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Ethanol

Economic and Policy Tradeoffs

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ABSTRACT

Federally supported ethanol use is one alternative for meeting environmental, energy security, and agricultural objectives. Additional expansion of the industry depends on a continuation of current favorable conditions, including extension of the Federal gasoline tax exemption. Under current conditions, ethanol should be able to compete with other additives as an octane enhancer. Expansion of the ethanol industry would increase ethanol's contribution to improving energy security, reducing air quality problems associated with carbon monoxide, and increasing corn prices. The report provides a basis for assessing the tradeoffs in using ethanol to meet national objectives.

Keywords: Ethanol, energy, production costs, energy security, environmental quality, Clean Air Act, octane enhancers, farm income, future technology.

This report was prepared by:

Project coordinators -- Michael LeBlanc and John Reilly.

Contributors -- Sally Kane, James Hrubovcak, James Hauver, Patricia Lavin Riely, and Mohinder Gill.

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EXECUTIVE SUMMARY

With the existing Federal fuel excise tax exemption, ethanol will likely remain cost competitive as a fuel blending agent, especially given ethanol's value as an octane enhancer. Without the exemption and given the agricultural and energy market conditions likely to prevail over the next 10 to 15 years, it may be difficult for ethanol to compete on a direct cost basis with many other fuel blending agents. While low corn and grain prices are favorable for ethanol, the glut in world petroleum markets works against ethanol's competitiveness. The nonmarket benefits of ethanol in meeting environmental, energy security, and agricultural goals are positive but limited, with alternatives for meeting these goals available.

The study develops an information base on current and future conditions in the industry. Current and future ethanol production technologies are assessed. Breakeven conditions for ethanol are established recognizing the sensitivity of ethanol's competitiveness to new production technologies and prices for corn, byproducts, crude oil, and alternative fuel blending agents. From this basis, the contribution of ethanol production and use to Federal policy objectives is addressed. The market price of ethanol may not fully reflect the value of ethanol in achieving various policy goals. Effects of ethanol production and use not captured by the market price may provide a justification for Federal involvement.

Ethanol production costs vary considerably among producers and over time. Since 1980, net corn costs have ranged from 70 cents per gallon of ethanol to as little as 6 cents during the first quarter of 1987, averaging 56 cents per gallon. Operating costs for large plants currently average 47 cents per gallon with a range of 40 to 59 cents. Capital costs of 19 cents per gallon of ethanol produced are achieved when fermentation and distillation capacity is added to an existing wet mill with excess corn grind capacity. Most future expansion would utilize abandoned industrial capacity at capital costs per gallon of 33 to 38 cents compared with as much as 48 cents for a fully new site.

A state-of-the-art plant built today would achieve a 9-cent cost advantage over the average of existing plants. Additional advances likely in the next 3 to 5 years could reduce costs by another 5 cents. In the longer term, technologies that convert feedstock material other than sugars and starches offer an opportunity to reduce feedstock costs. These technologies are likely to be more costly than current technologies given currently low corn costs but would become cost competitive if corn prices rise relative to other biomass feedstocks. Any decrease in crop production costs resulting from traditional crop breeding, applications of biotechnology, or from broader sets of reductions in input costs would reduce the cost of ethanol feedstocks.

Ethanol is cost competitive as a fuel blending agent with the Federal excise tax exemption, corn costs of $2.00 per bushel, and byproduct recovery of 50 percent of the cost of corn if crude oil prices are $20 dollars per barrel or more. Extension of the excise tax exemption to the year 2000 would provide the incentive to expand industry production by as much as 1 to 2 billion gallons by 1995, up from the current 800 million gallons. Without the Federal subsidy and with $2.00 per bushel corn, crude oil prices must be at least $40 per barrel for ethanol to be cost competitive.

Ethanol's competitiveness also depends on how it is used in fuel. A gallon of ethanol contains two-thirds the energy value of a gallon of gasoline but has an octane value over 30 percent greater than regular unleaded gasoline. Ethanol producers have begun marketing ethanol for its higher value as an octane enhancer. Currently, ethanol prices do not generally reflect the octane value of ethanol. Rather, ethanol is frequently priced, net of the Federal and applicable State subsidies, below wholesale gasoline prices to overcome costs of blending ethanol and resistance to blend fuels.

Domestically supplied energy has presumed benefits in enhancing energy security although even energy independence does not isolate the domestic economy from energy market shocks to the economies of our trading partners. Energy prices and their impacts are tightly linked through world trade markets. Current annual ethanol production accounts for approximately 1/200 of the energy content of gasoline and less than 1/1,000 of all energy used in the United States each year.

Ethanol production is self-limiting in terms of its contribution to national energy supplies. Production levels of two or three times current levels, while still a small proportion of total energy use, would begin to place strong upward pressure on corn and other grain prices, thereby increasing the production cost of ethanol and reducing its competitiveness compared with alternative energy sources. The broader range of ethanol feedstocks envisioned for the future offers greater production potential but they are constrained and relatively costly in terms of delivered energy content compared with other long-term liquid fuels based on abundant domestic resources such as coal and shale oil.

Ethanol use can help meet certain requirements of the Clean Air Act. Ethanol, blended at 10 percent with gasoline, has a demonstrated result of reducing vehicle carbon monoxide (CO) emissions. Other oxygenates including methanol and MTBE, an octane enhancing additive made from methanol and petroleum refinery products, also reduce CO emissions.

Use of ethanol blend fuels tends to increase ozone concentrations which are also limited by the Clean Air Act. Ethanol increases the volatility of the base gasoline with which it is blended, potentially increasing lower level atmospheric ozone concentrations. Carbon monoxide, however, is a winter problem whereas ozone is a summer problem, allowing seasonal blending of alcohols to contribute to reductions in CO emissions without increasing ozone problems. MTBE does not substantially increase fuel volatility.

Farm income would increase modestly if the ethanol industry expanded. The market price for corn would increase but the gain to total income would be small in the near term; government payments to corn producers would fall as the gap between the market and target prices of corn narrow. By 1995, when market prices push above target prices, gains to corn producers would be greater. Income to oilseed producers (such as soybean, cotton seed, and sunflower seed producers) would fall as a result of the expanded supply of corn oil and protein meal feeds that are byproducts of ethanol production. Other agricultural producers would experience minor effects. Producers of grains other than corn would benefit as prices of all grains followed corn prices. Livestock producers would gain from lower protein meal prices but lose as a result of higher grain prices, the net effect dependent on the specific price effects and the importance of grain versus protein feeds in the ration. The total increase in farm income from a 1.9-billion-gallon addition to the current 800-million-gallon ethanol industry would be less than $1 billion in 1995 and lower in earlier years.

To achieve significant increases in ethanol production and the estimated savings in agricultural program outlays, it would be necessary to extend the Federal excise tax exemption on ethanol blend fuels through the year 2000. The agricultural program savings would exceed the reductions in Highway Trust Fund revenues through 1995. Beyond 1995, however, Highway Trust Fund revenue losses exceed farm program savings under the assumption of recovery in the agricultural sector and continuance of current agricultural programs without significant change. By 1999, the added budget costs would exceed budget savings realized prior to 1995.

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INTRODUCTION

Alcohol fuels gained public attention during the 1970's as one solution to the "energy crisis" caused by the 1973 petroleum embargo. A search for less expensive and more reliable domestic fuel sources was hastened by an economic environment of rapidly rising fuel prices, high inflation rates, and dependence on foreign sources of energy. Alcohol produced from an agricultural feedstock offered the promise of a renewable domestic energy source which was also environmentally advantageous. The Energy Security Act of 1980 affirmed public support for alcohol fuels. A stated objective of the act was that alcohol fuel production should be equivalent to 10 percent of domestic gasoline consumption by 1990. For most of the 1980's, petroleum prices have declined and public concern over the need to develop alternative fuels has declined. Through this period ethanol production and use, supported by a mix of Federal and State incentives, grew steadily and substantially.

Ethanol relates to three major U.S. policy areas: environmental quality, energy security, and stabilizing agricultural income. Within the last year public attention has refocused on alcohol fuels as compliance deadlines of the Clean Air Act drew near, U.S. petroleum imports increased to levels of the early 1970's, and corn stocks reached nearly 6 billion bushels driving corn prices to their lowest levels in 15 years. Alcohol, including ethanol and methanol, blended with or used in place of gasoline, offers one approach for addressing national air quality standards set in the amended Clean Air Act. Ethanol production, using corn as a feedstock, offers the possibility of a significant expansion in the domestic market for grain. Continuing instability in the Middle East, particularly the Iran-Iraq war, has again raised energy security concerns with reinforced concerns about the vulnerability of the United States to energy supply and economic disruption from abroad.

Federally encouraged ethanol use is one alternative for contributing to environmental, energy security, and agricultural objectives. Ethanol production and use is unusual in that it has positive aspects across these three objectives. Our goal is to provide a factual basis for assessing the contribution of ethanol production to national objectives. An important first step is to develop estimates of current ethanol production costs and factors likely to affect costs. The forward-looking nature of our study required an assessment of ethanol production technology over the next 3-5 years as well as those changes that may be profitable in 10-15 years. Among the ethanol demand considerations examined were the roles of ethanol as a fuel extender and as a fuel octane enhancer. In addition, concerns regarding the performance of vehicles using ethanol blend fuels were assessed. Following the development of an information base regarding the ethanol industry, production technology, and demand, we evaluated the energy security, environmental, and agricultural implications of ethanol production and use. Finally, we brought together these diverse effects of ethanol, tradeoffs among policy goals, and alternative approaches for meeting these goals to bear directly on the future public benefits and costs of an ethanol industry.

THE FUEL-ETHANOL INDUSTRY

The fuel-ethanol industry was created by a mix of Federal and State subsidies, loan programs, and incentives. It continues to depend on Federal and State subsidies. The ethanol industry has grown and its product is able to compete as a gasoline blending agent because gasoline-ethanol blends are exempt from 6 cents of the 9-cent Federal excise tax on gasoline. The minimum 10-percent blend requirement for the exemption translates to an effective 60-cent subsidy per gallon of ethanol. In addition, 28 States offer State fuel tax exemptions or producer subsidies for ethanol averaging 20-30 cents per gallon. The Federal subsidy has been the target of the budget deficit reduction process through most of the 1980's, although most analyses show that with the current farm program and agricultural surplus conditions the tax loss due to the subsidy is more than offset by farm program savings.

From 20 million gallons of production in 1979 using 8 million bushels of grain, ethanol production rose fairly steadily, reaching 750 million gallons in 1986 using 300 million bushels of grain or approximately 3 percent of annual U.S. corn production. As of the second quarter of 1987, the United States had 56 ethanol production-related facilities in operation.

