JACKFAU-85-322-6

THE EFFECT OF GASOLINE VOLATILITY CONTROL ON SELECTED ASPECTS OF ETHANOL BLENDING

Final Report

Work Assignment 6-1

Contract No. 68-03-3244

Submitted to:

U.S. ENVIRONMENTAL PROTECTION AGENCY

Office of Mobile Sources

Ann Arbor, Michigan, 48105

November 4, 1985

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CHAPTER 1

INTRODUCTION AND SUMMARY

Waivers currently exempt ethanol blends from volatility controls such as Reid Vapor Pressure restrictions. As a result, ethanol (in volumes of up to 10 percent in unleaded gasoline) may currently be added to any legal gasoline to form an ethanol blend. If regulations are implemented requiring gasoline to be specifically blended for ethanol addition as a means of controlling evaporative hydrocarbon emissions, changes in the ethanol, gasoline, and gasohol marketing and distribution systems may result. This analysis evaluates potential adjustments in these distribution systems. The report includes the following:

- An overview of the domestic fuel ethanol industry, including detailed analyses of supply, demand, pricing, tax incentives, and other current issues affecting the market.

- An overview of present fuel ethanol distribution and blending practices, including analyses of transportation costs, gasohol distribution, the influence of state tax incentives and exchange agreements, and the relationship between the fuel ethanol distribution system and the gasoline distribution system.

- An evaluation of the effects of volatility control on the logistics and costs of ethanol distribution and blending practices for 10 percent ethanol blends.

- An evaluation of the effects of volatility control on the logistics and costs of ethanol distribution and blending practices for 5 percent ethanol blends (i.e., if mid-range volatility control limits the maximum ethanol content in gasoline to 5 percent).

Several assumptions of the analysis should be noted. Most importantly, effects of the proposed blending requirements on demand for gasohol were not analyzed. Gasohol demand in the 10 percent blending scenario was assumed to remain constant; demand in the 5 percent scenario doubles. (The latter results from holding ethanol demand unchanged.) Furthermore, in the distribution scenarios presented in Chapters 4 and 5, there is an implicit assumption that each refiner whose product is currently blended with ethanol will produce the special gasoline blends; and that the specially blended gasoline is mixed with the ethanol of the same producer and shipped to the same terminals as was the case without special blending. An analysis of the effects on fuel distribution systems of the change in blending practices that considers potential changes in demand for gasohol and in relationships among ethanol and gasoline suppliers and terminal operators is recommended as a means of refining the study. However, important conclusions about potential changes in ethanol, gasoline, and gasohol distribution systems can be drawn based on the current analysis.

The 10 percent ethanol blend analysis shows that requiring the use of specially blended gasoline for ethanol blending could increase the cost of delivering gasohol if terminal blending continues. Transportation costs increase if the specially blended gasoline must be shipped to the terminal using a transportation mode other than the mode used to transport the standard gasoline previously blended with ethanol. This would happen if the volume of specially blended gasoline did not meet the minimum batch requirement for the latter mode. The maximum cost increase is estimated to be 0.82 cents per gallon of gasohol for every 100 miles that the special gasoline is shipped to the terminal. If refinery blending occurs and the gasohol is transported to the terminal by the same mode as the previously used standard gasoline, transportation cost savings could occur if the ethanol plant is much closer to the refinery than the terminal and/or if the ethanol producer can realize sufficient transportation cost scale economies by consolidating shipments. If, however, the gasohol is transported by a different mode (as would be the case if a pipeline had transported the standard gasoline), gasohol transportation costs could increase by as much as 0.91 cents per gallon per 100 miles, less any cost savings in ethanol transport. Since it is probable that terminal blending of gasohol will dominate refinery blending in 1990, total transportation costs will increase by no more than 0.82 cents per gallon of gasohol for every 100 miles that the special gasoline is shipped to the terminal.

The 5 percent ethanol blend analysis also shows that requiring the use of specially blended gasoline for ethanol blending could increase the cost of delivering gasohol if terminal blending continues. Transportation costs increase if the specially blended gasoline must be shipped to the terminal using a transportation mode other than the mode used to transport the standard gasoline previously blended with ethanol. The maximum cost increase is estimated to be 0.87 cents per gallon of gasohol for every 100 miles that the special gasoline is shipped to the terminal, less the estimated minimum transportation cost savings associated with reducing the ethanol content of the blend to 5 percent (0.075 cents per gallon of gasohol). Similarly, refinery blending of 5 percent blends could result in transportation cost savings if the gasohol is transported to the terminal by the same mode as the standard gasoline and if the ethanol producer can realize sufficient transportation cost scale economies by consolidating shipments. If, however, the gasohol is transported by a different mode, transportation costs could increase.

Finally, analysis of the results of the 10 percent and 5 percent scenarios indicates that special blending requirements to control gasohol volatility will probably have a smaller impact on transportation costs if 5 percent blends are required. This is because reducing the ethanol content of blends replaces relatively expensive to transport ethanol with gasoline; and because larger quantities of specially blended gasoline and gasohol will generally move through the distribution system for 5 percent blends than for 10 percent blends, reducing the likelihood of modal changes.

CHAPTER 2:

INDUSTRY PROFILE

Ethanol, also known as grain alcohol, has been produced through a fermentation process for thousands of years for use as a beverage. Since the development of the internal combustion engine, ethanol has also competed with gasoline as a potential motor fuel. This section profiles the supply, demand, pricing, and other characteristics of ethanol used as a fuel.

2.1 SUPPLY

Fuel ethanol in the United States is supplied primarily through domestic production (77 percent in 1984), but increasingly through imports (23 percent), which have grown steadily since they first became a factor in the U.S. supply in 1981. The ethanol may be produced either synthetically from petroleum-derived naphtha or ethylene, or through fermentation. Current tax incentives for the production and use of fuel ethanol, which require that the ethanol be produced from renewable resources, favor the fermentation process. Therefore, synthetically produced ethanol is limited to uses as a solvent or a chemical feedstock by economic constraints. It is production through fermentation that is the focus of the discussion of domestic supply in this chapter.

Exhibit 2-1 details the volumes of fuel ethanol supplied by fermentation and imports since 1979. Detailed discussions of supply — including production processes, capacity, imports, and factors influencing supply — are provided in the following sections.

Domestic Production

Fermentation technology is the primary means of producing fuel ethanol in the United States today. Two fermentation processes are used — wet milling (70-80 percent) and dry milling (20-30 percent).[1] Both fuel-grade ethanol and beverage-grade ethanol may be produced by fermentation, but the processing requirements are sufficiently different to prevent inexpensive conversion of beverage ethanol capacity to fuel ethanol capacity. Stable beverage ethanol demand at 80-90 million gallons per year also works to prevent conversion of production facilities.[2]

[1] E.E. Ecklund, "Status and Directions of the Use of Alcohols and Other Oxygenated Hydrocarbons in North America," VI International Symposium on Alcohol Fuels Technology, May 1984.

[2] Thomas F. Killilea, Stanford Research Institute "Marketing Research Report: Ethyl Alcohol," Chemical Economics Handbook, p. 644.5022P.

EXHIBIT 2-1:

TOTAL FUEL ETHANOL SUPPLY
(million gallons)

Year	Domestic Production		Imports		Total Supply
	Volume	Percent of Supply	Volume	Percent of Supply	
1979	25	100	0	0	25
1980	50	100	0	0	50
1981	70	64	40	36	110
1982	170	81	40	19	210
1983	385	87	60	13	445
1984	420	77	123	23	543

Sources: 1979-1983 statistics from E.E. Ecklund, "Status and Directions of the Use of Alcohols and Other Oxygenated Hydrocarbons in North America," VI International Symposium on Alcohol Fuels Technology, May 1984. 1984 statistics from Alcohol Outlook, March 1985.

The production of fuel ethanol by fermentation requires four steps. First, starch or sugar feed is treated to yield a sugar solution. Second, the solution is fermented to produce ethanol and carbon dioxide using bacteria or yeast. Third, the fermentation product is concentrated into 190-proof ethanol by distillation. Finally, the remaining water is removed through a process called azeotropic distillation which involves distillation with a solvent added and recovery of the solvent. Water must be reduced below 0.3 percent of volume to prevent phase separation, which causes engine damage and poor performance. If a grain feedstock is used, the remaining material, after the ethanol has been removed, is a valuable by-product called distillers' grain, which is a high protein animal feed.[1] Beverage ethanol production does not require the azeotropic distillation step, but does require additional separation to remove toxic higher alcohols present as impurities in the distilled ethanol. Fuel ethanol is typically denatured by adding 2 percent gasoline, as required by law to discourage beverage use.[2]

Current fuel ethanol production capacity at all fermentation ethanol production facilities is approximately 625 million gallons per year.[3] Actual production levels (67 percent of capacity)[4] are considerably below capacity due to the downward pressure on demand caused by 1) the availability of low-priced imported fuel ethanol; 2) the declining price of gasoline relative to ethanol; and 3) generally soft demand for motor fuel (Exhibit 2-2). Capacity growth, which averaged 69 percent per year between 1979 and 1984, has slowed in recent years, to 29 percent in 1982-1983 and 13 percent in 1983-1984. At this time there are 53 major commercial facilities producing fuel-grade ethanol via fermentation in the United States.[5]

Factors affecting the availability of domestic fuel ethanol include the delivered price and availability of feedstocks, and the price and marketability of byproducts. Feedstocks, which account for as much as 80 percent of the price of fuel ethanol,

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[1] Office of Technology Assessment, Gasohol: A Technical Memorandum, 1979, pp. 3-4, 10.

[2] Mueller Associates, Inc., Gasoline Octane Enhancement: Technology, Economics, and Environmental, Health and Safety Considerations, 1985, p. VI-10.

[3] Office of Alcohol Fuels, Sixth Annual Report on the Use of Alcohol in Fuels, April 1985, p. 1.

[4] Peter Busowski, Editor, Alcohol Week, personal communication, August 5, 1985.

[5] Herman and Associates, July 1985.

EXHIBIT 2-2:

DOMESTIC CAPACITY AND OPERATING RATES

(million gallons/year)

Year	Capacity	Operating Rate[1]
1979	55	45.5%
1980	100	50.0%
1981	260	26.9%
1982	425	40.0%
1983	550	70.0%
1984	625	67.2%

[1] Domestic production ÷ domestic capacity x 100.

Sources: 1979-1983 statistics from E.E. Ecklund, "Status and Directions of the Use of Alcohols and Other Oxygenated Hydrocarbons in North America," VI International Symposium on Alcohol Fuels Technology, May 1984. 1984 statistics from Office of Alcohol Fuels, U.S. Department of Energy, Sixth Annual Report on the Use of Alcohol in Fuels, April 1985, p. 1.

include corn (92 percent of operating capacity in commercial facilities),[1] wood, sorghum, molasses, other grains, and various food processing wastes.[2] Variable grain prices due to seasonal effects such as weather and crop yields may result in large variability in the price at which fuel ethanol may profitably be sold. This increases the risk to investors and discourages future investment in fuel alcohol distilleries. Furthermore, aside from these yearly fluctuations, there may be a long run ceiling on the amount of feedstock available to the fuel ethanol industry. An estimated 1 to 2 billion gallons of ethanol per year may be produced in the United States before competition between food demand for grain and fuel demand for grain will significantly increase grain prices.[3]

A second factor which determines whether fuel ethanol can be produced competitively is the marketability and value of byproducts from the fermentation process. The two distinct fuel ethanol fermentation processes, wet milling and dry milling, yield different byproducts. In wet milling facilities, the byproducts contain most of the non-starch material in a grain feedstock and are recovered prior to the fermentation process. The byproducts are corn oil, corn gluten meal and corn gluten feed which are sold as food and high-protein animal feed. In dry milling facilities the byproducts are recovered from the material remaining after fermentation has consumed most of the starches and sugars in the feedstock. These byproducts, called distillers dried grains and solubles, are also a high protein animal feed. Furthermore, either fermentation process yields high quality carbon dioxide which may be recovered and sold for bottling, packing or tertiary oil recovery.[4]

The value of recoverable byproducts from feed ethanol produced from corn at a price of $2.80 per bushel would be 43 cents per gallon of ethanol produced by dry milling,[5] and 66 cents per gallon of ethanol produced by wet milling. If the fuel ethanol industry were to expand to such an extent that the market for the animal feed byproducts

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[1] Office of Alcohol Fuels, U.S. Department of Energy, Fourth Annual Report on the Use of Alcohol in Fuels, March 1983, pp. 6-7.

[2] "Alcohol Week Price Watch: Key Fuel Grain and Byproducts Prices," Alcohol Week, May 20, 1985, p.11.

[3] Office of Technology Assessment, op. cit., p. 31.

[4] David E. Hallberg, "Testimony before the Subcommittee on Energy Conservation and Power of the Committee on Energy and Commerce, U.S. House of Representatives," June 28, 1983.

[5] Office of Technology Assessment, op., cit., p. 20.

became saturated, then the price of fuel ethanol would no longer be competitive with other octane-boosting components of gasoline, even with the federal and state subsidies. It is estimated that the fuel ethanol industry would have to reach a production level of 2 billion gallons per year to saturate the market for byproducts; consequently, it is likely that the growth of the industry would be constrained by rising feedstock costs before the byproduct credit would be reduced.[1]

Ethanol Imports

Ethanol imports account for a substantial fraction of the fuel ethanol supply in the United States, 23 percent in 1984 (Exhibit 2-1). Brazil, which was the source of 80.3 percent of the ethanol imported into the United States in 1984[2] has lower labor costs and lower feedstock costs for ethanol production than the United States. Imports by country of origin are listed in Exhibit 2-3.

Ethanol imported for fuel use has increased from virtually nothing in 1980 to approximately 123 million gallons in 1984. In the past, imports have been encouraged by both federal and state tax subsidies: federal excise tax exemptions are available for both domestic and imported ethanol, as are some state exemptions. However, when imports were identified as a threat to the domestic industry, a customs duty was imposed on ethanol imported for fuel use (in addition to the 3 percent ad-valorem duty on ethanol imported for non-beverage purposes). The amount of this duty was 10 cents per gallon in 1981, 20 cents per gallon in 1982, 40 cents per gallon in 1983, 50 cents per gallon in 1984 and 60 cents per gallon in 1985, where it is to remain through 1992 when the federal excise tax exemptions will expire.[3] Since 1984, the customs duty on imported fuel ethanol has been high enough to offset the subsidization of imported ethanol by the federal excise tax exemption for gasohol.

Nevertheless, domestic consumption of imported fuel ethanol continues to grow. This may be because some foreign-produced ethanol remains exempt from the import duty on fuel ethanol. Of the 123 million gallons of ethanol imported into the United States in 1984, 83 million gallons entered paying the tariff on fuel ethanol while an estimated

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[1] Office of Technology Assessment, op. cit., p. 20.

[2] "International Alcohol Outlook," Alcohol Outlook, March 1985, p. 14.

[3] Salvatore Lazzari, Congressional Research Service, Federal Tax Provisions Relating to Alcohol Fuels Including Recent Changes Under the Tax Reform Act of 1984, November 6, 1984, pp. 15-16.

EXHIBIT 2-3:
1984 ETHANOL IMPORTS, BY COUNTRY OF ORIGIN

Country	Volume (Thousand Gallons)[1]	Percent
Brazil	136,575	80.3
United Kingdom	10,652	6.3
Canada	7,318	4.3
Argentina	6,455	3.8
Spain	3,868	2.3
France	2,385	1.4
South Africa	1,616	0.9
Netherlands	896	0.5
Others[2]	279	0.2
TOTAL	170,045	100.0

[1]Includes ethanol imported for nonfuel purposes.

[2]Other countries exporting ethanol were West Germany, Yugoslavia, Norway, Japan, China, South Korea, and Mexico.

Source: "International Alcohol Outlook," Alcohol Outlook, March 1985, p. 14.

40 million gallons more may have entered the country for fuel purposes without paying the tariff.[1] For example, importers may legally avoid the tariff by blending the ethanol with gasoline to make gasohol and importing the gasohol, in which case the only duty levied is the 1.25 cents per gallon duty on imported gasoline.[2] The tariff may also be avoided by blending imported fuel ethanol with 6 or 7 percent of another octane-boosting component of gasoline, such as toluene or xylene, and paying a duty on the shipment as though it were toluene or xylene instead of ethanol.[3] Pure fuel ethanol may also be imported duty-free into the United States if the ethanol has been upgraded from 190 proof ethanol to fuel grade ethanol in a country covered by the Caribbean Basin Initiative. Congressional action could possibly remove this last loophole within a year.[4]

2.2 DEMAND

Consumption of fuel ethanol has increased greatly in recent years, from 20 million gallons in 1979 to 570 million gallons in 1984. By 1984, fuels uses accounted for 73 percent of all nonbeverage ethanol consumption.[5] (Beverage ethanol is not considered further here because of different product quality and regulatory requirements which create a separate market for beverage ethanol.) Major nonfuel, nonbeverage uses include applications as a solvent and as a chemical feedstock. However, since solvent demand has been relatively stable, and feedstock demand has been declining in recent years, fuel demand for ethanol accounts for all of the recent growth in total ethanol demand.[6] Nonbeverage ethanol consumption since 1979 is detailed by use in Exhibit 2-4. (Fuel ethanol demand in Exhibit 2-4 does not match fuel ethanol supply in Exhibit 2-1 due to changes in inventories and the inexact nature of the import statistics.) Total fuel ethanol demand and factors influencing it are described below.

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[1] "International Alcohol Outlook," op. cit., p. 14.

[2] "U.S. Firm Seeking to Import Ethanol Through Foreign Trade Zone," Alcohol Update, May 27, 1985, p. 1.

[3] John Gordley, member of Senator Dole's Staff, personal communication, August 12, 1985.

[4] "Customs Refuses to Immediately Revoke CBI Rulings," Alcohol Update, May 6, 1985, p. 1.

[5] Migdon R. Segal, "Gasohol: The Alcohol Fuels." Prepared for Congressional Research Service, July 12, 1985, p.6.

[6] Thomas F. Killlea, Chemical Economics Handbook, op. cit., p. 644.5023L.

EXHIBIT 2-4:

NONBEVERAGE CONSUMPTION OF ETHANOL, 1979-1984

(million gallons)

	1979		1980		1981		1982		1983		1984	
	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent
Fuel Use	20	8.0	65	23.5	75	26.0	230	53.7	433	67.9	570	73.1
Solvent	114	45.6	106	38.3	109	37.9	100	23.4	105[1]	16.4	110[1]	14.1
Chemical Feedstock	107	42.8	96	34.6	94	32.6	90	21.0	90[1]	14.1	90[1]	11.5
Exports	9	3.6	10	3.6	10	3.5	8	1.9	10[1]	1.6	10[1]	1.3

[1] **Estimated from SRI projections.**

Sources: 1981 to 1984 fuel statistics from Migdon R. Segal, "Gasohol: The Alcohol Fuels." Prepared for Congressional Research Service, July 12, 1985, p. 6. Other statistics from Thomas F. Killilea, SRI, "Marketing Research Report: Ethyl Alcohol," Chemical Economics Handbook, May 1983, pp. 644.5022 P-Q, 644.5023L.

Fuel ethanol is marketed almost exclusively in 10 percent concentration as a component of gasohol. In 1984, 5.7 billion gallons of gasohol were consumed, representing 5.5 percent of total gasoline consumption.[1,2] This quantity of gasohol required 570 million gallons of fuel ethanol for blending.

Demand for gasohol has a strong regional character related to the availability of feedstocks for fuel ethanol production and state tax incentives for ethanol blending. In certain states, the gasohol market share as a percent of total gasoline sales is nearly five times the national average.[3] Market shares for gasohol by state since 1982 are shown in Exhibit 2-5. Gasohol sales volumes and market share by state for 1984 are listed in Exhibit 2-6. From these exhibits it can be seen that gasohol sales are particularly strong in the Midwest where corn, the primary feedstock for fuel ethanol, is most readily available.

Although gasoline consumption is projected to fall from 102 billion gallons in 1984 to 86 billion gallons by 1990,[4,5] demand for fuel ethanol as a blending agent in gasohol is expected to continue to grow because ethanol, with current federal and state tax incentives, is an economically viable subsitute for tetraethyl lead as an octane-boosting component of gasoline.[6] Consequently, demand for fuel ethanol may reach as much as 920 million gallons in 1986, over 60 percent more than 1984 fuel ethanol demand.[7]

Ethanol Demand and Octane Enhancement

Fuel ethanol can be marketed in two ways: as an additive to finished gasoline, and as an alternative to other sources of octane in standard gasolines. The former type of use,

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[1] Midgon R. Segal, CRS, op. cit., p. 6.

[2] 1984 gasoline consumption is from Energy Information Administration, U.S. Department of Energy, Petroleum Supply Monthly, December 1984, p. 25.

[3] "January Gasoline and Ethanol Blend Sales," Alcohol Outlook, May 1985, p. 7.

