Ethanol's Evolving Role in the U.S. Automobile Fuel Market

by

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Abstract: *Fuel ethanol in the United States is now predominately made from corn. However, future sources may include cellulosic materials, such as short-rotation woody and grass crops. Once considered a simple fuel extender, ethanol also is used as an octane enhancer and oxygenate. Provisions of the 1990 Clean Air Act Amendments, aimed at controlling carbon monoxide and ozone, are opening up new markets for ethanol. This article investigates the supply and demand for ethanol and compares ethanol prices with its main oxygenate competitor, MTBE.*

Keywords: Ethanol, renewable fuels, corn, oxygenates.

The idea of using alcohol as an automotive fuel is not new. The first modern combustion engine, the Otto Cycle, burned alcohol in 1876, and Henry Ford ran his 1908 Model T on alcohol, gasoline, or a mixture of the two. The major commercialization of fuel ethanol in the United States, however, did not occur until the 1970's.

The decade marked events critical to the ethanol industry, including two oil crises, the Soviet grain embargo, the passage of the 1977 Clean Air Act, and the 1978 Energy Tax Act. Conditions created by those events, such as high oil prices, an abundant corn supply, the phaseout of lead from gasoline, and Federal/State ethanol incentive programs, encouraged the growth of the U.S. industry.

Since the late 1970's, ethanol has been used as a gasoline extender by generally blending one part of ethanol with nine parts of gasoline to produce "gasohol." During the same time, the Environmental Protection Agency (EPA) was looking for a replacement for lead in gasoline. Because of its high octane content, ethanol emerged as a potential candidate.

In recent years, interest in ethanol has centered around its use as an oxygenate to help reduce automobile air pollution. Provisions of the 1990 Clean Air Act Amendments (CAAA) established the Oxygenate Fuels Program and the Reformulated Gasoline Program in an attempt to control carbon monoxide (CO) and ground-level ozone problems. Both programs require certain oxygen levels in gasoline: 2.7 percent by weight for oxygenated fuel and 2.0 percent by weight for reformulated gasoline.

Ethanol Production Capacity Is Over 1 Billion Gallons

Ethanol, also known as ethyl alcohol, can be produced from any source of fermentable sugars including starch, cellulose, and hemicellulose. Agricultural/forestry products and energy crops, as well as agricultural residues, provide a wide variety of biomass feedstocks for ethanol. The most predominant feedstock in the United States is corn, which is used to produce about 95 percent of U.S. ethanol. In 1992, domestic ethanol producers used 400 million bushels of corn, which accounted for over 5 percent of the 1991/92 U.S. corn crop (7,475 million bushels). During the same year, corn used for ethanol production was equal to about 25 percent of U.S. exports (1,584 million bushels).

Ethanol production has grown from 20 million gallons in 1979 to almost 1 billion gallons in 1992. Today, annual production capacity is estimated at about 1.1 billion gallons per year. The industry is expanding as new producers, such as Cargill (operating a new 28-million-gallon plant), enter the market. Construction currently underway will add another 690 million gallons of annual capacity.

The U.S. ethanol industry is highly concentrated. In 1992, 34 ethanol plants were operating in the United States. Of these, 16 have production capacities of over 10 million gallons per year, and together they account for 90 percent of total capacity. The industry giant, Archer Daniels Midland, controls nearly 70 percent.

Ethanol can be made from corn through dry milling or wet milling. Dry mills produce ethanol on a year-round basis, while several wet mills shift production to high fructose corn sweeteners when demand for sweeteners is high. Wet milling accounts for about 60 percent of total ethanol production. Compared to dry milling, it is capital-intensive, but compatible with new technologies such as producing starch for biodegradable polymers.

With current technologies, a bushel of corn from wet milling yields 2.5 gallons of ethanol, 12.4 pounds of 21-percent protein feed, 3 pounds of 60-percent gluten meal, and 1.5 pounds of corn oil. Dry milling yields 2.6 gallons of ethanol and 18 pounds of distillers' dried grains and solubles. In addition, both processes yield carbon dioxide, which is sold primarily to the soft drink industry. While wet milling attains slightly lower ethanol yields per bushel of corn, wet-milling coproducts are worth more than those from dry milling, as much as 30 to 50 cents per bushel of corn.

