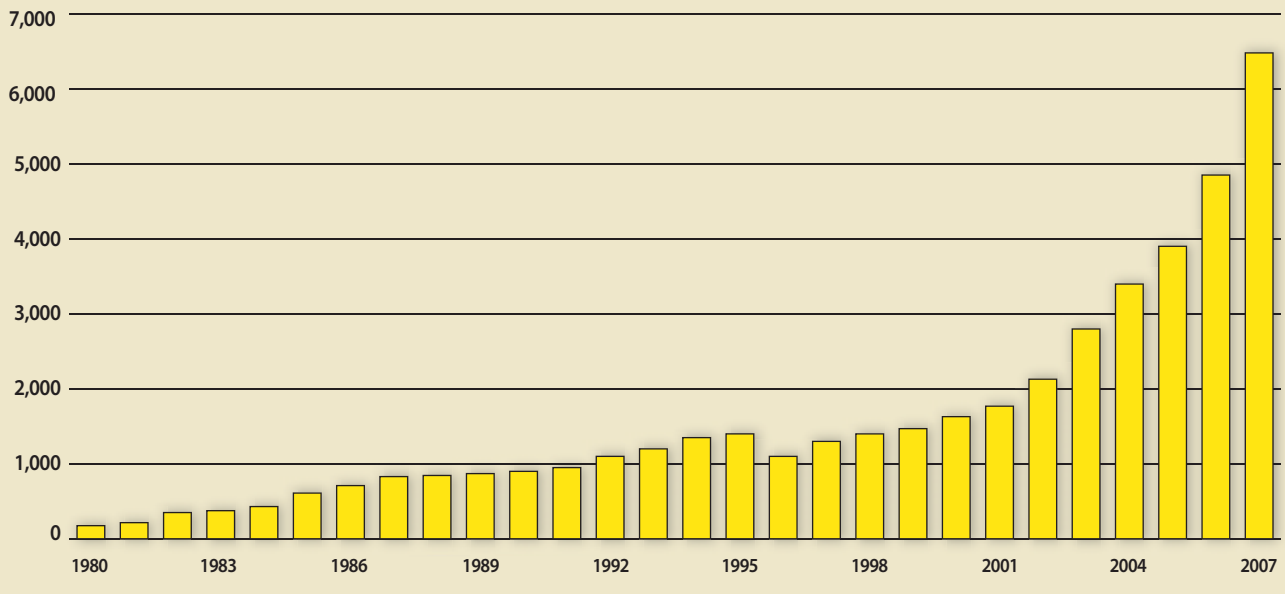
Cellulose can be converted into ethanol by two different methods — the sugar process or the thermochemical process. Acid hydrolysis and enzymatic hydrolysis, in turn, are rival processes used to produce ethanol via the sugar process.

Sugar Process:

In this process, biomass is processed at the ethanol plant. Biomass is ground up resulting in smaller

EXHIBIT 13-2

U.S. Ethanol Production, 1980-2007

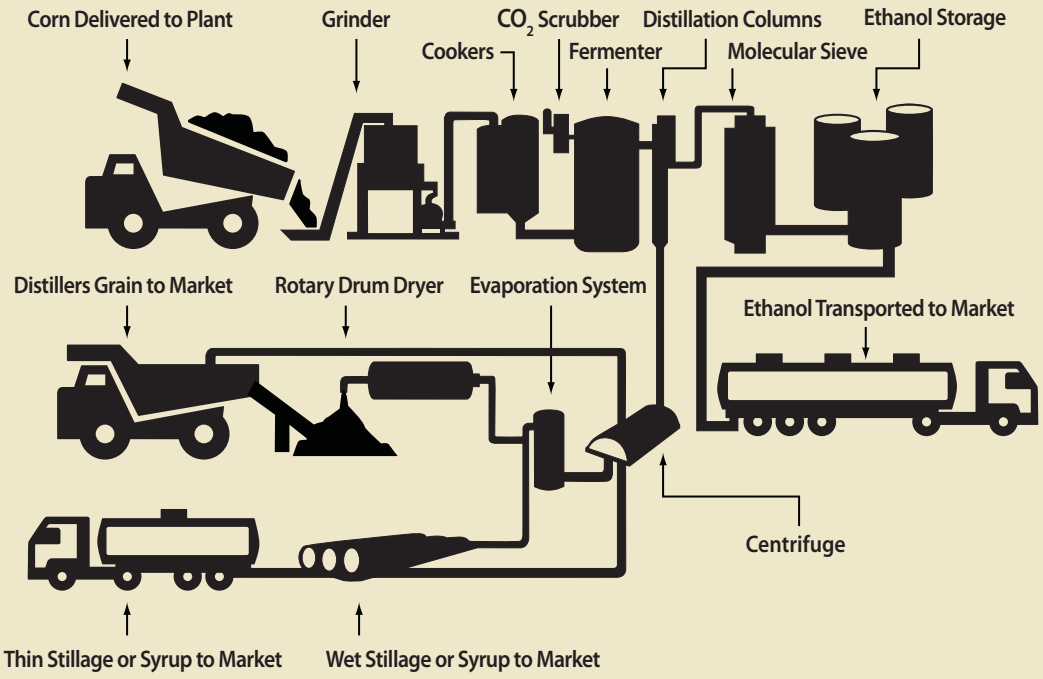


Source: Renewable Fuels Association.

EXHIBIT 13-3

Producing Corn Ethanol: Dry Milling

The ethanol production process starts by grinding up feedstock so that it can be processed more easily. Once ground, the sugar either is dissolved out of the material or the starch is converted into sugar. The sugar then is fed to microbes that use it for food, producing ethanol and carbon dioxide in the process. A final step purifies the ethanol to the desired concentration. Finally, the ethanol is stored in above-ground tanks until it can be transported.



Source: Renewable Fuels Association.

pieces. Pretreatment is needed to separate the cellulose from lignin in order to make the cellulose available for hydrolysis. Some pentose sugar molecules are freed during pretreatment. Pentose can be fermented into ethanol in limited quantities. The cellulose is hydrolyzed using either acids or enzymes.

Acid Hydrolysis

In this process, two different types of acid are used: dilute acid and concentrated acid. To produce ethanol from plants, a "traditional" process using acid was developed in the 1930s.[19] This process has several drawbacks, however, since the acid must be recycled, and the high processing temperatures can degrade the sugar and lower the ethanol yield.[20]