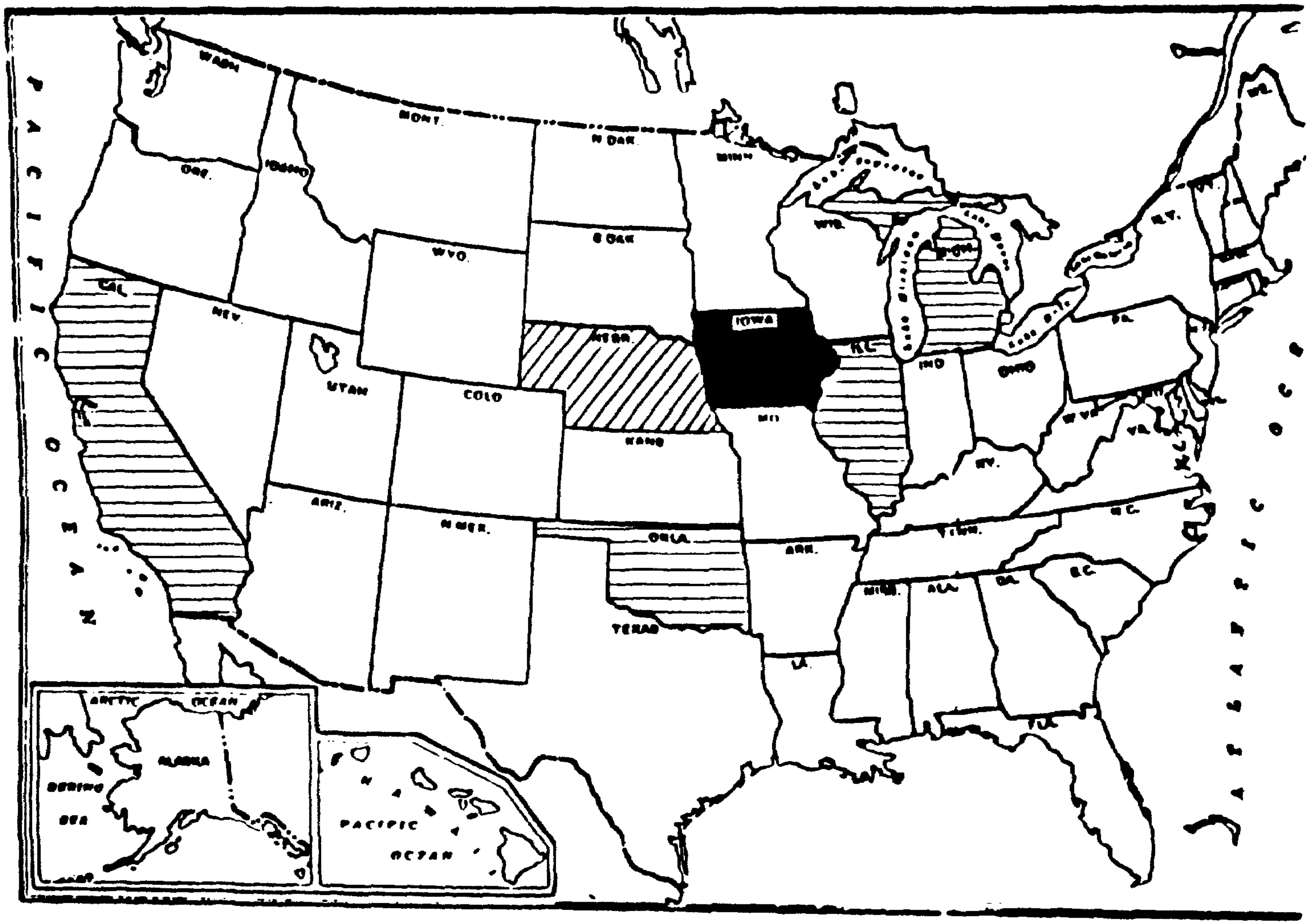
[4] Energy Information Administration, Petroleum Supply Monthly, op. cit., p. 25.

[5] Bonner and Moore Management Science, Impacts of Alcohol Fuels on the U.S. Refining Industry, Volume I, August 1983, pp. 2-3.

[6] The Environmental Protection Agency has required that the lead content in gasoline be phased down to 0.1 grams per leaded gallon of gasoline by January 1, 1986.

[7] "Congressional Ethanol Caucus Seeks Senate Sponsor for EITC Extension," Alcohol Week, May 13, 1985, p. 8.

EXHIBIT 2-5:
MARKET SHARE OF GASOHOL IN GASOLINE MARKET, BY STATE
JANUARY 1982



0 to 2% | 2 to 5% | 5 to 10% | 10 to 25% | 25%

EXHIBIT 2-5: (Continued)

MARKET SHARE OF GASOHOL IN GASOLINE MARKET, BY STATE

JANUARY 1983

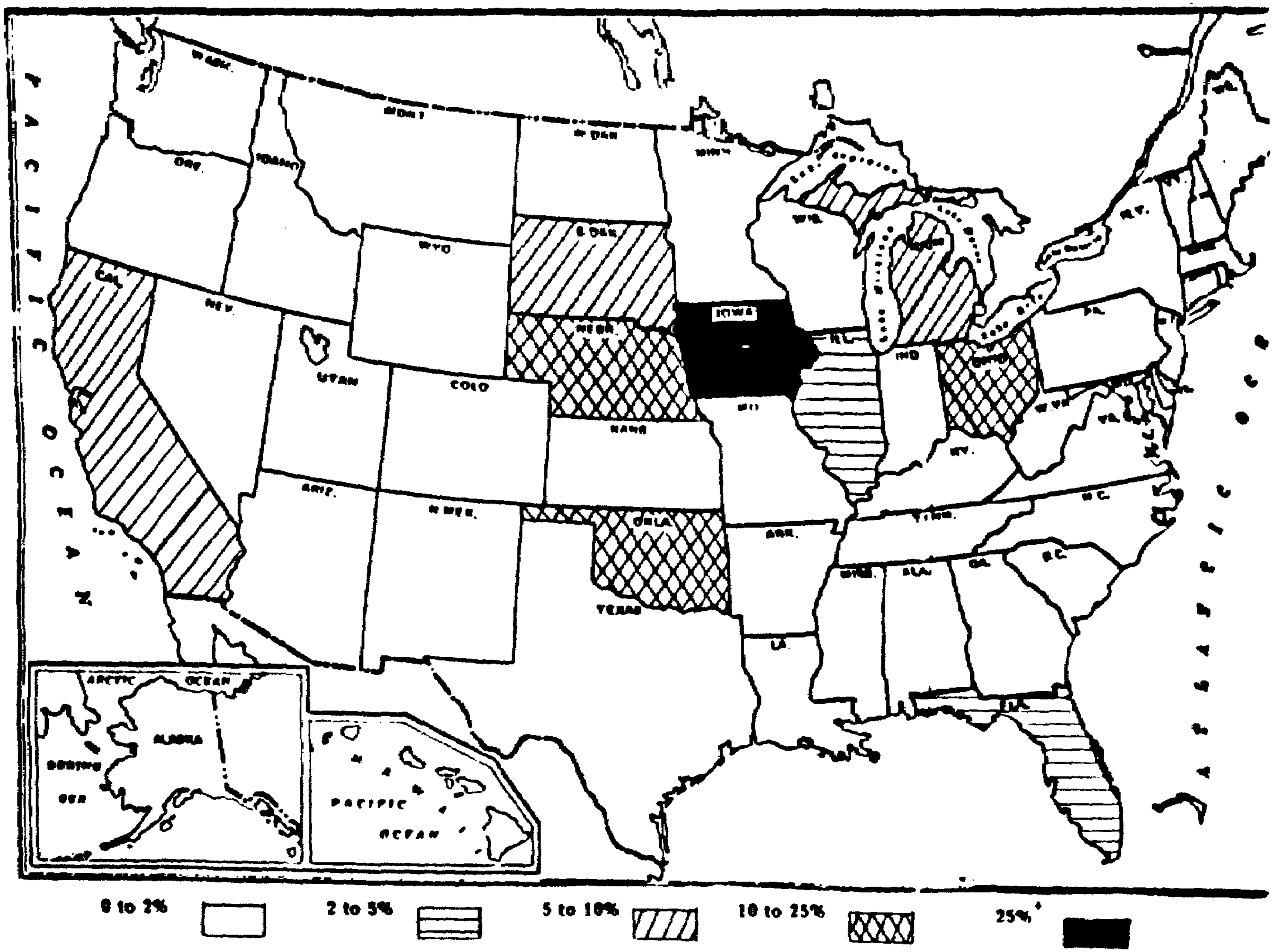


EXHIBIT 2-5: (Continued)

MARKET SHARE OF GASOHOL IN GASOLINE MARKET, BY STATE

JANUARY 1984

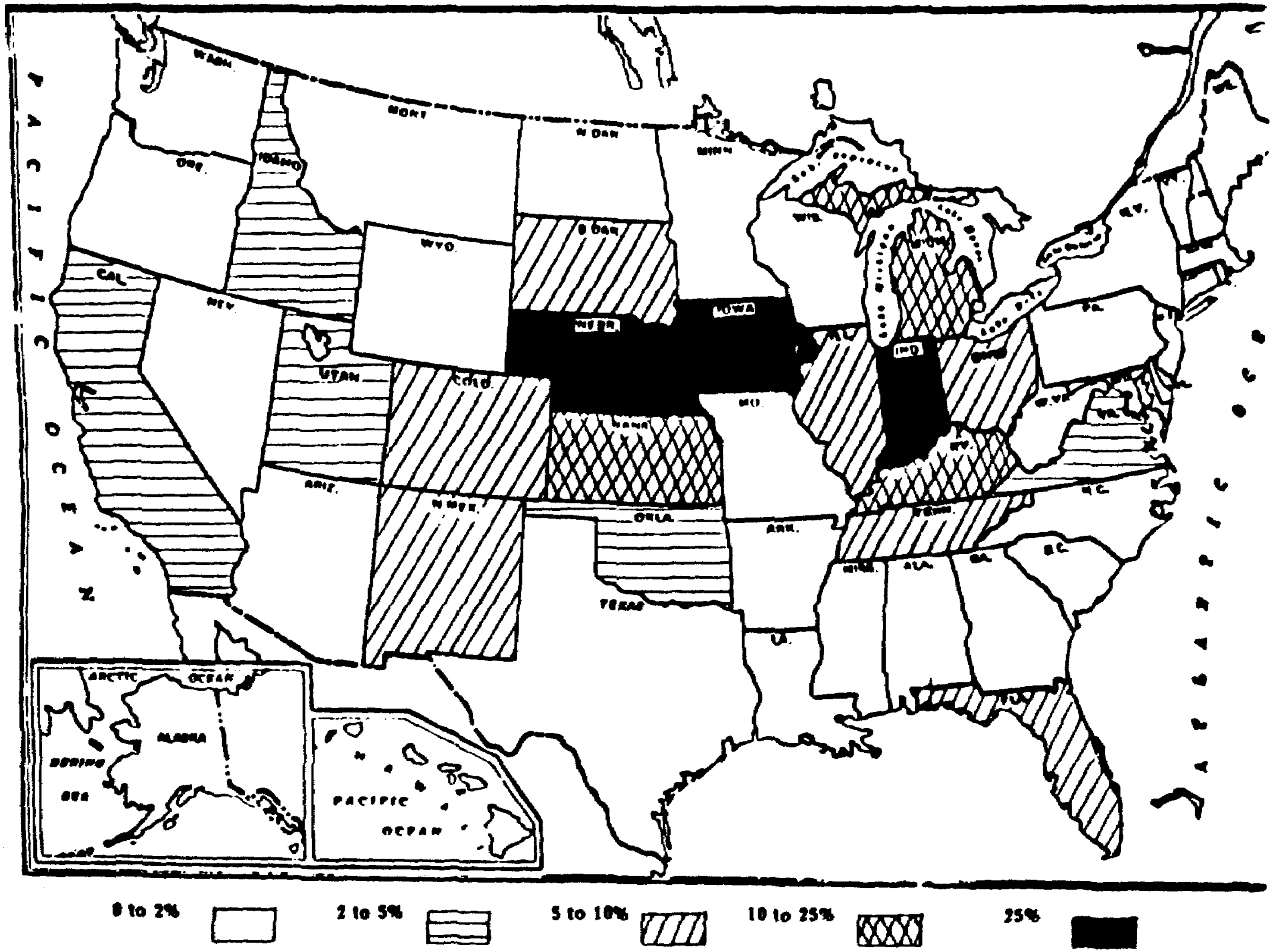
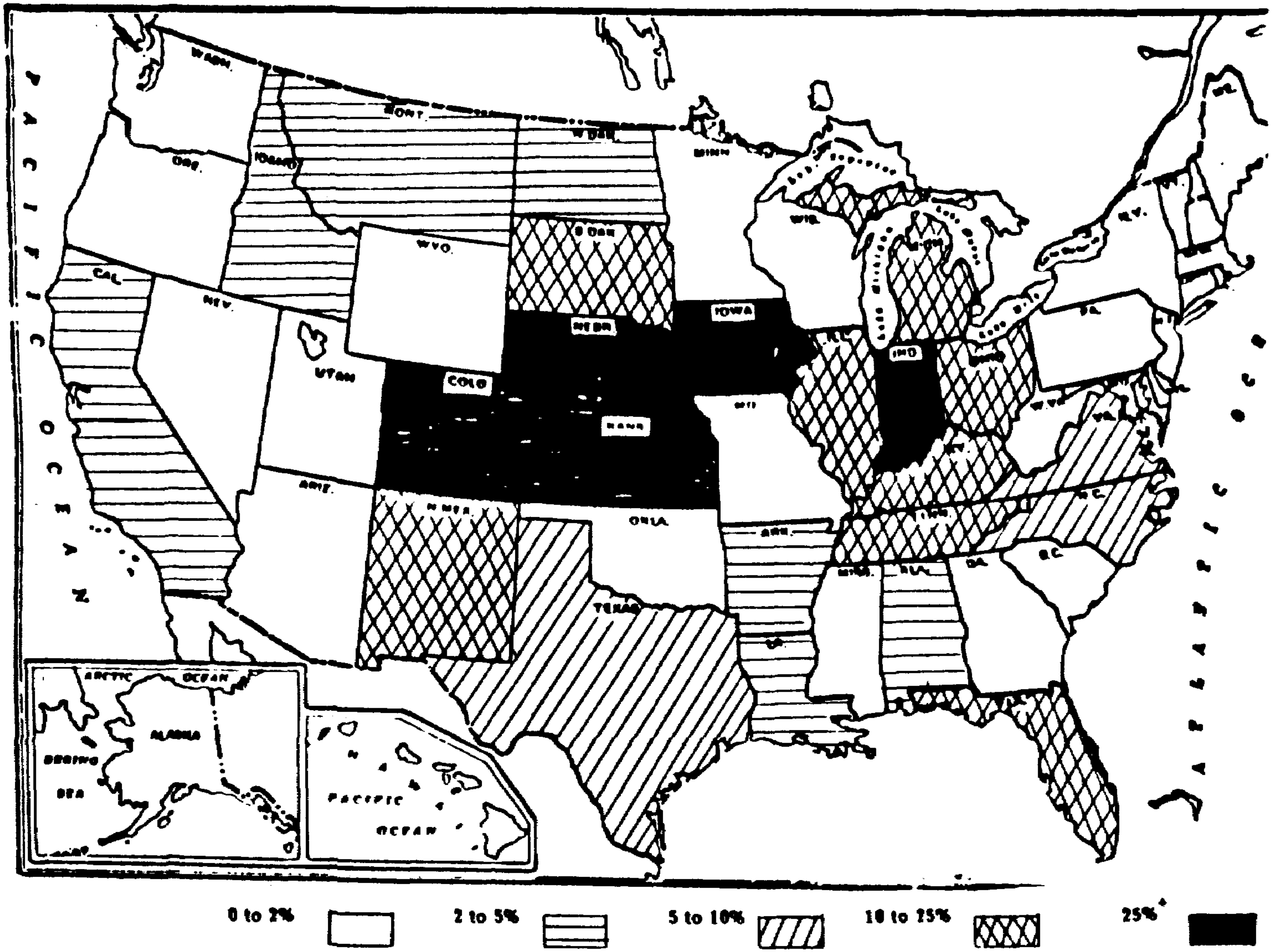


EXHIBIT 2-5: (Continued)

MARKET SHARE OF GASOHOL IN GASOLINE MARKET, BY STATE

JANUARY 1985



Sources: Alcohol Week and Alcohol Outlook, various issues.

EXHIBIT 2-6:

1984 GASOHOL SALES BY STATE
(thousand gallons)

State	Gasohol Sales	Gasoline Sales	Gasohol Market Share, Percent
Alabama	34,899	1,714,466	2.0
Arkansas	28,871	1,131,879	2.6
California	401,837	11,543,991	3.5
Colorado	62,371	1,564,085	4.0
Connecticut	5,421	1,324,617	0.4
District of Columbia	63	154,440	—
Florida	508,751	4,990,063	10.2
Georgia	16	2,817,217	—
Idaho	6,658	411,438	1.6
Illinois	263,127	4,171,725	6.3
Indiana	483,063	2,394,052	20.2
Iowa	457,228	1,421,217	32.2
Kansas	249,296	2,150,118	11.6
Kentucky	328,238	1,595,852	20.6
Louisiana	24,424	2,152,204	1.1
Maryland	82	1,785,164	—
Michigan	577,723	3,954,285	14.6
Minnesota	2,707	2,406,645	0.1
Montana	8,303	505,144	1.6
Nebraska	208,455	730,783	28.5
New Mexico	56,494	804,118	7.0
North Carolina	34,037	2,958,509	1.2
North Dakota	5,469	424,937	1.3
Ohio	399,988	4,497,646	8.9
Oklahoma	23,620	1,822,717	1.3
Oregon	298	1,299,318	—
South Carolina	154	1,485,242	—
South Dakota	37,850	381,163	9.9
Tennessee	109,762	2,623,163	4.2
Texas	207,152	10,455,038	2.0
Utah	25,862	703,798	3.7
Virginia	131,618	2,454,065	5.4
Washington	9,143	1,944,828	0.5
Wisconsin	1,962	1,998,435	0.1
Wyoming	288	300,638	0.1
TOTAL[1]	4,695,230	83,073,000	5.7

[1]Total does not include 15 states where gasohol is taxed at the same rate as gasoline and gasohol data are not available separate from gasoline data.

Sources: Gasohol sales from Office of Alcohol Fuels, U.S. Department of Energy, Sixth Annual Report on the Use of Alcohol in Fuels, April 1985, p. 6. Gasoline sales from Energy Information Administration, Petroleum Marketing Monthly, January 1984 through December 1984.

as a "fuel extender," is by far the most common in today's fuel ethanol market. However, there are signs that the second type of use may eventually dominate the market. Many refiners are now offering sub-octane gasolines specifically produced for blending with ethanol (Exhibit 2-7). This is part of a larger effort, among both small and large refiners, to find an economical substitute for tetraethyl lead in the wake of the EPA-mandated lead phasedown.

Demand for ethanol as an octane-enhancing additive to gasoline depends on tax subsidies and the price and availability of other octane enhancers. Octane improvement costs for increased refining severity and for several types of octane enhancing additives are listed in Exhibit 2-8.[1] As can be seen in these statistics, without a tax subsidy, ethanol is the most expensive means of octane enhancement. With a 5 cent per gallon gasohol subsidy, ethanol becomes competitive with tertiary butyl alcohol. With a 10 cent per gallon gasohol subsidy, ethanol becomes less expensive than any other means of octane enhancement. It is important to note, however, that even if ethanol is favored as an octane enhancer because of its attractive cost relative to alternatives, its supply is unlikely to be great enough to satisfy all demand for octane. By 1990, total demand for octane enhancement is expected to reach 7.4 billion octane number-barrels. (All demand for octane enhancement in 1990 will be for unleaded gasoline. Estimated 1985 octane requirements, in comparison, are 4.1 billion octane-number barrels for leaded gasoline and 5.4 billion octane number barrels for unleaded gasoline.)[2] If ethanol alone were used to meet the demand, ethanol consumption would reach 20 billion gallons in that year. This is at least ten times the projected capacity for fuel ethanol production and also far exceeds the 1 to 2 billion gallon fuel ethanol demand level beyond which fuel production would begin to compete with food uses for corn and other ethanol feedstocks.[3]

Ethanol Demand and Tax Incentives

In 1978 there were no laws favoring the production or blending of alcohol fuels. and the commercial production of fuel ethanol was virtually nonexistent. Rapid growth in fuel ethanol production and consumption since 1978 has been encouraged by federal and state legislation partially exempting ethanol blenders from federal and state excise taxes on gasoline, and federal legislation granting federal income tax credits to ethanol

[1] Some small refiners do not have the capability to increase octane ratings of their gasoline by increasing refining severity. These refiners have the choice of either selling their product to a large refiner for further processing or blending their gasoline with an octane-boosting agent to meet octane requirements.

[2] Mueller Associates, Inc., op. cit., pp. II-8, V-8.

[3] David E. Hallberg, op. cit.

EXHIBIT 2-7:
COMPANIES WHICH PRODUCE, EXCHANGE OR SHIP SUB-OCTANE GASOLINE WHICH CAN BE BLENDED WITH ETHANOL

Pipeline Companies Refiner/Marketer	Number Of Terminals With Ethanol
Amoco	16
Amber	2
Apex	6
Ashland	11
Buckeye Pipeline	0
Derby	1
Indiana Farm Bureau	4
Koch Refining	5
La Gloria	3
Mobil	3
Rock Island	2
Southland/Citgo	8
Sun Refining	1
Texaco	7
Total Petroleum	7
Triangle	2
Unocal	6
Williams Pipeline Co.	11
Wolvering Pipeline	0

Source: Archer Daniels Midland, ADM Ethanol.

EXHIBIT 2-8:

GASOLINE OCTANE IMPROVEMENT COSTS

Component	Volume Percent	Cost, Cents Per Octane Number-Barrel Unleaded Regular	Unleaded Premium	Leaded Regular
Tetraethyl Lead[1]	—	—	—	5
MMT[2]	—	—	—	25
Processing				
Low Severity	—	—	—	20
Typical Severity	—	—	—	26
High Severity	—	—	—	32
Toluene ($1.19/gal.)[3]	4.0	55.1	60.9	49.9
Tertiary Butyl Alcohol	16.0	81.2	114.2	66.1
($1.00/gal.)	8.0	88.2	125.5	72.0
Methyl Tertiary Butyl Ether	11.0	53.7	58.3	49.6
($1.19./gal.)[3]	4.0	58.1	62.6	53.8
Oxinol 50[4]	9.6	5.4	0.0	9.7
(70¢/gal.)	4.8	31.0	30.6	37.3
Ethanol ($1.63/gal.)[3]	10.0	143.9	164.5	186.9
with 5¢/gal. gasohol subsidy	10.0	68.4	75.1	91.0
with 10¢/gal. gasohol subsidy	10.0	-7.2	-14.3	-4.9
with no gasohol subsidy	5.0	161.1	180.6	214.3

[1] Average response, 1.1 grams per leaded gallon.

[2] Methylcyclopentadienyl manganese tricarbonyl, used in concentractions of 0.01 to 0.05 grams per gram lead in gasoline, typical response.

[3] Costs for toluene, MTBE and ethanol have been adjusted to reflect current prices.

[4] Oxinol 50 is 50 percent methanol, 50 percent tertiary butyl alcohol.