Production costs vary greatly from plant to plant, depending on plant efficiency, economies of scale, and coproduct revenues. Cost-reducing innovations in the last 5 years have emerged mainly in the areas of energy and ingredient uses and computerized control. Cogeneration facilities--plants that use the energy generated as a result of processing--now considerably reduce the energy costs of converting corn to ethanol. Also, new or improved organisms for prefermentation/fermentation speed up processing time and reduce capital costs. Automated operations have been a major source of labor cost savings.

Oxygenates Mean a New Market Environment

Until recently, the petroleum industry viewed ethanol as a product that could dilute gasoline demand, and ultimately, market share. But recently, refiners have begun to negotiate with ethanol producers on long-term contracts to ensure the continuous supply of oxygenates. As they provide necessary components for oxygenated fuel, major oil companies have reentered the ethanol business. Chevron, Shell, and Marathon today blend ethanol into their gasolines because it is a cost-effective way to meet clean air regulations.

The general mood of automobile manufacturers toward ethanol also is changing. In the late 1970's and early 1980's, the automotive industry was one of the major constraints preventing ethanol from penetrating the fuel market. Now, all auto manufacturers approve the use of ethanol-blended gasoline under their warranties. Some manufacturers, such as General Motors, actively encourage the use of ethanol blends by recommending oxygenated fuels in their 1990 owners' manual.

Low-Cost Feedstocks May Be Future Sources of Ethanol

Research to further lower production costs is under way. Improvements in membrane technology, bacterial fermentation, and coproduct development are being discovered [1]. Most important, there is considerable on-going research developing potentially low-cost feedstocks, including short-rotation woody crops, such as hybrid poplar, and herbaceous energy crops, such as switchgrass. These types of energy crops can be grown on a wide range of lands and in a variety of climates, and herbaceous crops can be harvested 1 to 3 times a year.

The cellulose and hemicellulose in wood and grass can be converted to sugars and then fermented to ethanol. The Department of Energy (DOE) is pursuing intensive development of energy crops under the Department's Biofuels Program. USDA is working with DOE to facilitate joint research efforts in feedstock development, conversion techniques, environmental and economic considerations, coproduct development, utilization, and testing.

While the expansion potential of corn-based ethanol may ultimately be constrained by limits on corn production, the use of cellulosic biomass has the potential to supply a significant portion of U.S. gasoline consumption. Some early cost estimates have been made for using cellulosic feedstocks. Successful research and development has reduced the estimated cost from over $2 per gallon to around $1.22. This is only slightly above corn-based ethanol at current corn prices. Further efforts to bring down production costs are underway. However, many difficulties--such as seed supply for energy crops, educating farmers to grow nonconventional crops, and developing a production strategy specific to each crop--still must be overcome.

Ethanol Was First Used as a Gasoline Extender

To provide economic incentives to ethanol producers in the 1970's, Federal and State governments initiated support programs, such as tax incentives and loan programs. Federal tax exemptions were initiated under the Energy Tax Act of 1978 by giving the minimum 10-percent ethanol blend a 4-cent-per-gallon exemption from the Federal gasoline excise tax [2].

Along with an increase in the Federal gasoline tax from 4 to 9.1 cents per gallon in 1983, ethanol-blend tax exemptions were raised to 5 cents per gallon and, subsequently, to 6 cents. Since January 1991, the current tax exemption has been set at 5.4 cents per gallon of 10-percent ethanol blends and extended until 2000. The minimum 10-percent-blend requirement translates into an effective 54-cent tax exemption per gallon of ethanol, and the exemption is provided through the Highway Trust Fund.

Beginning December 31, 1992, proportional excise tax exemptions are provided for alcohol-blended fuels at 7.7 and 5.7 percent by volume. These rates correspond to the oxygen content requirements of 2.7 and 2.0 percent by weight under Title II of the CAAA. Tax exemptions are typically taken at the wholesale level. A gasoline wholesaler purchasing fuel to be blended with ethanol at 10 percent pays 8.6 cents per gallon rather than the full 14 cents per gallon Federal gasoline excise tax. The same exemption process applies to the 4.2- and 3.1-cent tax exemptions available for 7.7- and 5.7-percent ethanol blends.