Dramatic industry growth has been combined with rapidly changing economic conditions that affect firm profitability. The industry suffered losses in 1986 when crude oil prices dropped to the $10 per barrel range. In addition, some plants have suffered from poor design and management. As a result, 88 plants are shut down, with 24 unlikely to reopen. Another seven plants were sold for other purposes or dismantled in the first quarter of 1987. Most of the closed plants are small, representing only 17 percent of industry capacity (IRI, 1987). Many small plants and many plants receiving Federal loan guarantees have closed or defaulted on loans. By the beginning of 1987, the industry profitability improved when crude oil price increases led to higher prices for ethanol. Corn prices fell and the prices received for byproducts of ethanol production increased, further enhancing profitability.

Industry Structure

Several features of the fuel-ethanol industry and technology have combined to create a diverse group of companies and production facilities. The industry is split between large plants (greater than a 40-million-gallon annual capacity) and small plants (less than 10 million gallons), between dry-milling and wet-milling technologies, between firms relying on Department of Energy (DOE) or Department of Agriculture (USDA) loan guarantees and those relying on purely private financing, between firms with traditional grain processing experience and those without, and between large diversified companies and new firms focused exclusively on ethanol. With fuel-ethanol production commercially unproven only 8 years ago, this diversity of approaches is not surprising. The diversity has created many different perspectives on both the fuel-ethanol industry and constraints to expansion.

A few large ethanol plants account for the bulk of ethanol production. Of the 151 ethanol plants in the United States at the beginning of 1987 only 17 have a capacity of least 10 million gallons per year. Nearly 50 percent of operating capacity in 1986 was accounted for by only four facilities. Nearly 75 percent of operating capacity was accounted for by the eight largest plants owned by five companies.

The Production Technology

Fuel ethanol is produced by an old technology in a new industry. The basic process of producing alcohol using yeasts to ferment the starches and sugars in fruits and grains has been the basis for beverage production for centuries. Figures 1 and 2 describe the basic dry- and wet-mill technologies used in fuel ethanol production. The two processes are very similar. Both require that the corn be ground. In most ethanol-producing dry mills, the ground corn is then slurried with water and cooked. Enzymes convert the starch to sugar and in the next stage yeasts ferment the sugars to produce beer. In the dry-mill process, the beer, containing alcohol, water, and dissolved solids, is separated from the solids. It is then distilled and dehydrated to create anhydrous ethanol. The solids are dried and sold as dried distillers grain (DDG). Some dry mills remove the corn germ, from which corn oil is derived, prior to fermentation.

Figure 1
Dry-mill processing

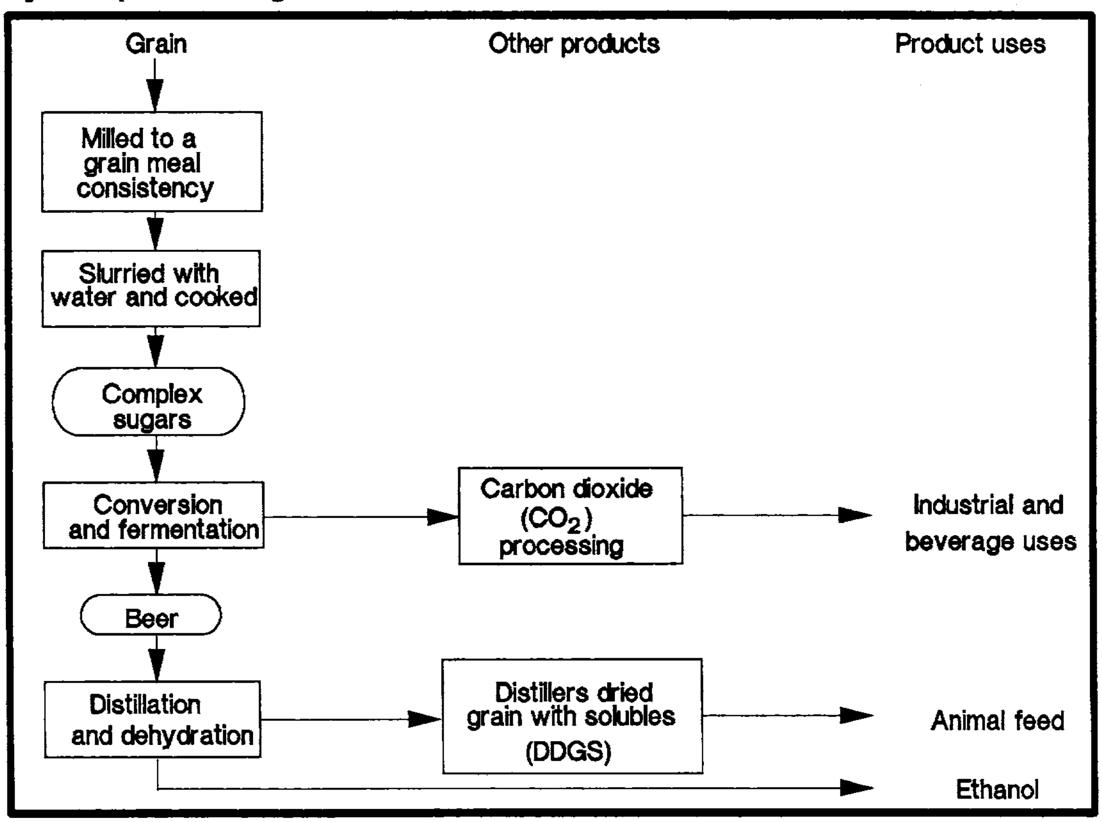
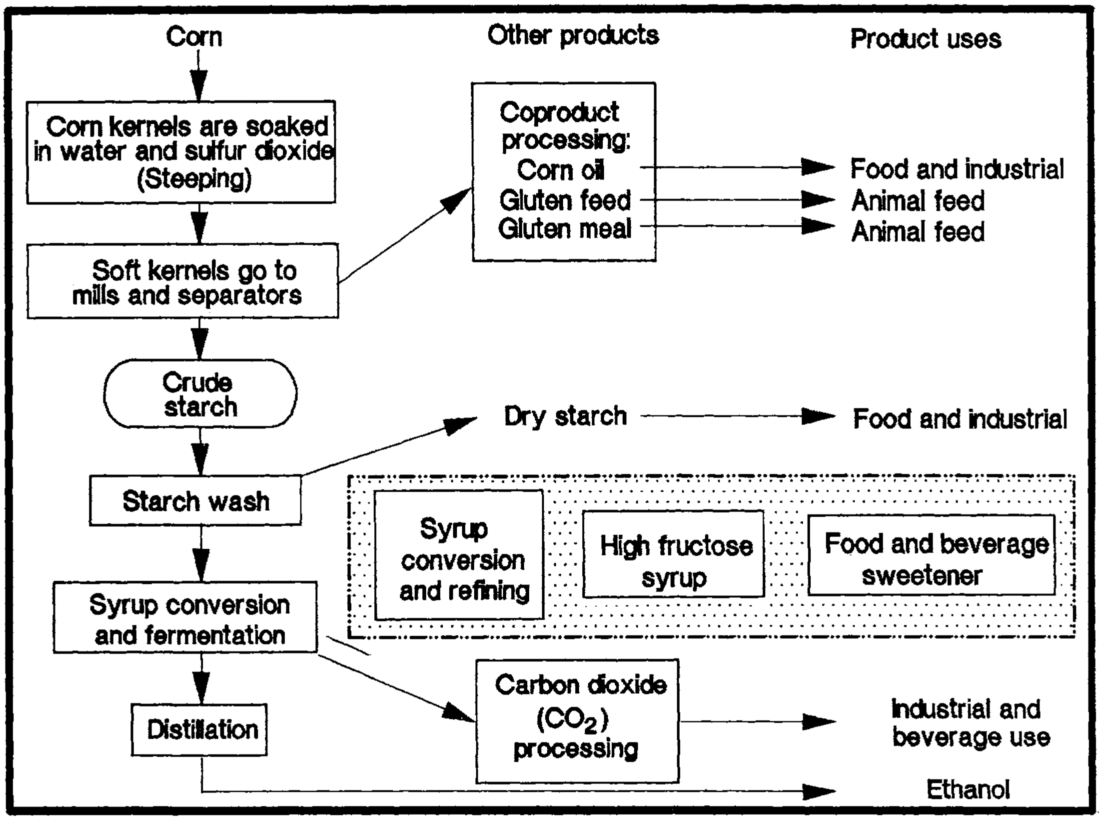


Figure 2
Wet-mill processing



The primary difference in the wet-mill process is that it produces essentially pure starch which is then converted to sugars. That is, all other portions of the corn kernel are removed prior to fermentation. These solids are used to produce three coproducts including corn gluten meal, corn gluten feed, and corn oil. Because the ethanol wet-mill plant is identical to a fructose plant through the starch production phase, the two facilities have been combined as illustrated in figure 2 with some cost advantages. While the byproducts differ, both byproduct streams require drying. Carbon dioxide is a minor byproduct of both processes, accounting for a credit of, at most, 2-3 cents per gallon of ethanol produced.

Production Costs

The cost of ethanol production is subject to wide variation over time and varies considerably among existing plants.1/ Large producers have a significant advantage over

1/ Cost estimates derived from confidential data provided by the ethanol producers. W. Robert Schwandt, under contract to the Economic Research Service of USDA, obtained voluntary data from the six largest ethanol producers (over 40 million gallons per year) and five small and medium producers (under 40 million gallons per year). Firms reported averages across plants for firms with multiple plants. To assure confidentiality, only the costs for five cost categories were given. Other characteristics such as wet- versus dry-mill, total capacity, total investment, and details of the production data are not part of the data set. Responses were obtained through completed questionnaires and telephone follow-up to assure that assignment of costs across categories was as complete and comparable across responses as possible.

small producers both in terms of economies of scale in the production technology and in terms of their ability to market the fuel. Economies of scale in the production technology, while difficult to quantify because of the diverse plant configurations in the industry, continue to exist for plants with annual capacities of 100-150 million gallons. In addition, the power and financial resources of larger producers are essential if the industry is to compete with the petroleum and petrochemical industry and effectively market ethanol. Small-scale producers will continue to depend on the large producers to establish the ethanol industry as a dependable supplier of fuel blending agents. Ethanol production, if the industry expands considerably, will continue to be dominated by plants of at least 60 million gallons per year. While a plant producing 40 million gallons per year is currently considered a large plant, a growing industry is likely to see the norm for large plants rise to 90-100 million gallons per year.

Despite the likely continued dominance of large plants, small plants with annual capacities of 0.5-10 million gallons can continue to be profitable under special circumstances. These conditions include location in areas with limited local grain production and high transportation costs to major grain markets, colocation with food processing or other industrial facilities where fermentable wastes (such as potato waste, fruit waste, or whey) are produced, or colocation with a feedlot thereby allowing the byproducts to be fed directly to the cattle, saving the substantial costs of drying and marketing the products.