Sources: G.H. Unzelman, "Problems Hinder Full Use of Oxygenates in Fuel," Oil and Gas Journal, July 2, 1984 and Mueller Associates, Inc., Gasoline Octane Enhancement: Technology, Economics and Environmental, Health and Safety Considerations, July 1985, pp. V-22, V-24. Current prices from Alcohol Outlook, May 1985, p. 2, and Alcohol Week, June 24, 1985, p. 13.

blenders. The federal tax exemptions for alcohol blends since 1978 are detailed in Exhibit 2-9, and the current state tax exemptions are detailed in Exhibit 2-10 and Appendix A.

The tax subsidies for alcohol blends have dictated a fuel ethanol market where fuel ethanol is blended with gasoline in a 1:9 ratio. The resultant 10 percent ethanol blend, commonly known as gasohol, is eligible for the highest subsidy through tax exemptions. Gasohol has the lowest concentration of alcohol in gasoline which is still eligible for the excise tax exemption.[1] Gasohol has the highest concentration of fuel ethanol in gasoline which is allowed by a waiver. Fuel ethanol that is blended in lower concentrations or that is not sold through retail outlets is qualified for an income tax credit designed to encourage fuel ethanol use where the excise tax exemption is not applicable.[2] The income tax credit is not as advantageous to the blender as the excise tax exemption, since use of the tax credit requires profitability. Consequently, no company has claimed the blender income tax credit.[3]

The impact of state tax incentives on gasohol sales may be seen by comparing the tax incentives shown in Exhibit 2-10 and Appendix A to state sales and market share statistics in Exhibits 2-5 and 2-6. The statistics suggest that the federal tax incentives alone are not sufficient to bring the price of ethanol down to the level where gasohol is competitive with gasoline. Of states with no tax incentive for the use of fuel ethanol, only Arkansas, California and North Carolina have gasohol market shares in excess of 2 percent. In each of these states tax incentives for fuel ethanol have been discontinued within the past two years and the gasohol market share may be expected to decline.[4,5]

The effects of state tax subsidies may be further analyzed by examining the demand impacts of changes in state tax subsidies, as illustrated in Exhibit 2-11. The doubling of the tax incentive in Louisiana in July 1984 led to an increase in gasohol sales of 24.4 million gallons in six months (an increase from virtually nonexistent gasohol sales to a 2.3 percent market share). However, as the statistics for Wyoming show, there may be very little change in consumption in a state where limited feedstock availability restricts ethanol production. In the case of California the impact on demand was also

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[1] Salvatore Lazzari, op. cit., p.3.

[2] Ibid, pp. 7-8.

[3] Eric Vaughn, President, Renewable Fuels Association, August 19, 1985.

[4] Herman and Associates, Survey of Federal and State Alcohol Fuel Regulations, July 1985.

[5] Office of Alcohol Fuels, Fourth Annual Report, op. cit., pp. 9-10.

EXHIBIT 2-9:

FEDERAL GASOLINE EXCISE TAX AND ALCOHOL BLEND TAX INCENTIVES
(cents per gallon)

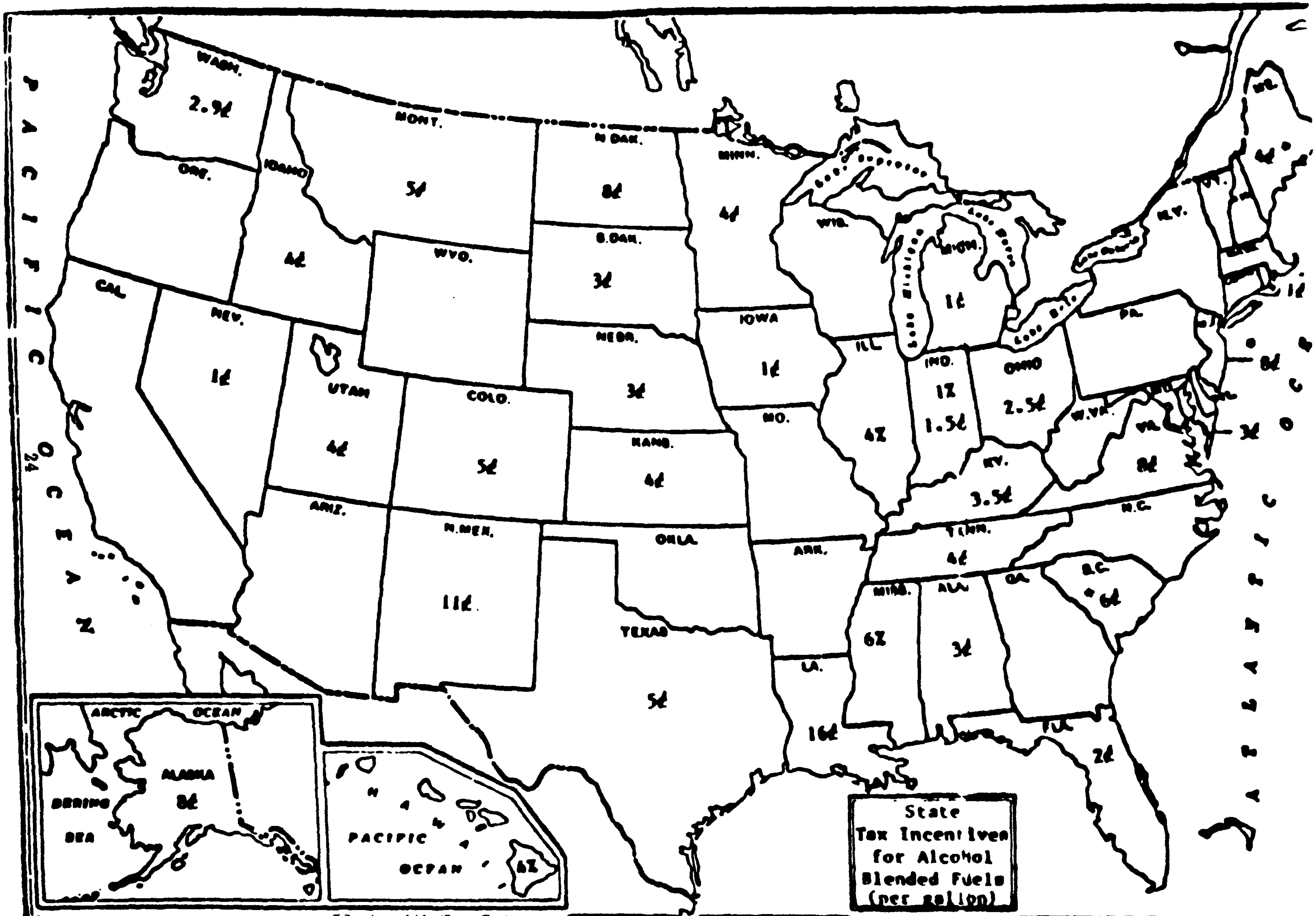
Year	Motor Fuel Excise Tax	Excise Tax Exemption[1] For Alcohol Blends (cents per gallon of gasohol)	Income Tax Credit[2] (cents per gallon of ethanol)
1978	4	0	0
1979	4	4	0
1980	4	4	40
1981	4	4	40
1982	9	5	50
1983	9	5	50
1984	9	5	50
1985	9	6	60

[1] For gasoline blended with a minimum of 10 percent alcohol of at least 190 proof and manufactured from renewable resources.

[2] Credit is per gallon of ethanol of at least 190 proof instead of per gallon gasohol. Cannot be taken if excise tax exemption is taken. A smaller income tax credit is available for 150 to 190 proof ethanol.

Sources: Salvatore Lazzari, Congressional Research Service, Federal Tax Provisions Relating to Alcohol Fuels Including Recent Changes Under the Tax Reform Act of 1984. November 6, 1984, pp. 3-8; Thomas F. Killilea, Stanford Research Institute, "Marketing Research Report: Ethyl Alcohol," Chemical Economics Handbook, May 1983, p. 644.5021I, and Congressional Quarterly, Inc., Energy Policy, 2nd Edition, March 1981, pp. 201, 223-235.

EXHIBIT 2-10:
STATE TAX INCENTIVES FOR ALCOHOL BLENDED MOTOR FUELS[1]



[1] Additional information is provided in Appendix A.

* Not yet in effect.

Source: Herman and Associates, July 1985.

EXHIBIT 2-11:

EFFECT OF CHANGES IN STATE TAX EXEMPTIONS FOR GASOHOL IN SELECTED STATES

State	Date of Tax Exemption Change	State Tax Exemption		Gasohol Sales (thousand gallons)		Gasohol Market Share (percent)		
		Before Change	After Change	6 Month Period Before Change	6 Month Period After Change	6 Month Period Before Change	6 Month Period After Change	Difference
Louisiana	7-1-84	8¢/gal.	16¢/gal	0	24,424	0	2.3	+2.3
Utah	7-1-84	5¢/gal.	0	25,243	619	7.3	0.2	-7.1
Wyoming	7-1-84	4¢/gal.	0	101	187	0.1	0.1	0
California	12-31-83	3%	0	223,695	255,750	4.6	4.5	-0.1
Minnesota	1-1-83	0	2¢/gal.	0	2,126	0	0.2	+0.2

Sources: Office of Alcohol Fuels, Sixth Annual Report on the Use of Alcohol in Fuels, April 1985, pp. 6-8; Office of Alcohol Fuels, Fourth Annual Report on the Use of Alcohol in Fuels, March 1983, pp. 8-10; and Energy Information Administration, Petroleum Marketing Monthly, July 1982 through December 1984.

slight, since California is a major market for imported ethanol that can be sold profitably without a tax incentive. Furthermore, any growth in the federal tax subsidy for alcohol fuels will have the effect of reducing or eliminating the state tax incentive necessary to make gasohol competitive, tending to reduce regional differences in gasohol demand.

2.3 ETHANOL PRICING

Historically, ethanol prices have been significantly higher than gasoline prices, preventing the large-scale use of ethanol as a motor fuel (Exhibit 2-12). The recent marketing of ethanol as an octane enhancer, the federal and state tax subsidies for alcohol fuels, and the escalation of gasoline prices in the 1970's and early 1980's have made ethanol more competitive with gasoline. The current wholesale price for fermented fuel ethanol is between $1.42 per gallon and $1.72 per gallon.[1] The current price of gasoline averages $0.82 per gallon wholesale, without taxes, and $1.199 per gallon retail.[2,3] Thus, gasoline still holds a considerable price advantage over ethanol if factors such as tax incentives are not accounted for. If the price of ethanol is adjusted for the federal excise tax exemption on gasohol as shown in Exhibit 2-12, the net price of ethanol to the blender becomes much lower. For example, the current federal excise tax exemption on gasohol of 6 cents per gallon of gasohol reduces the net price of ethanol by 60 cents per gallon of ethanol blended in a 10 percent concentration. Thus the net price of fermented ethanol to a blender is $0.82 to $1.12 per gallon when the federal tax exemption is taken into account. If the blender can take advantage of a state tax exemption for alcohol fuels, the net price of ethanol to the blender would be even lower.

2.4 GASOHOL PRICING

Gasohol may be either regular unleaded gasoline blended with ethanol (a premium blend), or ethanol which has been blended with a specially prepared leaded or unleaded suboctane gasoline so that the octane rating of the blend qualifies it as a regular leaded

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[1] Information Resources, Inc., Alcohol Outlook, May 1985, p. 3.

[2] Energy Information Administration, U.S. Department of Energy, Petroleum Marketing Monthly, March 1985, p. 43.

[3] Energy Information Administration, U.S. Department of Energy, Monthly Energy Review, June 1985, p. 98.

EXHIBIT 2-12:

ETHANOL AND GASOLINE PRICES, 1975-1985

(dollars per gallon)

Year	Average Midyear Wholesale Ethanol Prices		Average Annual Retail Gasoline Prices				
	Denatured, 200 Proof	Net of Federal Tax Exemption	Regular Leaded	Regular Unleaded	Premium Leaded	Premium Unleaded	Average
1975	1.100	1.100	0.567	—	0.609	—	—
1976	1.250	1.250	0.590	0.614	0.636	—	—
1977	1.250	1.250	0.622	0.656	0.674	—	—
1978	1.220	1.220	0.626	0.670	0.694	—	0.652
1979	1.365	0.965	0.857	0.903	0.922	—	0.882
1980	1.730	1.330	1.191	1.245	1.281	—	1.221
1981	1.940	1.540	1.311	1.378	1.439	1.470	1.353
1982	1.815	1.315	1.222	1.296	1.417	1.261	1.415
1983	1.815	1.315	1.157	1.241	1.372	1.383	1.225
1984	1.815	1.315	1.129	1.212	—	1.366	1.198
1985[1]	1.635	1.035	1.119	1.205	—	1.340	1.199

[1] Current prices.

Sources: Ethanol prices from "Current Prices of Chemicals and Related Materials," Chemical Marketing Reporter, midyear issues and Alcohol Week, June 24, 1985, p. 13. Gasoline prices from Energy Information Administration, U.S. Department of Energy, Monthly Energy Review, various issues.

or regular unleaded grade. It is most common at present for gasohol to be blended by wholesalers using 87 octane regular unleaded gasoline from pipeline terminals and ethanol from fuel ethanol manufacturers. In this case, the gasohol blend is a premium unleaded fuel of 90 to 91 octane, comparable to nonalcohol unleaded premium gasoline with an octane rating of 91. Currently, the retail price of premium unleaded gasoline is 8.7 cents higher than the retail price of regular unleaded gasoline,[1] while the gasohol blended in this manner commanded a price over regular of about 4 cents in 1984.[2]

Gasohol prices may be estimated from gasoline prices and ethanol prices if it is assumed that the blender will price the gasohol in order to receive the same income and net profit per volume of gasohol sold as per volume of gasoline sold. The methodology for this calculation is shown in Exhibit 2-13, using current data for wholesale prices of regular unleaded gasoline and gasohol and the retail price of regular unleaded gasoline. The net profit per gallon of retail sales of 100,000 gallons of gasoline is determined first as a base case. Case 1 is gasohol blended in a state where there is a 15 cent per gallon state excise tax on gasoline and no state excise tax exemption for gasohol. Case 2 is gasohol blended in a state where there is a 15 cent per gallon state excise tax on gasoline and a 5 cent per gallon state excise tax exemption for gasohol. The calculations show that where there is no state tax exemption for gasohol, the gasohol would be priced 1.3 cents per gallon higher than regular unleaded gasoline. Where there is a state tax exemption of 5 cents per gallon for gasohol, the gasohol would be priced 3.5 cents per gallon lower than regular unleaded gasoline. However, since gasohol blended from 87 octane regular unleaded gasoline would be a premium unleaded fuel of 90 to 91 octane, gasohol could sell at a much higher price in either case, a price closer to the price of premium unleaded (in this example, $1.31 per gallon).[3] Thus, the blender could improve his profits either by expanding his profit margin or by increasing sales at the price of gasohol determined by a constant margin.

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[1]Energy Information Administration, Monthly Energy Review, op. cit., p. 98.

[2]Office of Alcohol Fuels, Sixth Annual Report, op. cit., p. 3.

[3]Energy Information Administration, Monthly Energy Review, op. cit., p. 98.

EXHIBIT 2-13:

DETERMINATION OF GASOHOL PRICING BY BLENDER'S PROFIT MARGIN

	Gasoline	Gasohol (10% Ethanol)	
	Base Case	Case 1	Case 2
Federal tax credit (¢/gal.)	0	6	6
State tax credit (¢/gal.)	0	0	5
REVENUES			
Total Sales Revenue (100,000 gal.)	115,900	117,210	112,210
EXPENSES			
Gasoline Cost ($0.829/gal.)[1]	82,900	74,610	74,610
Ethanol Cost ($1.56/gal.)[2]	0	15,600	15,600
Total Fuel Cost (100,000 gal.)	82,900	90,210	90,210
State Tax ($0.15/gal.)	15,000	15,000	10,000
Federal Tax ($0.09/gal.)	9,000	3,000	3,000
Total Expenses	106,900	108,210	103,210
Operation Income	9,000	9,000	9,000
Tax Liability (45%)	4,140	4,140	4,140
Net Profit After Tax	4,860	4,860	4,860
Gross Margin ($/gal.)	0.090	0.090	0.090
Net Profit ($/gal.)	0.0486	0.0486	0.0486
Retail Sales Price	1.159[3]	1.1721	1.1221

[1] March 1985 wholesale price for regular unleaded gasoline.

[2] March 1985 wholesale price for fermented, 200 proof fuel alcohol.

[3] March 1985 retail price for regular unleaded gasoline.

Sources: Ethanol wholesale price from Alcohol Outlook, May 1985, p. 3. Gasoline wholesale price from Energy Information Administration, Petroleum Marketing Monthly, March 1985, p. 45. Gasoline retail price from Energy Information Administration, Monthly Energy Review, March 1985, p. 98.

2.5 CURRENT ISSUES

The regulatory environment and economic situation of the domestic fuel ethanol industry are in a state of constant change. Current issues which will affect the long-term growth and stability of the fuel ethanol industry include: the EPA mandated phasedown of lead in gasoline; a Clean Air Act waiver approval by the EPA for a DuPont gasoline blend containing methanol, cosolvent higher alcohol, and a DuPont proprietary corrosion inhibitor; a number of proposed legislative changes to tax incentives and import regulations for fuel ethanol; and ongoing research in alcohol fuels technology.

Lead Phasedown

On March 7, 1985, the EPA announced a final ruling on its proposed regulation regarding gasoline lead phasedown. A limit of 0.1 grams of lead per leaded gallon of gasoline was imposed, effective January 1, 1986, with an interim standard of 0.5 grams per leaded gallon, effective July 1, 1985.[1] The intent of this regulation was to reduce the health risks of airborne lead and to reduce the use of leaded gasoline in unleaded gasoline vehicles, which can poison the catalytic converter and significantly increase exhaust emissions.

The phasedown of lead in gasoline could have a major impact on the fuel ethanol market. While some major refiners may find it economically and/or logistically attractive to make the capital investment needed to enhance octane ratings by increasing reformer severity, others, especially small refiners, may turn to an alternative octane boosting additive such as ethanol.[2] Ethanol availability and price, as well as possible regulatory factors, will influence what part ethanol will have in filling the increased demand for nonleaded octane enhancers.[3]

The DuPont Waiver

On January 14, 1985, the EPA conditionally granted DuPont a waiver of the Clean Air Act for a gasoline blend containing methanol, cosolvent alcohol, and a DuPont proprietary corrosion inhibitor, DGOI-100. The waiver request, as submitted, called for a maximum of 5 volume percent methanol and a minimum of 2.5 volume

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[1] Volume 50, FR 9386 (March 7, 1985)

[2] Information Resources, Inc., Alcohol Outlook, March 1985, pp. 2, 17.

[3] "Under EPA's Lead Phase-Down Will Ethanol Blends Save the Independent," Lundberg Letter, November 9, 1984, pp. 1-6.

percent cosolvent alcohol with a maximum of 3.7 weight percent oxygen in the finished fuel. The cosolvent alcohol could be one or a mixture of ethanol, propanols, and butanols. Existing ASTM volatility standards for gasoline would need to be met, as well as specifications for maximum temperature for phase separation. Due to potential increases in evaporative emissions with the use of such a fuel, EPA attached certain conditions to the waiver before granting it. The major condition is an Evaporative Index standard — a function of Reid Vapor Pressure, fraction distilled at 200 degrees Fahrenheit, and fraction distilled at 100 degrees Fahrenheit. Also, fuel blended with DuPont blendstock may not be used as a base gasoline to blend with other oxygenates, such as alcohols and ethers, and alcohol purity specifications must be met.[1]

Some members of the energy industry consider the terms of the DuPont waiver to be restrictive, and so blenders and refiners have been slow initially to begin blending methanol and ethanol into gasoline according to the terms of the DuPont waiver. However, the potential demand for ethanol as a component of DuPont waiver blends is large. The DuPont waiver blend is a less expensive octane-boosting gasoline additive than blending gasoline with pure ethanol, and could increase blenders' profit margins.[2] Ethanol may be preferred to the propanols and butanols as a cosolvent alcohol in the DuPont blend since ethanol blended in this proportion would be eligible for the blender's federal income tax credit of $0.60 per gallon of ethanol. The DuPont blend may make it possible to market ethanol economically in states where there is no state tax incentive for ethanol blends, particularly in the heavy population centers on the East and West Coasts.[3]

Ethanol Legislation

At the federal level, both the tax subsidies for alcohol fuels and the duties on imported fuel ethanol are subject to potential revision. Various state legislatures are also considering legislation which will affect alcohol fuels regionally.

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[1] "Vol. 50, FR 2615 (January 17, 1985)

[2] "U.S. Fuel Alcohol Market Analysis," Alcohol Outlook, September 1984, p. 4.

[3] "EPA DuPont Decision Seen Putting Ethanol in States Without Tax Breaks," Alcohol Week, January 15, 1985, p. 2.

Elimination of the federal tax incentives for alcohol fuels would have serious consequences for the domestic fuel ethanol industry, since gasohol could not currently compete with gasoline without the federal subsidy. Extension of the energy investment tax credit would have the effect of encouraging continued growth of domestic fuel ethanol production capacity. Legislation which would strengthen the fuel ethanol import duty laws would provide a greater deterrent to fuel ethanol imports, and thus encourage the development of domestic capacity. Such legislation includes a 60 cents per gallon tariff on gasohol imports, which are not currently subject to the 60 cents per gallon fuel ethanol tariff; a bill closing the loophole for wet ethanol upgraded to fuel ethanol in the Caribbean, presently exempt from duties under the Caribbean Basin Initiative; a fuel ethanol duty imposed on all imported ethanol, followed by remission of the duty to an end user of ethanol who could verify that the ethanol was used for nonfuel purposes; and closure of the loophole for imported ethanol blended with another octane enhancer, such as toluene or xylene, to avoid the tariff.