The Federal government has also encouraged ethanol industry development in other ways. In 1978, the Federal government authorized $1.2 billion in loan guarantees to finance alternative fuel investment projects, including ethanol and methanol production from renewable sources. These Federal programs also extended to the research and development of ethanol technology. Since the 1973 Arab oil embargo, more than $40 million has been allocated to alcohol fuel research.

States have also assisted ethanol producers by providing gasoline sales tax exemptions and/or direct payments to producers. Historically, sales tax exemptions were widely used as an incentive program, but are no longer the only mechanism employed in developing new ethanol markets. By the end of 1980, 25 States exempted 10-percent blends from all or part of State gasoline sales taxes, and the initial State exemptions were estimated on average as 30 cents per gallon. During the 1980's, due to budget problems and little in-state ethanol production, many States eliminated or curtailed exemptions.

Recently, with renewed interest in ethanol prompted by the CAAA, some States, such as Oregon and Illinois, have been moving toward initiating or renewing State tax incentives. Presently, 12 States make partial sales tax exemptions available and only one, Alaska, grants full exemption (table

B-1). Most also allow proportional excise tax exemptions for 7.7- and 5.7-percent blends.

State-sponsored producer incentives apply if certain qualified feedstocks (produced within the State), fuel sources, plant capacities, or processing techniques are used. Generally, payments are made directly to ethanol producers. Direct producer incentives stimulate investment in new plants and equipment and, in some cases, have given small producers a competitive advantage within the State. Currently, seven States provide direct producer payments ranging from 20 to 40 cents per gallon.

Because ethanol mixes with water, pipeline transportation is difficult without some level of maintenance. Therefore, it is usually not blended with gasoline at the refinery but by local wholesalers when they deliver to gas stations. Ethanol producers have often offered ethanol at discounted prices and allowed blenders a margin to encourage them to use ethanol as a blending agent.

The market share of ethanol-blended gasolines has increased from virtually nothing to over 8 percent of all gasolines today. This implies that ethanol displaces about 1 percent of conventional gasoline consumption, since ethanol is blended mostly at 10 percent.

Ethanol Enhances Octane Levels

Other government actions, although not targeted to enhance ethanol use, have greatly influenced the industry. In the late 1970's, EPA initiated a public information and education campaign to remove lead from gasoline. At the time, lead was used to increase octane content. One easy alternative to boost octane content was to blend gasoline with a high-octane alcohol such as ethanol. When ethanol is blended with gasoline at a rate of 10 percent, it raises the fuel's octane level by an average of 3 octane points.

The octane rating is a measure of a fuel's ability to resist knock and ping in gasoline engines. A typical grade of unleaded gasoline has an octane rating of 87 and premium unleaded gasoline has a rating of 91 to 93, while pure ethanol has a rating of 113. Ethanol-blended gasoline is sold in the fuel market as regular unleaded or as super unleaded. Automobile users increasingly are demanding high-octane gasoline and, at the same time, automobile manufacturers are once again producing numerous high-performance engines that can take advantage of higher octane gasoline. As a result, refiners will continue to search for octane sources at the lowest possible cost.

Methyl tertiary butyl ether (MTBE), which was developed primarily as an octane enhancer, has an octane rating of 110. First produced as a fuel additive in 1979, MTBE has become a popular blending agent and oxygenate. Ether products such as MTBE can easily be blended with gasoline at the refinery and transported by pipeline.

Ethanol Can Help Meet the Demand for Oxygenates

The key chemical property that differentiates ethanol from gasoline is the presence of oxygen. Ethanol can be used as an oxygenate to help control both carbon monoxide and ozone pollution.

Carbon Monoxide. The CAAA calls for the use of oxygenated fuels in the Oxygenated Fuels Program, beginning in November 1992, to control carbon monoxide problems. CO in urban atmospheres comes primarily from the exhaust emissions of internal combustion engines, such as those in most cars and trucks. The presence of oxygen in the fuel raises the effective air-to-fuel ratio for more complete combustion and reduces carbon monoxide emissions.