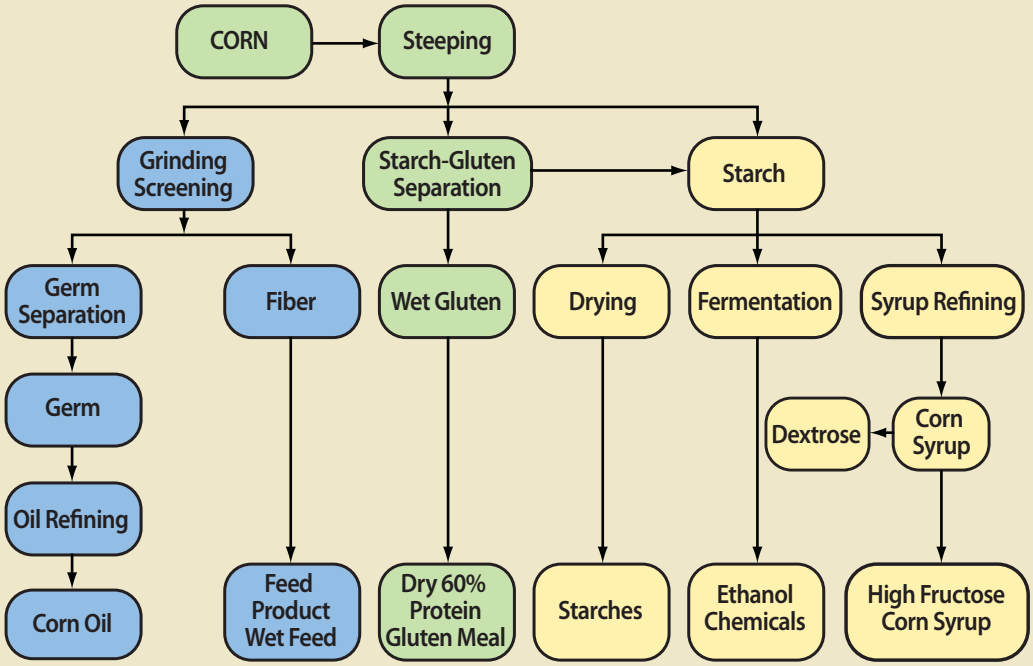
Enzymatic Hydrolysis

Before the enzymes can work to break down the molecules, a pretreatment process breaks down their crystalline structure. The enzymes can come from many sources, such as elephant dung and termite or cow intestines. This process appears to have promise if prices for the enzymes continue falling.

EXHIBIT 13-4

Producing Corn Ethanol: Wet Milling

Most large ethanol producers use this process, which also yields products such as high-fructose corn sweetener.



Source: Renewable Fuels Association.

The hydrolysis of cellulose results in the formation of glucose — a sugar. Glucose is then fermented into ethanol by yeast or bacteria.

Thermochemical Process:

In this process, biomass is gasified into synthesis gas, or "syngas." The gasification process employs different combinations of temperature, pressure, water and air to convert the cellulosic matter into gas. The syngas then is passed over a catalyst and converted to ethanol.[21] Research at several laboratories across the country is attempting to use thermo-catalytic processes to produce higher-value fuels more closely resembling gasoline and diesel.

Producing ethanol from cellulosic material currently is more expensive than corn-based ethanol, since it can involve many different enzymes as well as genetically engineered organisms (**Exhibit 13-6**). The enzymes used in the sugar process are expensive, although their price has dropped considerably in the past five years. In 2001, the enzyme cost per gallon of ethanol produced was about $5; by 2005, this cost had fallen to between 10 cents and 18 cents per gallon.[22] Many ethanol companies are working with major chemical companies to genetically engineer new types of enzymes and microorganisms, such as bacteria or fungi, for ethanol production.

Another economic barrier to commercial production of cellulosic ethanol is the fermentation step. Currently, the yeasts used for this step cannot process some of the sugars (five-carbon sugars) generated by the breakdown of hemicellulose. Research is being conducted to increase ethanol yields by overcoming this challenge.[23]

Status and Summary of Texas Ethanol Plant Projects

At the time of this report, Texas has two operational ethanol plants. Two other ethanol production facilities are under construction, and 12 more facilities are being planned.[24]

White Energy, Hereford — Deaf Smith County *(completed)* and Plainview — Hale County *(under construction)*

100 million gallons/year at each facility

Feedstock: corn and milo

Hereford facility completion: January 15, 2008, operational

Plainview facility completion: 2008

The Hereford facility was completed in January 2008 and the Plainview facility is under construction. Each plant will add 40 full-time jobs to the local community and support 350 jobs during construction. Each facility is expected to generate about $100 million annually in the local economy. These facilities expect to provide distillers wet grain as feed to local livestock producers.[25]

Panda Ethanol, Hereford *(under construction)*

115 million gallons/year

Feedstock: corn and milo

Completion: 2008

When completed, this plant will be the largest biomass-fueled ethanol refinery in the U.S. About 500 to 600 workers will be needed during its construction. Once operational, it will employ 61 full-time employees. The $120 million facility will be located on a 383-acre site. The steam used in the processing will be generated by gasifying cattle manure.[26]

Levelland/Hockley County Ethanol *(completed)*

40 million gallons/year

Feedstock: corn

Operational: first quarter of 2008

Ground breaking on this facility occurred in October 2006 and construction began in January 2007. Opened in February 2008, the plant is located on a 223-acre site three miles from Levelland, Texas. The plant will process about 15 million bushels of corn annually and employ 30 to 35 employees. The plant is expected to produce 130,000 tons of wet distillers grain and dried distillers grain each year for sale to local livestock producers.[27]

Panda Energy, Sherman County *(planned)*

115 million gallons/year

Feedstock: corn

This facility will refine 38 million bushels of corn annually and generate energy by gasifying 1 billion pounds of cattle manure per year. The site is located on 1,200 acres about three miles from Stratford. This facility is expected to create 138 jobs and generate more than $220 million in the Sherman County economy over the next 10 years.[28] As of this writing, permits for the plant are still pending with TCEQ.

Panda Energy, Muleshoe — Bailey County *(planned)*

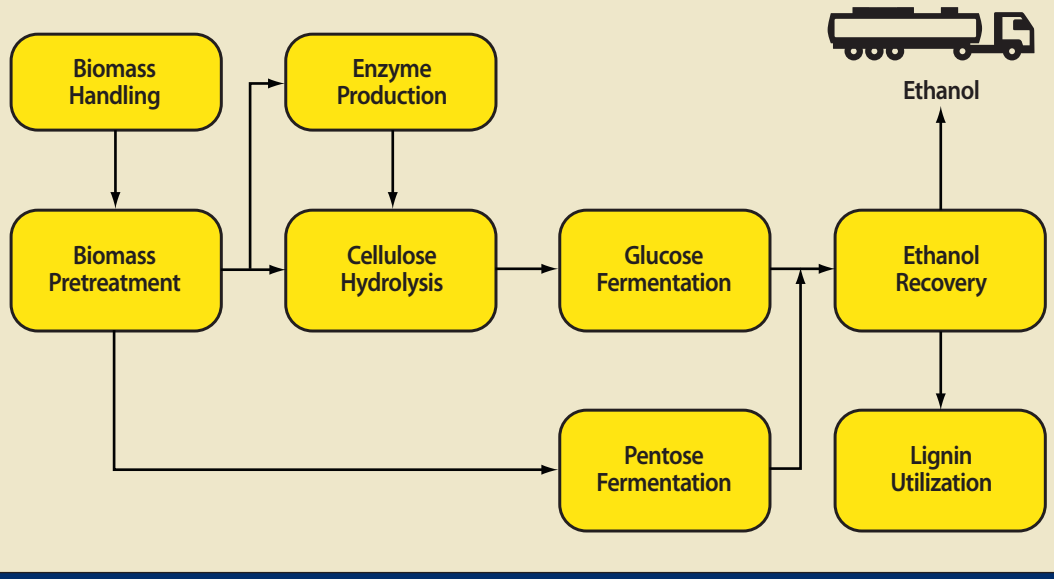
115 million gallons/year

Feedstock: corn

This facility will be one of the nation's most fuel-efficient ethanol facilities. The site is located on 305 acres about eight miles from Muleshoe, Texas. This facility is expected to produce distillers grain, carbon dioxide and ash as co-products.[29] The steam used in the processing will be generated by gasifying cattle manure. At this writing, permits for the plant are still pending with TCEQ.