In the state legislatures, South Carolina, New Jersey and Maine have passed excise tax exemptions which took effect between October 1, 1985 and January 1, 1986. These exemptions will be 6 cents per gallon, 8 cents per gallon and 4 cents per gallon respectively.[1] California is currently considering a 2 cent per gallon gasohol excise tax exemption on gasohol, and Illinois is currently considering a bill to reduce the state sales tax exemption by one percent for every cent increase in the federal excise tax exemption.[2]

Ethanol Research

Currently, research is being conducted to develop an economically competitive process technology for the production of ethanol from cellulosic materials, such as wood. Work is also being done to develop new strains of yeast which could increase ethanol yields from fermentation by 30 to 40 percent.[3] The economic analysis in this report assumed no major breakthrough would occur in ethanol production technology in the next five years. A breakthrough in either of these areas is unlikely to result in production scale units in that time frame, but if such a breakthrough were to occur it could dramatically lower the price of domestic fuel ethanol and increase demand for ethanol as a gasoline additive.

[1] Herman and Associates, op. cit.

[2] "State Tax and Regulation Update," Alcohol Update, July 1, 1985, p. 10.

[3] Office of Alcohol Fuels, U.S. Department of Energy, Annual Report to the President and the Congress, December 1984, p. 2

CHAPTER 3

ETHANOL DISTRIBUTION AND BLENDING

This distribution system for ethanol has three components:

- distribution of gasoline to be blended with ethanol, from the refinery to the blender;

- distribution of ethanol to be blended with gasoline, from the producer to the blender; and

- distribution of gasohol, from the blender to the retailer.

The following pages describe each of these aspects of the ethanol distribution system, focusing on the characteristics of each that could be affected by gasohol special blending requirements and/or a reduction in the ethanol composition of gasohol from 10 percent to 5 percent. The patterns of distribution described here, and their costs, serve as the basis for the analyses of proposed changes in ethanol blending practices presented in Chapters 4 and 5.

3.1 THE GASOLINE DISTRIBUTION SYSTEM

Gasoline is blended with ethanol in two forms. Standard gasolines that could be sold as finished product are the most common (75 to 80 percent of the gasoline blended with ethanol). When blended with ethanol, the resulting gasohol has a higher octane rating than the standard gasoline, and with federal and state tax incentives, may have a lower cost. The second type of gasoline blended with ethanol is the specially produced sub-octane blend. Sub-octane blends of gasoline are blends that, when mixed with the higher octane ethanol in a 9:1 ratio, result in motor fuels with standard octane ratings, such as 87 octane regular unleaded and 88 octane regular leaded. The distribution system for standard gasolines blended with ethanol is believed to be essentially identical to that for gasolines not blended with ethanol. The distribution system for sub-octane blends differs somewhat because they have not, until recently, been transported by pipeline. An overview of the distribution systems for both forms of gasoline follows.

Where there is no distinction made between standard and sub-octane gasolines, the discussion should be assumed to apply to both.

Overview

The gasoline distribution system is not a single system optimized either nationally or regionally. It has developed gradually and consists of many competing and overlapping parts. Its institutional structure is composed of many companies carrying out both sequential and parallel operations. It involves complex relationships between major refiners; independent refiners; resellers such as branded jobbers, commission agents, and private-branded jobbers; and a variety of types of retail outlets. Exhibit 3-1 illustrates these institutional aspects of the flow of product from refiner to retailer.

The physical transportation system for petroleum products is, like the institutional structure, a highly complex system. Petroleum products are transported by five modes: pipelines, ocean vessel, barge, rail tank car, and tank truck (Exhibit 3-2). The methods for any given shipment are selected to minimize the cost of transportation for the level of service required.[1]

Pipelines

Pipelines play a large and growing role in the distribution of petroleum products. In the early 1950's, they accounted for only about 15 percent of petroleum product transportation.[2] By the early 1970's, they had reached 40 percent of the total ton-miles. In 1984, the pipeline market share stood at 57 percent.[3] The most frequent use of product pipelines is in shipment of products from the refinery to distribution terminals. In a few cases, the pipeline may deliver product directly to an end user.[4]

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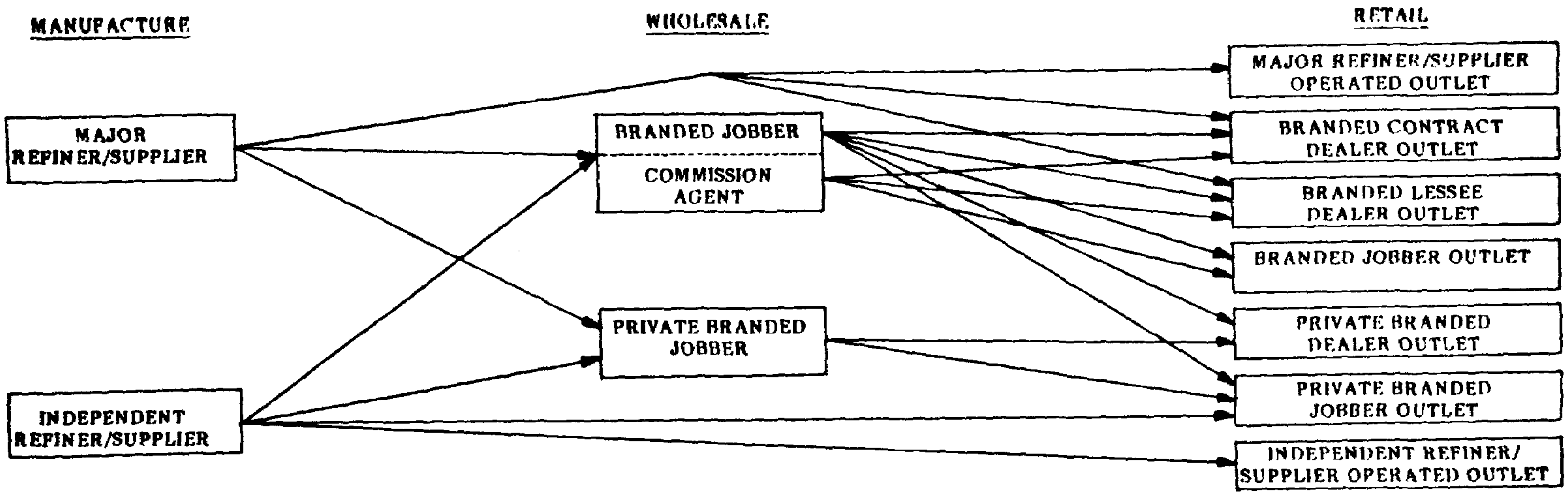
[1] DHR, Inc., Phase I: Methanol Use Options Study; Volume III, Appendix D, "Transportation and Distribution of Methanol Fuels." Prepared for the U.S. Department of Energy, May 1, 1981, p. D-12.

[2] D. Atkinson, Distribution of Methanol as a Transportation Fuel. Prepared for U.S. EPA, June 1982, p. 2.

[3] Transportation Policy Associates, Transportation in America; Supplement to the 3rd Edition. Washington, D.C: July 1985, p. 13.

[4] Larie W. Harold, "Distribution Options for Alcohol Fuels," Fuel Alcohol: An Energy Alternative for the 1980's; Appendix. Final Report, U.S. National Alcohol Fuels Commission; Washington, D.C.: 1981, pp. 768-769.

EXHIBIT 3-1:
GASOLINE DISTRIBUTION SYSTEM[1]



[1] For further information on the gasoline distribution system, see Jack Faucett Associates, Gasoline Price Data Systems. Prepared for Economic Regulatory Administration, U.S. Department of Energy, 1980.

Source: DHR, Inc., op. cit., p. D-2.

EXHIBIT 3-2:

TRANSPORTATION OF PETROLEUM PRODUCTS
1972-1984

(billions of ton-miles)

Year	Total	Pipelines Ton-Miles	Pipelines %	Water Carriers Ton-Miles	Water Carriers %	Motor Carriers Ton-Miles	Motor Carriers %	Railroads Ton-Miles	Railroads %
1972	476.8	191.3	40.1	254.0	53.3	22.0	4.6	9.5	2.0
1973	480.4	205.0	42.7	238.0	49.5	23.7	4.9	13.7	2.9
1974	488.8	203.0	41.5	244.0	49.9	27.7	5.7	14.1	2.9
1975	515.2	219.0	42.5	257.4	50.0	26.2	5.1	12.6	2.4
1976	523.9	212.0	40.5	269.1	51.4	30.4	5.8	12.4	2.3
1977	530.9	219.4	41.3	270.2	50.9	27.6	5.2	13.7	2.6
1978	536.7	226.3	42.2	269.3	50.2	28.6	5.3	12.5	2.3
1979	534.2	236.1	44.2	257.4	48.2	27.8	5.2	12.9	2.4
1980	492.3	225.6	45.8	230.4	46.8	24.3	5.0	12.0	2.4
1981	477.7	230.6	48.3	212.3	44.4	22.7	4.8	12.1	2.5
1982	448.0	230.6	51.5	184.2	41.4	20.7	4.6	12.5	2.8
1983	416.5	223.7	53.7	159.3	38.3	22.2	5.3	11.3	2.7
1984p	416.0	234.8	56.5	146.6	35.2	23.6	5.7	11.0	2.6

P = Preliminary

Source: Transportation Policy Associates, Transportation in America; Supplement to the 3rd Edition, Washington, D.C: July 1985, p.13.

Pipelines are concentrated near highly populated areas and refinery centers, especially in the East, Gulf Coast, and Midwest (Exhibit 3-3). In length, they range from a few miles to a few thousand miles, and in diameter from 4 to 58 inches.[1] The minimum batch size on a given pipeline may be as little as 5,000 barrels or as much as 75,000, as set by the pipeline company.[2]

Pipeline acceptance of a gasoline product is sometimes based on the concept of "fungibility," the ability to treat gasolines supplied by different producers as identical. Thus, when a pipeline operating on this basis agrees to deliver product, it agrees to deliver a barrel like in quality to the one received from the producer, but not necessarily the same barrel. For each product, the pipeline operator develops a specification that must be met by shippers. Other pipelines offer "segmentation" of product, agreeing to deliver the same barrels provided by the shipper to the destination.

The limited demand for sub-octane blends to date, combined with the emphasis on quality control (which can more easily be compromised in a small volume shipment), has prevented pipelines from accepting sub-octanes for transportation in the past. With a recent announcement by Williams Brothers Pipe Line that it is prepared to begin transporting sub-octane leaded regular, this impediment to the widespread use of this type of gasoline in ethanol blending may begin to be less important. The company operates a pipeline system based on fungibility in twelve midwestern states that moves product from refineries and junctions with other pipeline systems to 41 company-owned terminals, and off-line to 85 shipper-owned facilities. After considerable discussion with its shippers regarding their plans for meeting octane requirements under lead phasedown Williams Brothers elected to establish a regular leaded sub-octane grade and to expand its terminal ethanol blending facilities. In October 1985, the company began handling an 85 sub-octane leaded at eight terminals. The specification for the sub-octane is the same as that for 88 octane regular leaded grade, except that the (R x M)/2 octane number specifies a minimum of 85. A sub-octane unleaded regular grade may also be established in mid-1986 if demand materializes.[3] Colonial Pipeline, the nation's largest pipeline company, is considering a similar proposal.[4]

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[1] Atkinson, op. cit., p. 1.

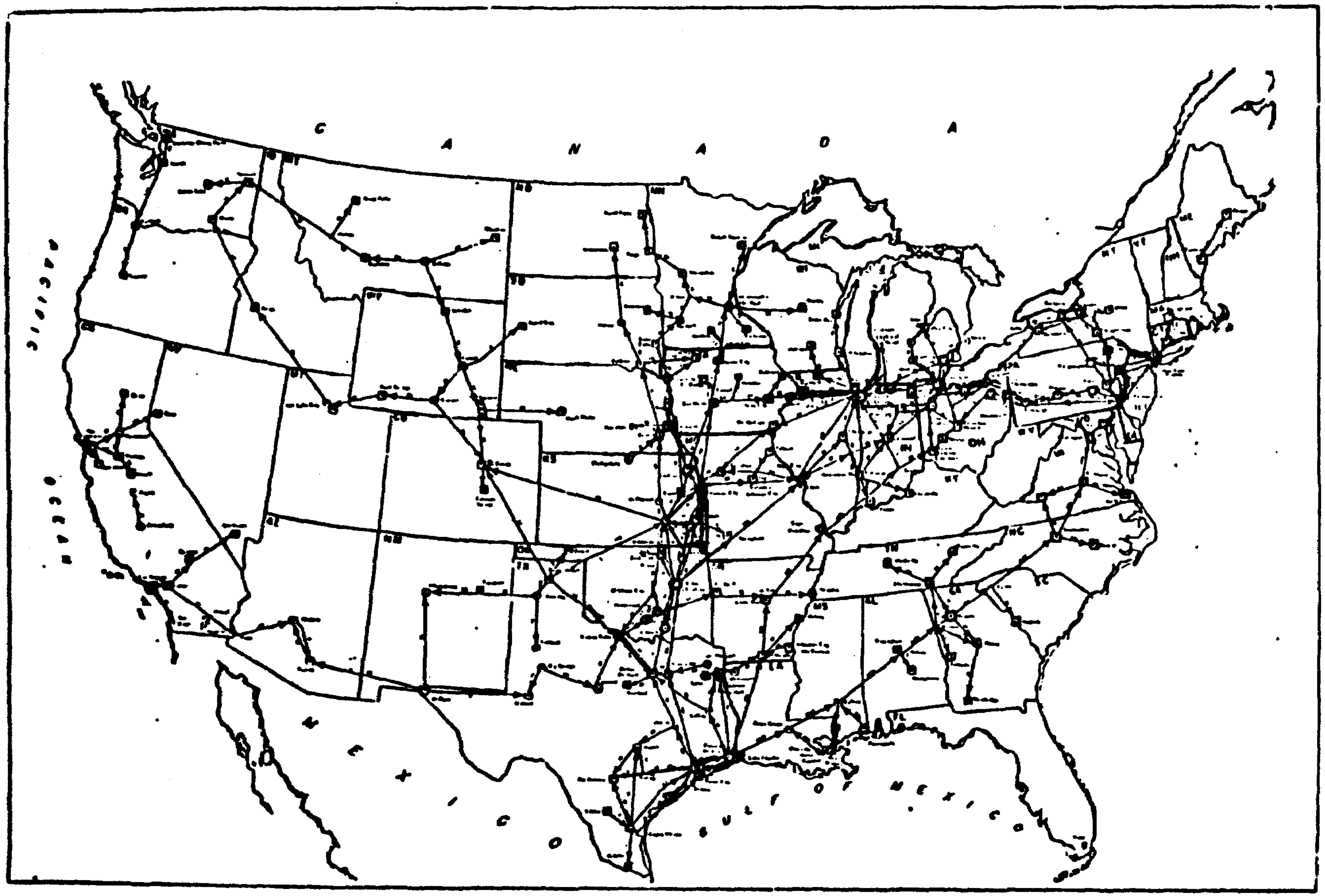
[2] Industry information obtained through interviews with pipeline companies and the American Petroleum Institute.

[3] H. L. Teel, "Sub-Octane and Oxygenated Fuels in Williams Pipe Line Company." Presented to the 1985 National Conference on Alcohol Fuels, Washington, D.C., September 1985.

[4] Industry information obtained through discussions with pipeline companies.

EXHIBIT 3-3:

THE U.S. PETROLEUM PRODUCT PIPELINE SYSTEM



Source: National Petroleum Council

Water Transportation

Water transportation, where available, provides a low cost method of delivering fuel when pipeline movement is not feasible. Waterborne vessels transport petroleum products both on oceans and the nation's 25,000 miles of inland waterways, with the latter concentrated in the Great Lakes region, along the Ohio and Mississippi Rivers and parallel to the Atlantic and Gulf Coasts (Exhibit 3-4). Movements ranging from less than 10 miles to over a thousand miles can be economical.[1] Self-propelled tankers are used in coastal and ocean transportation. Tank barges are used for inland transportation. Both are currently used extensively for petroleum product transportation.[2] In 1984, water carriers accounted for 35 percent of the transportation ton-miles for petroleum products.[3]

Tank Trucks

Tank trucks are commonly used for local distribution of petroleum products and are best suited for use in distances of less than 150 miles. Their most common use in the gasoline distribution system is in transporting fuel from the terminal, or possibly the refinery, to the end user. Trucks are also occasionally used in longer hauls in areas of the country where pipeline and barge transportation are not available.[4]

Truck shipments of petroleum products account for only a small portion of the total transportation ton-miles, about 6 percent in 1984.[5] This measure severely understates the importance of this mode to gasoline and petroleum product transportation however. Virtually all gasoline is at some point transported by truck.[6]

Rail Tank Cars

Rail movement, once an important mode of transportation for refined petroleum products,[7] now accounts for less than 0.2 percent of all gasoline tonnage transported.[8]

[1] DHR, Inc., op. cit., p. D-12.

[2] Atkinson, op. cit., pp. 6, 8.

[3] Transportation Policy Associates, op. cit., p. 13.

[4] Harold, op. cit., pp. 768-769.

[5] Transportation Policy Associates, op. cit., p. 13.

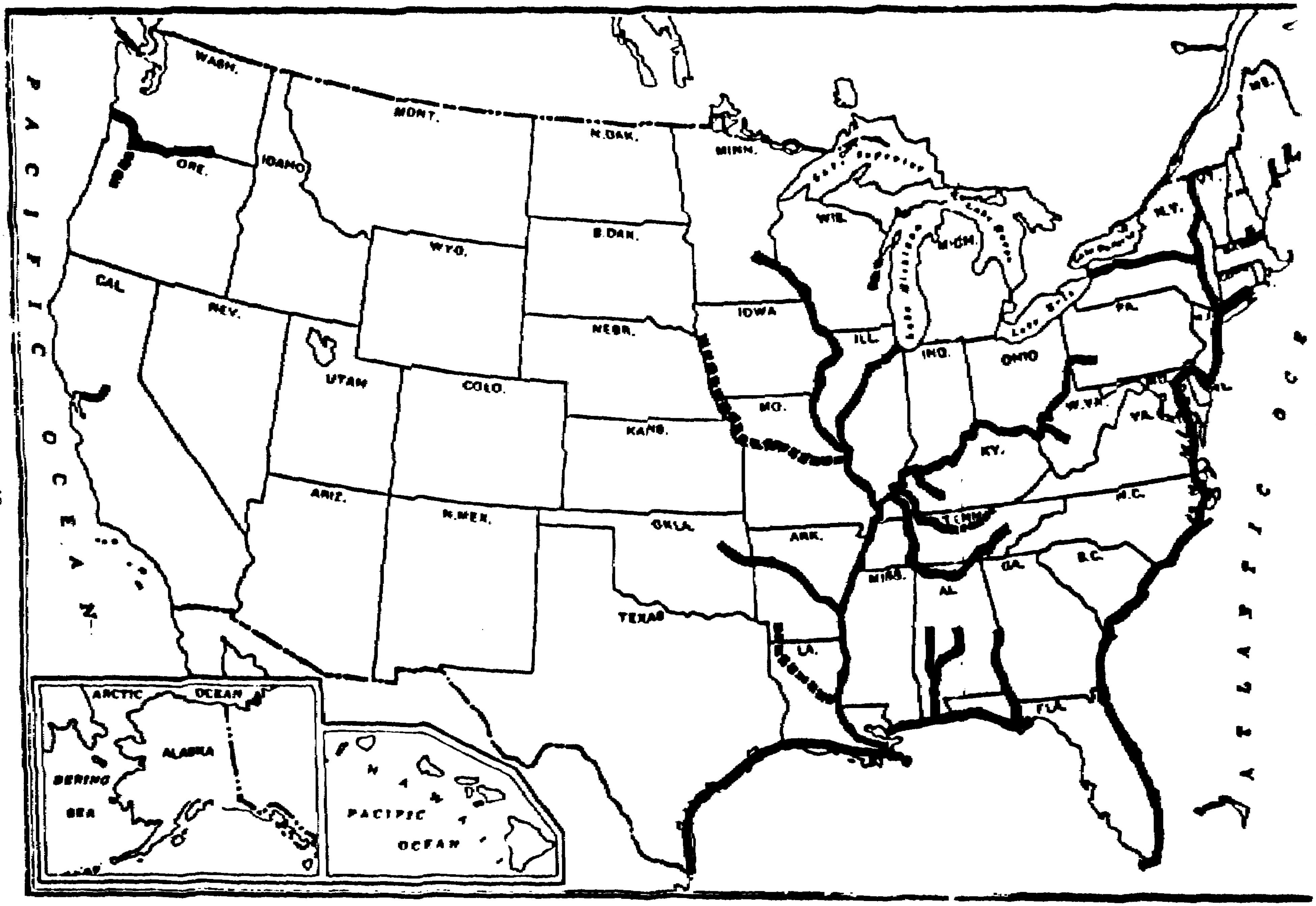
[6] Atkinson, op. cit., pp. 8, 10.

[7] Harold, op. cit., p. 769.

[8] U.S. Department of Transportation, 1981 Carload Waybill Statistics: Territorial Distribution, Traffic, and Revenue by Commodities Classes. February 1983, pp. 137-138.

EXHIBIT 3-4:

THE U.S. WATERWAY SYSTEM



---- Less than 9 feet deep.

▬▬ 9 or more feet deep.

Intense competition from other modes and the limited ability of rail carriers to supply and move product to diverse locations quickly are cited as the primary causes of the decline.[1]

3.2 ETHANOL AND GASOHOL DISTRIBUTION

The institutional and physical distribution systems for fuel ethanol are closely related to those for gasoline and other petroleum products. Like petroleum products, the institutional structure is currently comprised of many companies carrying out both sequential and parallel operations, including producers, resellers, and retailers. It involves transportation by a variety of modes, with each shipment planned to minimize the cost of movement. The institutional and physical aspects of ethanol distribution are discussed in the following sections.

Institutional Structure

Like the system for petroleum products, the institutional structure of the ethanol marketing system is composed of producers, name brand and independent jobbers and wholesalers, and name brand and private brand retailers. The elements of the marketing chain are discussed further in the following paragraphs.

As discussed in Chapter 2, there are presently 53 major commercial facilities producing fuel ethanol in the United States.[2] Most are located in the Midwest and corn-producing regions. To date, all of the ethanol plants are owned by companies other than oil refining companies. However, this may change if moves continue by major oil companies to acquire shares in ethanol companies, such as the partial ownership of South Point Ethanol by Ashland Oil Company.