Much controversy over the cost of ethanol production is due to its dependence on highly variable corn and byproduct prices. Over the past 7 years, corn prices have varied from $1.41-$3.16 per bushel (tables 1 and 2). Byproduct sales recouped as little as 30 percent of

Table 1 -- Net corn costs of wet milling

Period	Corn cost	Byproducts 1/ Oil	Feed	Meal	Total value	Share of corn cost	Net corn cost	Net ethanol cost 2/
	Dollars/ bushel	Cents/ pound	-- Dollars/ton - -		Dollars/ bushel	Percent	Dollars/ bushel	Dollars/ gallon
1981	3.16	23.8	115	257	1.42	44.9	1.74	0.70
1982	2.48	23.8	114	235	1.38	55.8	1.10	.44
1983	3.12	24.7	124	267	1.50	48.2	1.62	.65
1984	3.11	29.8	94	243	1.37	44.0	1.74	.70
1985	2.52	26.3	76	200	1.14	45.4	1.37	.55
1986	1.95	18.5	95	214	1.16	59.3	.79	.32
1987 3/	1.41	23.3	99	216	1.26	89.1	.15	.06
6-year avg.	2.72	24.5	103	236	1.33	48.9	1.39	.56

1/ CO_2 recovery not included. Range is 0.8-2.5 cents per gallon of ethanol for unprocessed CO_2 and 10-15 cents per gallon of ethanol for purified, liquid CO_2. Processing costs for purifying CO_2 are substantial.

2/ Ethanol yield assumed to be 2.5 gal./bu.

3/ First quarter.

Table 2 -- Net corn costs of dry milling

Period	Corn cost	Distillers dried grain 1/ Value	Distillers dried grain 1/ Share of corn cost	Net corn cost	Net ethanol cost 2/
	- - Dollars/bushel - -		Percent	Dollars/ bushel	Dollars/ gallon
1981	3.16	1.29	41.0	1.86	0.71
1982	2.48	1.28	51.5	1.20	.46
1983	3.12	1.39	44.6	1.73	.66
1984	3.11	1.06	34.0	2.05	.79
1985	2.52	.85	33.8	1.67	.64
1986	1.95	1.07	54.7	.88	.34
1987 3/	1.41	1.10	78.6	.30	.11
6-year avg.	2.72	1.16	42.6	1.56	.60

1/ DDG is assumed to be valued at 125 percent of corn gluten feed and yield is assumed to be 18 pounds per bushel.

2/ One bushel of feedstock is assumed to yield 2.6 gallons of ethanol.

3/ First quarter.

the corn cost for dry mills to 90 percent of the cost of corn for wet mills in early 1987. For the most part, corn prices fell consistently over those 7 years.

Byproduct prices have also varied but not nearly as much as corn prices. In recent years, byproduct prices rose and corn prices declined. These trends resulted in the net cost of corn for ethanol production being more variable than the cost of corn. With ethanol yields of 2.5-2.6 gallons per bushel of corn, the net cost of corn has ranged from nearly 79 cents per gallon of ethanol produced to less than 10 cents for a short period in early 1987.

Cash operating costs other than corn costs vary considerably by plant size (tables 3 and 4). Large plants spend about 40-59 cents per gallon of ethanol produced. Costs for small and midsized plants vary more markedly, 32-65 cents per gallon. The greatest outlay is for energy, averaging 36 percent of cash operating costs. Cash operating costs for small and midsized plants, particularly energy and labor costs, tend to be higher than for large plants by 5-10 cents per gallon. Among the reasons for higher costs: small plants are less able to take advantage of coal boiler cogeneration applications while meeting environmental regulations, economies of scale limit recovery of waste heat, and personnel costs are higher. While small plants tend to be more costly on average than large plants, the costs exhibited by plant 2 in table 4 indicate the savings possible in energy costs if distillers grains are fed wet.

The investment required to build an ethanol plant can range from $1-$2.50 per gallon of installed capacity (table 5). Estimated construction cost for a new dry mill with an annual capacity of 40 million gallons or a wet mill with an annual capacity of 100 million gallons is $2-$2.50 per gallon of capacity. Where wet-mill capacity associated with corn fructose

Table 3 -- Operating costs excluding net corn costs in 1987: Large plants

Cost item	Surveyed plant					
	1	2	3	4	5	6
	Dollars per gallon of anhydrous ethanol					
Energy	0.115	0.159	0.136	0.239	0.160	0.209
Ingredients	.060	.111	.135	.070	.090	.147
Personnel and maintenance	.140	.228	.097	.135	.140	.079
Management and administration	.048	.068	.032	.040	.050	.016
Insurance and taxes	.034	.020	.011	.030	.015	.020
Total cash operating cost	.397	.586	.411	.514	.455	.471

Table 4 -- Operating costs excluding net corn costs in 1987: Small and medium plants

Cost item	Surveyed plant and size				
	1	2	3	4	5
	Small	Small	Medium	Medium	Medium
	Dollars per gallon of anhydrous ethanol				
Energy	0.217	0.053	0.190	0.251	0.215
Ingredients	.091	.073	.065	.126	.059
Personnel and maintenance	.160	.160	.180	.233	.197
Management, administration, insurance, taxes	.040	.035	.050	.048	.080
Total cash operating cost	.508	.321	.485	.658	.551

Table 5 -- Capital cost summary

Capacity addition	Investment cost per annual gallon	Capital charge per 1/ gallon produced
	Dollars	
Incremental addition to operating wet mill	1.00 - 1.50	0.19 - 0.29
Adaption of abandoned oil refinery distillation capacity or wet-mill capacity	1.75 - 2.00	.33 - .38
New plant	2.00 - 2.50	.38 - .48

1/ Capital charge of 19 cents per dollar invested computed as a capital rental rate based on the following assumptions: (1) Tax Reform Act of 1986 (8-year tax life for equipment, no investment tax credit or energy investment tax credit, 38-percent income tax rate), (2) Nominal, pretax equity return of 15 percent, (3) nominal interest on loan of 8.5 percent, (4) debt/equity equal to 78/22, (5) annual inflation rate of 4 percent, and (6) an actual asset life of 30 years.

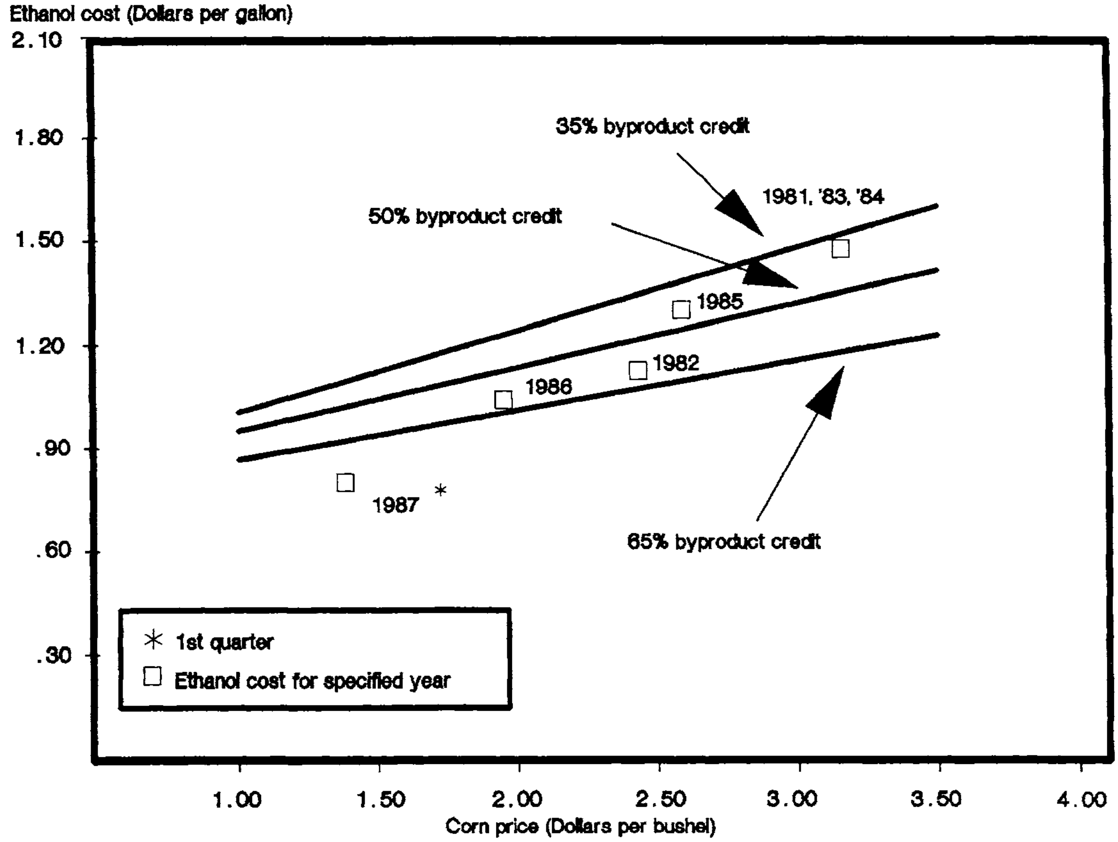
production already exists, the fermenter and distillation capacity for production of ethanol can be added at a cost of $1-$1.50 per annual gallon. For an operating wet mill with seasonal excess corn grind capacity and requiring minimal adjustments to boost corn grind capacity to efficiently produce ethanol and corn sweeteners (or other corn product), the $1-$1.50 represents the full additional capital cost of ethanol production.

Capital charges in table 5, ranging from 19 cents to 48 cents, assume the tax provisions established under the Tax Reform Act of 1986.2/ A critical assumption in calculating capital charges per gallon is the average operating level of the plant relative to rated capacity. Table 5 assumes plants operate at full capacity. Large plants have achieved consistent records of producing at or above rated capacity. Midsized and small plants have shown mixed operating records overall even though some have operated continuously. The relative inability of small plants to operate continuously due to difficulty in finding markets for ethanol or byproducts, difficulty in maintenance and repairs, or problems of fermenter contamination contribute further to economies of scale in operations. The very small, onfarm plants producing on the order of 300,000 gallons per year or less have been particularly plagued by fermenter contamination. As an example, a plant able to achieve operation at 75-percent capacity faces capital charges 33 percent higher than one operating at 100-percent capacity, adding from 12-16 cents to production costs for a stand-alone plant.

Combining operating, capital, and net corn costs results in the total production costs. Using these average costs, figure 3 emphasizes the effect on ethanol production costs of the variability in net corn costs. The calculated full cost of production from a stand-alone

2/ Previous tax law treated investment more favorably with shorter tax lives, a 10-percent investment tax credit, and the energy investment tax credit reducing the capital charge per gallon by roughly 3 cents per dollar invested.