EXHIBIT 13-5

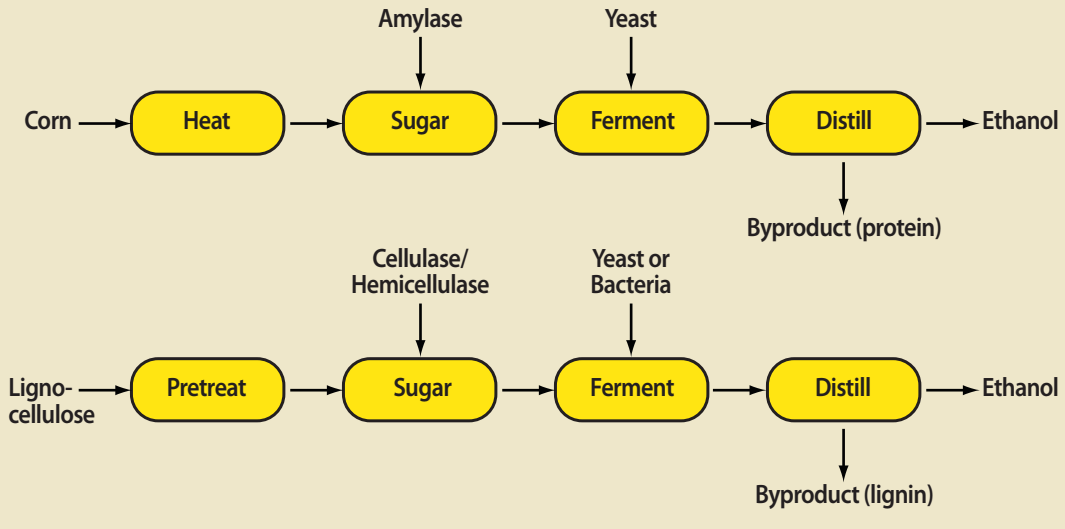
Cellulosic Ethanol Production Process



Sources: U.S. Department of Energy and Renewable Fuels Association.

EXHIBIT 13-6

Ethanol Production, Corn vs. Lignocellulosic Material



Sources: Dr. Mark Holtzapple, Texas A&M University and Texas Comptroller of Public Accounts.

Ethanol from Sugarcane

Producing ethanol from sugar removes the starch-to-sugar step from the production process, thus making it a more efficient feedstock. Currently, no U.S. ethanol plants use sugarcane, but sugar producer Gay & Robinson of Hawaii plans to build the nation's first sugarcane-to-ethanol plant, using sugar juice and molasses as raw material.[30] The plant could open as early as mid to late 2008.[31]

Production of ethanol from sugarcane makes economic sense in Hawaii because the state produces a large amount of sugar cane and its gasoline prices are much higher than on the mainland.

The U.S. imports some sugarcane-based ethanol from Brazil. American-made, corn-based ethanol is cheaper, however, due in large part to a high import tariff on Brazilian ethanol and a blender credit of 51 cents per gallon available in the U.S . In the continental U.S., moreover, sugarcane can be grown only in the southernmost regions of Texas, Louisiana, Florida and California because it is intolerant to cold weather. Texas ranks fourth in the nation for sugarcane production.[32]

Sugarcane production is strictly controlled by a market allotment system for food use, but no such system is in place for nonfood uses such as biofuel. In addition, the federal government controls the price of sugar, keeping it at twice the price available on world markets, due to high import tariffs.[33] Because of these factors, Texas sugarcane growers can make more money selling their cane to sugar refineries than to ethanol distilleries.

Texas A&M's Agri LIFE Research is crossing sugarcane with miscanthus, a tall perennial grass, to extend its geographical range for lignocellulosic biofuels production. Research also is being conducted to increase the sucrose content of sugarcane and the sugarcane-miscanthus hybrids.

Cellulosic Ethanol From Sorghum

Texas A&M University's Texas Agricultural Experiment Station (TAES) is working on a high-yield variety of sorghum to be used in producing cellulosic ethanol. This variety of sorghum can yield 15 to 20 or more dry tons per acre planted; traditional forage sorghums produce about 10 to 13 dry tons per acre. TAES has estimated that its version of high-yield sorghum would cost between $42 and $50 per dry ton to deliver to a local facility, compared to $50 to $60 per dry ton for traditional forage sorghums and grasses.

The high-yield sorghum being grown by Agri LIFE Research is drought-tolerant, an important trait in Texas. It also uses the same amount of water as corn while producing 33 percent more biomass.[34]

The U.S. Department of Energy (DOE) is pursuing the world's most aggressive cellulosic ethanol initiative. On February 28, 2007, DOE announced funding of up to $385 million in all to construct six cellulosic ethanol plants expected to produce more than 130 million gallons of ethanol per year. None of these DOE-funded plants are in Texas. The funding will last through fiscal 2010. These facilities are expected to produce commercial quantities of ethanol once completed.

Transportation

Ethanol cannot travel in pipelines because it is water-soluble, and as a result will mix readily with any water present in a pipeline. Water often enters pipelines at the terminals, and ethanol that absorbs too much water during transport is unsuitable for use. As a result, ethanol must be transported by truck, train or barge, resulting in higher transportation costs. Most ethanol plants, therefore are situated near major highways or rail lines to ensure efficient movement.

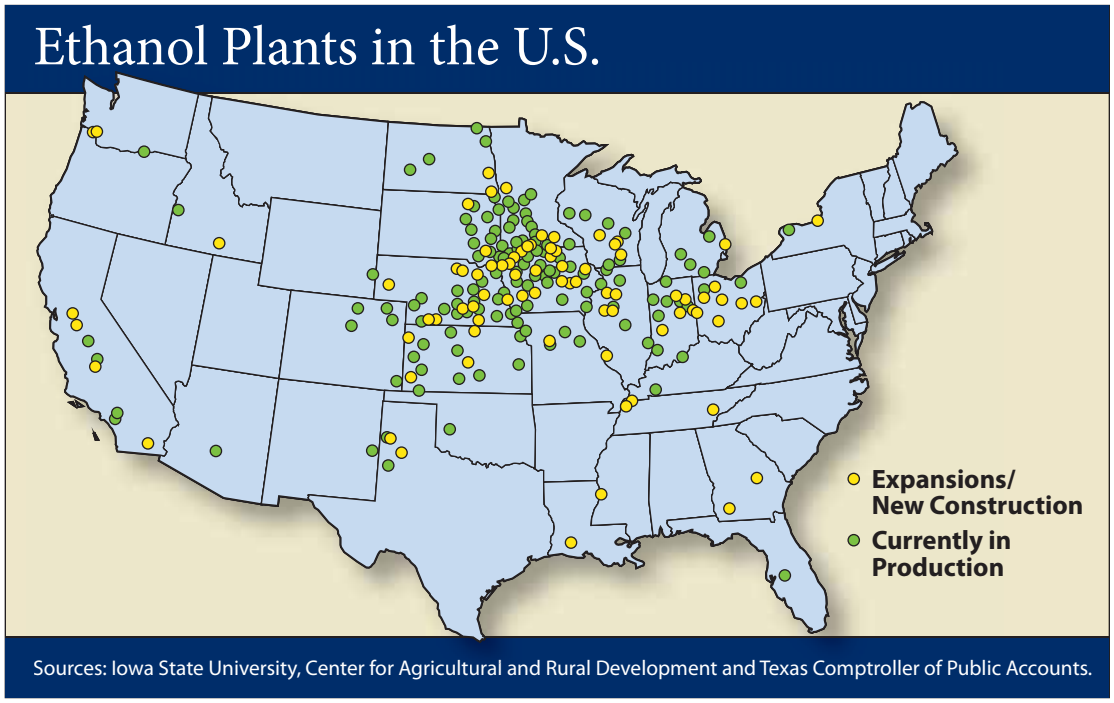
Transportation of corn also can entail costs, and most ethanol plants are located near areas where corn is grown. (To date, the majority of ethanol plants are located in the Midwest because of this constraint.)

