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Renewable Liquid Fuels: Current Situation and Prospects

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Ethanol produced from grain and biodiesel produced from vegetable oils and animal fats are the major renewable liquid fuels being produced in the United States. Cellulosic ethanol and Fischer-Tropsch diesel are also renewable liquid fuels of considerable interest, but additional development is needed before they become significant parts of the renewable liquid fuels market. Thus, the discussion in this article will focus on ethanol from grain and biodiesel.

The production and use of both fuels has been favored by state and federal government programs. The rationale for this encouragement is not only to improve the air and water quality and reduce dependence on foreign oil, but also to shore up farm prices, save on farm program expenditures, and promote economic growth in rural areas. Both fuels have increased in consumer acceptance as the quantities consumed have increased in recent years, and the recent increases in petroleum prices have stimulated interest in the possibility of producing both fuels as extenders of the gasoline and diesel fuel supplies. This paper discusses the drivers behind the rapid growth in ethanol and biodiesel production and use, and the prospects for continued growth in the future. It briefly notes the economics of production under current price conditions and U.S. capacity to produce larger amounts of these fuels from agricultural products.

Ethanol

Ethanol is typically sold in the United States in various ethanol-gasoline blends. Blends of 10 percent or less ethanol are consumed with almost no reported incompatibility with vehicles and equipment. Nearly all recent-model conventional gasoline vehicles produced for international sale are fully operable with such blends.

Ethanol is also sold as E85, a blend of 85 percent ethanol and 15 percent gasoline. High ethanol fuels are more corrosive and have a lower vapor pressure than gasoline. The flexible fuel vehicles (FFVs) sold in the U.S. to consume E85 include compatible components for rubber fuel lines and o-rings, and stainless steel for parts subject to corrosion. The FFVs typically have an engine control and sensor system that recognizes the combination of fuel being used. The engine can run on gasoline, E85, or any mixture of the two. A computer calibrates the fuel flow and injection system to provide smooth performance.

Industry Structure

The ethanol industry experienced a rapid rate of growth over the past 15 years, with production increasing to 4 billion gallons in 2005. The industry is composed of a combination of wet mills (producing ethanol, corn gluten meal, corn gluten feed, corn oil, and CO2) and dry mills (producing ethanol, dried distillers grains and solubles, and CO2). Approximately 25 percent of the production during 2005 was from wet mills and the remainder from dry mills. Most of the new plants built during the past decade are dry mill plants because they have lower investment costs. The industry continues to add new capacity at a rapid rate. Production is expected to reach 5.0 billion gallons in 2006.

Growth during the past decade was composed primarily of the entry of a number of new companies building medium-sized dry mill facilities. Many of the companies that initially built plants of 15 to 25 million gallons annual capacity (mmgpy) expanded them to 40 to 50 mmgpy within the past five years. With the addition of more small to medium plants, ownership of the industry capacity became more fragmented over time. In 1990, 13