Figure 3
Ethanol costs, byproduct credits, and the price of corn



plant has ranged from as low as $0.75 per gallon with the unusually high byproduct prices of early 1987 to the $1.40-1.50 range during 1981, 1983, and 1984. An ethanol plant addition to an existing wet mill could achieve costs as much as $0.20 cents per gallon lower.

THE FUTURE OF ETHANOL TECHNOLOGY

Fuel ethanol is a distinct commodity from the traditional beverage and industrial alcohol products that have a much longer history of production. Today's fuel ethanol industry dates only to 1978. While the basic technology is old, establishment of the fuel ethanol industry has been accompanied by significant learning. The opportunity for improvements in the cost and efficiency of fuel ethanol production has arisen because of the considerably different set of constraints applicable to fuel production than for traditional uses of ethanol.

In the near term, changes in technology relevant to the United States relate primarily to grain-based production focusing on the conversion of starches to sugars (saccharification), fermentation, distillation, and energy production and use throughout the plant. Research with likely applications in the longer term has focused on technologies capable of using other feedstocks. Overall, the industry measures significant savings in terms of cents or fractions of a cent per gallon of output.

State-of-the-Art Technology

Table 6 contrasts the average operating costs experienced by existing plants and engineering design costs for a planned plant incorporating state-of-the-art technology. Such technology includes the best plant components among those commercially demonstrated. The state-of-the-art plant will achieve an estimated 17-percent reduction in operating costs, unevenly distributed among the cost categories.

While some of the savings in operating costs occur as a result of larger capital expenditures (for example, added heat exchangers), others reduce capital requirements. For example, both rate and yield increase in fermentation reduces fermenter capital costs. As a result, a state-of-the-art plant should not entail a significant construction cost increase over existing plants. In addition, many existing plants suffered from various degrees of overbuilding or required modifications after construction. Experience gained from these plants will help to minimize the extent of overbuilding and required modifications of future plants. Annual capital charges in the state-of-the-art plant are on the order of $0.40 per gallon assuming some site-related costs could be saved through use of an existing industrial site. A completely new facility requiring complete site development including such items as railroad sidings, electrical transmission, and sewer and waste treatment would incur capital charges of $0.47 per gallon.

Reduction in net corn costs resulting from new technology is extremely sensitive to corn and byproduct prices. For example, a 4-percent improvement in yield for wet mills through technologies that are able to separate all the starch for conversion (that is, moving from a yield of 2.5 to 2.6 gallons per bushel) would reduce the net corn cost less than 0.5 cent when corn prices are low and byproduct prices high as they were in the spring of 1987. With corn prices of $2.50 per bushel and byproduct recovery of only 40 percent of the corn cost, the savings per gallon for the same yield increase would be over 1.5 cents or more than three times larger. Further enhancement of the market value of byproducts through, for example, the production of human consumption grade byproducts offers much higher byproduct credit recovery. But sizable markets for the products do not yet exist and may offer a significant marketing challenge.

Table 6 -- Average versus state-of-the-art operating costs, excluding net corn costs

Cost category	Current average 1/	State of-the-art 2/
	Dollars/gallon of anhydrous ethanol	
Energy	0.17	0.11
Ingredients, personnel, and maintenance	.24	.24
Management, administration, insurance, taxes	.06	.03
Total	.47	.38

1/ Unweighted average of large plants from industry survey.

2/ Engineering estimate for a specific plant site.

Improvements in the Near Term

There are three new technologies whose potential has been demonstrated at less than the commercial level but still involve risk in successful scaling up of the technology: (1) the replacement of yeast with the Zymomonous mobilis bacteria, (2) membrane separation of solubles to reduce the energy required for boiling away water in the wastewater treatment phase, and (3) the immobilization of enzymes and yeasts (or the Z. mobilis bacteria) in the wet-mill process.

The three technologies are in various stages of development, but all have at least been tested in pilot plants. The major advantage of Z. mobilis is its faster rate of fermentation compared with yeasts now used. Its desirable features also include greater temperature tolerance and higher yields due to its higher selectivity for producing ethanol. Membrane separation of solubles might allow 40 percent of the water to be separated out prior to the boiling process, greatly reducing the energy needed. The remaining obstacle is reducing the tendency for the membrane to become clogged with the solubles. Immobilization of yeasts and enzymes involves passing the starch or sugar solution, the clarified substrate, through a medium containing the enzyme, yeast, or bacteria. This would allow improved control of the process and maximize the use of the yeast or bacteria and enzymes. Immobilization replaces yeast recycling by holding the yeast in place. As a result, it will likely reduce concerns of contamination associated with yeast recycling. Because the process requires a clarified substrate, it is applicable only to wet milling.

Beyond the specific technologies discussed above, continued small gains can be expected through improvements in process control and waste heat utilization. It is difficult to predict the specific source of cost savings. But, it is likely that the state-of-the-art plant of 3-5 years in the future may obtain an additional 5-cent savings in operating costs per gallon over the state-of-the-art plant of today without substantial changes in capital costs.

Longer Term Considerations

The focus of near- and long-term ethanol research and development differs to a degree. With excess agricultural capacity and low corn and other grain prices, near-term research and development efforts can be examined in the narrower context of the ethanol production facility itself. To examine the potential of the industry beyond a role as a user of surplus corn and other grain production, one must consider trends in production cost and capabilities of grains and alternative feedstocks, ethanol production technologies capable of using a broader set of feedstocks, and the development of and markets for byproducts from both new and existing technologies.

Technologies that may prove beneficial in the longer term include alternative feedstocks such as potatoes, sweet potatoes, Jerusalem artichokes, sugar beets, fodder beets, sweet sorghum, and grains other than corn. Use of these crops for ethanol does not present particular technological hurdles. But, should corn prices rise, these crops may prove to be a cheaper feedstock because they can be grown on a broader range of lands and in climates unsuited to corn production. Bioengineering and traditional plant breeding technologies that increase per acre yields or increase starch and sugar contents of corn and other crops also offer the potential for lower cost ethanol through reduction in feedstock costs. Any advances in crops that reduce production costs or increase the starch yield will lower ethanol feedstock costs.

Processes to break down the various types of cellulosic biomass materials into sugars that can then be fermented constitute an active research area. Breakthroughs in biomass pretreatment and conversion would allow higher yields from grain since part of the grain is cellulose. Also, herbaceous plant matter could be used. For example, crops such as alfalfa and cellulosic material such as corn stover or bagasse could be fermented. These technologies could ultimately allow ethanol production from woody plants and a broader spectrum of organic waste. Direct-cost competitiveness of these technologies will be difficult to achieve if grain prices remain low. However, the byproducts derived from these technologies will be considerably different from existing ethanol byproducts and, hence, their market potential is speculative at this time. With some of the proposed technologies, ethanol would become a complementary output, with demand for relatively high-valued chemicals derived from the process driving the production process.

The best current estimates for cellulose place production costs at $1.00-$1.20 per gallon (Ladisch and Tsao, 1986; Wright and D'Agincourt, 1984). This estimate includes CO_2 and the energy value of unconverted cellulose as byproduct credits. It is difficult to make a direct comparison to corn processing, but processing costs for a grain plant at current corn prices would place a comparable set of costs at 60-90 cents per gallon. If corn prices rose to the $3.50-$4.00 per bushel range, cellulose conversion would be competitive with grain-based production without further major breakthroughs.

Cellulose conversion and processing of renewable resources into oxygenated fuels and chemicals will be the next major development in agriculture. The timeframe over which this will occur depends on the level of research and development in the growth, harvesting, transportation, storage, processing, fermentation, and final product recovery related to cellulosic materials. Fundamental research on the biochemical, chemical, and microbial transformation of renewable resources into value-added products is critical. Some of the key developments will be: (1) microorganisms which efficiently ferment a broad range of sugars in addition to glucose, (2) processes to readily convert biomass materials into processed cellulose, lignin, hemicellulose, and coproduct streams, (3) chemical modification of cellulosic materials to products which supplant current materials derived from other sources such as petroleum, and (4) development of an industrial infrastructure based on utilization of renewable resources. These developments also may lead to improved economics in the current corn processing industries and, hence, could result in multiple benefits to agriculture.

ETHANOL DEMAND AS A GASOLINE ADDITIVE

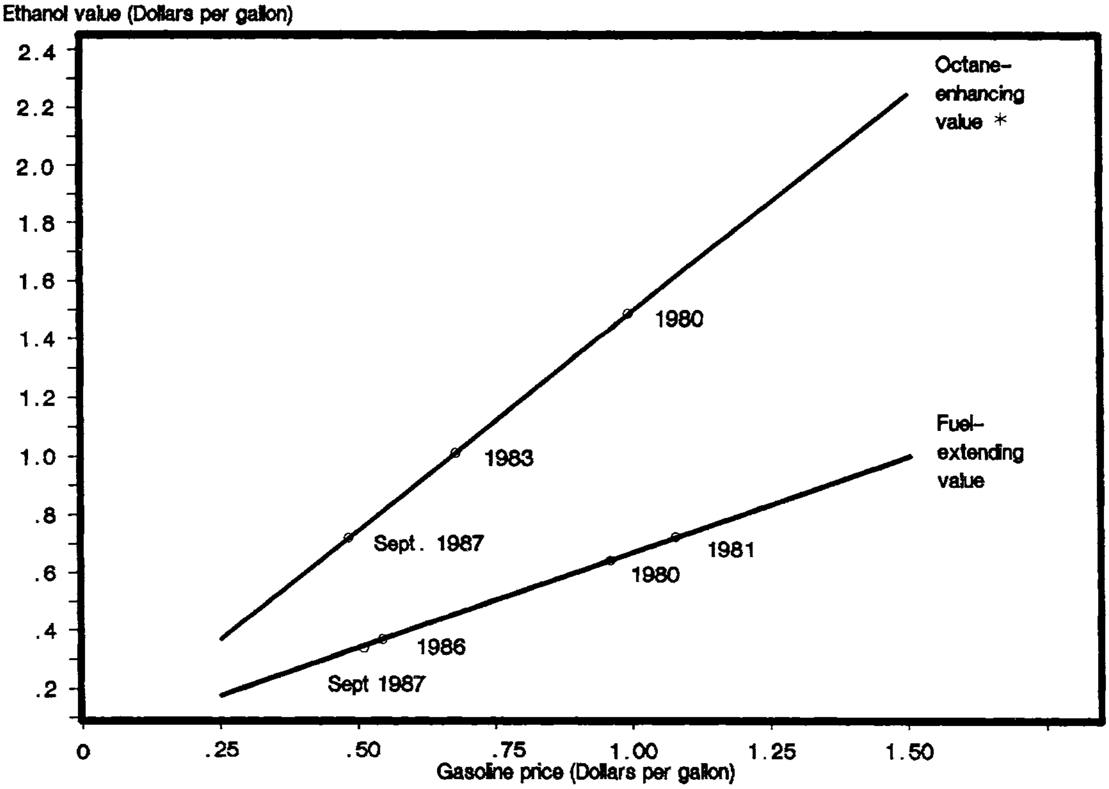
Ethanol has competed in the transportation fuels market primarily as a blending agent with gasoline, thereby extending gasoline supplies. Ethanol has recently begun to be marketed for its value in raising the octane of gasoline. Ethanol blended with gasoline both extends gasoline supplies and enhances octane. A third potential use of ethanol is as a cosolvent with methanol. Methanol blended alone with gasoline is not compatible with the current vehicle fleet. The addition of ethanol moderates the corrosive effects of methanol. As a fuel blending agent, ethanol has been associated with a variety of relatively minor vehicle performance problems.