From the producer, ethanol is typically moved to a bulk terminal near the market, the blending point for about 90 percent of ethanol blends. (With the exception of small amounts blended at refineries, the remainder is blended at the retail outlet). In some cases, the producer rents space from a terminal operator who also offers gasoline to

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[1] Harold, op. cit., p. 769.

[2] Herman and Associates, op. cit.

buyers. In other cases, the ethanol terminal is entirely separate from a gasoline distribution facility, and may be as many as 25 to 50 miles away. Generally, a purchaser arrives with a tank truck that will be 90 percent filled with gasoline and 10 percent with ethanol. Some buyers fill their truck tanks solely with ethanol, which may be taken to another terminal for blending, or blended at the retail outlet.[1]

Ethanol blending occurs for two reasons — to increase the margin which the gasoline marketer can earn on a grade of fuel, and to increase the octane value of a sub-octane grade to a marketable level. The impetus of the former reason is strongly dependent on the level of the state tax exemption, as ethanol blending is not usually profitable when only the federal tax exemption is available. The latter reason is related to the desire of refiners to earn lead credits in the face of lead phasedown, as well as the desire to take advantage of tax incentives so as to earn a higher margin on each gallon of fuel sold.[2]

The type of gasoline with which the ethanol is blended depends upon the level of the state tax exemption. In those states where the state tax exemption is one cent or more per gallon of gasohol, ethanol is blended with unleaded regular and premium gasolines, leaded regular gasoline, and sub-octane gasolines from each grade. The resultant blends are marketed as premium (or super) grade fuels and as regular grade fuels. In states where the state tax exemption is less than one cent per gallon of gasohol, ethanol is blended primarily with 87 octane unleaded to produce a 90 octane premium gasohol.[3]

In states where the tax exemption is one cent or more per gallon of gasohol, ethanol/gasoline blends constitute 20 to 25 percent of the market for each grade of gasohol, i.e. unleaded regular, unleaded premium, and leaded regular. In these states, the gasohol market share of each grade of ethanol blend is approximately the same as the market share for that grade of gasoline in the gasoline market.[4] Thus, it is estimated that 44 percent of ethanol blends sold nationally in 1984 were leaded regular blends, 46 percent were unleaded regular blends, and 10 percent were premium blends.[5]

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[1] Industry information obtained through interviews with ethanol producers, oil refiners, pipeline companies, industry associations, and other industry analysts.

[2] Discussions with various industry representatives.

[3] Personal communications with Mr. Bob Reynolds, Manager, Marketing Department, New Energy Company of Indiana, October 9, 1985.

[4] Ibid.

[5] Petroleum Marketing Monthly, U.S. Department of Energy, Energy Information Administration, June 1985, Table 9, p. 16.

Gasohol is sold at branded and unbranded service stations operated by independent dealers (lessee and contract), and at branded and unbranded retail outlets operated by the fuel supplier, who may be a refiner, a superjobber, or a chain discounter. It is not sold by ethanol producers, who enter into long or short-term arrangements with gasoline marketers to provide ethanol at spot prices for blending at the terminal. An estimated 80-100 chain discounters of motor fuel sold an estimated 2.83 billion gallons of ethanol blends in 1984, 50 percent of total sales of 5.7 billion gallons. By comparison, the same independent gasoline marketers sold 15.9 billion gallons of gasoline in 1984, roughly 15 percent of total gasoline sales. Thus, gasohol sales represented 17.8 percent of total gasoline sales by these marketers, three times the national share of 5.5 percent of total gasoline sales.[1]

Although all of the large integrated and large independent refiners except Exxon market gasohol to some extent, Texaco, Amoco, Chevron, Sun, Ashland, Mobil, and Union are more active than others. Their activities are primarily in those states with tax incentives. Data detailing their gasohol sales are not publicly available.[2]

Independent gasoline marketers such as the chain discounters discussed above sell a disproportionate amount of ethanol blend fuels for several reasons. Major brand dealers and small jobbers do not sell a lot of gasohol because their refiner/suppliers do not blend ethanol to a significant degree, or encourage ethanol blending. This is because many major refiners and independent refiners see ethanol as being competitive only if state tax incentives exist. These refiners fear that the tax breaks will disappear if gasohol achieves a substantial market share since the cost of the incentives to the federal and state governments (in the form of reduced tax revenues) grows as the gasohol market expands. Consequently, they are unwilling to make the investments necessary to permit the wide distribution of alcohol fuels through the existing national pipeline and terminal system. Furthermore, the widespread marketing of ethanol blends could result in reduced refinery utilization, a situation which the refiners are not likely to favor, especially given the high capital cost of a refinery. Consequently, multi-branded superjobbers and chain discounters do the majority of blending. These

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[1] Remarks by Kenneth A. Doyle, Executive Director of the Society of Independent Gasoline Marketers of America (SIGMA) before the Renewable Fuels Association, 1985 Conference on Alcohol Fuels, September 19, 1985, Washington, D.C.

[2] Personal Communication with Eric Vaughn, President, Renewable Fuels Association, October 10, 1985.

companies are small enough to be able to blend when it is profitable and to stop blending when it is not. They are used to squeezing the extra 1/2 cent to 1 cent of margin out of each gallon sold. Unlike major dealers and small jobbers, they are not restricted by comingling or labeling requirements as they have substantial private brand and unbranded business. Furthermore, they usually have sufficient market power to influence refiners who do not favor ethanol blending.[1]

The Physical Distribution System

Ethanol and gasohol are transported by barge, rail, and tank truck. Shipments from the producer to the terminal may be by any one of these means, or may combine two or more modes.[2]

Published statistics are not available describing the market shares of each mode. However, a few comments can be made based on interviews with individual producers and industry analysts.

- Water transportation, the least costly means of shipping ethanol or gasohol, is a primary source of ethanol transportation in the Midwest. Barge movements account for as much as 50 to 80 percent of the movements from the ethanol producer to the terminal in this region. Water transportation is of little importance in the transportation of domestic product in other regions of the country.

- The distance the ethanol travels from the producer to the terminal determines whether rail or tank truck will be used. Rail transportation becomes attractive when trips exceed 200 to 300 miles.

- Distances from the ethanol plant to the terminal vary considerably. The average distance from the plant to the terminal cited by individual producers ranges from 100 to 700 miles, with 200 miles a common estimate. Actual distances cited range from 9 miles to more than 1,000 miles.

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[1] Kenneth A. Doyle, op. cit.

[2] Harold, op. cit., pp. 769-772.

- A 60,000,000 gallon per year plant would typically ship ethanol to 30 to 50 terminals.

Shipments of gasohol from the terminal to the reseller are typically made by tank truck, though they may be by another mode. The distance from the terminal to the retailer is generally within a radius of 150 miles.[1]

There are no pipeline shipments of ethanol or gasohol because of the special handling required in their transport. Because multi-product pipelines are not dehydrated, water can collect in them and cause phase separation in gasohols. Though multi-product pipelines can handle alcohol blends satisfactorily if separate facilities are dedicated to this service, the capital investment required to provide the separate line segments, tankage, and loading facilities is substantial.[2] The investment cannot be justified based on current pipeline and refiner expectations for long-term demand that depends on the continuation of state tax incentives.

3.3 TRANSPORTATION COSTS

Until recently, the tariff rates for movement of non-beverage alcohol were primarily based on shipments of chemical grade ethanol for industrial use which requires special handling. After manufacturers succeeded in negotiating improved rates for fuel ethanol in the early 1980's, transportation costs dropped by almost half.[3] Estimates of current rates for fuel ethanol are provided in the following table:

1985 Tariff Rates for Fuel Ethanol[4]

Mode	Rate/Gallon	Typical Shipment Size (Gallons)
Truck	2.94¢/100 miles[5]	7,800 gallons
Rail	3.76¢/100 miles 5¢/200 miles 6.5¢/300 miles	29,000 gallons
Barge	0.75¢/100 miles	420,000 gallons

[1] Industry information obtained through interviews of ethanol producers, oil refiners, pipeline companies, industry association, and other industry analysts.

[2] Teel, op. cit.

[3] Harold, op. cit., p. 769.

[4] Estimates based on interviews of ethanol producers, industry analysts, and railroad marketing personnel.

[5] Truck rates are often quoted in "running miles," i.e., the miles needed for a round trip. The rate in running miles is 1.47¢ per 100 running miles. Truck rates are presented here in destination miles for purposes of comparison with other rates.

Gasoline transportation costs, in contrast, are significantly less due to the availability of low cost pipeline transportation, and correspondingly smaller reliance on expensive truck and rail modes. Pipeline transportation costs 0.12¢ to 0.35¢ per gallon per 100 miles. Barge and truck rates for gasoline are somewhat lower than those for ethanol. Barge movement of gasoline costs 0.15 to 0.47¢ per gallon per 100 miles. Tank truck transportation costs for gasoline are 1.6¢ to 2.1¢ per gallon per 100 miles. Ethanol/gasoline blends are transported at the same rate as gasoline on all modes except pipelines, which are not available for gasohol movements.[1]

3.4 STATE TAX INCENTIVES AND EXCHANGE AGREEMENTS

The distribution of ethanol and ethanol blends is dominated by a policy factor outside the control of ethanol producers or other members of the distribution chain: state tax incentives. State tax incentives determine whether ethanol blends can be sold at prices competitive with gasoline in the state. Also, where state tax incentives require production of ethanol from state-produced resources, they determine whether a given producer can distribute products for sale in that state.

The impacts are substantial. Exchange agreements, a distribution and marketing device used heavily by the oil industry, have been relied upon to a significant extent by some ethanol producers. In an exchange agreement among oil companies, a company with product in, for example, Texas, may arrange for an East Coast oil company to supply product to a customer in New York. In exchange, the Texas refiner delivers product to the East Coast refiner's customer in Texas or another location. The exchanges are usually arranged as a means of reducing transportation costs. In the ethanol industry, in contrast, they are frequently used as a means of supplying product to a buyer when the producer's product cannot qualify for the tax exemption in the buyer's state. Thus, an ethanol producer in Nebraska, who has a customer in Minnesota, may arrange for a producer in Minnesota (or elsewhere) whose product qualifies for the Minnesota tax credit to deliver product to the customer. In exchange, the Nebraska producer will provide product to an agreed upon customer for the other party to the exchange agreement.

[1] Harold, op. cit., p. 768. Costs of transportation for liquid petroleum fuels were updated from 1981 to 1985 prices using the January 1981 and 1985 price indexes for rail transportation (STCC 29) published by the Bureau of Labor Statistics.

CHAPTER 4

IMPACT OF SPECIAL BLENDING REQUIREMENTS FOR ETHANOL BLENDS ON THE FUEL DISTRIBUTION SYSTEM

Waivers currently exempt ethanol blends from ASTM volatility specifications. As a result, ethanol may be added to any legal gasoline to form an ethanol blend which may be more volatile than the base (alcohol-free) gasoline. In the future, it may be necessary to control the volatility of ethanol blends to reduce automotive evaporative hydrocarbon emissions. This would mean that instead of adding ethanol to any legal gasoline, gasoline would have to be specifically blended for ethanol addition. This chapter examines the effects of such a change on the logistics and costs of ethanol distribution and blending practices. Among the issues addressed are:

- Where will the ethanol be blended into the gasoline?
- What transportation modes will be used for shipping the specially blended gasoline, ethanol, and gasohol?
- What will be the effect on transportation costs of the change?
- What changes may take place in relationships between ethanol producers, refiners, and terminal operators? What will be their cost?
- What storage or equipment issues may arise as a result of the change in blending practices?

The results of the analysis indicate that with special requirements for the gasoline blended with ethanol, if gasohol is blended at the terminal, transportation costs will increase by a maximum of 0.82 cents per gallon of gasohol for every 100 miles that a special gasoline is shipped to the terminal. If gasohol is blended at the refinery, transportation costs will increase by a maximum 0.91 cents per gallon of gasohol per 100 miles. However, several constraints of the study should be noted in interpreting these findings. First, the effects of the proposed blending requirements on demand for gasohol were not analyzed. Gasohol demand was assumed to remain unchanged. If gasohol demand were to fall, the transportation cost increase would tend to be at the high end of the maximums cited above, but would not exceed it. If gasohol demand were to increase, the transportation cost would increase by less than the maximum increase, and could even decrease.

Second, there is an implicit assumption that each refiner whose product is currently blended with ethanol will produce the special gasoline blends; and that the specially blended gasoline is mixed with the ethanol of the same producer and shipped to the same terminals as was the case without special blending. This assumption has more significant implications for the analysis. If, for example, a terminal that previously offered ethanol ceases to accept it after the new requirements are imposed, an ethanol producer who supplied that terminal may have to ship the product to a more distant terminal. With truck and rail rates of 2.94 cents per 100 miles and 3.76 cents per 100 miles for ethanol, respectively, the cost impacts could be substantial. Analysis of this aspect of special blending requirements is suggested as a refinement to the study.

4.1 BLENDING LOCATION

Ethanol may be mixed with specially blended gasoline at any of three locations: the refinery, the terminal, or the retail outlet. At present, 90 percent of all gasohol is blended at terminals by adding ethanol to a tank containing any legal gasoline. The remaining 10 percent is blended primarily at the retail level. The regulatory action proposed by EPA could change these blending practices if an alternative location becomes more economical. Factors that will influence the choice of blending location are discussed below.

Refinery Blending

Refinery blending of gasohol provides the best control for a correct blend. With refinery blending, the blending is carried out by skilled operators under optimum conditions. The laboratory facilities needed to test the fuel are already in place. The ethanol producers would need to deliver their product to only one refinery location, rather than to dozens of terminals.[1] Finally, if volumes are large enough, the gasohol

[1] R. W. Hooks, R. Sagawe, "Gasoline Fuel Distribution and Handling Trial," Proceedings of the Third International Symposium on Alcohol Fuels Technology, May 1979, p. 2.

could in the long-term be transported by pipeline, the lowest cost fuel transportation mode available. However, as discussed in Section 3.2, while pipeline transportation has been determined in tests by Amoco and others to be technologically feasible, current demand levels do not justify the expenses associated with preparing and monitoring a pipeline for alcohol fuels.[1]

There are also several disadvantages to refinery blending. Gasohol is more susceptible than gasoline to degradation during movement from the refinery through contamination with water or sediment.[2] This is particularly true when refinery blending tanks, which normally have only floating roofs that allow some entry of rainwater, are used as storage tanks.[3] Thus, there is an incentive to make the blend later in the distribution chain when water or sediment intrusion into the solvent-like gasohol (and subsequent phase separation) are less likely.[4]

Storage Terminal Blending

An alternate blending site for gasohol is the storage terminal. Blending at the terminal would involve reduced risk of phase separation compared with refinery blending because the risk of water ingress into storage depot tanks, which are normally fixed roof tanks, should be lower than with the floating roof tanks found at refineries.[5] Furthermore, storage depots, which have performed most of the blending to date, are already equipped to handle and store ethanol. Finally, in many areas the volume of gasohol consumed is great enough that refiners could still use their current transportation modes, including pipelines, to move a specially blended gasoline to the terminal. Section 3.1 details the recent Williams Brothers Pipe Line agreement to transport specially blended gasolines.[6]

There are also some potential disadvantages to terminal blending. Their importance depends on the testing requirements for the fuel. Gasoline refiners presently subject their fuels to constant laboratory testing at the refinery to achieve a consistent product. If either EPA or the refiner requires that the gasoline be tested after being combined with the ethanol, rather than solely at the refinery, there will be significant costs associated with purchasing testing equipment and staffing the facility with quality

[1] Industry information obtained through interviews with pipeline companies.

[2] Harold, op. cit., p. 778.

[3] Hooks, op. cit., p. II-32.

[4] Harold, op. cit., p. 778.

[5] Hooks, op. cit., pp. II-31 and II-32.

[6] Industry information based on interviews with refiners and pipeline companies.

control personnel. It is possible that a few simple tests could be performed on the blended gasohol at a reasonable cost. However, any requirement (either self- or government-imposed) that involves terminal testing could reduce the interest of refiners in providing the specially blended gasoline.[1]

Service Station Blending

The final option for blending ethanol with gasoline is the service station. One advantage is the minimal risk of phase separation because of reduced time during which the gasohol is exposed to water ingress.[2] Only the alcohol portion of the blend would have to be carefully guarded against impurities. The 90/10 blend percentage would be virtually guaranteed by the gearing in the ratio-type service station blending pump.[3]

Disadvantages are significant. The distribution and storage costs would be higher for this approach than for refinery or terminal blending. Installation of blending pumps at every location would represent a sizable investment to any retailer,[4] and would entail higher maintenance costs than standard pumps. There would be no opportunity for routine lab testing. Also, storage of pure alcohol at the station would be complicated by the more stringent safety practices associated with the fuel because of its different flammability limits and fire foam compatibility in comparison to gasoline. Higher insurance costs could result.[5]

Conclusions

The choice of blending location will depend on the geographic availability of pipelines, the proximity of the ethanol production facility to a refinery and to the market, and the total demand for gasohol. The choice of location will also depend on whether there are testing requirements for the blended fuel. For most producers, assuming demand is held constant and testing requirements for the blended gasohol are not extensive, gasohol will continue to be blended at the terminal. Key advantages to terminal blending are that many refiners will be able to continue shipping specially blended product to the

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[1] Harold, op. cit., p. 778.

[2] Hooks, op. cit., p. II-32.

[3] Harold, op. cit., p. 779.

[4] Hooks, op. cit., p. II-32.

[5] Harold, op. cit., p. 779.

terminal by the low cost pipeline method presently being used for other gasoline, whereas if gasohol were blended at the refinery, volumes are not large enough to justify the investment and operating costs involved in preparing and maintaining pipelines for fuel containing alcohol.

4.2 TRANSPORTATION MODES

In most areas of the country, about 50 percent of fuel ethanol is shipped to the distribution facility by rail and 50 percent by truck. Along the nation's navigable waterways, primarily in the Midwest, barge transportation may account for 50 to 80 percent of distribution, with the remainder divided evenly between truck and rail. Gasoline for splash blending typically meets the ethanol at the same or a nearby terminal after being transported there by pipeline, barge, or in some areas, truck. Pipeline transportation is concentrated in the South Central states, the Midwest, and the Northeast. Barges are primarily used on the Mississippi, Missouri, and Ohio Rivers, as well as on intracoastal waterways. Trucks tend to be relied upon for transportation of gasoline in the West where neither pipelines nor water transportation are available. In all locations, the blended gasohol is shipped primarily by truck from the terminal to the station.

A requirement that gasoline be specially blended for mixing with ethanol could affect the transportation modes used to move gasoline, ethanol, and gasohol. The first step in the analysis of such changes is identification of the likely blending point for the fuel. Since it was concluded in the previous section that terminal blending would probably continue to dominate the industry, one of the scenarios considered here assumes terminal blending. Since it is also likely that some blending will be shifted to refineries, a scenario based on refinery blending is also considered. The effects on transportation mode choice of service station blending are not evaluated because it is expected to be a very small portion of the market.

Effects on Transportation Mode Assuming Terminal Blending

With terminal blending, the transportation mode used to move ethanol from the producer to the terminal will not be affected if special blending requirements are instituted. The mode used to transport gasohol from the terminal to the service station will also be unaffected. It is only the transportation of gasoline from the refinery to the terminal that may change. The effects will vary depending on the current transportation mode used and the level of demand for the special blend.[1]

For refiners currently transporting gasoline by pipeline, two requirements must be met if pipelines are to continue to be used for special blends: 1) the pipeline operator must be willing to accept the special blend, and 2) the shipments of the special blend must exceed the minimum batch requirements for the pipeline. Programs for transporting sub-octane blends for mixing with ethanol have been recently initiated by Colonial Pipeline, the largest pipeline operator in the United States, and by Williams Brothers Pipe Line Company, a medium-sized company. These initiatives indicate pipeline companies will also be willing to carry the special blends.[2]

The second criteria, achieving the minimum batch size, may be more difficult to meet. Minimum batch sizes range from 5,000 to 75,000 barrels, depending on the diameter of the pipeline; the typical minimum batch is 25,000 barrels. Assuming monthly shipments, demand for the special blends must exceed 2.5 million to 37.8 million gallons per year (2.8 to 42.0 million barrels of gasohol). This does not mean, however, that demand for each refiner's special blend must exceed this level at each of the terminals to which he delivers. In some cases, individual refiners can combine their shipments with those of other refiners in order to achieve the minimum batch. In addition, most pipeline operators permit multiple delivery points for a single batch. Thus, the shipment volumes required between a given refiner and terminal may be substantially less than the pipeline operator's minimum batch size.[3] Where the necessary volumes are not achieved, consolidation of special blend distribution and ethanol blending (i.e. refiner or terminal exit from the market) will be necessary if gasoline is to continue to be transported by pipeline. Otherwise, special blends will shift to alternative modes.

For refiners currently using water transportation, the analysis is similar. Minimum barge shipments range from 4,000 to 12,000 barrels. Assuming monthly shipments, this would correspond to annual gasohol demand of 2.2 to 6.6 million gallons. Where demand proves insufficient for barge transportation, the refiner will likely turn to tank trucks.

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[1]For purposes of the following scenarios, it is assumed that the shipping method currently used to move motor gasoline to a given terminal is the most economical method available and that, consequently, the shipper will want to continue to use that method if possible for specially blended gasoline.

[2]Industry information obtained through interviews with pipeline companies.

[3]Ibid.

For refiners currently using tank trucks to transport gasoline to the distribution terminal, the requirement for special blending of gasoline to be combined with ethanol should have no impact. The minimum batch size for trucks ranges from 1,000 to 8,000 gallons. Assuming monthly shipments, gasohol demand in the terminal area would have to exceed 13,000 to 107,000 gallons per year. In 1984, the smallest gasohol demand listed for any state with gasohol sales was 16,000 gallons in Georgia, with the second smallest being 63,000 gallons in the District of Columbia. Thus, it is unlikely that tank truck shipments to any area would become infeasible.