The largest corn-producing states are Iowa, Illinois, Minnesota and Nebraska. While Texas produces a significant amount of corn, it is not in the top tier for production, ranking 11th nationwide in 2007, with 296 million bushels of corn grown.[35] In fact, Texas is a net corn importer, using more corn than is grown.

Some ethanol plants, called "destination plants," are located close to feed yards and dairies, because the by-products of milling (distiller's wet grain and dry distiller's grain) are then fed to livestock. Manure from feed yards also can be used as fuel for the plant, as with the plant currently under construction in Hereford, Texas.

The largest ethanol plants planned for Texas will be located in the Panhandle, close to feedyards and as

EXHIBIT 13-7



close as possible to Midwestern corn farms (**Exhibit 13-7**). There are more than 1 million head of cattle and 100,000 dairy cows within a 100-mile radius of Hereford, the current home of one completed ethanol plant and one under construction, which could benefit from grain residue.[36]

Storage

Currently, storage of the corn feedstock is becoming a concern due to the extraordinarily large corn harvest expected this year in the U.S. This will be an ongoing problem until more permanent storage sites can be constructed. Once the ethanol is produced, it is stored in above-ground storage tanks where it waits to be transported to a blender.

Availability

In Texas, ethanol (E85) is available to the public as a motor fuel at only 26 locations.[37]

E85 is available at the H.E. Butt Grocery Company (H-E-B) at eight public E85 fueling sites in Schertz, Austin, Killeen, Buda, Waco, Kyle, Mission and Laredo. The Kroger Co., a supermarket chain, operates 17 E85 fueling sites located across Texas. CleanFuel USA, a fueling equipment manufacturer has one E85 fueling site in San Antonio.

In addition, some federal facilities such as military bases in Amarillo, Houston, San Antonio and Wichita Falls have E85 pumps, but these are not open to the public. The Texas Department of Transportation is a national leader for alternative fuel vehicle use in fleet management and is considering using E85 in some of its vehicles. **Exhibit 13-8** shows E85 fueling stations in Texas.[38]

Cellulosic ethanol could greatly increase the volume of ethanol fuel that can be produced and made available to consumers. A 2005 report conducted by the U.S. Department of Energy and the U.S. Department of Agriculture determined that the U.S. could have more than 1.3 billion dry tons of available biomass potential each year by 2030, about 27 percent of it from forest resources and the remaining 73 percent from agricultural resources. If all of this were used to produce biofuels, about a third of the country's transportation fuel needs would be met.[39]

COSTS AND BENEFITS

Ethanol fuel (E85) costs less per gallon *at the pump* than gasoline, due to the federal ethanol blender tax credit of 51 cents per gallon, but it is less efficient because, as noted earlier, it contains

EXHIBIT 13-8

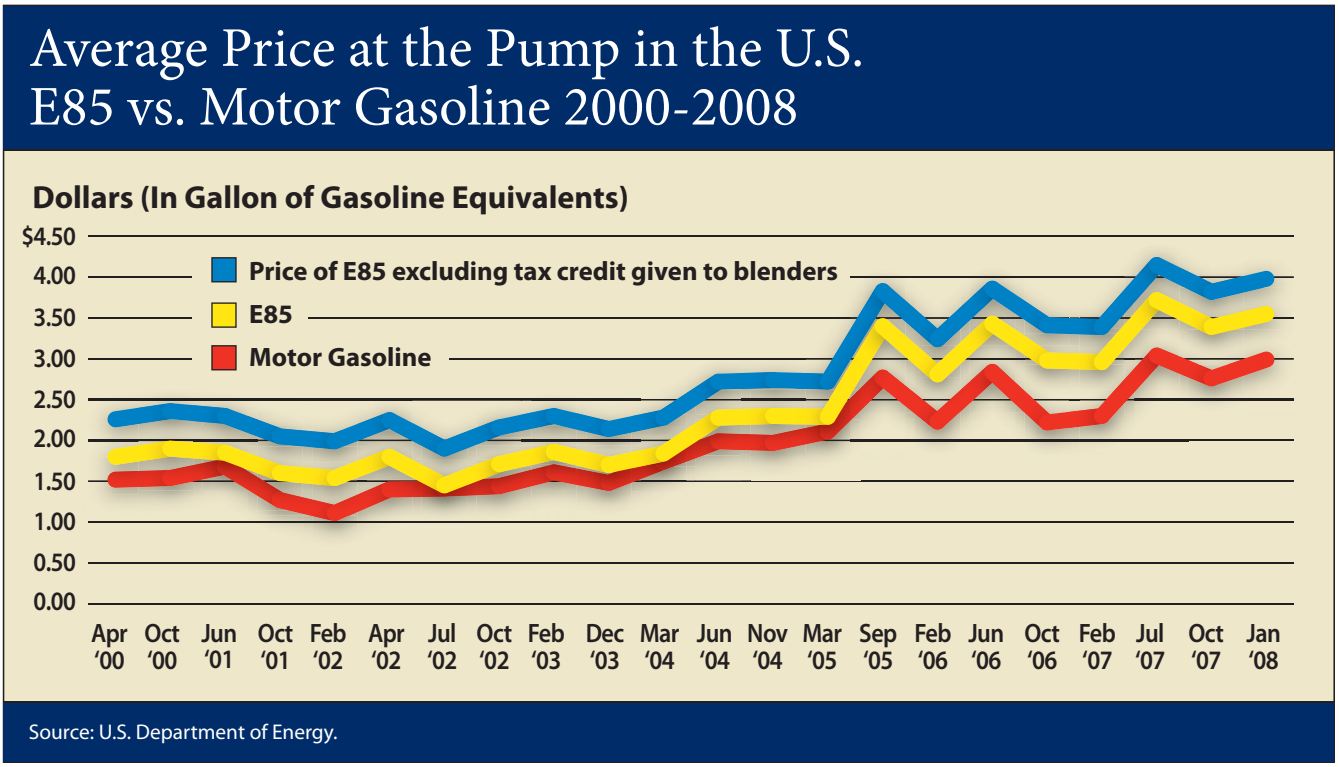
Source: U.S. Department of Energy.

less energy than traditional gasoline. Thus a gallon of E85 cannot take a vehicle as far as conventional gasoline would, and depending on current market prices, it can be more expensive to use.

Both the price of E85 and motor gasoline have risen dramatically since 2000. In April 2000, the price of E85 was $1.44 per gallon ($1.80 in gallon of gasoline equivalents). Since then, the national average price has risen to $2.51 per gallon ($3.55 in gallon of gasoline equivalents). The price of E85 has been consistently higher than the price of motor gasoline (**Exhibit 13-9**).[40]

Typically, the price of building an ethanol plant depends largely on the amount of ethanol it will produce. In other words, the larger the production capacity of the facility, the more it costs to build. For example, a plant that could produce 220 million gallons of ethanol per year would cost about $300 million.[41] A plant that could produce 115 million gallons of ethanol per year would cost only $120 million.[42]

EXHIBIT 13-9



Source: U.S. Department of Energy.