Fuel Extender and Octane Enhancer

As a fuel extender, ethanol contains about two-thirds the energy content of gasoline with a possible negative effect on mileage.3/ The effective price of ethanol after Federal and State excise tax exemptions must therefore be two-thirds the price of gasoline to be economically competitive on a mileage basis. The octane of ethanol, however, is about 30 percent higher than regular gasoline and about 7 percent higher than MTBE (methyl tertiary butyl ether), a primary competitor in the octane enhancer market. Octane enhancers such as MTBE tend to sell at about 40 percent higher than the price of gasoline. Thus, ethanol's value as an octane enhancer is considerably greater than the value of gasoline. The value of ethanol in the market should reflect the combined characteristics, with its selling price between its value as a fuel extender and as an octane enhancer.

Figure 4 illustrates the difference in ethanol's value as an octane enhancer and as a fuel extender. Market recognition of ethanol's octane value should increase the price blenders

Figure 4
Ethanol value: Octane enhancer versus fuel extender



* As an octane enhancer, ethanol is assumed to compete with MTBE at 40% over the cost of gasoline.

3/ Blended at 10 percent, ethanol would reduce mileage by 3.4 percent as a result of lower Btu content. Improvements in combustion due to the octane boost would be expected to offset this decline. Test results have shown results including a 0.5 MPG loss to a slight improvement in mileage (RFF). A DOE study found vehicles using alcohol/gasoline blends average 4.7-percent mileage reduction (Tosh).

will pay for ethanol. The difference in value can be significant. For example, in the early 1980's, when gasoline and MTBE prices were high, the value of ethanol as a fuel extender was about $0.75 per gallon, implying that ethanol was competitive as an extender if it sold for $1.35 with the Federal excise tax exemption and up to $1.75 in States with additional subsidies. As an octane enhancer, ethanol's value was about $1.50 per gallon, allowing it to be competitive at a price of $2.10-$2.70 with the subsidy. As of September 1987, the value of ethanol as a fuel extender had fallen to about $0.35 per gallon, whereas its value as an octane enhancer was about $0.75 plus subsidies.

The current ethanol subsidy structure places some limits on taking full advantage of ethanol as an octane enhancer. Because of ethanol's high octane value, normally available gasoline grades do not require a 10-percent blend to achieve a high octane fuel. But, the 10-percent blend is required to take advantage of the Federal and most State excise tax exemptions. A Federal income tax credit can be taken in lieu of the direct excise tax exemption allowing tax incentives for varying blend ratios. Reasons cited as to why this credit has not been used effectively are that the blender must have taxable income to realize the credit, and the blender does not, in any case, receive the credit until income taxes are filed.

Compatibility with Current Vehicles and the Fuel Distribution System

Ethanol and competing fuel blending agents have different effects on vehicle performance, vehicle emissions, and the fuel distribution system (table 7). Four vehicle performance considerations are associated with ethanol: warm weather stalling due to high fuel volatility, clogging of the fuel filter, phase separation of the fuel in the presence of water, and vehicle fuel mileage. Except for phase separation in a limited set of vehicle fuel applications, most vehicle manufacturers do not recommend against alcohol-blend fuels. In all cases, vehicle manufacturers honor vehicle warranties if ethanol-blend fuels are used, recommending that vehicle operators switch to straight gasoline if they experience problems. Chrysler, while honoring warranties, recommends against the use of ethanol-blend fuels (RFF, 1987).

If base-stock gasoline meets existing volatility standards, the 0.5- to 1-pound increase in Reid vapor pressure due to ethanol blending at 10 percent is unlikely to result in vapor lock and stalling. No enforcement mechanism of the voluntary volatility standards exists, and some gasoline reportedly exceeds the standards. EPA is currently involved in rulemaking that will create mandatory volatility standards. The proposed standards consider a 1-pound Reid vapor pressure addition for ethanol fuels blended at 10 percent (EPA, 1987c).

The potential for fuel filter clogging in first-time use of the blend in older vehicles is widely recognized. Ethanol is a solvent, cleaning residues that normally accumulate in vehicles using straight gasoline. When these residues break loose, they are captured in the fuel filters present in all vehicles. Clogging of the filters prevents fuel from being supplied to the engine. If such clogging occurs, it typically requires a one-time filter change. The chance of sufficient accumulation to cause fuel filter clogging is low in newer cars.

Phase separation of blended fuel in the presence of water has been implicated in more severe problems. Under normal operations of most vehicles, where the vehicle is operated regularly, phase separation is not a concern. In recreational vehicles (RV's), some gasoline-powered farm vehicles, and similar applications where the vehicle might sit idle for several months, water is more likely to accumulate. In extreme cases, blended fuels have been cited as the cause of deterioration in plastic fuel lines that rupture under operation and lead to vehicle fires. This problem has led to a general warning by some RV and boat

Table 7 -- Characteristics of octane enhancement strategies

Characteristics	Increased refinery severity	MTBE	Ethanol	Methanol
Vehicle compatibility performance	Fuel injector fouling; requires detergent additives. Gasoline naturally somewhat corrosive requiring addition of anticorrosive additives.	Negligible effects on relevant fuel characteristics (volatity, phase separation). No vehicle performance problems identified.	Increased volatility can contribute to warm weather engine stalling; should not be a problem if gasoline blend stock meets volatility standards.	Not with current vehicle fleet without a cosolvent. TBA/ methanol blends are widely used in Europe.1/
			Fuel filter clogging due to solvent action for first time use of ethanol in older vehicles.	Lower Btu content than ethanol.
			Phase separation in the presence of water. Some manufacturers advise against use of ethanol blends in vehicles that stand idle (for example, recreational vehicles).	
			Due to lower Btu content per gallon, vehicle mileage may be lower.	
Carbon monoxide (CO) emissions	No benefits	An oxygenate, reduces CO.	An oxygenate, reduces CO.	An oxygenate, reduces CO.
Volatility (hydrocarbon emissions, ozone.)	Increases lighter gasoline fractions but able to meet EPA volatility standards.	Negligible effect on volatility.	A 10% blend increases volatility by 1/2 to 1 lb. Reid vapor pressure. The increase is currently exempt from EPA standards. Meeting standards with ethanol blending would require lowering the base gasoline volatility.	Greater volatility increase than ethanol.
Fuel distribution system	No modification in fuel distribution system required.	No modification in fuel distribution system required.	Concern regarding phase separation in the presence of water that is likely to exist in pipelines, service station tanks. Assure that service station tanks are clean and dry prior to converting to ethanol blends. Blends must be physically separated in pipelines.	Methanol less water tolerant than ethanol unless blended with a cosolvent.

1/ TBA = tertiary butyl alcohol.

manufacturers against using blended fuels in such vehicles. Recent tests with outboard motors on boats where fuel was allowed to sit for months did not reveal any problems. MTBE has not been associated with poor vehicle performance. Furthermore, it does not suffer from the phase separation problem associated with ethanol blends and is, therefore, fully compatible with existing fuel delivery systems.

The Economics of Octane Enhancement

Most observers agree that, in the United States, with the existing Federal and State ethanol excise tax exemption, ethanol and MTBE are the primary competitors on a cost basis for octane requirements that are not met through increased refinery severity. The increasing role of oxygenates in regional air quality plans may contribute further to the desirability of ethanol and MTBE. Methanol combined with cosolvents, allowed in fuel supplies under the Dupont Waiver, while test marketed in the United States, has not seen extensive marketing. Such methanol/gasoline blends using TBA (tertiary butyl alcohol) as a cosolvent are marketed widely in Europe. If oxygenates become important in regional air quality plans as a way to meet carbon monoxide emission standards, blends allowed under the Dupont Waiver, including methanol/ethanol/gasoline, could play an important role. MTBE and ethanol production capacity alone could be insufficient to meet oxygenate demand in the short term. Methanol blends are, however, not currently exempt from proposed fuel volatility standards as is ethanol when blended at 10 percent.

The costs of competing octane enhancers will depend on several highly uncertain variables including the price of crude oil, the price of methanol as an ingredient of MTBE, and a combination of excess supplies of certain products and shortages of others. Crude oil prices briefly dropped to near $10 per barrel during 1986 but have recovered to about $20 per barrel. In the early 1980's, oil prices were predicted to be $60-$100 per barrel by the 1990's or earlier. DOE has recently warned of potentially tighter supplies, but few analysts currently predict prices above $30 per barrel by the mid-1990's (DOE, 1987).

The glut in crude oil and petroleum refining capacity has forced refiners to price their products, some of them octane enhancers or octane-enhancing ingredients, below full-cost recovery. Refineries are very flexible in determining their product mix, but demand for gasoline and distillate oils tends to be the driving force behind refinery operations. Managers then price other products at the level the market will bear.

Methanol production is similarly glutted by large expansions of capacity in the Middle East as oil-producing countries have attempted to make use of natural gas, associated with oil production, that would otherwise be vented or flared. Countries without direct markets for natural gas will continue to be low-cost producers of methanol for many years.