Title II of the CAAA designates 39 regions in the Nation as CO nonattainment areas. To meet CAAA regulations, re-

Table B-1--State gasoline taxation and ethanol incentives, March 1993

State	Gasoline tax	Ethanol incentive: Reduction in tax	Ethanol incentive: Direct producer payments 1/
		--Cents per gallon--	
Arkansas	8.0	8	--
Connecticut	23.0	2/ 1	--
Hawaii	19.4	3/	--
Illinois	24.5	4/	--
Iowa	20.0	1	--
Ohio	21.0	5/ 1.5	--
Oregon	20.0	6/ 5	--
Washington	22.0	3.7	--
Wyoming	9.0	4	--
Minnesota	20.0	2	20
South Dakota	18.0	2	20
Missouri	11.0	2	20
Kansas	16.0	--	20
Montana	20.0	--	30
Nebraska	23.9	--	20
North Dakota	17.0	--	40

-- = Not applicable.

1/ Only for ethanol produced in the State. 2/ Ethanol or methanol, 10 percent by volume. 3/ 4-percent reduction from existing tax imposed on retail sale of ethanol blends. 4/ 2-percent reduction from existing tax imposed on retail sale of ethanol blends. 5/ Tax credit expires September 30, 1993.
6/ Effective January 1, 1992.

Source: Alcohol Outlook, March 1993.

finers and blenders must use oxygenates, including ethanol, MTBE, or other ethers such as ethyl tertiary butyl ether (ETBE), tertiary amyl ethyl ether (TAEE), or tertiary amyl methyl ether (TAME). MTBE, the most widely used oxygenate in the market today, and TAME are methanol-based ethers derived primarily from natural gas. ETBE and TAEE are ethanol-based ethers.

The CAAA mandate that gasoline sold in all 39 CO nonattainment areas for at least 4 winter months should contain 2.7 percent oxygen by weight at a minimum, unless a State chooses to adopt an averaging program or places a cap on the oxygen content [3]. Some of the worst CO problem areas--such as Denver, Phoenix, and Tucson--required oxygenated fuels during winter months even before the Oxygenated Fuels Program became mandatory.

Ethanol has a higher oxygen content than MTBE, 35 percent versus 18 percent by weight. Therefore, the 2.7-percent oxygen requirement dictates a 15-percent MTBE blend, a 7.7-percent ethanol blend, or a 17-percent ETBE blend.

Ozone. Ground-level ozone is a greenhouse gas that contributes to global warming and human health problems. In urban areas, ozone is created from ultraviolet light acting on local concentrations of volatile organic compounds (VOC's), CO, and nitrogen oxides (NOx). VOC's result from the evaporation of gasoline and other solvents and from vehicle exhaust. NOx mainly come from burning fossil fuels, including gasoline and coal.

Beginning in January 1995, the nine worst ozone nonattainment areas designated in CAAA Title II--the regions of Los Angeles, New York, Hartford, Baltimore, Philadelphia, Chicago, Milwaukee, Houston and San Diego--are required to sell reformulated gasoline year-round. In addition, the CAAA designated 87 other regions as ozone nonattainment areas. The CAAA allows these areas to opt in voluntarily to the Reformulated Gasoline Program. Almost half of the U.S. population lives in the ozone nonattainment areas designated by the CAAA.

The CAAA requires a certified reformulated gasoline to reduce emissions of ozone-forming VOC's by 15 percent compared to the 1990 reference fuel. The central problem with ethanol is that current ethanol blends increase volatility, thereby increasing VOC emissions caused by fuel evaporation. For example, 10-percent ethanol blends boost volatility by 1 pound per square inch (psi).

Ethanol is expected to play a role in the reformulated gasoline market to the extent that the program requires 2.0 percent oxygen by weight in gasoline. However, how the volatility issue will be resolved is uncertain until the rules and regulations for the Reformulated Gasoline Program are completed.

Volatility is not a problem associated with all ethanol blends. The first few percent of ethanol added to gasoline will increase volatility measured in terms of the Reid vapor pressure (RVP). However, the low volatility of ethanol compared to regular gasoline begins to dominate when the blending rate reaches around 20 to 40 percent. Volatility further declines to a RVP of 2.3 psi for 100 percent ethanol, compared to 9 psi for regular gasoline and 7.8 psi for MTBE.