Ethanol and Corn Prices

Due to increased demand, in March 2008, the price of corn reached a 10-year high at $4.83 per bushel.[43] The average annual corn price has been volatile since the 1980s, but has risen steadily and rapidly since the Renewable Fuel Standard was established in 2005. Oil and gasoline prices also have risen during this period. The average annual farm price for corn reached $4.30 per bushel in 2007. In 2007, 23.7 percent (3.1 billion bushels) of the domestic corn crop was used for ethanol production; this is up from 0.5 percent (35 million bushels) of the corn crop in 1980 (**Exhibit 13-10**).[44]

Production Costs

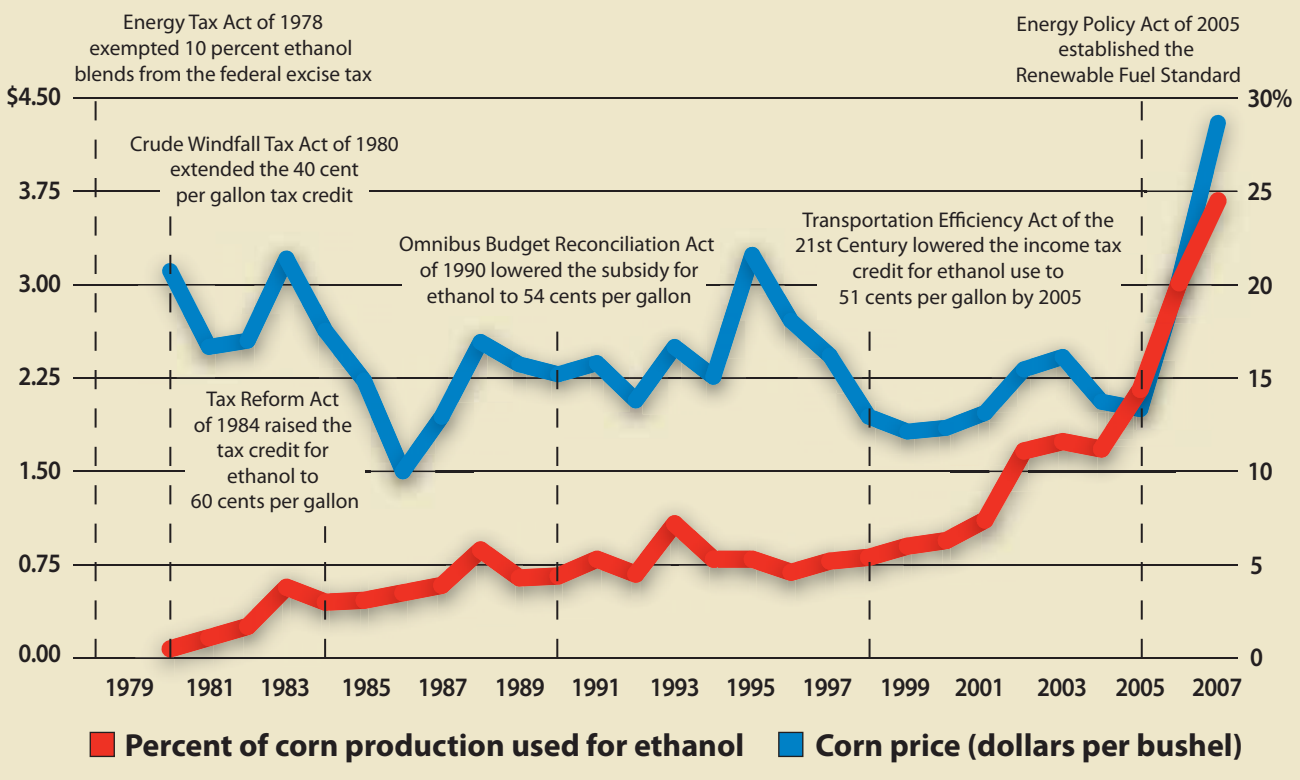
Many factors enter into calculating the production costs of ethanol. In 2005, Dr. David Pimentel, a

Cellulosic Ethanol in Texas

Verenium, an enzyme production and ethanol refining company, has plans to build a cellulosic ethanol facility in the Beaumont area. The company anticipates that the 30 million gallon per year facility will cost between $150 and $180 million and could create 250 construction-related jobs. Once complete, the facility could employ 50 people and have a $750 million impact to the Texas economy over a 20-year period. The facility would use sugar cane, energy cane, and/or sorghum as feedstocks. Given the technology available, with high yields per acre, the company expects that they could generate 2,000 gallons of ethanol for every acre of biomass used. The company plans to submit permit applications in spring 2008, with construction beginning in spring 2009.[45]

EXHIBIT 13-10

Percentage of U.S. Corn Used to Produce Ethanol and Price per Bushel, 1980-2007



Sources: U.S. Department of Agriculture–Economic Research Service and U.S. Energy Information Administration.

Ethanol's Effect on Crop Prices

The rapid expansion of ethanol production has resulted in both increased corn production and higher corn prices with consequences for other agricultural commodities, animal feed prices and human food prices as well. As **Exhibit 13-10** shows, corn prices have been rising rapidly in recent years.

About 55 percent of the U.S. corn crop is used for animal feed. Less than 10 percent of the crop is used for corn-based human foods.[46] The effects of higher grain prices on animal feeders vary somewhat depending on the ability of some species to use the byproducts of ethanol production - distiller's grains - as feed. Ruminants like beef and dairy cattle can digest this product better than hogs or poultry, for example.

Livestock and poultry feeders across the country are feeling the effects of higher feed prices. The nations' biggest meat and poultry producers have announced cutbacks in production related to rising costs. The largest hog producer in the U.S., Smithfield Foods Inc., based in Smithfield Virginia, announced it will cut production by 5 percent, or 1 million animals, because of high feed costs. Tyson Foods Inc., the largest U.S. meat company, said it will close a beef plant in Kansas resulting in 1,800 lost jobs. The company, based in Springfield, Arkasas, cited a $500 million increase in grain costs and a 40 percent drop in profit.[47]

Texas based companies are reacting, too. Pilgrim's Pride, Inc., based in Pittsburg, Texas, announced that it would close a chicken processing plant in Siler City, North Carolina, and 6 of its 13 distribution centers. The company said record high prices for corn and soybean meal combined with an oversupply of chicken made it necessary to cut costs, resulting in elimination of 1,100 jobs.[48]

Using food and feed crops for fuel also has resulted in economic effects beyond corn prices and livestock production costs. According to the U.S. Department of Agriculture, other field crops and food prices have been affected by rising demand for corn ethanol. Farmers previously cut cotton and soybean plantings, raising prices for those commodities, too.[49]

Soybeans compete most directly with corn in terms of acres planted, particularly in the Midwest where they are planted in rotation with corn. While higher corn prices led some soybean producers to reduce plantings, the demand for soybean oil to make biodiesel increased at the same time. Biodiesel uses 15 percent of U.S. soybeans.[50] Like corn, soybean prices have risen dramatically, from $6.37 a bushel in January 2007 to $11.00 in January 2008.[51] Until 2008 spring planting is complete, it will not be clear what competing crops farmers will choose to plant, a decision some make at planting time in response to commodities futures prices.