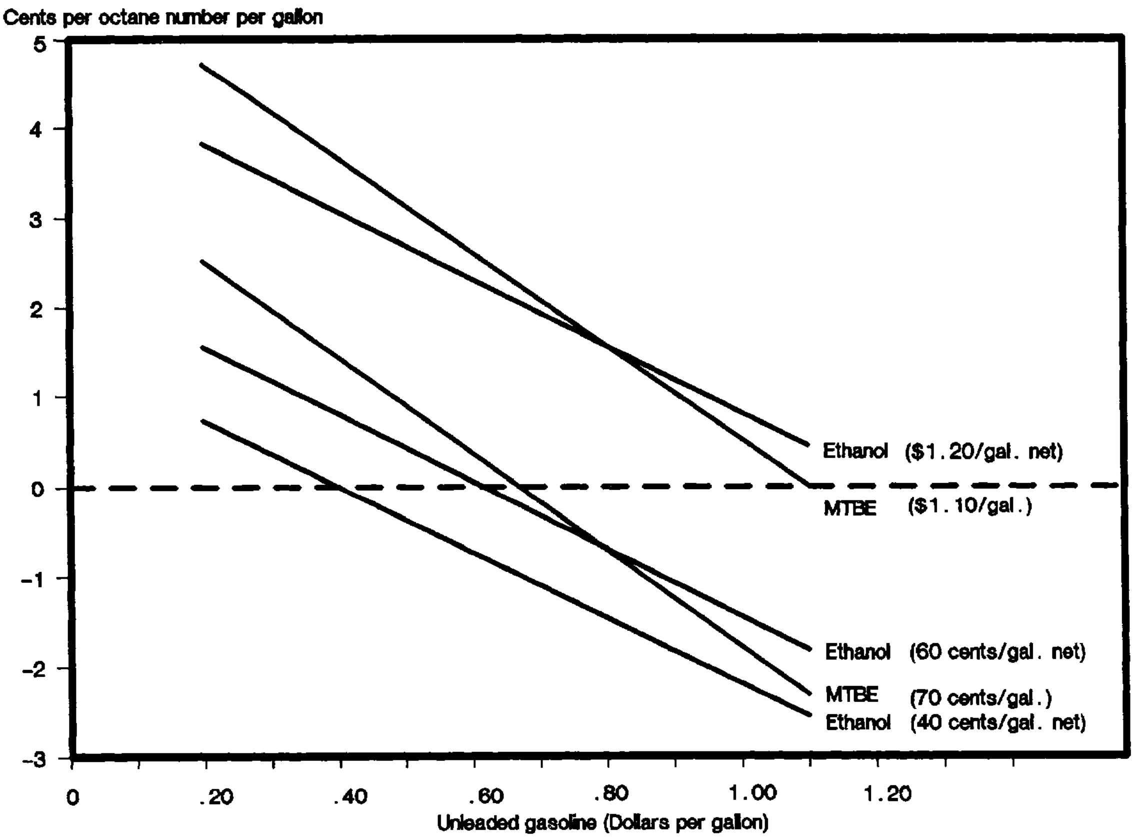
Coexisting with the excess refinery capacity is a shortage of severe refining capacity able to meet octane demand. Earlier estimates suggested that, during 1982-93, refiners would face an average octane deficit of about 3.2 octane points per gallon from the combined effects of the lead phase-down and increased demand for premium grades of unleaded gasoline (Pierce and Bansal, 1986). The shortage of octane-enhancement capability combined with changing refining technology and new octane-enhancing ingredients have allowed a variety of octane-enhancing additives to garner a share of the market. Increased refining severity, supplemented by ethanol and MTBE, will generate most of the required octane improvement.

There are 37 MTBE plants worldwide producing an estimated 107,000 barrels per day (Ludlow, 1987). Another 27 plants are planned with a production capacity of 107,000 barrels per day. MTBE production costs are sensitive to the price of methanol and butanes from which isobutylene is frequently derived. Therefore, most expansion of MTBE capacity will probably be outside the United States and Europe, taking direct advantage of low-cost methanol supplies and increased refinery capacity in oil producing regions.

Reliance on MTBE as an octane enhancer represents further dependence on uncertain foreign suppliers. If MTBE were produced from domestic methanol derived from U.S. coal, methanol prices would likely double, making ethanol relatively more attractive. For example, doubling the price of methanol from 30 cents per gallon to 60 cents per gallon would increase the cost of MTBE by 62 percent.

Figure 5 illustrates the close competition between MTBE and ethanol under conditions that will probably exist over the next 5-10 years. If unleaded regular gasoline sells at $0.60 per gallon, ethanol selling for $1.20 per gallon and blended at 10 percent is less expensive than MTBE when the Federal subsidy of $0.60 per gallon is considered. MTBE currently sells for roughly $0.70 per gallon. The difference between ethanol and MTBE is increased with a State tax exemption. The ethanol blending cost is negative in some gasoline price ranges, reflecting the fact that the additive is less expensive per gallon than gasoline and offers a relatively cheap way to extend gasoline volume. MTBE and ethanol are also closely competitive if the Federal subsidy for ethanol expires and methanol prices double as might occur if methanol were produced at full cost from domestic coal.

Figure 5
Octane-enhancement cost relationships: MTBE versus ethanol



The close cost relationship between the two additives suggests that refiners who have committed to MTBE by producing it internally will continue to use it rather than purchase ethanol even though MTBE is slightly more expensive. Refiners also have not had particularly strong incentives to incorporate ethanol into their marketing or distribution systems. Ethanol transported in existing pipelines would have to be physically separated from gasoline to minimize the possibility of phase separation in the presence of water. The small volumes and cost advantages of ethanol have not provided sufficient incentive to encourage refiner/distributors to undertake such shipments on a large scale. Independent fuel distributors who do not use pipeline transport of fuel and must purchase high octane blending agents are likely to continue to be the primary customers for fuel-ethanol.

INDUSTRY EXPANSION AND COMPETITIVENESS WITH PETROLEUM

In the next 5-10 years, most ethanol in the United States is likely to be produced from grain. Considerable expansion of the industry can occur at a savings over construction of new production facilities by expanding production at existing ethanol plants, by adding ethanol production capability at existing corn wet mills, and by converting abandoned industrial plants. Whether industry expansion occurs depends on the cost competitiveness of ethanol as a gasoline blending agent. Both petroleum prices and factors affecting the net cost of ethanol such as the corn prices, Federal and State ethanol subsidies, byproduct prices, and the technology are subject to uncertainty and variability.

Industry Expansion

Current industry plans are for only modest capacity expansion at existing sites despite a relatively high return to ethanol production as of the first half of 1987. Subdued interest in capacity expansion has been attributed to the expiration of the motor fuel excise tax exemption in 1993 combined with expectations of only modest increases in world petroleum prices. However, the industry would considerably expand production capacity if it were reasonably assured that the currently favorable conditions would continue through 2000. Some combination of higher petroleum prices, extension of the excise tax exemptions, low corn prices, and high byproduct prices would generate favorable conditions. Without extension of the excise tax exemption to the year 2000, petroleum prices would have to increase to at least $40 per barrel, with corn prices remaining at less than $2.50 per bushel for profitability to be reasonably assured. Most producers do not expect petroleum prices to rise to these levels and, therefore, extension of the excise tax exemption appears necessary to elicit further industry expansion.

Many abandoned industrial facilities could be converted to ethanol plants. Abandoned corn wet mills in Morrisville, Pennsylvania, and Montezuma, New York, built in the 1970's, are prime expansion sites for ethanol because they are near the Northeast gasoline market. This market has not yet been penetrated by ethanol blends because of the cost of transporting ethanol from Midwest plants and the lack of State incentives. In addition, 24 abandoned oil refineries in the Midwest are located near the major corn markets. Distillation capacity of these refineries is 17 billion gallons per year, compared with ethanol production-distillation capacity of 1.1 billion gallons per year. An oil refinery in Louisiana has been successfully converted to ethanol production. Other sites with potential for conversion to ethanol production include fertilizer plants, chemical plants, and breweries.

Substantial investment will be required to convert abandoned industrial plants, but savings over building a new plant from the ground up will exist for a substantial number of sites.

The best sites will require an investment of about $1.75 per installed gallon to acquire and upgrade, compared with estimates of $2.00-$2.50 for a new plant. Use of the sites is likely to require tradeoffs between saving large parts of the facility and incorporating state-of-the-art design. Even if most of the facility must be razed, new site requirements such as construction of railroad siding, vehicle access, power lines, and zoning requirements can be avoided at investment savings of $0.30-$0.40 per gallon of installed capacity.

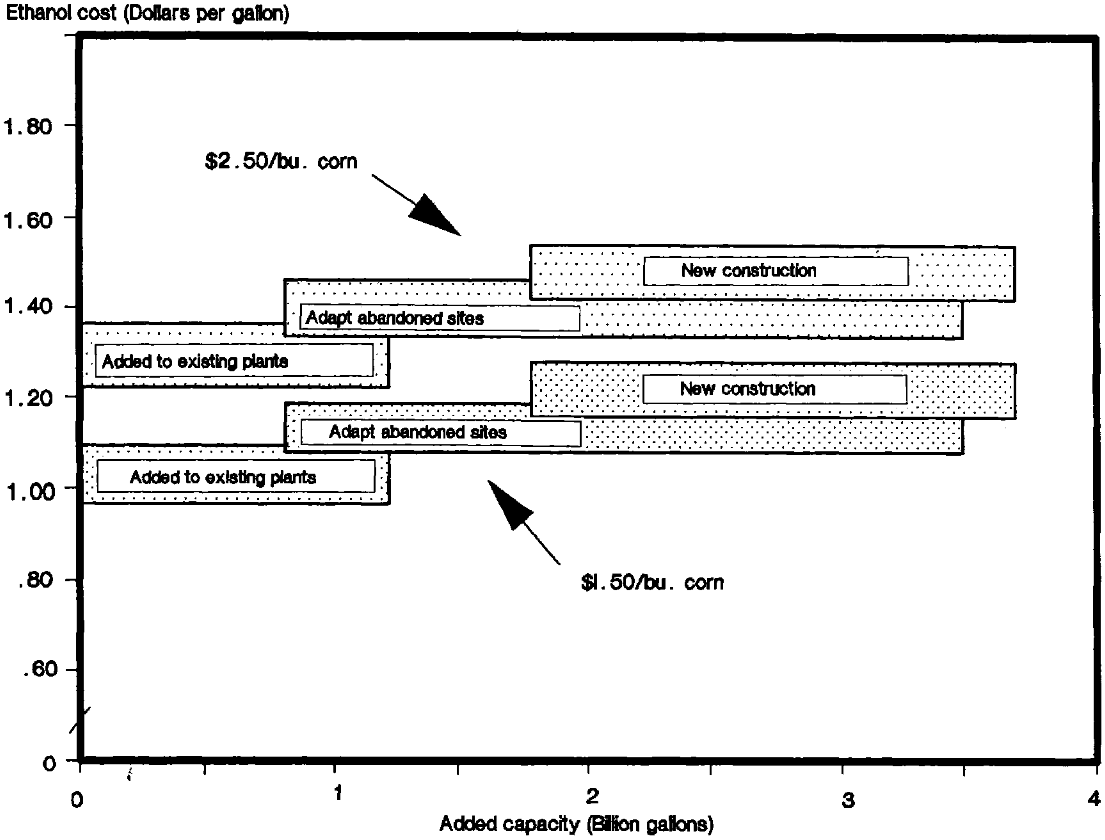
Figure 6 provides approximate longrun supply expansion potential for the industry, representing the ability of producers to make use of existing excess industrial capacity. On the order of 1 billion gallons of ethanol capacity may be available through additions to the 15 existing wet mills without such capacity and through incremental additions of capacity to existing ethanol production facilities. With corn at $1.50 per bushel, the full cost of ethanol production before subsidies would be roughly $1.00 per gallon, assuming byproduct cost recovery of 50 percent. With corn at $2.50 per bushel, ethanol costs would be roughly $1.30 per gallon. Adapting the best of abandoned industrial sites could easily add another 1-2 billion gallons of capacity or more at ethanol production costs of $1.15-$1.40, depending on corn prices. Fully new ethanol plant construction will be limited to geographic areas of strategic marketing interests such as favorable State subsidies or proximity to grain or ethanol markets where industrial sites are unavailable. Production costs at these sites will range from $1.20-$1.45, depending on corn prices.