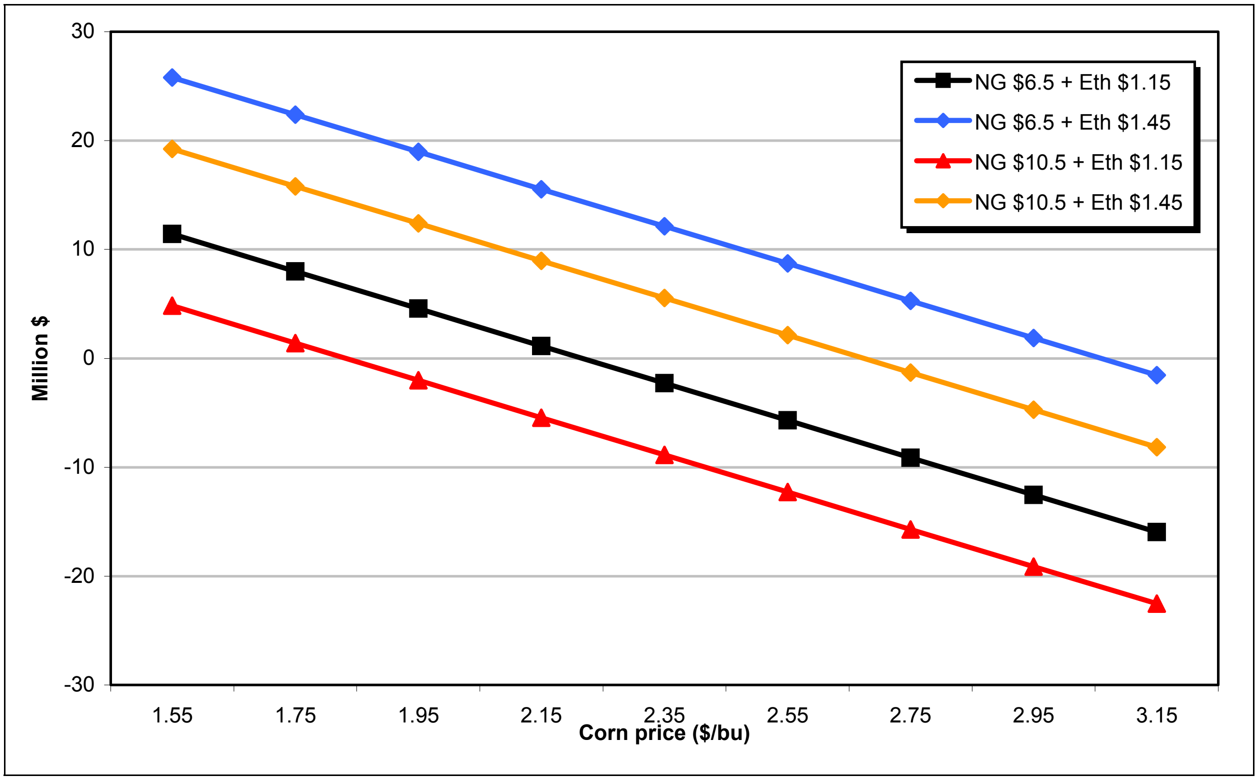

Figure 1. Net margin for 48 MMGPY dry mill plant for selected corn, ethanol, and natural gas price combinations.

companies operated 17 facilities with 1.11 billion gallons of annual capacity. One firm owned 55 percent of the capacity. In mid 2005, 71 organizations operated 84 facilities with 3.7 billion gallons of annual capacity. The largest firm owned 29 percent of the capacity.

Much of the procurement of corn and natural gas, and marketing of the ethanol and byproducts, as well as risk management, is being handled by a few firms that specialize in this area. Thus, the industry structure that has evolved is ownership of the production facilities by a large number of relatively small firms, with the marketing concentrated in the hands of a much smaller number of firms.

Economics of Ethanol Plants

Producing ethanol is a commodity business with wide swings in profitability, dependent largely on the price of the feedstock (primarily corn, with some grain sorghum), the price of ethanol, and the price of natural gas. The sensitivity of the plant's net margin to these factors is illustrated in Figure 1. Given the price of ethanol and natural gas, all four lines in Figure 1 indicate that raising the price of corn reduces profitability of the plant. The figure also illustrates that for any price of corn and natural gas, increasing the price of ethanol greatly increases the net margin. Finally, the figure shows that raising the price of natural gas for given corn and ethanol prices reduces the net margin. The figure illustrates that an increase in the price of natural gas from $6.50 per million British Thermal Units (Btu) to $10.50 reduces the annual net margin of a 48 mmgpy plant by approximately $6.6 million.

The net margins presented here do not include any subsidies paid to the plant by the state and federal governments. Receipt of subsidies would obviously increase the profitability of a plant, other things being equal. Two types of production subsidies have been available in recent years from the federal government. Both apply to small plants. New plants and those expanding production have been eligible for the Commodity Credit Corporation Bioenergy Program. This program, scheduled to end in 2006, provides incentive cash payments to U.S. ethanol and biodiesel producers that increase their purchases of agricultural commodities and convert that commodity into increased bioenergy production. A second program provides a 10-cent per gallon production income tax credit on up to 15 million gallons of production annually. Originally, the size of the plant eligible for the income tax credit was limited to 30 million gallons per year. Under the Energy Policy Act of 2005, the size limitation on the production capacity for small ethanol plants increased from 30 million to 60 million gallons. The credit can be taken on the first 15 million gallons of production. In addition to the federal programs, many states offer incentives for ethanol plants built in their state.

Ethanol Demand

The domestic demand for fuel ethanol has developed over time largely as a result of various federal and state policies. The recent boost in ethanol demand is largely the result of several states banning the use of a gasoline additive called MTBE because of its propensity to contaminate drinking water. Ethanol is the only economic substitute for MTBE. Ethanol is expected to receive another major boost due to the renewable fuels standard (RFS), a provision of the Energy Policy Act of 2005. The RFS requires the U.S. fuel industry to produce a minimum of 7.5 billion gallons of renewable fuel by 2012. (See Collins and Duffield in this set of papers for a complete discussion of federal policies).

Many in the U.S. ethanol industry feel the outlook is bright for an expanding market, particularly because they feel the oil industry will replace more MTBE with ethanol and use more ethanol as a fuel extender. Some argue that the RFS could expand demand more rapidly than the domestic industry can supply, significantly boosting opportunities for the countries in the region that have preferential access to U.S. markets, such as through the Caribbean Basin Initiative, and those with low production costs that can pay the $0.54 per gallon import tax duty.