DOE-Funded Cellulosic Ethanol Projects

Abengoa Bioenergy Biomass of Kansas, LLC

Plant site: Colwich, Kansas

Source of fuel: Corn stover, wheat straw, milo stubble, switchgrass and other feedstocks

Production: 11.4 million gallons per year

DOE Funding: Up to $76 million

Alico Inc.

Plant site: LaBelle, Florida

Source of fuel: Yard waste, wood waste, citrus peels and vegetations

Production: 13.9 million gallons per year

DOE Funding: Up to $33 million

BlueFire Ethanol, Inc.

Plant site: Southern California

Source of fuel: Assorted green waste and wood waste from landfills

Production: 19 million gallons per year

DOE Funding: Up to $40 million

Brion Companies

Plant site: Emmetsburg, Iowa

Source of fuel: Corn fiber, cobs and stalks

Production: 31 million gallons per year

DOE Funding: Up to $80 million

Iogen Biorefinery Partners, LLC

Plant site: Shelley, Idaho

Source of fuel: Wheat straw, barley straw, corn stover, switchgrass and rice straw

Production: 18 million gallons per year

DOE Funding: Up to $80 million

Range Fuels

Plant site: Soperton, Georgia

Source of fuel: Wood residues and wood-based energy crops

Production: 40 million gallons per year

DOE Funding: Up to $76 million

Source: U.S. Department of Energy.

professor of entomology at Cornell University, and Dr. Tad Patzek, a professor of civil and environmental engineering at the University of California at Berkeley, estimated that it costs about 42 cents per liter, or about $1.59 per gallon, to make ethanol from corn. These costs include costs of corn feedstock, transportation, electricity to run the plant and the cost of waste disposal, among others. They, however, do not include the value of co-products, the market value of which might reduce the net costs of ethanol production.[52] It also should be noted that Pimentel and Patzek used a corn price of 28 cents per liter of ethanol produced. This equates to about $3 per bushel, assuming 2.8 gallons of ethanol produced per bushel of corn. At this writing, corn prices are $4.83 per bushel. This increased feedstock cost would add about 67 cents per gallon to the cost estimated by Pimentel and Patzek.

In 2005, Dr. Hosein Shapouri, an agricultural economist at the USDA, and Dr. Paul Gallagher, a professor of agricultural economics at Iowa State University, estimated that it cost about $0.96 per gallon to make ethanol from corn in 2002. Unlike the Pimentel and Patzek study, these costs include money made from the sale of co-products.[53] Similar to Pimentel and Patzek's study, the feedstock cost is much lower than current costs. In this study, the cost of corn was assumed to be $2.14 per bushel. As noted above, corn prices are $4.83 per bushel at this writing. This increased feedstock cost would add about 96 cents per gallon to the cost estimated by Shapouri and Gallagher.

Demand for ethanol and biodiesel crops has driven up the price of commodities such as corn, palm oil and sugar, contributing to food-price inflation, including beef, eggs and soft drinks.[54] In the U.S., food-at-home prices rose 4.2 percent in 2007, although it is difficult to determine exactly how much of this increase is attributable to ethanol's impact on corn.[55] Many other factors contribute to the cost of food, including transportation, advertising and other costs associated with the food industry. The increased demand for corn for ethanol has affected the livestock industry as well, by increasing feed prices and cutting into livestock feed supplies.

Cellulosic Ethanol

In the absence of any commercial cellulosic ethanol plant, it is not possible to estimate the cost per gallon of ethanol from this process. Experts such as Dr. Bruce Dale, a professor of chemical engineering and materials science at Michigan State University, believe that cellulosic ethanol can be produced for about $2.50 per gallon today. In about five years, using advancements made through DOE funding, Professor Dale anticipates that the price of producing cellulosic ethanol could fall to $1.20 per gallon.[56]

Environmental Impact

Supporters of the ethanol industry say that its use helps the environment by reducing air pollutants. No conclusive studies have shown this to be the case, however. And while alternative fuels, such as ethanol, can reduce America's dependence on foreign oil, the U.S. simply does not have enough acres of farmland to replace most of its gasoline with corn ethanol.

Air Quality

Ethanol supporters also say that its production and consumption are carbon-neutral (**Exhibit 13-11**).

A report by DOE's Lawrence Livermore National Laboratory identified several environmental concerns regarding the use of ethanol as a substitute for MTBE in gasoline:

- When ethanol replaces MTBE, the major concerns are the production of acetaldehyde (a toxic air contaminant) and peroxyacetyl nitrate (an eye irritant).
- Ethanol is shipped by truck or rail. Additional transportation needs could slightly increase the nation's total emissions due to heavy-duty truck and train engines.

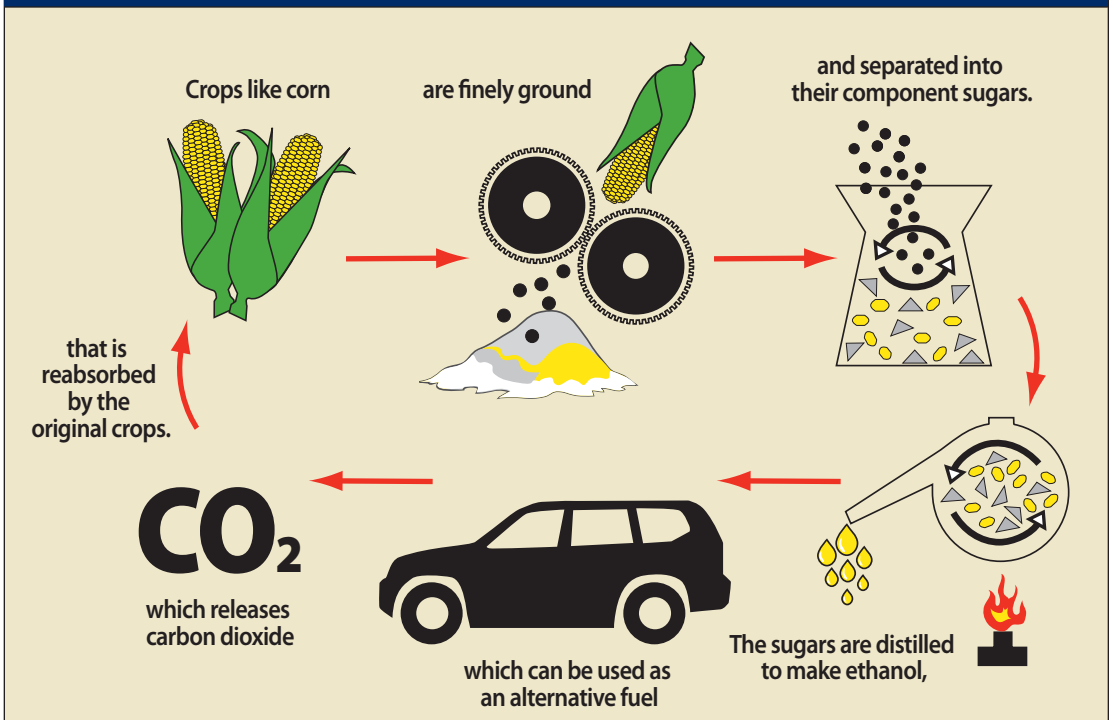
Even so, areas of the country with air pollution problems are focusing on ethanol to help meet the Environmental Protection Agency's (EPA's) clean air standards. According to the Texas State Energy Conservation Office, adding ethanol to gasoline helps it to burn more completely and significantly reduces vehicle emissions. Carbon monoxide emissions are cut by up to 30 percent, Volatile Organic Compounds by about 12 percent and particulates by about 25 percent.[57]

In October 2002, the EPA, U.S. Department of Justice and state of Minnesota settled with 12 Minnesota ethanol manufacturing plants for al-

Demand for ethanol and biodiesel crops has driven up the price of commodities such as corn, palm oil and sugar.