ETBE blends can meet and surpass the reformulated gasoline requirements because ethers have a low vapor pressure. In the future, more ethanol may be used as a feedstock for ETBE and TAEE. Natural gas-based methanol has a current economic advantage over ethanol as an ether feedstock because of its lower price. But the low vapor pressure of ETBE blends--3 to 5 psi compared with 9 to 10 psi for MTBE blends--may offset that price disadvantage in the future when more strict RVP regulations are imposed.

In addition, research addressing ethanol's volatility problem continues. Activities include VOC emission reduction strategies, such as co-solvent and azeotrope research to mitigate ethanol's RVP effects, and emission testing on mixed alcohol and ether blends.

Future Demand Looks Promising

The net effects of the CAAA are promising new market opportunities for ethanol. Near-term demand will come as a blending component in gasoline, but ethanol's future potential exists as a feedstock for ethers as well as an alternative fuel.

The initial increase in demand for ethanol will come from CO nonattainment areas to meet the oxygenate requirements. During 1992, ethanol consumption reached nearly 1 billion gallons and MTBE consumption exceeded 2 billion gallons. According to American Petroleum Institute estimates, the oxygenate demand from CO nonattainment areas during 1992/93 will be almost twice the pre-program level.

Prior to 1995, ethanol demand depends primarily on the scale of the gasoline market in CO nonattainment areas, the length of the CO season, and the transportation economics of moving oxygenates from attainment areas to nonattainment areas.

Beginning in 1995, the demand for oxygenates will expand further to meet the 2-percent-oxygen requirement for reformulated gasoline. The magnitude of the expansion in demand will largely depend on how many of the ozone nonattainment areas opt into the program. Around 20 percent of U.S. gasoline demand is in the nine worst ozone nonattainment areas. If all eligible areas opt in, 70 percent of gasoline consumption would be in reformulated markets. The opt-in decision is voluntary and will be greatly affected by the oxygenate market that exists at the time the decision is made.

Nearly pure ethanol--85 to 95 percent--holds promise as an alternative fuel for dedicated or flexible fuel vehicles [4]. The Alternative Motor Fuels Act of 1988 and the clean fuel and fleet provisions of the CAAA add impetus to reducing imported and petroleum-based transportation fuels by promoting alternative fuels. The Comprehensive National Energy Policy Act of 1992 also includes provisions to help develop alternative fuels.

Competing with MTBE

Market demand for ethanol in the oxygenate market depends on the supply of ethanol's principal competitor, MTBE. Many chemical companies and major refiners are planning MTBE production or expansion. The United States is currently the world's leading MTBE producer, with 1.9 billion gallons of capacity, which is expected to more than double by 1994.

Future MTBE production depends greatly on feedstock availability. As domestic production grows in response to increased demand for oxygenates, a substantial portion of MTBE feedstocks, methanol and butylene, may have to be imported. Even now, about one-quarter of the methanol consumed in the United States comes from abroad.

Because all oxygenates are also octane enhancers, their prices generally reflect the value of both uses. In the past, the upward trend of MTBE prices--from 67 cents per gallon in 1987 to 97 cents in 1990--may have been partly due to its octane value, which can be priced at about 1.25 cents per octane number at the wholesale level. Unlike MTBE, ethanol's octane value has not been fully realized in its price. During the same period, ethanol prices ranged from $1.28 per gallon in August 1987 to $1.06 in January 1988.

In the past, the value of ethanol has been derived mostly from its role as a gasoline extender. Now, with oxygenated fuel use mandated by the CAAA, the oxygen value of ethanol will likely be an important factor in its pricing. To examine the oxygen value of ethanol, MTBE-compatible ethanol prices were calculated for given prices of MTBE and regular gasoline (table B-2).

A MTBE-equivalent ethanol price represents a threshold ethanol price at which a gasoline blender is economically indifferent between MTBE and ethanol as a choice of oxygenate. This exercise mainly investigates how ethanol prices may change with the prices of MTBE and gasoline.