Cost Competitiveness with Petroleum

Ethanol competes with gasoline and gasoline blending agents. The prices of gasoline and gasoline blending agents are closely tied to an uncertain price of crude oil. The greatest variability in future ethanol costs will result from variability in the price of corn or other

Figure 6

Ethanol costs and industry capacity expansion



feedstock. An additional uncertainty is introduced by the future status of the Federal subsidy for ethanol through the fuel excise tax exemption. The effect of these factors on the competitiveness of ethanol is displayed in figure 7. The basic assumptions are that a new state-of-the-art plant is used to produce ethanol with byproduct recovery of 50 percent of the cost of corn. Ethanol is assumed to compete on a direct cost per gallon basis with gasoline. Wholesale gasoline sells at 25 percent over crude oil prices. The assumption that ethanol competes on a direct cost per gallon basis reflects a middle position between decreasing the value and competitiveness of ethanol on the basis of its lower Btu level and increasing its value on the basis of its higher octane value. The figure does not include the contribution of State subsidies which contribute to ethanol competitiveness in some States.

With $2.00 per bushel corn and the Federal subsidy, ethanol is competitive with crude oil prices at a level of $20 per barrel. Without the subsidy, crude oil prices would have to rise to at least $40 per barrel. Without the subsidy, there is no corn price that would make ethanol competitive with crude oil prices below $25 per barrel as long as the byproduct credit does not exceed the cost of the corn.

The cost savings due to use of existing wet-mill capacity or industrial sites can be similarly represented (fig. 8). With $2 per bushel corn and the Federal subsidy, the use of existing industrial sites results in ethanol competitiveness at $18 per barrel crude oil. With additions to existing wet mills, ethanol is competitive at $13 per barrel crude oil.

The state-of-the-art plant illustrated in the previous two figures represents an improvement over the average existing technology and has, therefore, enhanced the competitiveness of ethanol (fig. 9). With $2 per bushel corn and the Federal subsidy, ethanol is competitive

Figure 7

Ethanol breakeven curve: Effect of subsidy (State-of-the-art new plant)

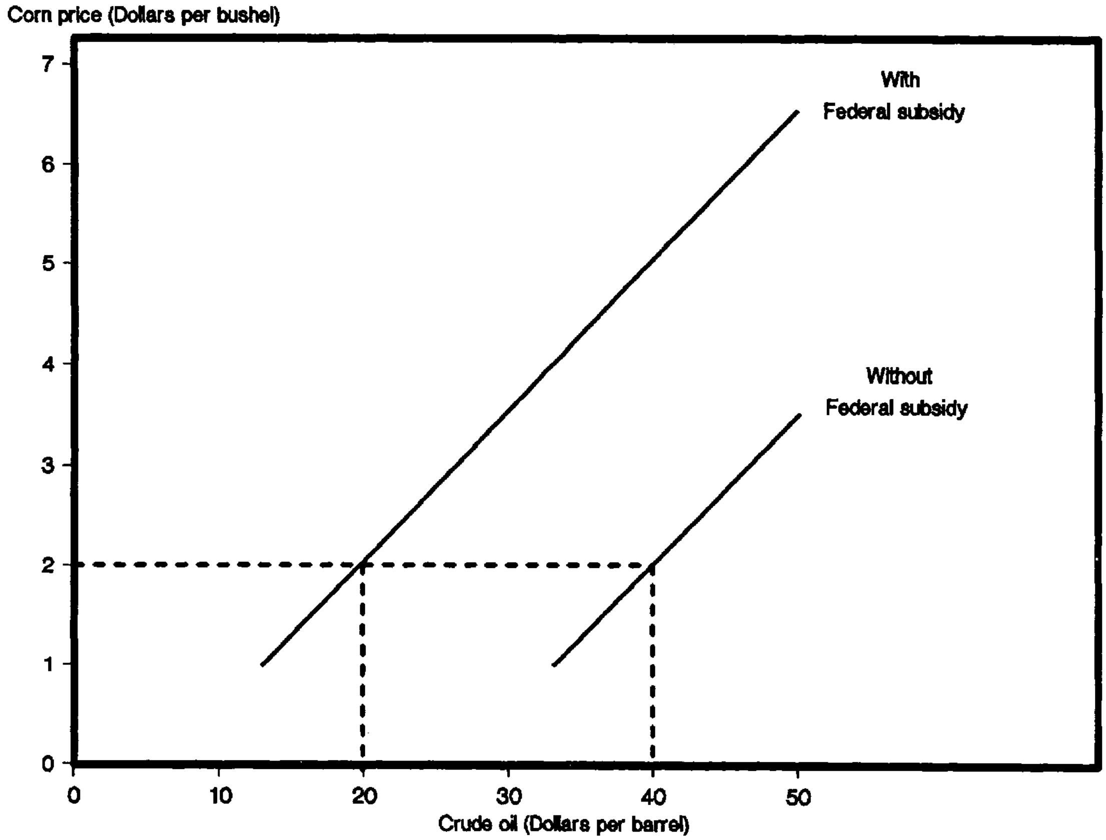


Figure 8
Ethanol breakeven curve: Expansion options (With Federal subsidy)

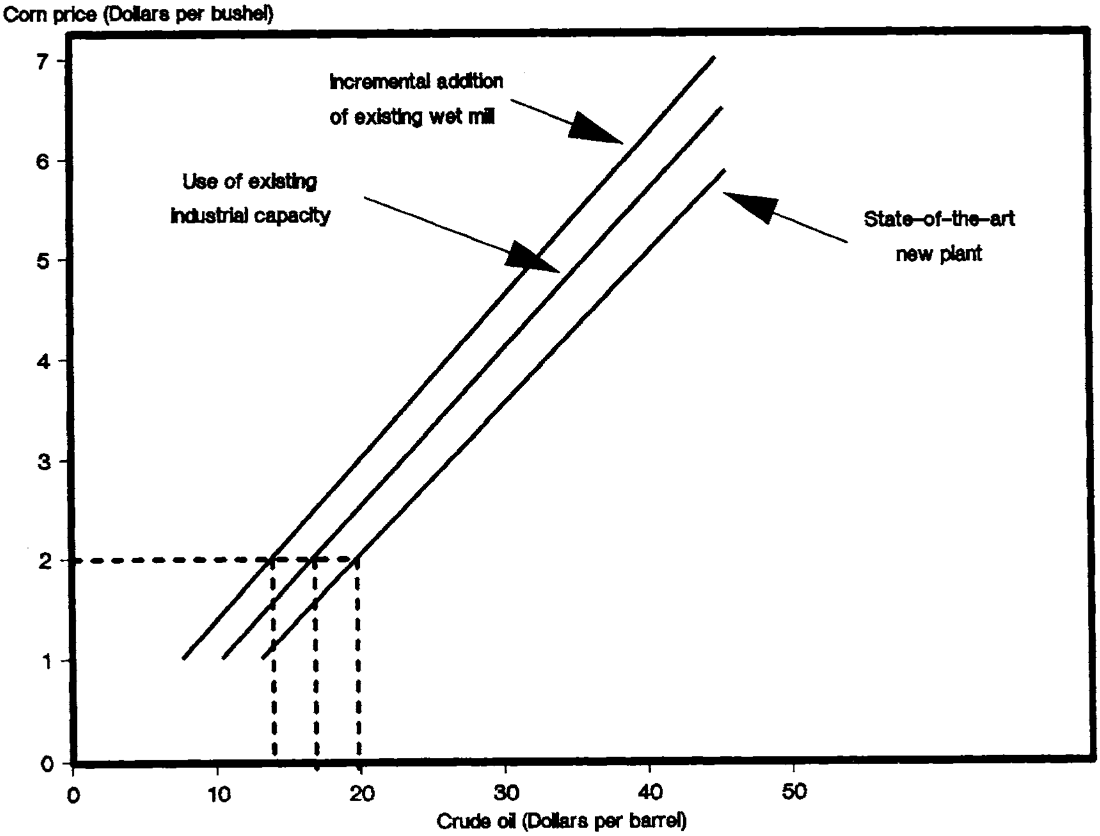
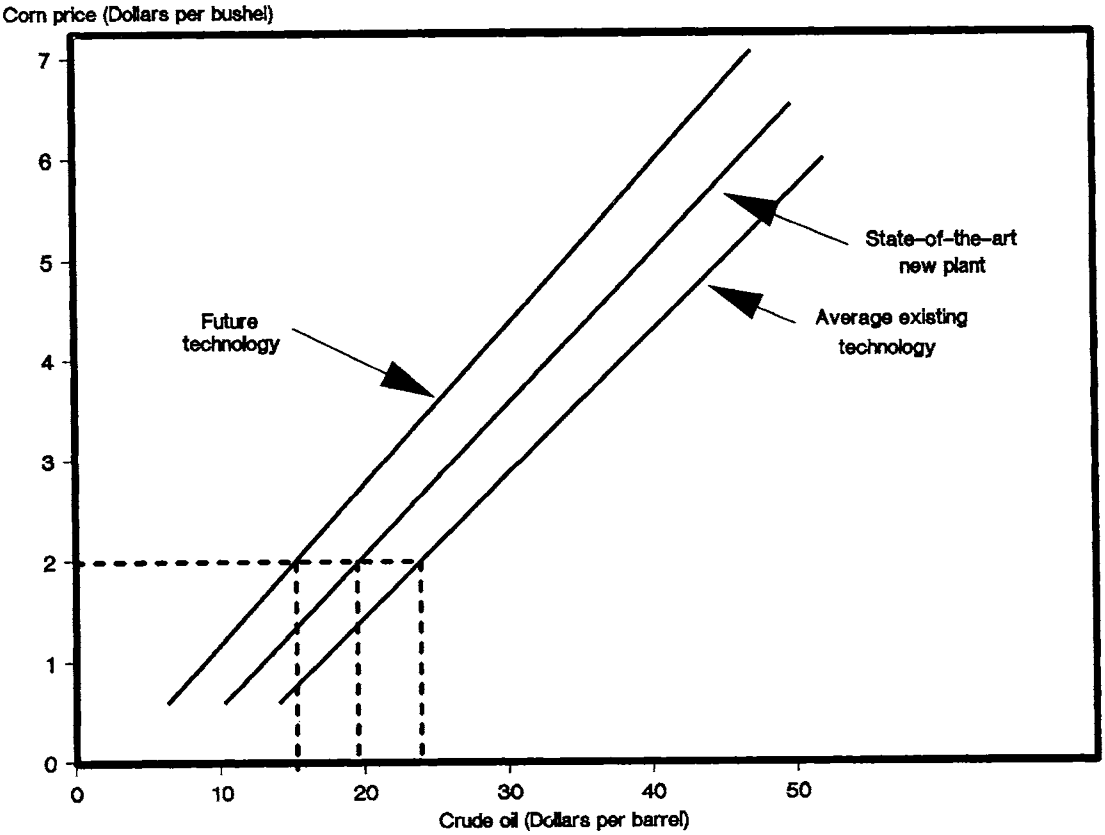


Figure 9
Ethanol breakeven curve: New technology (With Federal subsidy)



using average existing technology with crude oil at $22-24 per barrel, compared with $20 per barrel with state-of-the-art technology. Further improvements in the next 3-5 years could make ethanol competitive at $18 per barrel crude oil.