EXHIBIT 13-11

The Carbon Cycle



Source: U.S. Energy Information Administration.

Growing corn requires a significant amount of water, fertilizer and pesticides.

leged Clean Air Act violations. The New Source Review provisions of the Clean Air Act require such sources to install pollution controls and undertake other pre-construction obligations to control air pollution emissions. The Minnesota plants were required to install air pollution control equipment to reduce emissions of harmful VOCs, carbon monoxide, nitrogen oxides, particulate matter and other hazardous air pollutants produced during the manufacturing process.[58]

Water Use

Growing corn requires a significant amount of water, fertilizer and pesticides, which can have a negative impact on the environment. On average, farmers use about 134 pounds of nitrogen fertilizer per acre of corn each year.[59] Each irrigated acre of corn also requires about 1.2 acre-feet of water (391,021 gallons). By comparison, wheat requires 1.5 acre-feet of water per acre and soybeans require 0.8 acre-feet.[60]

According to a March 2007 *Wall Street Journal* article, critics of ethanol say, "Ethanol plants deplete aquifers, draw heavy truck traffic, pose safety concerns, [and] contribute to air pollution."[61]

According to the U.S. Department of Energy, depending upon climate conditions, corn-based ethanol requires between 2,500 gallons and 29,000 gallons of water per million Btu of energy produced, primarily for crop irrigation; cellulosic crops require significantly less water.[62] A study by the U.S. Department of Agriculture found that water use to irrigate corn averaged 784.6 gallons of water per gallon of ethanol, which equates to more than 9,000 gallons of water per million Btu of energy produced.[63] By comparison, crude oil production and refining can require between one gallon and 2,500 gallons of water per million Btu of heat energy produced, depending primarily on how much water was required to extract crude oil from underground sources.[64] In 2002, water use at

ethanol plants averaged 4.7 gallons per gallon of ethanol produced.[65] Biodiesel production typically requires less water than ethanol.

Land Use

Since cellulosic ethanol can be made from any type of plant material, some critics fear that wider use could affect the environment due to tree cutting and additional water use to grow cellulosic materials. It should be noted that some potential cellulosic energy crops can be drought-tolerant and use less water than corn. In 2003, almost 16 percent of the nation's cropland in the U.S. was not being cultivated. This amounts to 58 million acres of land that could be used to grow low-input, drought-tolerant crops for making cellulosic ethanol.[66]

Ethanol is biodegradable, so accidental spills pose few risks to the environment.

To date, the EPA has not studied the overall environmental impact of both producing and consuming ethanol. A March 2007 DOE study found that greenhouse gas emissions from corn-based ethanol are 18 to 28 percent lower than those from gasoline, while cellulosic ethanol greenhouse gas emissions are 87 percent lower. This study did not take into account the environmental effects of producing ethanol, however.[67]

Other Risks

Ethanol corrodes rubber, steel and aluminum, and most vehicles are not designed with this in mind. Ethanol has a higher freezing temperature than gasoline and cannot travel in pipelines because it absorbs water.

A diverse and growing group of detractors, from ranchers to some environmentalists, oppose expanded use of corn-based ethanol, prompting a "food versus fuel" debate as the cost for corn spirals upward due to high demand. The National Cattlemen's Beef Association, National Chicken Council, National Turkey Federation and National Pork Producer's Council all testified before Congress in March 2007 to end corn ethanol subsidies.[68] In August 2007, the National Cattlemen's Beef Association sent a letter to Congress in opposition of increasing the Renewable Fuel Standard.[69]

The National Corn Growers Association maintains that:

- increased demand is being met with increased production, which should allow corn growers to satisfy both domestic and export demand;
- the ethanol process creates useful livestock feed and food products; and
- corn demand has no noticeable impact on food prices.[70]

Tyson Foods, however, the world's largest processor and marketer of chicken, beef and pork, has warned that ethanol-driven corn prices will push up the cost of chicken and beef for American consumers.[71]

In Texas, Dr. David Anderson, a Texas Cooperative Extension economist, stated that as ethanol production grows, livestock producers should consider the following possibilities:

- higher feed costs;
- feeder cattle and calf prices adjusted to the price of corn;
- reduced production in terms of cattle weights and profitability; and
- a livestock industry that is less competitive in the world market.[72]

The food versus fuel debate has generated increased interest in cellulosic ethanol. Due to the complexity of the process, however, only relatively small-scale production has been possible to date. Cellulosic ethanol research continues to be conducted in Texas.

The food versus fuel debate has generated increased interest in cellulosic ethanol.

State and Federal Oversight

The federal Clean Air Act and Clean Water Act both affect ethanol plants.

On April 12, 2007, EPA set emissions rules for ethanol plants. Ethanol plants that use carbohydrate feed stocks such as corn are not required to count "fugitive" emissions (those not coming from stacks or vents) to determine if they exceed emission limits.

EPA now allows new ethanol plants to emit up to 250 tons of regulated pollutants per year in certain areas, not including non-attainment areas.[73] Previously, these plants were permitted to emit only 100 tons of regulated pollutants per year; many think the new limits will mean more pollution and cause breathing problems for residents located near the plants.

The Texas Commission on Environmental Quality (TCEQ) grants permits for air and wastewater quality. It typically takes a year to obtain an air permit for a new ethanol facility in Texas. It can also take about one year to obtain a wastewater permit from TCEQ. These timelines can encounter significant delays, however, depending on public meeting requests or contested case hearings.[74]

Subsidies and Taxes

The largest federal ethanol subsidy is the volumetric Ethanol Excise Tax Credit (VEETC) of 51 cents per gallon of ethanol. The incentive reduces the amount of excise tax the blender has to pay on a dollar-for-dollar basis. If a blender uses the ethanol to make E85, the tax credit amounts to 43.4 cents per gallon of E85 produced (0.85 * $0.51 = $0.434). Congress has extended this incentive through 2010. Often, the blender is the oil company that produces the gasoline.

The largest federal ethanol subsidy is the blender tax credit of 51 cents per gallon of ethanol.

In 1980, Congress placed a 2.5 percent tariff on foreign-produced ethanol. According to the *Wall Street Journal*, this tariff was designed "to protect prices for U.S. corn growers in Farm Belt states."[75] Brazil produces ethanol for much less than the U.S. can because Brazilian ethanol is sugarcane-based. (Again, producing ethanol from sugar removes the starch-to-sugar step of the production, making production costs lower than ethanol produced from corn.)

The import duty on ethanol, currently 54 cents per gallon, has kept the price of Brazilian and other foreign ethanol higher than domestic production. A so-called "Caribbean Loophole" to the law, however, provides an exception for ethanol imported through or from the Caribbean islands, up to a total equivalent to 7 percent of U.S. production. Lawmakers from some farm states want to close this loophole.

Most states offer tax incentives related to ethanol, including exemptions, deductions, credits and loans. Each state's program is different. In South Carolina, producers of corn-based ethanol receive a production tax credit of 20 cents per gallon and producers of ethanol from other feedstocks receive 30 cents per gallon. In Indiana, ethanol producers can claim a credit of 12.5 cents per gallon.[76]

Additionally, some states offer retailer tax credits. For example, Indiana provides E85 retailers a credit against state gross sales tax of 18 cents per gallon of E85 sold. In New York, E85 used to operate motor vehicles is exempt from state sales and use taxes entirely.