Effects on Transportation Mode Assuming Refinery Blending

Refinery blending of gasohol may affect the mode used by an ethanol producer to transport fuel ethanol if the ethanol producer can combine shipments of ethanol that once traveled to numerous locations into a shipment to a single destination. By combining shipments, the ethanol producer may be able to shift from truck or rail to more economical barge or unit train transportation.[1]

Changes in the modal choice of the refiner will be observed only if the refiner previously used pipeline transportation. Although transportation of gasohol by pipeline has been shown to be technically feasible, it is not expected that gasohol will be transported by pipeline unless demand for gasohol increases substantially and appears to have a long-term market that justifies the required capital investment. Blended gasohol will be transported, therefore, by a mode other than pipeline, possibly barge where available. In any case, if the gasoline it replaces was transported from the refinery to the terminal by any mode other than pipeline, the gasohol can be expected to move by the same mode.

4.3 TRANSPORTATION COSTS

Any shift in transportation mode or destination for ethanol, gasoline, or gasohol has implications for the cost of delivering gasohol to the consumer. Shifting gasoline from pipeline to barge would increase transportation costs by 0.07¢ per gallon per 100 miles, an increase of about 30 percent. Shifting gasoline from pipeline to truck would have far greater impacts: truck transportation would cost an average of 0.94¢ per gallon per 100 miles more than pipeline transportation — almost 5 times the pipeline cost.

[1] A unit train is a freight train with 100 or more cars carrying a single commodity. Unit train freight rates are lower than rates for a single tank car.

Transportation costs could change in the event of either terminal blending or refinery blending. In the refinery blending case, costs could either increase, decrease, or stay the same. A decrease in ethanol transportation costs would occur if large, less frequent shipments to the refinery replaced high cost, smaller shipments to numerous terminals. Such benefits could arise when the plant is nearer to the refinery than to some terminals or more economical modes of transportation become available. These cost savings, however, could be offset by the higher cost of transporting the gasohol to the terminal if the standard gasoline used in terminal blending had previously been moved by pipeline. In the terminal blending case, costs could either increase or stay the same. Transportation costs for gasoline will increase if there is a modal shift and there would be no reduced ethanol transportation cost to offset them.

Examples of the potential impacts on transportation costs of special gasoline blending requirements, with blending performed at either the terminal or the refinery, are provided in Exhibits 4-1 to 4-4. Assumptions underlying these analyses are listed below:

1) Batch minimums are 25,000 barrels for pipeline (1,050,000 gallons); 8,000 barrels for barge (336,000 gallons); 595 barrels for rail (25,000 gallons); and 119 barrels for truck (8,000 gallons). In order to determine the maximum cost increases, these minimums were assumed to be required of shipments between any given refiner and terminal location.

2) Shipments of the ethanol, special blends, and gasohol are made at least once a month.

3) The cost of gasoline transportation is 0.24¢ per gallon per 100 miles by pipeline; 0.31¢ per gallon per 100 miles by barge; and 1.18¢ per gallon per 100 miles by truck.

4) The cost of ethanol transportation is 0.75¢ per gallon per 100 miles by barge; 2.94¢ per gallon per 100 miles by truck; and 3.76¢, 5¢, and 6.5¢ per 100, 200, and 300 miles, respectively, by rail.

5) Terminal blending scenarios assume there is no impact on transportation costs from the ethanol producer to the terminal since the terminal will probably continue to be supplied by the same ethanol producer.

EXHIBIT 4-1:

SCENARIO 1

Distance from Refinery to Terminal = 500 miles
Distance from Ethanol Plant to Terminal = 150 miles
Distance from Ethanol Plant to Refinery = 400 miles
Terminal Demand for Gasohol = 50,000 barrels per month

Base Case: Terminal Blending of Gasohol with Standard Gasolines
Transportation of Gasoline from Refinery to Terminal by Pipeline
Transportation of Ethanol from Ethanol Plant to Terminal by Average of Rail and Truck Rates

Transportation Costs:

Gasoline:	1.2¢ per gallon; $22,680 for 45,000 barrels
Ethanol:	5.025¢ per gallon; $10,553 for 5,000 barrels
Total:	$33,233

Alternative A: Terminal Blending of Gasohol with Specially Blended Gasoline
Transportation of Gasoline from Refinery to Terminal by Pipeline
Transportation of Ethanol from Ethanol Plant to Terminal by Average of Rail and Truck Rates

Transportation Costs:

Gasoline:	1.2¢ per gallon; $22,680 for 45,000 barrels
Ethanol:	5.025¢ per gallon; $10,553 for 5,000 barrels
Total:	$33,233
Impact:	None
Comment:	No transportation cost change since no change in modes, volumes, or distances.

Alternative B: Refinery Blending of Gasohol with Specially Blended Gasoline
Transportation of Gasohol from Refinery to Terminal by Barge
Transportation of Ethanol from Ethanol Plant to Refinery by Barge

Transportation Costs:

Ethanol:	3.0¢ per gallon; $6,300 for 5,000 barrels
Gasohol:	1.55¢ per gallon; $32,550 for 50,000 barrels
Total:	$38,850
Impact:	Cost Increase of $5,617 Over Base Case and Alternative A
Comment:	Transportation cost increases because gasohol must travel by more expensive mode, barge, than gasoline. Increase here is greater than cost savings realized in ethanol transportation. Ethanol transportation cost savings result from consolidation of shipments permitting use of less expensive mode, barge.

EXHIBIT 4-2:
SCENARIO 2

Distance from Refinery to Terminal = 50 miles
Distance from Ethanol Plant to Terminal = 100 miles
Distance from Ethanol Plant to Refinery = 50 miles
Terminal Demand for Gasohol = 50,000 barrels per month

Base Case:

Terminal Blending of Gasohol with Standard Gasolines
Transportation of Gasoline from Refinery to Terminal by Barge
Transportation of Ethanol from Ethanol Plant to Terminal by Truck

Transportation Costs:

Gasoline:	0.155¢ per gallon; $2,930 for 45,000 barrels
Ethanol:	2.94¢ per gallon; $6,174 for 5,000 barrels
Total:	$9,104

Alternative A:

Terminal Blending of Gasohol with Specially Blended Gasoline
Transportation of Gasoline from Refinery to Terminal by Barge
Transportation of Ethanol from Ethanol Plant to Terminal by Truck

Transportation Costs:

Gasoline:	0.155¢ per gallon; $2,930 for 45,000 barrels
Ethanol:	2.94¢ per gallon; $6,174 for 5,000 barrels
Total:	$9,104

Impact: None

Comment: No transportation cost change since no change in modes, volumes, or distances.

Alternative B:

Refinery Blending of Gasohol with Specially Blended Gasoline
Transportation of Gasohol from Refinery to Terminal by Barge
Transportation of Ethanol from Ethanol Plant to Refinery by Barge

Transportation Costs:

Ethanol:	0.375¢ per gallon; $788 for 5,000 barrels
Gasohol:	0.155¢ per gallon; $3,255 for 50,000 barrels
Total:	$4,043

Impact: Costs Savings of $5,061 Over Base Case and Alternative A.

Comment: Transportation cost savings occur because consolidation of ethanol shipments permits use of a less expensive mode, barge; and because ethanol is shipped a shorter distance to the refinery than to the terminal.

EXHIBIT 4-3:

SCENARIO 3

Distance from Refinery to Terminal = 500 miles
Distance from Ethanol Plant to Terminal = 150 miles
Distance from Ethanol Plant to Refinery = 400 miles
Terminal Demand for Gasohol = 20,000 barrels per month

Base Case:

Terminal Blending of Gasohol with Standard Gasolines
Transportation of Gasoline from Refinery to Terminal by Pipeline
Transportation of Ethanol from Ethanol Plant to Terminal by Average of Truck and Rail Rates

Transportation Cost:

Gasoline:	1.2¢ per gallon; $9,072 for 18000 barrels
Ethanol:	5.025¢ per gallon; $4,221 for 2,000 barrels
Total:	$13,293

Alternative A:

Terminal Blending of Gasohol with Specially Blended Gasoline
Transportation of Gasoline from Refinery to Terminal by Barge
Transportation of Ethanol from Ethanol Plant to Terminal by Average of Rail and Truck Rates

Transportation Cost:

Gasoline:	1.55¢ per gallon, $11,718 for 18,000 barrels
Ethanol:	5.025¢ per gallon, $4,221 for 2,000 barrels
Total:	$15,939
Impact:	Cost Increase of $2,646 Over Base Case
Comment:	Transportation costs increase because special blend volume is not sufficient to move by pipeline: must be moved by barge, a more expensive mode.

Alternative B:

Refinery Blending of Gasohol with Specially Blended Gasoline
Transportation of Gasohol from Refinery to Terminal by Barge
Transportation of Ethanol from Ethanol Plant to Refinery by Barge

Transportation Costs:

Ethanol:	3.00¢ per gallon; $2,520 for 2,000 barrels
Gasohol:	1.55¢ per gallon; $13,020 for 20,000 barrels
Total:	$15,540
Impact:	Cost Increase of $2,247 Over Base Case, but Cost Savings of $399 Over Alternative A.
Comment:	Transportation costs increase in comparison to the Base Case because gasohol must travel by a more expensive mode, barge, than gasoline. The increase here is greater than the cost savings realized in the transportation of ethanol, which are due to the consolidation of shipments permitting use of a less expensive mode.

EXHIBIT 4-4:

SCENARIO 4

Distance from Refinery to Terminal = 50 miles
Distance from Ethanol Plant to Terminal = 100 miles
Distance from Ethanol Plant to Refinery = 50 miles
Terminal Demand for Gasohol = 20,000 barrels per month

Base Case: Terminal Blending of Gasohol with Standard Gasolines
Transportation of Gasoline from Refinery to Terminal by Barge
Transportation of Ethanol from Ethanol Plant to Terminal by Truck

Transportation Cost:

Gasoline: 0.155¢ per gallon; $1,172 for 18,000 barrels
Ethanol: 2.94¢ per gallon; $2,470 for 2,000 barrels
Total: $3,642

Alternative A: Terminal Blending of Gasohol with Specially Blended Gasoline
Transportation of Gasoline from Refinery to Terminal by Barge
Transportation of Ethanol from Ethanol Plant to Terminal by Truck

Transportation Cost:

Gasoline: 0.155¢ per gallon; $1,172 for 18,000 barrels
Ethanol: 2.94¢ per gallon; $2,470 for 2,000 barrels
Total: $3,642

Impact: None

Comment: No transportation cost impact since no change in modes, volumes, or distances.

Alternative B: Refinery Blending of Gasohol with Specially Blended Gasoline
Transportation of Gasohol from Refinery to Terminal by Barge
Transportation of Ethanol from Ethanol Plant to Refinery by Truck

Transportation Costs:

Ethanol: 1.47¢ per gallon; $1,235 for 2,000 barrels
Gasohol: 0.155¢ per gallon; $1,302 for 20,000 barrels
Total: $2,537

Impact: Cost Saving of $1,105 Over Base Case and Alternative A.

Comment: Transportation costs fall in comparison to the Base Case and Alternative A because the ethanol is shipped a shorter distance to the refinery than to the terminal via the same mode, truck.

6) Transportation costs from the terminal to the service station served by the terminal remain constant.

7) Gasohol is transported at the same rates as gasoline.

8) Pipelines do not transport gasohol.

As can be seen in the exhibits, several factors jointly determine the effect of transportation costs on the delivered cost of gasohol at a distribution terminal. These include transportation mode, shipment distance, volume of shipment, destination of shipment, and point of blending. Implementation of special blending requirements for gasoline blended with ethanol to control gasohol volatility can have a significant effect on each of these factors and thus on the impact of transportation costs on the delivered cost of gasohol. Of critical importance in terminal blending is whether the use of special gasoline for blending will require the use of a more expensive transportation mode to deliver the specially blended gasoline to the terminal blending point. If specially blended gasoline shipments are not of sufficient size to meet the minimum batch requirements of the mode currently used to move gasoline to the blending point, the special gasoline will have to be delivered by a more expensive mode, and the cost of delivering gasohol to the distribution terminal will rise. In this case, total transportation costs could be controlled only through consolidation of the market for special blends in that area, resulting in the exit of firms from the gasohol distribution system. If the gasoline transportation mode to the terminals blending gasohol remains the same, however, transportation costs will not change, and consolidation will not be necessary. Thus, where terminal blending continues under the proposed regulatory environment, the major factor affecting transportation costs is whether the specially blended gasoline will have to be transported by a more expensive mode than the standard gasoline previously blended with ethanol to make gasohol.

The maximum increase in transportation costs due to terminal blending can be estimated if it is assumed that:

- the existing ethanol and gasoline supply relationships continue to exist;
- all special gasoline is shipped to the terminal by truck; and
- the gasoline previously blended with ethanol at the terminal was shipped by pipeline and barge in proportions equal to those shown in Exhibit 3-2 for 1984 (62 percent of ton-miles by pipeline, 38 percent by barge).

Given the gasoline transportation costs presented at the beginning of this chapter, shifting from pipeline to truck increases the gasoline transportation cost by 0.94 cents per gallon per 100 miles; shifting from barge to truck increases gasoline transportation costs by 0.87 cents per gallon per 100 miles. The maximum average cost increase per gallon of gasoline per 100 miles, therefore, is 0.9134 cents (equal to (0.94)(0.62) + (0.87)(0.38)). Since gasoline constitutes 90 percent of the gasoline/ethanol blend, and since the cost of transporting the ethanol to the terminal does not change with terminal blending, the maximum cost impact on a gallon of gasohol at the terminal is an increase of 0.82 cents per gallon for every 100 miles that the special gasoline is shipped to the terminal (equal to (.90)(0.9134) + (.10)(0)). The total maximum cost impact, then, depends on the gasoline shipping distance.

In the case of refinery blending, several opposing cost factors must be considered. Since gasohol will not move by pipeline in 1990 due to limited market penetration, the cost of delivering the gasohol to a terminal will rise if the gasoline previously blended with ethanol was transported by pipeline. Assuming that the gasoline previously shipped to terminals for blending was shipped by pipeline and barge in proportions equal to those shown in Exhibit 3-2 for 1984 (62 percent and 38 percent, respectively), and that all gasohol blended at refineries is shipped by truck, the maximum cost increase will be 0.91 cents per gallon of gasohol per 100 miles. These costs may be offset partially or totally if the ethanol plant is much closer to the refinery than to the terminal. The largest potential for cost savings in this case, however, occurs when the ethanol producer is able to realize economies of scale in transportation costs by shipping to one point (a refinery) rather than to multiple points (terminals). The net result will depend upon the individual circumstance.

Since it is probable that terminal blending of gasohol will dominate refinery blending in 1990, total transportation costs are likely to increase with special blending. This is because terminal blending does not offer as many opportunities for transportation cost savings as refinery blending, and then only if market consolidation occurs and ethanol producers realize economies of scale in transportation costs by shipping product to fewer terminal locations.

4.4 EFFECTS ON MARKET RELATIONSHIPS AND TRANSACTION COSTS

Terminal blending of special gasoline with ethanol will not affect existing business relationships in the ethanol/gasohol distribution system, and therefore should not affect transaction costs, if all refiners who provided gasoline previously blended with ethanol also provide the special gasoline to be blended at the terminals; and if all terminals previously blending ethanol continue to blend ethanol. If some refiners do not provide special gasoline, or if some terminals no longer blend ethanol, transaction costs could increase, assuming that terminals and gasohol retailers previously had a least cost supply relationship with a refiner and a terminal, respectively.

Transaction cost savings could occur with refinery blending if ethanol suppliers are able to negotiate delivery contracts with fewer refiners than terminals. These cost savings, however, could be offset by transaction cost increases if gasohol is not produced by every refiner and if it is not supplied to every terminal previously involved in ethanol blending.

4.5 STORAGE AND EQUIPMENT ISSUES

Since the volume of liquid product moved in the distribution system will remain constant if special blending is required, it is not expected that major investments will be needed in storage capacity or transportation equipment beyond those currently planned between 1985 and 1990. Some modifications may be necessary in this capital stock, however, to reduce technical problems in distribution. The construction of barges and rail and truck tankers should present no problem to the distribution of ethanol or gasohol, although improved seals may be needed to minimize water ingress. In bulk storage, floating roof tanks with improved seals will be needed to minimize water ingress. This type of tank, however, has become widespread in use in the past ten years.[1]

Similarly, tanks suitable for the storage of ethanol and/or gasohol but not previously used for that purpose may need to be cleaned or upgraded before they are put into service. Tanks used to store petroleum products are likely to contain sediment and water. To prevent contamination and subsequent phase separation of the gasohol blend, these must be removed prior to using the tanks for alcohol fuel storage. Costs will thus be incurred if the number of tanks containing gasohol or ethanol increases beyond the number used when blending with standard gasoline. This may occur if special blending requirements eliminate the current predominant practice of blending the gasohol as it is placed into a distribution vehicle such as a tank truck.

[1]Atkinson, op. cit., p. 17.

Although it is anticipated that no additional transportation stock will be needed to move the specially blended gasoline, ethanol, and gasohol, it is possible that the usage patterns of the available stock will change. For example, either terminal blending or refinery blending may result in increased usage of the existing barge and truck fleets and lower usage of pipelines by refiners. Similarly, refinery blending may increase the usage of unit trains to deliver ethanol to the refinery, and reduce the usage of individual tank cars to deliver ethanol to terminals. Changes in shipment destinations could affect transportation company routings and the geographical distribution of the transportation stock. These changes will have economic costs and benefits associated with them. Although these will be transitional in nature, they may be significant.

CHAPTER 5

IMPACT OF REDUCING THE ETHANOL CONTENT OF GASOHOL TO 5 PERCENT

Ethanol is typically added to gasoline to produce a fuel that is 10 percent ethanol. One means of reducing the mid-range volatility (e.g., percent evaporated at 160 degrees Fahrenheit) of such ethanol/gasoline blends is to reduce the ethanol content of the fuel. This chapter analyzes the effects on the logistics and costs of ethanol distribution and blending practices of reducing the ethanol content of gasohol to five percent. The analysis assumes that the gasoline mixed with the fuel must be specially blended for mixing with ethanol, as discussed in Chapter 4. Total ethanol demand is assumed to be the same as for 10 percent blending. Thus, gasohol sales are twice the level considered in the 10 percent alternative, and demand for the specially blended gasoline is more than twice its former level.

As in Chapter 4, the following issues are addressed:

- Where will the ethanol be blended into the gasoline?
- What transportation modes will be used for shipping the specially blended gasoline, ethanol, and gasohol?
- What will be the effect on transportation costs of the change?
- What changes may be observed in market relationships and transaction costs?
- What storage or equipment issues may arise as a result of the change in blending requirements?

In the case of terminal blending, the analysis shows that the maximum transportation cost increase per gallon of gasohol is 0.87 cents for every 100 miles the special gasoline is shipped, less the estimated minimum transportation cost savings associated with reducing the ethanol content of the blend to 5 percent (0.075 cents per gallon of gasohol). The maximum net increase would occur if transportation of gasoline shifted from pipeline (the least expensive mode) to truck (the most expensive). In the case of refinery blending, transportation costs could increase a maximum of 0.91 cents per gallon of gasohol, again an increase that could be observed only if transportation from the refinery to the terminal shifts from pipeline to truck. Actual increases are expected to be much smaller because shifts in transportation mode for gasoline and gasohol may not be necessary or may be less costly than shifting from pipeline to truck as in the example above.

5.1 BLENDING LOCATION

The factors influencing the choice of a gasohol blending location are the same for gasohol composed of 5 percent ethanol as for gasohol composed of 10 percent ethanol. These include the total demand for the fuel, the location of the terminal and the ethanol plant relative to the refinery, the transportation modes available, and the technical factors (and associated costs) related to reducing or eliminating contamination of the gasohol.

The advantages and disadvantages of refinery, terminal, and service station blending were presented in Chapter 4. The conclusions reached after analysis of these advantages and disadvantages are the same for 5 percent blends as for 10 percent blends. Assuming that testing requirements for the blended gasohol are not extensive, most producers will continue to blend gasohol primarily at the terminal. Some refiners and ethanol producers who are in close proximity, however, may choose to blend at the refinery due to reduced transportation costs (Section 5.3). The number in this category is likely to be small, however. Furthermore, given other costs associated with refinery blending, such as the cost of adapting existing refinery storage facilities to ethanol or gasohol storage and the cost of preventing water contamination of the fuel for a longer time and/or distance, few gasohol marketers are likely to choose refinery blending.

5.2 TRANSPORTATION MODE

A requirement that gasohol be composed of 5 percent ethanol rather than 10 percent ethanol could change the transportation modes used to move gasoline, ethanol, and gasohol. These changes will depend upon the blending location and the respective volumes of each fuel. In the following sections, the logistical considerations affecting modal choice are examined for both terminal and refinery blending. Cost impacts are examined in Section 5.3.[1]

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[1] For purposes of the following scenarios, it is assumed that the shipping method currently used to move motor gasoline to a given terminal is the most economical method available and that, consequently, the shipper will want to continue to use that method if possible for specially blended gasoline.

Effects on Transportation Mode Assuming Terminal Blending and Constant Ethanol Demand

If gasohol blending occurs at the terminal, the ethanol transportation mode will not change because ethanol demand at a given terminal stays the same and the ethanol producer continues to make the same number of shipments to the same destinations. However, if the special blend volume is less than the minimum batch required for the mode used to transport the standard gasoline previously blended with the ethanol, the mode used to transport the specially blended gasoline will change to a more expensive mode with smaller volume requirements. Because demand for gasohol is assumed to double, this shift is less likely to occur than under a 10 percent terminal blending scenario since over twice as much (2.11 times) specially blended gasoline will be shipped.

Effects on Transportation Mode Assuming Refinery Blending and Constant Ethanol Demand

If 5 percent gasohol blending occurs at refineries, an ethanol producer may be able to combine numerous truck shipments to terminals into a single shipment to a refinery, permitting use of a less expensive mode such as barge. As in the case of terminal blending, however, there may be shifts in the modes used to transport product from the refinery to the terminal if volumes are not large enough for use of the mode used for standard gasolines. A change in transportation mode will also occur wherever the standard gasoline previously blended with ethanol at the terminal was shipped by pipeline, since pipelines will not be used for gasohol.