The recent increase in petroleum and gasoline prices seems to have opened a new market for ethanol as a fuel extender. This is potentially a very large market, and one that should absorb any amount of ethanol the industry could produce in the foreseeable future. The U.S. consumed 136 billion gallons of gasoline during 2004. Compared to the 2005 ethanol production level of 4.0 billion gallons, ethanol was only 2.9 percent of U.S. gasoline consumption. If the oil industry uses ethanol as a fuel extender, the price of gasoline will effectively place a floor on the price of ethanol (net of the tax credit and blending costs).

Production Potential

What are the implications of the expanding ethanol industry for the way we use the U.S. corn and sorghum supplies? Approximately 11.7 percent of the corn supply and 11.3 percent of the sorghum supply were used to produce ethanol in 2004. Assuming that the proportion of ethanol made from each crop remains about the same as ethanol production increases to 5.0 billion gallons in 2006, more than 17 percent of both crops will be required. That is, the 5.0 billion gallons will require 1,845 million bushels of corn, more than 17 percent of what is currently considered to be a normal corn crop of 10.8 billion bushels. Although large carryover stocks are expected to provide part of the increased corn needed in 2006, when the stocks are reduced to more normal levels, continuing to produce ethanol at this and higher levels will require some adjustment in the way the U.S. corn supply is used. Additional corn needed for ethanol production could be diverted from the export market or from feed usage. Increases in ethanol demand could also lead to planting more acres of corn.

Biodiesel

Biodiesel can be used as an alternative to petroleum diesel in its pure form (B100) or as a blend with petroleum diesel at various ratios, such as B20 (20 percent biodiesel and 80 percent petroleum diesel). Engine performance with biodiesel is generally comparable to that of petroleum diesel, with some advantages and disadvantages concerning engine emissions.

Industry Structure

The biodiesel industry in the United States began to organize much later than ethanol, and is in an earlier stage of industry development. Production of biodiesel increased from 0.5 million gallons in 1999 to 91 million gallons in 2005. Production capacity, however, is much larger and growing rapidly. The National Biodiesel Board reports 53 commercial biodiesel plants in early 2006 with listed production capacity of 354 million gallons. The average size is about 6.7 million gallons, with some larger plants in the 30 million gallon range. The National Biodiesel Board reports an additional 40 plants and 4 plant expansions under construction that will add 329 million gallons of annual capacity. Thus the industry has the processing capacity to increase production rapidly as demand increases.

Economics of Biodiesel Plants

Haas et al. (2005) estimate the capital and operating costs of a 10 million gallon annual capacity industrial biodiesel production facility. They assume current production practices, equipment and supply costs, and model a continuous-process vegetable oil transesterification plant with ester and glycerol recovery. The analysis is based on purchasing degummed soybean oil as the feedstock.

With the plant operating at capacity, the estimated cost per gallon ranges from $1.48 with degummed soybean oil costing $.15

per pound to $2.96 with degummed soybean oil costing $0.35 per pound. The analysis assumes 7.4 pounds of virgin degummed soybean oil are required per gallon.

The feedstock cost is the largest single component of the biodiesel production costs. Recycled fats and oils are less expensive than virgin oils and can also be used to produce biodiesel. Yellow grease and trap grease are the most common types. Yellow grease is produced from used cooking oil collected from large-scale food service operations. Renders collect used cooking oil and trap grease and remove the solids and water to meet industry standards. These products are limited in supply, and they have other uses. For example, yellow grease is used in animal feed and also to produce soaps and detergents. Assuming a yellow grease price of 49 percent of soybean oil prices (the historic relationship) and that the amount required to produce a gallon of biodiesel is somewhat greater, 7.65 pounds, the cost per gallon ranges from $0.94 to $1.68 per gallon. The lower cost of biodiesel from yellow grease suggests that the market for biodiesel will bid up the price of yellow grease relative to soybean oil.

Biodiesel Demand

The amount of biodiesel demanded has remained relatively low because until recently, the cost of biodiesel has been well above the wholesale price of petroleum diesel. However, as was the case for ethanol, several pieces of federal legislation, including a new tax credit and the Renewable Fuels Standard (RFS), are expected to enhance the demand for biodiesel. In addition, new diesel fuel standards that require refiners to produce ultra-low-sulfur diesel fuel beginning in July 2006 could create a new market for biodiesel as a lubricity additive (again these are discussed in Collins and Duffield in this issue).