To meet the minimum 2.7-percent-oxygen-by-weight requirement, a gallon of oxygenated gasoline can be either an ethanol blend, 10-percent ethanol with 90-percent gasoline, or a MTBE blend, 15-percent MTBE with 85-percent gasoline. (Even though only a 7.7-percent ethanol blend could meet the requirement, the 10-percent blend was used in the calculations because the 10-percent blend will more likely be used to maximize the tax benefits.)

For a given price of oxygenated gasoline, the economic choice of oxygenate depends on the gasoline price, as well as the price of the oxygenate. As gasoline price rises, there will be an incentive to shift to MTBE because the MTBE blend uses less gasoline than the ethanol blend. When gasoline prices are falling, the shift will be to ethanol.

For example, when MTBE is 80 cents and gasoline is 60 cents per gallon, a gallon of MTBE oxygenated gasoline would be sold at 63 cents (80 cents x 15 percent + 60 cents x 85 percent). The MTBE-equivalent ethanol price is calculated using the computed oxygenated gasoline price, 63 cents, and the predetermined regular gasoline price, 60 cents. The MTBE-equivalent ethanol price, 90 cents, would produce an ethanol oxygenated gasoline at 63 cents per gallon (90 cents x 10 percent + 60 cents x 90 percent).

Another interpretation of the MTBE equivalent ethanol price can be made. Given prices of MTBE and gasoline at 80 and 60 cents per gallon, respectively, the highest price at which ethanol could be sold in the marketplace would be 90 cents, assuming that MTBE leads the price of oxygenates and ethanol blending and handling costs are zero.

Ethanol blends usually incur additional costs in transportation, blending, and possibly a margin for the blender. Therefore, the actual MTBE-compatible ethanol price would be lower by these additional costs. Using the earlier example, when the MTBE-compatible ethanol price is 90 cents, the actual market price of ethanol would be 80 cents per gallon, assuming 10 cents of additional costs.

Ethanol also receives Federal and State (if available) excise tax exemptions. These tax benefits would be reflected in the ethanol price by raising the market price of ethanol by the amount of tax exemption. Following the example, adding the Federal exemption of 54 cents per gallon would bring the price up to $1.34 (80 cents + 54 cents). State exemptions would further increase the value of ethanol.

Notes and References

1. Neil Hohmann and Matthew Rendleman. *Emerging Technologies in Ethanol Production.* USDA, ERS, Agricultural Information Bulletin 663, January 1993.

Table B-2--MTBE-equivalent ethanol price 1/

Gasoline prices	MTBE prices (--Dollars per gallon--) .80	.90	1.00	1.10	1.20
.50	2/ 0.95 (.55)	1.10 (.56)	1.25 (.57)	1.40 (.59)	1.55 (.60)
.60	0.90 (.63)	1.05 (.64)	1.20 (.66)	1.35 (.67)	1.50 (.69)
.70	0.85 (.72)	1.00 (.73)	1.15 (.74)	1.30 (.76)	1.45 (.77)
.80	0.80 (.81)	0.95 (.82)	1.10 (.83)	1.25 (.84)	1.40 (.86)

1/ A similar calculation was presented in Oxy-Fuel News, May 27, 1991. 2/ Numbers in parentheses are the prices of oxygenated gasoline, using either MTBE or ethanol.

2. A fixed exemption was granted for all ethanol blends, 10 percent and above. This effectively eliminates any blends above 10 percent from the market, because with no tax incentive above 10 percent, it is not economical to replace gasoline with more expensive ethanol.

3. States have the option of adopting a per-gallon program or an averaging program. Averaging permits industry to use marketable oxygen credits for gasolines with a higher oxygen content than required to offset the sale or use of gasolines with a lower oxygen content. Averaging programs are a cost-effective wayof implementing the Oxygenated Fuels Program because averaging allows the market additional flexibility and full utilization of valuable oxygenates. A State also can impose a limit or cap on the oxygen content of oxygenated gasoline, if EPA approves the cap is necessary. For instance, California currently imposes a cap at 1.8 to 2.2 percent oxygen by weight.

4. Pure, 100-percent ethanol is legally prohibited from being used as a fuel according to the Bureau of Alcohol, Tobacco, and Firearms. Thus, all alcohol fuels must be denatured by mixing them with toxic substances such as gasoline.