5.3 TRANSPORTATION COSTS

Any shift in transportation mode or destination for ethanol, gasoline, or gasohol would have implications for the cost of delivering gasohol to the consumer. Four scenarios are presented as a means of analyzing the potential transportation cost impacts of a change from 10 percent to 5 percent ethanol content in gasohol (Exhibits 5-1 to 5-4). The scenarios correspond to those presented in Chapter 4. Each contains a base case and two alternatives, as follows:

- The base case is that developed for the corresponding scenario in Chapter 4, in which volatility controls do not exist.

EXHIBIT 5-1:

SCENARIO 1

Distance from Refinery to Terminal = 500 miles
Distance from Ethanol Plant to Terminal = 150 miles
Distance from Ethanol Plant to Refinery = 400 miles

Base Case:

Terminal Blending of 10 Percent Ethanol with Standard Gasoline
Ethanol Blend Demand = 50,000 barrels per month
Transportation of Gasoline from Refinery to Terminal by Pipeline
Transportation of Ethanol from Ethanol Plant to Terminal by Average of Truck and Rail Rates

Transportation Costs:

Gasoline:	1.2¢ per gallon; $22,680 for 45,000 barrels
Ethanol:	5.025¢ per gallon; $10,553 for 5,000 barrels
Total:	$33,233 for 50,000 barrels
Average:	1.58¢ per gallon

Alternative A:

Terminal Blending of 5 Percent Ethanol with Specially Blended Gasoline
Ethanol Blend Demand = 100,000 barrels per month
Transportation of Gasoline from Refinery to Terminal by Pipeline
Transportation of Ethanol from Ethanol Plant to Terminal by Average of Truck and Rail Rates

Transportation Costs:

Gasoline:	1.2¢ per gallon; $47,880 for 95,000 barrels
Ethanol:	5.025¢ per gallon; $10,553 for 5,000 barrels
Total:	$58,433 for 100,000 barrels
Average:	1.39¢ per gallon

Comment: Transportation cost per gallon of gasohol falls in comparison to the base case because the proportion of gasoline in the blend increases, and gasoline costs less to deliver than ethanol. No change in modes.

Alternative B:

Refinery Blending of 5 Percent Ethanol with Specially Blended Gasoline
Ethanol Blend Demand = 100,000 barrels per month
Transportation of Gasohol from Refinery to Terminal by Barge
Transportation of Ethanol from Ethanol Plant to Refinery by Barge

Transportation Costs:

Gasohol:	1.55¢ per gallon; $65,100 for 100,000 barrels
Ethanol:	3.0¢ per gallon; $6,300 for 5,000 barrels
Total:	$71,400 for 100,000 barrels
Average:	1.70¢ per gallon

Comment: Transportation cost per gallon of gasohol increases in comparison to the base case (and Alternatives A and B) because the gasohol is shipped by a more expensive mode, barge, than the standard gasoline previously blended at the terminal (pipeline). The increase is greater than the cost savings in ethanol transportation, which were achieved by consolidating of shipments and shifting to a less expensive mode.

EXHIBIT 5-2:

SCENARIO 2

Distance from Refinery to Terminal = 50 miles
Distance from Ethanol Plant to Terminal = 100 miles
Distance from Ethanol Plant to Refinery = 50 miles

Base Case:

Terminal Blending of 10 Percent Ethanol with Standard Gasoline
Ethanol Blend Demand = 50,000 barrels per month
Transportation of Gasoline from Refinery to Terminal by Barge
Transportation of Ethanol from Ethanol Plant to Terminal by Truck

Transportation Costs:

Gasoline:	0.155¢ per gallon; $2,930 for 45,000 barrels
Ethanol:	2.94¢ per gallon; $6,174 for 5,000 barrels
Total:	$9,104 for 50,000 barrels
Average:	0.43¢ per gallon

Alternative A:

Terminal Blending of 5 Percent Ethanol with Specially Blended Gasoline
Ethanol Blend Demand = 100,000 barrels per month
Transportation of Gasoline from Refinery to Terminal by Barge
Transportation of Ethanol from Ethanol Plant to Terminal by Truck

Transportation Costs:

Gasoline:	0.155¢ per gallon; $6,185 for 95,000 barrels
Ethanol:	2.94¢ per gallon; $6,174 for 5,000 barrels
Total:	$12,359 for 100,000 barrels
Average:	0.29¢ per gallon

Comment: Transportation cost per gallon of gasohol falls in comparison to the base case because the proportion of gasoline in the blend increases, and gasoline costs less to deliver than ethanol. No change in modes.

Alternative B:

Refinery Blending of 5 Percent Ethanol with Specially Blended Gasoline
Ethanol Blend Demand = 100,000 barrels per month
Transportation of Gasohol from Refinery to Terminal by Barge
Transportation of Ethanol from Ethanol Plant to Refinery by Barge

Transportation Costs:

Gasohol:	0.155¢ per gallon; $6,510 for 100,000 barrels
Ethanol:	0.375¢ per gallon; $788 for 5,000 barrels
Total:	$7,298 for 100,000 barrels
Average:	0.17¢ per gallon

Comment: Transportation cost per gallon of gasohol falls in comparison to the base case and Alternative A because consolidation of ethanol shipments permits use of a less expensive mode, barge; because ethanol is shipped a shorter distance to the refinery than to the terminal; and because gasohol is shipped by the same mode as gasoline (barge).

EXHIBIT 5-3:

SCENARIO 3

Distance from Refinery to Terminal = 500 miles
Distance from Ethanol Plant to Terminal = 150 miles
Distance from Ethanol Plant to Refinery = 400 miles

Base Case:

Terminal Blending of 10 Percent Ethanol with Standard Gasoline
Ethanol Blend Demand = 20,000 barrels per month
Transportation of Gasoline from Refinery to Terminal by Pipeline
Transportation of Ethanol from Ethanol Plant to Terminal by Average of Truck and Rail Rates

Transportation Costs:

Gasoline:	1.2¢ per gallon; $9,072 for 18,000 barrels
Ethanol:	5.025¢ per gallon; $4,221 for 2,000 barrels
Total:	$13,293 for 20,000 barrels
Average:	1.58¢ per gallon

Alternative A:

Terminal Blending of 5 Percent Ethanol with Specially Blended Gasoline
Ethanol Blend Demand = 40,000 barrels per month
Transportation of Gasoline from Refinery to Terminal by Barge
Transportation of Ethanol from Ethanol Plant to Terminal by Average of Truck and Rail Rates

Transportation Costs:

Gasoline:	1.55¢ per gallon; $24,738 for 38,000 barrels
Ethanol:	5.025¢ per gallon; $4,221 for 2,000 barrels
Total:	$28,959 for 40,000 barrels
Average:	1.72¢ per gallon

Comment: Transportation cost per gallon of gasohol increases in comparison to the base case because the specially blended gasoline must be shipped by a more expensive mode than the standard gasoline, offsetting any transportation cost reductions related to the decreased proportion of ethanol in the blend.

EXHIBIT 5-3: (Continued)

SCENARIO 3

Alternative B: Refinery Blending of 5 Percent Ethanol with Specially Blended Gasoline

Ethanol Blend Demand = 40,000 barrels per month

Transportation of Gasohol from Refinery to Terminal by Barge

Transportation of Ethanol from Ethanol Plant to Refinery by Barge

Transportation Costs:

Gasohol:	1.55¢ per gallon; $26,040 for 40,000 barrels
Ethanol:	3.0¢ per gallon; $2,520 for 2,000 barrels
Total:	$28,560 for 40,000 barrels
Average:	1.70¢ per gallon

Comment: Transportation cost per gallon of gasohol increases in comparison to the base case because the gasohol is shipped by a more expensive mode, barge, than the standard gasoline previously blended at the terminal (pipeline). Increase here is greater than cost savings in ethanol transportation, where consolidation of shipments permits use of less expensive mode. These cost savings, however, are sufficient to reduce transportation cost per gallon below those for Alternative A, where consolidation of ethanol shipments does not occur.

EXHIBIT 5-4:

SCENARIO 4

Distance from Refinery to Terminal = 50 miles
Distance from Ethanol Plant to Terminal = 100 miles
Distance from Ethanol Plant to Refinery = 50 miles

Base Case:

Terminal Blending of 10 Percent Ethanol with Standard Gasoline
Ethanol Blend Demand = 20,000 barrels per month
Transportation of Gasoline from Refinery to Terminal by Barge
Transportation of Ethanol from Ethanol Plant to Terminal by Truck

Transportation Costs:

Gasoline:	0.155¢ per gallon; $1,172 for 18,000 barrels
Ethanol:	2.94¢ per gallon; $2,470 for 2,000 barrels
Total:	$3,642 for 20,000 barrels
Average:	0.43¢ per gallon

Alternative A:

Terminal Blending of 5 Percent Ethanol with Specially Blended Gasoline
Ethanol Blend Demand = 40,000 barrels per month
Transportation of Gasoline from Refinery to Terminal by Barge
Transportation of Ethanol from Ethanol Plant to Terminal by Truck

Transportation Costs:

Gasoline:	0.155¢ per gallon; $2,474 for 38,000 barrels
Ethanol:	2.94¢ per gallon; $2,470 for 2,000 barrels
Total:	$4,944 for 40,000 barrels
Average:	0.29¢ per gallon

Comment: Transportation cost per gallon of gasohol falls in comparison to the base case becuase the proportion of gasoline in the blend increases, and gasoline costs less to deliver than ethanol. No change in modes.

Alternative B:

Refinery Blending of 5 Percent Ethanol with Specially Blended Gasoline
Ethanol Blend Demand = 40,000 barrels per month
Transportation of Gasohol from Refinery to Terminal by Barge
Transportation of Ethanol from Ethanol Plant to Refinery by Truck

Transportation Costs:

Gasohol:	0.155¢ per gallon; $2,604 for 40,000 barrels
Ethanol:	1.47¢ per gallon; $1,235 for 2,000 barrels
Total:	$3,839 for 40,000 barrels
Average:	0.23¢ per gallon

Comment: Transportation cost per gallon of gasohol falls in comparison to the base case and Alternative A because ethanol is shipped a shorter distance to the refinery than to the terminal by the same mode (truck), and because gasohol is shipped by the same mode as standard gasoline (barge).

- Alternative A is a terminal blending scenario for 5 percent blends where it is assumed that ethanol demand equals that for 10 percent blending. This means that twice as much gasohol is sold.

- Alternative B is a refinery blending scenario for 5 percent blends where it is assumed that ethanol demand equals that for 10 percent blending.

The assumptions relating to batch minimums, shipment frequency, transportation costs by mode, and pipeline availability presented in Chapter 4 also apply to these scenarios.

As can be seen in Exhibits 5-1 to 5-4, several factors jointly determine the effect which volatility controls requiring 5 percent ethanol blends will have on transportation costs. As in the case of controlling the volatility of 10 percent ethanol blends, these include transportation mode, shipment distance, volume of shipment, destination of shipment, and point of blending. Implementation of special blending requirements necessitating the production of 5 percent ethanol blends can affect each of these factors and thus affect transportation costs and the delivered cost of gasohol.

As with 10 percent blends, of importance in terminal blending is whether the use of special gasoline will require a more expensive transportation mode to deliver the specially blended gasoline to the terminal blending point. Similarly, with refinery blending, transportation costs could increase if the gasohol shipped from the refinery must be shipped by a more expensive mode than was gasoline. If the ethanol producer is able to realize economies of scale in transportation costs by shipping to one point (a refinery) rather than to multiple points (terminals), however, total transportation costs could fall.

Two additional factors will affect transportation costs if 5 percent ethanol blends are required. First, reducing the ethanol content of gasohol blends to 5 percent to control mid-range volatility reduces the total transportation cost per gallon of gasohol because ethanol transportation costs are substantially higher than gasoline transportation costs. Second, if ethanol blend demand doubles, more than twice as much specially blended gasoline will be required than in 10 percent blending; and changes in gasoline transportation mode and increases in transportation cost will be less likely to occur than in the 10 percent case.

The maximum increase in transportation costs due to terminal blending of 5 percent blends can be estimated if it is assumed that:

- the existing ethanol and gasoline supply relationships continue to exist if 5 percent blends are required;

- all special gasoline is shipped to the terminal by truck;

- the gasoline which would have been blended with ethanol to produce a 5 percent blend in the absence of volatility controls would have been shipped to the terminal by pipeline and barge in proportions equal to those shown in Exhibit 3-2 for 1984 (62 percent of ton-miles by pipeline, 38 percent by barge); and

- the ethanol is transported an average of 200 miles by barge to the terminal.

Given the gasoline transportation costs presented in Chapter 4, gasoline transportation costs increase with terminal blending by 0.94 cents/gallon per 100 miles if the mode changes from pipeline to truck; and by 0.87 cents/gallon per 100 miles if the mode changes from barge to truck. The maximum average cost increase per gallon of gasoline per 100 miles, therefore, is 0.913 cents (equal to (0.94)(0.62) + (0.87(0.38)). Since gasoline constitutes 95 percent of the gasoline/ethanol blend, the delivered cost of the gasohol at the terminal will increase by a maximum of 0.87 cents/gallon for every 100 miles that the special gasoline is shipped to the terminal. The total cost increase, however, will be slightly less than this amount since the ethanol transportation cost component of the gasohol will at a minimum be reduced from 0.15 cents per gallon of gasohol (10 percent of the cost of transporting a gallon of ethanol 200 miles to the terminal by barge) to 0.075 cents per gallon of gasohol (5 percent of the ethanol transportation cost), a saving of 0.075 cents per gallon. The maximum cost increase is less likely to occur than in the case of terminal blending of 10 percent blends, however, because modal changes are less likely to occur if 5 percent blends are required.

In the case of refinery blending of 5 percent blends, the cost of delivering gasohol to the terminal will rise if the gasoline previously blended with ethanol was transported by pipeline, or if shipping the gasohol requires a more expensive mode than for gasoline. Again assuming that the gasoline shipped to terminals for blending was shipped by pipeline and barge in proportions equal to those shown in Exhibit 3-2 for 1984 (62 percent and 38 percent, respectively), and that the gasohol blended at the refineries is shipped by truck, the maximum cost increase will be 0.91 cents/gallon of gasohol for every 100 miles that it is shipped. This cost increase, however, may be offset partially or totally if the ethanol plant is much closer to the refinery than to the terminal; or if the ethanol producer is able to realize reduced transportation costs by consolidating shipments and by shipping to the refinery rather than to several terminals. The net result will depend upon the individual circumstance.

Exhibit 5-5 presents the average transportation cost per gallon of gasohol (either a 5 percent blend or a 10 percent blend) delivered at the terminal for each scenario and alternative examined in Chapters 4 and 5. Analysis of the results for comparable alternatives indicates that, for both terminal blending and refinery blending, a 5 percent alternative offers the smallest cost increase or largest cost decrease in comparison to the base case. This is because reducing the ethanol content of blends replaces relatively expensive to transport ethanol with gasoline; and because larger quantities of specially blended gasoline and gasohol are assumed to move through the distribution system for 5 percent blends than for 10 percent blends, reducing the likelihood that mode changes will be required for transporting these products. If, however, ethanol demand falls because sales of ethanol blends do not at least double, it is possible that modal changes will be required and that the total transportation cost impact could be more severe than with a 10 percent blend. Consequently, it is not possible to conclude that in all circumstances the transportation cost impact of requiring 5 percent ethanol blends to control gasohol volatility will be less than that for 10 percent blends. Generally, however, 5 percent blends offer greater opportunities for controlling transportation costs in the event of volatility controls.

5.4 EFFECTS ON MARKET RELATIONSHIPS AND TRANSACTION COSTS

Terminal blending of special gasoline with ethanol will not affect existing business relationships in the ethanol/gasohol distribution system, and therefore should not affect transaction costs, if all refiners who provided gasoline previously blended with ethanol also provide the special gasoline to be blended at the terminals; and if all terminals previously blending ethanol continue to blend ethanol. If some refiners do not provide special gasoline, or if some terminals no longer blend ethanol, transaction costs could increase, assuming that terminals and gasohol retailers previously had a least cost supply relationship with a refiner and a terminal, respectively.

Transaction cost savings could occur with refinery blending if ethanol suppliers are able to negotiate delivery contracts with fewer refiners than terminals. These cost savings,

EXHIBIT 5-5:

TRANSPORTATION COST ESTIMATES FOR ANALYTICAL SCENARIOS

(Cents per Gallon of Gasohol at the Terminal)

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Base Case (10 percent)	1.58	0.43	1.58	0.43
10 Percent Alternatives				
A	1.58	0.43	1.90	0.43
B	1.85	0.19	1.85	0.30
5 Percent Alternatives				
A	1.39	0.29	1.72	0.29
B	1.70	0.17	1.70	0.23

however, could be offset by transaction cost increases if gasohol is not produced by every refiner and if it is not supplied to every terminal previously involved in ethanol blending.

5.5 STORAGE AND EQUIPMENT ISSUES

Controlling the mid-range volatility of gasohol by requiring 5 percent ethanol blends probably will not necessitate major investments in storage capacity or transportation equipment since the volume of liquid product moved by the distribution system will remain constant. As with 10 percent blends, some modifications may be necessary in the capital stock to reduce technical problems in distribution. For example, improved seals may be needed to reduce water ingress in storage and distribution tanks, and receptacles suitable for storage of ethanol and/or gasohol but not previously used for that purpose may need to be cleaned or upgraded before they are put into service. Thus, costs will be incurred if the stock of tanks and transport equipment used to store and ship gasohol or ethanol increases beyond that used when blending with standard gasoline. This will certainly occur if the requirement for 5 percent blends results in an increase in the number of gallons of gasohol produced, and may occur even if gasohol production stays constant but refinery blending becomes prevalent.

Although it is anticipated that additional transportation stock will not be needed, it is possible that the usage patterns of the available stock will change. This is less likely to occur for 5 percent blends than for 10 percent blends when ethanol demand is constant because the production of larger volumes of specially blended gasoline and gasohol will reduce the probability of a need for modal change (except in the instance of pipeline transportation of gasoline and refinery blending of gasohol).

REFERENCES

Alcohol Week, various issues.

Wayne Alexander, Staff of the Trade Subcommittee of the House Ways and Means Committee, August 19, 1985.

American Petroleum Institute.

D. Atkinson, Distribution of Methanol as a Transportation Fuel. Prepared for U.S. Environmental Production Agency, June 1982.

Bonner and Moore Management Science, Impacts of Alcohol Fuels on the U.S. Refining Industry, Volume I, August 1983.

Peter Busowski, Alcohol Week, August 5, 1985.

Congressional Quarterly, Inc., Energy Policy, 2nd Edition, March 1981.

Congress of the United States, Office of Technology Assessment, Gasohol: A Technical Memorandum, 1979.

"Current Prices of Chemicals and Related Materials," Chemical Marketing Reporter, July 1984 to June 1975.

Department of Energy, Energy Information Administration, Monthly Energy Review, DOE/EIA-0035, various issues.

Department of Energy, Energy Information Administration, Petroleum Marketing Monthly, DOE/EIA-0380, July 1982 to March 1985.

Department of Energy, Energy Information Administration, Petroleum Supply Monthly, DOE/EIA-0109, December 1984.

Department of Energy, Office of Alcohol Fuels, Annual Report to the President and the Congress, December 1984.

Department of Energy, Office of Alcohol Fuels, Fourth Annual Report on the Use of Alcohol in Fuels, March 1983.

Department of Energy, Office of Alcohol Fuels, Production Incentives, April 1985.

Department of Energy, Office of Alcohol Fuels, Sixth Annual Report on the Use of Alcohol in Fuels, April 1985.

Department of Labor, Bureau of Labor Statistics, Producer Prices and Price Indexes, January 1981, January 1985.

Department of Labor, Bureau of Labor Statistics, Wholesale Price Indexes, 1975-1984.

Department of Transportation, 1981 Carload Waybill Statistics: Territorial Distribution, Traffic, and Revenue by Commodities Classes, February 1983.

DHR, Inc., Phase I: Methanol Use Options Study; Volume III, Appendix D, "Transportation and Distribution of Methanol Fuels." Prepared for the U.S. Department of Energy, May 1, 1981.

E.E. Ecklund, "Status and Directions of the Use of Alcohols and Other Oxygenated Hydrocarbons in North America," VI International Symposium on Alcohol Fuels Technology, May 1984.

General Accounting Office, Potential of Ethanol as a Motor Vehicle Fuel, June 3, 1980.

Federal Register, Vol. 50, FR 2615 (January 17, 1985)

Federal Register, Vol. 50, FR 9386 (March 7, 1985)

John Gordley, Staff of Senator Robert Dole, August 12, 1985.

David E. Hallberg, "Testimony Before the Subcommittee on Energy Conservation and Power of the Committee on Energy and Commerce, U.S. House of Representatives," June 28, 1983.

Larie W. Harold, "Distribution Options for Alcohol Fuels," Fuel Alcohol: An Energy Alternative for the 1980's: Appendix. Final Report, U.S. National Alcohol Fuels Commission; Washington, D.C.: 1981.

Herman and Associates, July 1985.

Herman and Associates, Survey of Federal and State Alcohol Fuel Regulations, July 1985.

R.W. Hooks, R. Sagawe, "Gasoline Fuel Distribution and Handling Trail," Proceedings of the Third International Symposium on Alcohol Fuels Technology, May 1979.

Jerry Hurley, Transportation Section, American Petroleum Institute, August 22, 1985.

Information Resources, Inc., Alcohol Outlook, various issues.

Information Resources, Inc., Alcohol Update, various issues.

Thomas F. Killilea, et. al., Stanford Research Institute, "Marketing Research Report: Ethyl Alcohol," Chemical Economics Handbook.

Salvatore Lazzari, Congressional Research Service, Federal Tax Provisions Relating to Alcohol Fuels Including Recent Changes Under the Tax Reform Act of 1984, November 6, 1984.

Jay Matley, "CE Plant Cost Index — Revised," Chemical Engineering, April 19, 1982.

Mueller Associates, Inc., Gasoline Octane Enhancement: Technology, Economics and Environmental, Health and Safety Considerations, July 1985.

National Petroleum Council.

Migdon R. Segal, Congressional Research Services, Gasohol: The Alcohol Fuels, July 12, 1985.