At the state level, many states passed legislation favorable to biodiesel in recent years ranging from tax exemptions to infrastructure incentives. Minnesota enacted a statewide law requiring the state's diesel fuel to be comprised of 2 percent biodiesel. The law became effective in September 2005 when the state's biodiesel production capacity moved above 8 million gallons per year.

An important source of current biodiesel demand is for specialized uses where the air emission characteristics of biodiesel are a major advantage. These uses include marine craft and diesel engines operating in enclosed areas, such as mines. In addition, the National Biodiesel Board reports that in May 2004, more than 400 fleets associated with school districts, city governments, state governments, and federal agencies were using biodiesel. Much of this growth can be attributed to the Energy Policy Act of 1992 (EPACT) that requires government entities to purchase alternative-fueled vehicles. These uses are expected to grow as government policies continue to contribute to this demand in the future. The Energy Information Agency estimates the EPACT use will increase to 6.5 million gallons of biodiesel per year by 2010. The 2 percent Minnesota mandate will add about 17 million gallons of demand per year. The ultra-low-sulfur diesel rule could expand the biodiesel market significantly. EIA notes that if refiners use 1 percent biodiesel to improve the lubricity of diesel fuel, this will add 470 million gallons to demand by 2010.

The current use of 91 million gallons per year, plus the potential markets, total more than 500 million gallons per year. With the excise tax credit in place, biodiesel would also be competitive as a fuel extender, but how much can the United States produce from the available feedstocks?

Production Potential

The feedstock used for biodiesel production depends largely on the available supply and its price. Potential feedstocks for biodiesel are the vegetable oils, yellow grease and other grease, lard, and edible and inedible tallow. Over the 2000-2004 period, soybean oil made up 57 percent of the total U.S. annual feedstock supply, while yellow grease and other grease made up 8 percent. Other vegetable oils made up smaller percentages of the total supply and had higher prices during the past five years than soybean oil and yellow grease. Among animal sources, inedible and edible tallow made up 11 and 6 percent, respectively. Large proportions of the inedible tallow are exported, suggesting these oils may be candidates for biodiesel production. However, the animal fats are less uniform than the processed vegetable oils and require more processing to produce a uniform biodiesel product. Considering price, uniformity of product, and supply, yellow grease and soybean oil are considered to be the preferred feedstocks for biodiesel production.

Yellow grease and other grease have alternative uses in livestock feed and the production of soaps. There is also the difficulty of collecting and transporting the yellow grease to a biodiesel plant that is processing this material. Considering the alternative uses and the logistical problems, perhaps one-half to two-thirds of the total yellow grease and other grease could be processed into biodiesel. This total would provide 172 to 228 million gallons per year.

A recent U.S. Department of Agriculture (2002) study estimated the effect of increasing the amount of biodiesel produced from current levels to 124 million gallons in 2012. This study, conducted to analyze the effect of a RFS for motor vehicle fuel, assumed all of the biodiesel was produced from soybean oil. The projected increase in the demand for soybean oil required to produce the biodiesel leads to an increase in the domestic price of soybean oil. The domestic price of soybean oil is projected to increase 17 percent over the baseline as a result of a RFS. Higher prices reduce other domestic uses of soybean oil and exports. Processing additional soybeans puts downward pressure on soybean meal prices and leaves the price of soybeans about 1 percent above the baseline. The change in protein prices results in minor changes in livestock production and profitability over the decade.

These data suggest the U.S. could produce 300 to 350 million gallons of biodiesel from yellow grease and soybean oil without major disruption of soybean oil markets. It appears the United States would need to utilize other feedstocks or import other oils to expand biodiesel production much beyond this level.

Concluding Comments

Ethanol and biodiesel appear to be moving into a new market environment brought on by a combination of the increase in petroleum prices and some new legislation and regulations. The increase in petroleum prices moved the wholesale price of regular gasoline and diesel fuel up rapidly during 2005, while the cost of producing ethanol and biodiesel has not increased appreciably, except for the cost of natural gas used in the processing plants.

For ethanol, the new energy bill replaces the mandated markets with a Renewable Fuels Standard (RFS). While the industry's production capacity will exceed the RFS, the petroleum industry is expected to purchase the additional ethanol to produce reformulated gasoline and for use as a fuel extender. This additional demand is expected to keep the ethanol markets reasonably strong as long as petroleum prices remain high, encouraging further growth of the industry. As the industry expands beyond this level in future years, the ethanol industry is expected to place some pressure on the market for corn and sorghum, reducing exports and/or increasing the acreage planted to these two crops.

With the new excise tax credit and current prices, biodiesel has an opportunity to compete in the diesel fuel market as a fuel extender and a lubricity additive. However, the country's supply of feedstock fats and oils will limit biodiesel to a small part of this potential market.

For More Information

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