Cellulosic Ethanol

In addition to the Energy Policy Act of 2005, the Energy Independence and Security Act of 2007 contains several incentives focused on the research and development of ethanol derived from cellulosic biomass.

In June 2007, DOE announced $375 million in funding grants for three cellulosic ethanol research centers. The centers will be led by Oak Ridge National Lab in Tennessee, the University of Wisconsin in Madison and the Lawrence Berkeley National Laboratory in California.[77]

The Tennessee center will attempt to genetically engineer plant cell walls and new bioenzymes to break down plant cell walls, particularly in switchgrass and poplar trees. The Wisconsin center will work to improve the characteristics of feedstock plants, feedstock processing and the conversion of feedstocks to fuel, focusing on switchgrass and poplar trees as well as corn stover (stalks). It will also educate farmers and society as a whole on current technology related to biofuels. The California center will focus on developing specially designed feedstock crops, increasing the activity of enzymes and studying the microbes used in the ethanol distilling process.[78]

In July 2007, Texas Governor Rick Perry awarded $5 million out of the Texas Emerging Technology Fund for biofuels research, particularly for research into cellulosic ethanol.[79] The grant went to Texas A&M University's Agriculture and Engineering BioEnergy Alliance, a partnership between AgriLIFE Research (formerly the Texas Agricultural Experiment Station) and the Texas Engineering Experiment Station.[80]

More information on subsidies and incentives for ethanol can be found in Chapter 28.

Biobutanol

Many experts in the biofuels industry believe that butanol and other higher molecular weight fuels are the next-generation biofuels with potential to surpass both corn-based and cellulosic ethanol. These fuels can be made from biomass feedstocks and have many advantages over ethanol:

- they are compatible with current fuel infrastructure (pipelines) because of low water affinity;
- they have a higher energy content per gallon than ethanol, almost as high as gasoline; and
- butanol can be used in blends of up to 17 percent without engine modifications, compared to blends of up to only 10 percent with ethanol.[81] Higher molecular weight biofuels may be used as a direct substitute for gasoline and diesel.

Depending on the fuel, new processing systems will be required. These second generation biofuels are still many years away from commercial production, and many technological barriers must be overcome before a large market for this biofuel can emerge.[82]

Other States and Countries

Brazil is the world's largest producer of sugarcane and the largest producer of ethanol. In 2006, Brazil shipped 3.4 billion liters (898 million gallons) of ethanol out of the country. About half of Brazil's ethanol exports went to the U.S.[83]

To support the ethanol industry, the Brazilian government places large sales taxes on gasoline and subsidizes ethanol production. Achim Steiner, the head of the United Nations Environment Program, has expressed concerns that ethanol production in Brazil will further harm the Amazon rainforests, due to an increased need for farmland.[84]

Columbia and China also have significant ethanol programs. In June 2007, the Associated Press reported that China was banning the production of ethanol from corn and other food crops because authorities are worried about food-price inflation. China is considering switching to cassava, a plant native to South America but grown throughout the world, or other types of biomass such as sorghum.[85]

Outlook for Texas

Availability of E85 remains an issue, especially in Texas. Two ethanol production facilities were recently completed and there are two ethanol production facilities currently under construction. But Texas has only a handful of E85 pumps.

Heavy federal subsidies have resulted in a rapid and large expansion of ethanol production throughout the U.S. As a result, an increasing percentage of the U.S. corn crop is being devoted to ethanol production.

Controversy has arisen regarding the amount of energy needed to produce ethanol compared to gasoline. Numerous studies on this question have yielded varying results. A 2005 study by Dr. David Pimentel of Cornell University and Dr. Tad Patzek of U.C. Berkeley concluded that producing ethanol from corn requires 29 percent more fossil energy than is contained in the resulting product.[86] A 2004 study by Dr. Hosein Shapouri of the USDA, however, concluded that producing ethanol with corn creates a 67 percent net energy gain.[87] The debate over energy conversion efficiency continues, but higher production efficiency processes are emerging.

An increasing percentage of the U.S. corn crop is being devoted to ethanol production.

An article produced by Oxford Analytica, an international consulting firm representing both private businesses and governmental agencies, cautions that the ethanol boom in the U.S. requires careful management because heavy federal subsides and import barriers may distort trade, which could prompt challenges by the World Trade Organization. At present, ethanol depends upon high oil prices and subsidies to be economically feasible.[88]

As noted above, EPA has not studied the overall environmental impact of producing and consuming ethanol, but many experts across the nation are concerned about both.

High corn prices are good for farmers, but bad for livestock producers and consumers, because so many products are made from corn. Texas has a large livestock industry, and high feed prices

Butanol and Ethanol from Glycerin

Another use for waste glycerin is being developed by University of Alabama at Huntsville Professor Katherine Taconi and her colleagues; they are using bacteria from wastewater treatment plants to convert crude glycerin into butanol. Professor Taconi says the butanol "has a higher energy yield per gallon than ethanol, and also blends better with petroleum-based fuels."[89]

At Rice University in Houston, engineers are working on still another use for glycerin waste. Chemical engineer Ramon Gonzalez has developed a fermentation process using common bacteria in an oxygen-free environment that converts glycerin to ethanol. According to Gonzales, producing ethanol from glycerin could be 40 percent cheaper than making it from corn.[90]

The research has lead to a startup company, Glycos Biotechnology, Inc., based in Houston. The company plans to form partnerships with companies in the biodiesel, glycerin and ethanol industries. Glycerin-to-ethanol plants could be built alongside biodiesel production facilities, using glycerin waste generated on site as a feedstock.[91]

This technology provides a way to make a biofuel even more efficient by turning related waste into energy. It would help maximize the energy yield from fuel crops and mitigate the environmental effects of biodiesel production.[92]

affect it. Consumers are likely to feel some impact of high corn prices through increased food costs, even though many other factors may have a greater effect on prices at the grocery store.

Many different choices are needed to meet the growing demand for fuel in Texas. Ethanol can play a role in reducing dependence on foreign oil, but corn-based ethanol clearly is not the only answer to the nation's fuel problems. The nation simply does not grow enough corn to meet its energy needs. Even if the *entire U.S.* corn harvest in 2007, 13.1 billion bushels, were turned into ethanol, it would have produced only 36.6 billion gallons of ethanol, enough to replace about 30.2 percent of U.S. gasoline consumption in 2007.[93]

It is, of course, not feasible to devote the entire U.S. corn harvest to producing ethanol. If it is to make a significant impact on the U.S. fuel supply, ethanol must be imported from other countries or cellulosic ethanol production must be improved and made more cost-efficient. Possible alternative feedstocks include sorghum, energy cane, wood chips and switchgrass, among others.

Scientists have been working to make the cellulosic process economically feasible for commercial production for years, and it is still too expensive to be a viable fuel option. But Texas A&M University recently has shown initiative in this research, forming a four-year partnership with Chevron to study lignocellulosic biofuels. The partnership aims to identify and optimize production of non-food and non-feed energy feedstocks for biofuels; develop harvest, transportation and storage systems for energy feedstocks; and develop technology for biofuels processing.[94]

The ethanol industry in Texas will continue to grow over the next several years. With the promise of federal subsidies and the recently increased federal Renewable Fuel Standard, ethanol production will continue to increase and there will be a noticeable impact to local rural economies.

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