M.D. Tindall, Gasohol — Adding Octane to the Marketing Mix. Presented at the 1981 National Petroleum Refiners Association Annual Meeting, March 29-31.

Transportation Policy Associates, Transportation in America; 2nd Edition, Washington, D.C: March 1984.

"Under EPA's Lead Phase-Down Will Ethanol Blends Save the Independents," Lundberg Letter, November 9, 1984.

George H. Unzelman, "Problems Hinder Full Use of Oxygenates in Fuel," Oil and Gas Journal, July 2, 1984.

Eric Vaughn, President, Renewable Fuels Association, August 19, 1985.

Steven B. Will, Social Cost of Alcohol Fuel Subsidies. Prepared for Argonne National Laboratory, July 1982.

APPENDIX A:

DETAILS OF STATE ALCOHOL BLENDING TAX INCENTIVES

SUMMARY OF STATE TAX INCENTIVES
FOR ALCOHOL BLENDED MOTOR FUELS
(July 1985)

STATE	QUALIFYING ALCOHOL (type and amount)	EXEMPTION OR CREDIT	RESTRICTIONS AND QUALIFICATIONS	STATUS
Alabama	At least 10% ethanol (gasohol)	3¢ gallon	Derived from "agricultural forest products or other renewable sources". Reciprocity for states reducing or exempting Alabama-produced alcohol.	In Effect No expiration date
Alaska	At least 10% alcohol	8¢ gallon	None	In Effect No expiration date
Colorado	At least 10% alcohol	5¢ gallon	At least 60% must be derived from "cereal grains, cereal grain by-products, potatoes or other tubers, sugar beets, sugar beet by-products, or forest products," and limited to the first 2.5 million gallons per year from plants with a 5 million gallon per year or less capacity."	In Effect Expires: 7/1/86
Connecticut	At least 10% ethanol or methanol (gasohol)	1¢ gallon	None	In Effect No expiration date
Florida	At least 10% ethanol (gasohol)	2¢ gallon	None	In Effect Expires: 6/30/89
Hawaii	At least 10% ethanol (gasohol)	4% gallon (gross excise tax)	"Biomass-derived"	In Effect Expires: 6/30/92
Idaho	At least 10% ethanol (gasohol)	4¢ gallon	"Manufactured" in Idaho "from agricultural or forest products grown" in Idaho "or wastes of those products."	In Effect Expires: 4/30/86

Herman & Associates: Survey of Federal and State Alcohol Fuel Regulations

SUMMARY OF STATE TAX INCENTIVES FOR ALCOHOL BLENDED MOTOR FUELS (Cont'd)

STATE	QUALIFYING ALCOHOL (type and amount)	EXEMPTION OR CREDIT	RESTRICTIONS AND QUALIFICATIONS	STATUS
Illinois	At least 10% alcohol (gasohol)	4% gallon (sales tax)	Made from "agricultural products or by-products."	In Effect Expires: 12/31/92
Indiana	At least 10% ethanol (gasohol)	1% gallon (sales tax)	"Agriculturally-derived ethyl alcohol"	In Effect Expires: 7/1/86
		15¢ gallon production grant (on alcohol)	"Agricultural ethanol produced in the U.S. only"	In Effect Expires: 7/1/92
Iowa	At least 10% alcohol (gasohol)	1¢ gallon	"Distilled from cereal grains...grown in the U.S."	In Effect Expires: 6/30/92
Kansas	At least 10% ethanol	4¢ gallon 3¢ (7/1/86) 2¢ (7/1/87)	"Agricultural ethyl alcohol...distilled in U.S. from U.S. produced grain"	In Effect No expiration date
Kentucky	"fuel-grade alcohol" (10% or less ethanol or methanol)	35¢ gallon credit (on alcohol)	Derived from U.S. coal or U.S. renewable resources and "produced in a plant or facility powered primarily by U.S. produced coal or U.S. renewable resources." Reciprocity not to exceed value of credit for Kentucky-distilled alcohol.	In Effect Expires: 6/30/86
Louisiana	At least 10% alcohol (gasohol)	16¢ gallon	"Distilled in Louisiana from agricultural commodities", at least 10% of which must be grown in Louisiana (by monetary value)	In Effect Expires: 1/1/92

SUMMARY OF STATE TAX INCENTIVES FOR ALCOHOL BLENDED MOTOR FUELS (Cont'd)

STATE	QUALIFYING ALCOHOL (type and amount)	EXEMPTION OR CREDIT	RESTRICTIONS AND QUALIFICATIONS	STATUS
Maine	At least 10% ethanol	4¢ gallon (1/1/86) 3¢ (1/1/87) 2¢ (1/1/88) 1¢ (1/1/89)	"Distilled in the State". Reduced by increase in Federal exemption prior to Jan. 1990. Reciprocity for states providing at least equal exemption. Annual cap of $1.25 million, total cap of $5 million.	To Be Effective: 1/1/86 Expires: 12/31/89
Maryland	10% or more ethanol	3¢ gallon	None	In Effect Expires: 6/30/86
Michigan	10% ethanol	1¢ gallon	Produced in Michigan from other than petroleum or natural gas. Reduced by increase in Federal exemption. Reciprocity for states providing equal or greater tax exemption, credit or reduction.	In Effect Expires: 12/31/85
Minnesota	At least 10% ethanol	4¢ gallon	"Derived from agricultural or forest products or other renewable resources distilled in the U.S. and derived from agricultural products produced in the U.S."	In Effect Expires: 6/30/92
Mississippi	At least 10% ethanol	6% gallon (sales tax)	"Distilled in Mississippi", and "produced from renewable resources	In Effect Expires: 12/31/92
Montana	Not less than 10% ethanol	50¢ gallon 30¢ (4/1/87) production credit (on alcohol)	"Distilled in Montana from Montana agricultural products including Montana wood or wood products". Cap of $2.5 million per year.	In Effect Expires: 4/1/89
Nebraska	At least 10% ethanol	3¢ gallon	"Produced from cereal grains or domestic agricultural commodities"	In Effect Expires: 12/31/92

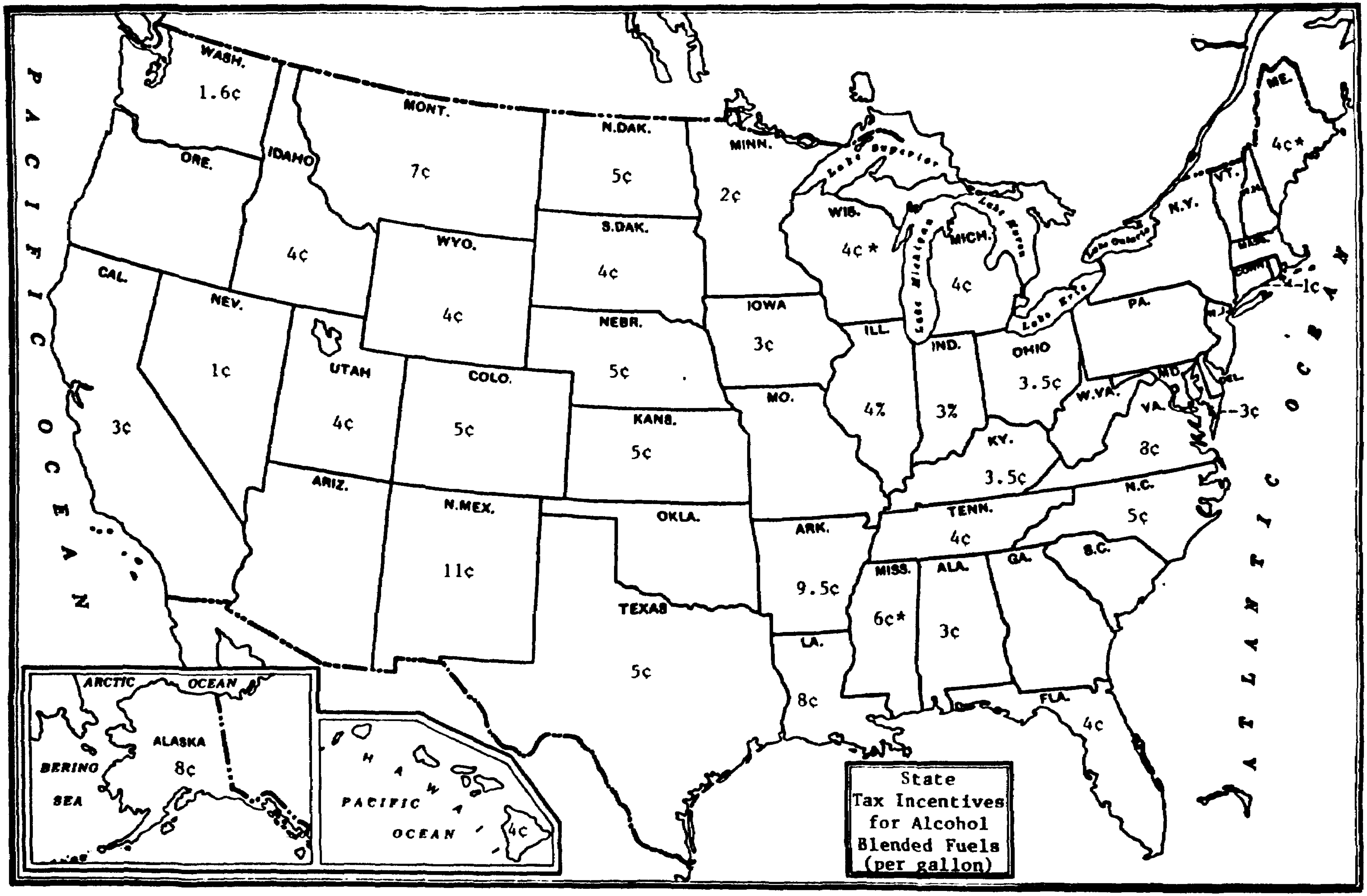
SUMMARY OF STATE TAX INCENTIVES
FOR ALCOHOL BLENDED MOTOR FUELS (Cont'd)

STATE	QUALIFYING ALCOHOL (type and amount)	EXEMPTION OR CREDIT	RESTRICTIONS AND QUALIFICATIONS	STATUS
Nevada	At least 10% ethanol	1¢ gallon	"Derived from agricultual products"	In Effect No expiration date
New Jersey	At least 10% ethanol	8¢ gallon (10/1/85) 6¢ (1/1/88) 4¢ (1/1/90)	"Grain derived" and "produced in the State from whole grain"	To Be Effective: 10/1/85 Expires: 1/1/92
New Mexico	At least 10% ethanol	11¢ gallon 8¢ (7/1/87) 5¢ (7/1/88) 3¢ (7/1/89) 2¢ (7/1/90)	Until 7/1/87, "manufactured exclusively in New Mexico." After 7/1/87 also requires at least 50% of "agricultural feedstock by volume used in fermentation" be produced in New Mexico	In Effect Expires: 7/1/91
North Dakota	At least 10% ethanol or methanol	8¢ gallon 4¢ (7/1/87)	Methanol from coal or "agricultural products produced entirely in the U.S." Reciprocity equal to what other state provides, but not to exceed N. Dakota exemption.	In Effect Expires: 12/31/92
Ohio	Not more than 10% ethanol	25¢ gallon credit (on alcohol)	Wood or cereal grains in facilities of less than 2 million gallons per year, or produced from wood or cereal grains through a "coal-fired process." Reciprocity for "similar fuel" produced out-of-state not to exceed Ohio's credit.	In Effect No expiration date
South Carolina	10% ethanol	6¢ gallon	Distilled in South Carolina facility with principal feedstock wood, cereal grain, potatoes, sugar beets, or turnips (and by-products). Reciprocity for states providing at least equal incentive. Reduced by increase in Federal exemption prior to June 30, 1992.	To Be Effective: 1/1/86 Expires: 6/30/92

SUMMARY OF STATE TAX INCENTIVES
FOR ALCOHOL BLENDED MOTOR FUELS (Cont'd)

STATE	QUALIFYING ALCOHOL (type and amount)	EXEMPTION OR CREDIT	RESTRICTIONS AND QUALIFICATIONS	STATUS
South Dakota	A minimum of 10% ethanol	3¢ gallon	"Derived from cereal grain"	In Effect Expires: 6/30/92
Tennessee	A minimum of 10% ethanol (gasohol)	4¢ gallon	"Derived from agricultural or forest products or other renewable resources" and manufactured in Tennessee. Reciprocity for states reducing or exempting Tennessee ethanol from its motor fuel tax not to exceed value of Tennessee exemption or reduction.	In Effect Expires: 12/31/88
Texas	At least 10% ethanol	5¢ gallon 4¢ (1/1/87) 3¢ (1/1/88) 2¢ (1/1/89) 1¢ (1/1/90)	"Produced or distilled from a renewable source." Applies first to ethanol produced in-state, and then to ethanol from states with reciprocal exemptions, not to exceed a maximum annual limit of $10.85 million.	In Effect Expires: 1/1/91
Utah	Ethanol	40¢ gallon production credit (on alcohol)	"Produced from organic material" at a Utah plant with name-plate capacity of 1 million gallons per year. Must be decreased by 10¢ for every 1¢ increase in Federal exemption.	In Effect Expires: 7/1/90
Virginia	At least 10% ethanol or "synthetic motor fuel"	8¢ gallon 6¢ (7/1/86) 4¢ (7/1/88) 2¢ (7/1/90)	Ethanol must be "distilled in Virginia from agricultural, forestry, or waste products" in a plant not using natural gas or petroleum as a primary fuel. Synthetic motor fuel must be "produced in Virginia from coal."	In Effect Expires: 7/1/92
Washington	At least 9.5% alcohol (gasohol)	2.9¢ gallon blend (blender tax credit)	Must be "produced from renewable resources in-state". Reciprocity for states providing at least equal tax exemption or credit.	In Effect Expires: 12/31/92

1984 STATE TAX INCENTIVES



* Legislation Pending to Establish Exemption

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SUMMARY OF STATE TAX INCENTIVES FOR ALCOHOL BLENDED MOTOR FUELS (1984)

STATE	QUALIFYING ALCOHOL (type and amount)	EXEMPTION OR CREDIT	RESTRICTIONS AND QUALIFICATIONS	STATUS
Alabama	10% ethanol	3¢ gallon	produced from renewables reciprocity for similar tax exemption	Current law (8/1/80) No expiration date
Alaska	10% ethanol	8¢ gallon	None	Current law (1/1/81) No expiration date
Arkansas	10% ethanol (anhydrous)	9.5¢ gallon (full exemption)	full reciprocity to states which exempt Arkansas ethanol from excise taxes effective 5/1/84.	Current law (7/1/81) Expires: 7/1/91
California	10% ethanol or methanol	3¢ gallon	produced "from agricultural commodities, renewable resources or coal."	Current law (1/1/81) Expires: 1/1/87
Colorado	10% ethanol	5¢ gallon	applies only to first three million gallons of ethanol produced at plants under 17 million gallon capacity	Current law (1/1/82) Expires: 7/1/85
Connecticut	10% ethanol	1¢ gallon	None	Current law (7/1/79) No expiration date
Florida	10% ethanol	4¢ gallon	decreases to 2¢ per gallon on 7/1/85. Proposal to extend full 4¢ per gallon exemption pending.	Current law (7/1/80) Expiration Date Current: 6/30/87 Proposed: 6/30/92

Continued:

SUMMARY OF STATE TAX INCENTIVES FOR ALCOHOL BLENDED MOTOR FUELS (1984)

STATE	QUALIFYING ALCOHOL (type and amount)	EXEMPTION OR CREDIT	RESTRICTIONS AND QUALIFICATIONS	STATUS
Hawaii	10% ethanol	4¢ gallon	must be produced or manufactured in Hawaii from biomass	Current law Expires: 1992
Idaho	10% ethanol	4¢ gallon	must be produced, manufactured or blended in Idaho	Current law (5/1/81) Expires: 4/30/86
Illinois	10% ethanol	4% gallon	sales tax exemption only	Current law (12/1/83) Expires: 1992
Indiana	10% ethanol	3% gallon exemption (to 6/30/84) 2.5% gallon (7/1/84 to 6/30/85) gross retail tax)	effictive 7/1/84, some funds collected from the motor fuel tax will be earmarked for Indiana "ethanol fuel production in incentive grants" disbursement of accumulated funds will begin 7/1/85	Current law Expires: 7/1/85
Iowa	10% ethanol	3¢ gallon	None	Current law (7/1/78) Expires: 6/30/86
Kansas	10% ethanol	5¢ gallon	U.S. agricultural products distilled in the U.S.	Current law (7/1/82) (H.B. 3070 would modify)

Continued:

SUMMARY OF STATE TAX INCENTIVES FOR ALCOHOL BLENDED MOTOR FUELS (1984)

STATE	QUALIFYING ALCOHOL (type and amount)	EXEMPTION OR CREDIT	RESTRICTIONS AND QUALIFICATIONS	STATUS
Kentucky	10% ethanol or methanol ("fuel grade alcohol" - 198 proof)	35¢ credit per gallon "fuel grade alcohol"	produced from U.S. coal or renewable resources at plants powered primarily by U.S. coal or renewable resources reciprocity for similar "fuel grade alcohol" if Kentucky product similarily exempted	Current law (7/1/82) Expires: 6/30/86
Louisiana	10% ethanol	8¢ gallon (full exemption)	fuel must be produced in Louisiana	Current law (7/1/79) Expires: 7/1/89
Maine	10% ethanol	4¢ gallon (1/1/86) 3¢ (1/1/87) 2¢ (1/1/88) 1¢ (1/1/89)	reciprocity if other states provide similar exemptions to ethanol produced in Maine	Proposed law L.B. #418 (effective 1/1/86) would expire 2/31/89
Maryland	10% ethanol or methanol	3¢ gallon	will not expire as long as Dept. of Transportation "sinking fund" is maintained	Current law (7/1/83) No expiration date
Michigan	10% ethanol	4¢ gallon 2¢ (1/1/85) 1¢ (1/1/85)	reciprocity with states having equal exemptions entitles product to full exemption; otherwise, only 2¢ per gallon allowed now, or half of full exemption	Current law(12/21/80) Expires: 12/31/86 (H.B. 5339 pending would revoke exemption)
Minnesota	10% ethanol	2¢ gallon 4¢ (1985)	None	Current law (7/1/83) Expires: 1991

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Continued:

SUMMARY OF STATE TAX INCENTIVES

FOR ALCOHOL BLENDED MOTOR FUELS

(1984)

STATE	QUALIFYING ALCOHOL (type and amount)	EXEMPTION OR CREDIT	RESTRICTIONS AND QUALIFICATIONS	STATUS
Mississippi	10% ethanol	6¢ gallon	None	Proposed laws S.B. 2350, 2503, 2505, 2506
Montana	ethanol	70¢ gallon of ethanol 50¢ (4/1/85) 30¢ (4/1/86)	available only to in-state producers using Montana-grown agricultural products	Current law (7/1/83) Expires: 4/1/89
Nebraska	10% ethanol	5¢ gallon	available only to agricultural ethyl alcohol produced in Nebraska	Current law (6/1/79) Expires: 12/31/92
Nevada	10% ethanol	1¢ gallon	None	Current law (1981) No expiration date
New Mexico	10% ethanol	11¢ gallon (7/1/87) 8¢ gallon (7/1/88)	Must be produced from New Mexico agricultural products	Current law (7/1/80) Expires: 6/30/92
North Carolina	10% ethanol	5¢ gallon	must be produced from agricultural or forestry waste products for full credit of 5¢, until 6/30/85. Thereafter, all ethanol qualifies.	Current law (10/1/83) Expires: 6/30/92

Continued:

SUMMARY OF STATE TAX INCENTIVES FOR ALCOHOL BLENDED MOTOR FUELS (1984)

STATE	QUALIFYING ALCOHOL (type and amount)	EXEMPTION OR CREDIT	RESTRICTIONS AND QUALIFICATIONS	STATUS
North Dakota	10% ethanol or methanol	6¢ gallon (1/1/84 - 12/31/85) 4¢ gallon (1/1/86 - 6/30/92)	must be produced from agricultural products	Current law (3/20/79) Expires: 6/30/92
Ohio	ethanol or methanol	35¢ gallon ("tax forgiveness)	produced from other than natural gas or petroleum	Current law (7/1/81) No expiration date
South Dakota	10% ethanol	4¢ gallon	must be derived from grain or forest products produced in the U.S.	Current law (1979) Expires: 6/30/85
Tennessee	10% ethanol	4¢ gallon	blended with unleaded gasoline	Current law (1/1/83) Expires: 12/31/88
Texas	10% ethanol	5¢ gallon 4¢ (1/1/86) 3¢ (1/1/87) 2¢ (1/1/88) 1¢ (1/1/89)	produced from renewable resources only maximum credit: $10.8 million total per year in-state ethanol has first priority in claiming exemption reciprocity provided when other states provide a similar exemption	Current law (9/1/81) Expires: 12/31/90

Continued:

SUMMARY OF STATE TAX INCENTIVES

FOR ALCOHOL BLENDED MOTOR FUELS

(1984)

STATE	QUALIFYING ALCOHOL (type and amount)	EXEMPTION OR CREDIT	RESTRICTIONS AND QUALIFICATIONS	STATUS
Texas (con't.)			quarterly pro-rated adjustment made so limit is not exceeded	
Utah	ethanol or methanol	40¢ gallon tax rebate	must be made of plant in Utah producing 1 million gallons per year or more and certified by the Utah Energy Office	Current law (1981) and new revisions Expires: 6/30/89
Virginia	10% ethanol	8¢ gallon 6¢ (6/30/86) 4¢ (6/30/86) 2¢ (6/30/90)	ethanol produced in-state from agricultural, forestry, or waste products at a plant not using natural gas or petroleum as a primary fuel	Current law Expires: 7/1/92
Washington	ethanol	16¢ gallon (tax credit)	None	Current law (1/1/80) Expires: 12/31/86
Wisconsin	10% ethanol (with unleaded gasoline)	4¢ gallon	reciprocity for equal exemption, otherwise, only Wisconsin products qualify	Proposed law (introduced 4/14/83)
Wyoming	10% ethanol	4¢ gallon	"from agricultural products or other renewable sources"	Current law (7/1/79) Expires: 7/1/84

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