Under the current conditions and using a state-of-the-art plant, ethanol is competitive as a fuel blending agent. Major expansion of the industry is not occurring at this time because the favorable existing conditions are unlikely to continue long enough to recoup capital investment except for inexpensive additions to already operating ethanol facilities. In general, industry expectations include continued low corn prices and modest increases in crude oil prices, both favoring ethanol industry expansion. The major expected negative effect on ethanol competitiveness is the expiration of the Federal excise tax exemption in 1993. A plant planned today, under expectations common in the industry, would begin operating around 1990, operate profitably for 3 years, and suffer losses at least through 2000. If corn prices remained low the plant could regain profitability after 2000 as crude oil prices rose.

ETHANOL IN U.S. ENERGY POLICY

The primary goal of U.S. energy policy is to assure both short-term and long-term energy stability. This policy goal has generally been called "energy security." Major policy initiatives for long-term energy security have been aimed at research and development and at assuring timely commercial production of alternative fuels based on plentiful domestic resources such as coal and shale oil. Policy initiatives for short-term energy security have been aimed at minimizing the effects on the U.S. economy of global energy market disruptions. Energy policy, in attempting to foster energy security, has led to large subsidies to all energy industries including ethanol.

Energy Security

Energy security includes both the ability of the United States to defend itself in time of war and such broader concerns as the ability of foreign countries to exert control over U.S. policy by withholding or threatening to disrupt energy supplies. Energy independence or reduced dependence on foreign supplies and strategic fuel stockpiles represent two broad policy responses to energy security concerns. Ethanol subsidies, by encouraging ethanol production, reduce foreign oil dependence. Congressional authorization of a Strategic Alcohol Fuel Reserve (SAFURE) in 1982, while not yet implemented, offered a fuel stockpile approach for ethanol policy.

Energy independence or reduced dependence has limited energy security value. The Project Independence response to the 1973-74 embargo attempted to move the United States toward energy independence. Energy independence gained by forcing consumption of relatively expensive domestic fuels retards economic growth by raising energy expenditures at the expense of savings and investment. A less vigorous economy may compromise national security in the longer run. Energy independence also would hasten the depletion of domestic nonrenewable natural resources, leading to either a return to energy dependence or rising costs of maintaining independence. In this sense, switching to a domestic renewable resource like ethanol or an abundant resource like coal is preferable to merely switching to domestic petroleum and natural gas.

Even with energy independence, international energy shocks would reduce global income and output which would affect the United States through international trade (DOE, 1987;

Hickman, Huntington, and Sweeney, 1987). Lower income abroad reduces demand for U.S. exports, hurting domestic export industries and inducing ripple effects throughout the U.S. economy. Recognizing that an oil price shock or an embargo would not just affect a single country, member nations of the Organization for Economic Cooperation and Development (OECD) including the United States, through the International Energy Agency (IEA), have pledged to support one another in the case of an embargo or similar international fuel disruption.

Fuel stockpiles offer the most effective energy security strategy. Whereas a domestic industry producing at full capacity can do little in the short term to respond to a supply disruption, fuel reserves can be released relatively quickly, giving the economy and domestic energy industries time to respond to the supply disruption. Excess production capacity or the ability of energy consumers to reduce fuel consumption quickly or easily switch to other fuels offers similar advantages during supply disruption.

Since Project Independence, creation of the Strategic Petroleum Reserve (SPR) has been the primary U.S. response to energy security threats. The congressionally authorized SAFURE was found by DOE (1982) to be more costly than an equivalent increase in the SPR. A subsequent study (GAO, 1984) noted the importance of assumptions concerning the value of government-owned stockpiles of corn. The GAO study stated that a "fuel ethanol reserve [is] probably feasible but [its] cost effectiveness is questionable." However, GAO concluded that "cost elements of either existing programs or the SAFURE option are not sufficiently developed to be conclusive." A SAFURE, not yet implemented, continues to be examined.

Ethanol Production and Military Fuel Needs

The United States is in a good position to supply military operations from domestic energy resources. Military operations account for only 2-3 percent of domestic petroleum consumption; more than 60 percent of that demand is for jet fuel. In a large-scale conventional military conflict, military demand would double or triple but still remain only a small share of total U.S. use (DOE, 1987). During a war military operations would have priority over domestic operations.

Beyond the direct supply of the military, energy supplies to defense-supporting industries during a large-scale, protracted military operation is a potential concern. The largest share of petroleum will continue to be consumed as gasoline in personal automobiles. Automotive use could be reduced significantly during wartime through mandatory car-pooling, increased use of public transportation, or direct fuel allocations. Fuel saved in this manner would be diverted to supply industry and other necessary uses. Even a relatively modest fuel savings of 10-15 percent of petroleum use in the transportation sector through such actions is 30-40 times current ethanol production.

U.S. Energy Dependence

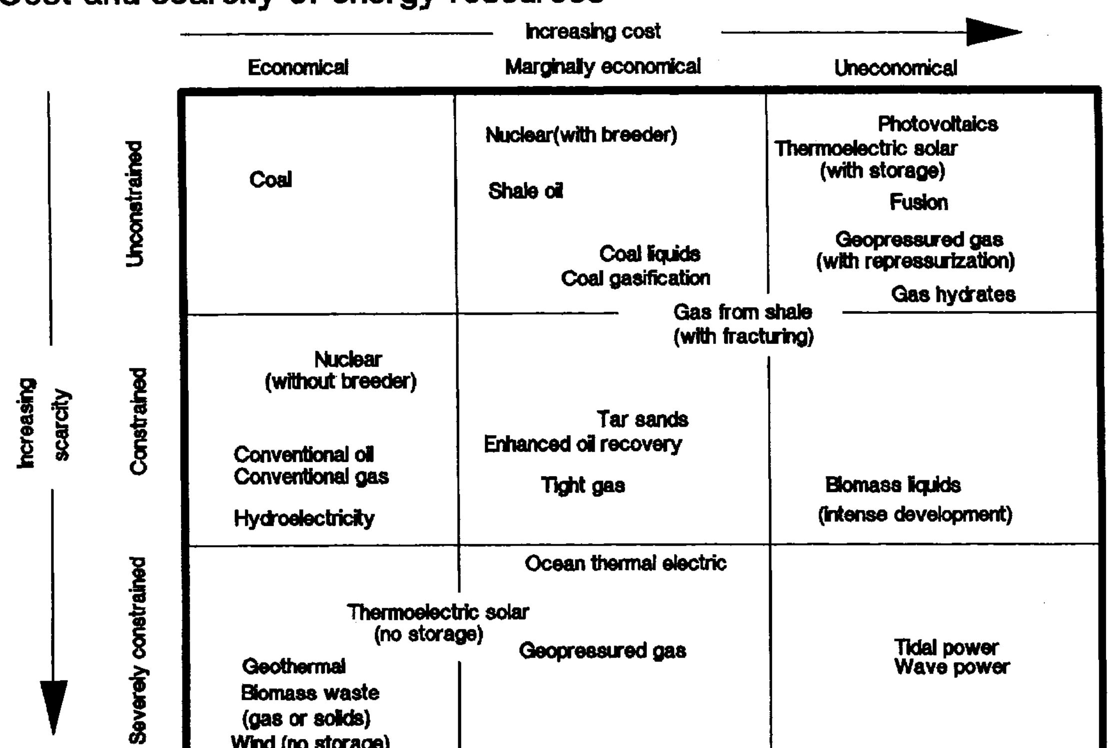
While energy independence has limited value pursued for its own sake, the development of cost competitive fuel-producing industries through research, development, and commercialization of promising technologies offers significant advantages for overall U.S. competitiveness. Successful energy industries based on U.S. coal or shale oil resources could result in the United States becoming a net energy exporter in the next century as conventional petroleum supplies dwindle abroad. Current support for ethanol, synfuels, and other advanced energy technologies can be evaluated from this perspective.

The relative level of support that can be justified for individual fuel-producing technologies depends on the potential supply available, accounting for both the quantities of fuel and the prices at which the fuel would be available. Biomass fuels generally do not compare well with future cost and quantity estimates for many other technologies (fig. 10). Liquid fuels from coal and shale oil appear likely to be less expensive and are essentially available in unconstrained quantities for the next 100 years or more. Tar sands and further efforts at enhanced oil recovery, while somewhat limited in terms of quantity, can provide a significant contribution to conventional oil production.

A closer comparison (fig. 11) indicates that ethanol generally is expected to cost more than other competitor liquid fuels such as shale oil and liquids from coal. But, the comparison also indicates considerable overlap of the estimated cost ranges. A significant difference in these cost ranges exists. Fuel ethanol production, while still a relatively new industry, is operating commercially, yielding relative certainty about the cost of the conversion technology compared with that of coal liquids and shale oil. The cost range for ethanol represents uncertainty and future upward pressure on ethanol feedstocks. The development of crops or silviculture that produce high levels of dry matter per acre combined with further breakthroughs in cellulosic conversion processes could lower feedstock costs if grain prices rise. The cost of large-scale scenarios of biomass use would, however, remain high in terms of traditional inputs and in terms of disruptions of the environment through increases in land under cultivation (Edmonds and Reilly, 1985). The more successful ethanol is in contributing to long-term energy supplies, the more it will drive up feedstock prices and its own cost of production. Thus, ethanol production tends to limit itself to the role of a small fuel contributor using temporary agricultural surpluses and organic waste.

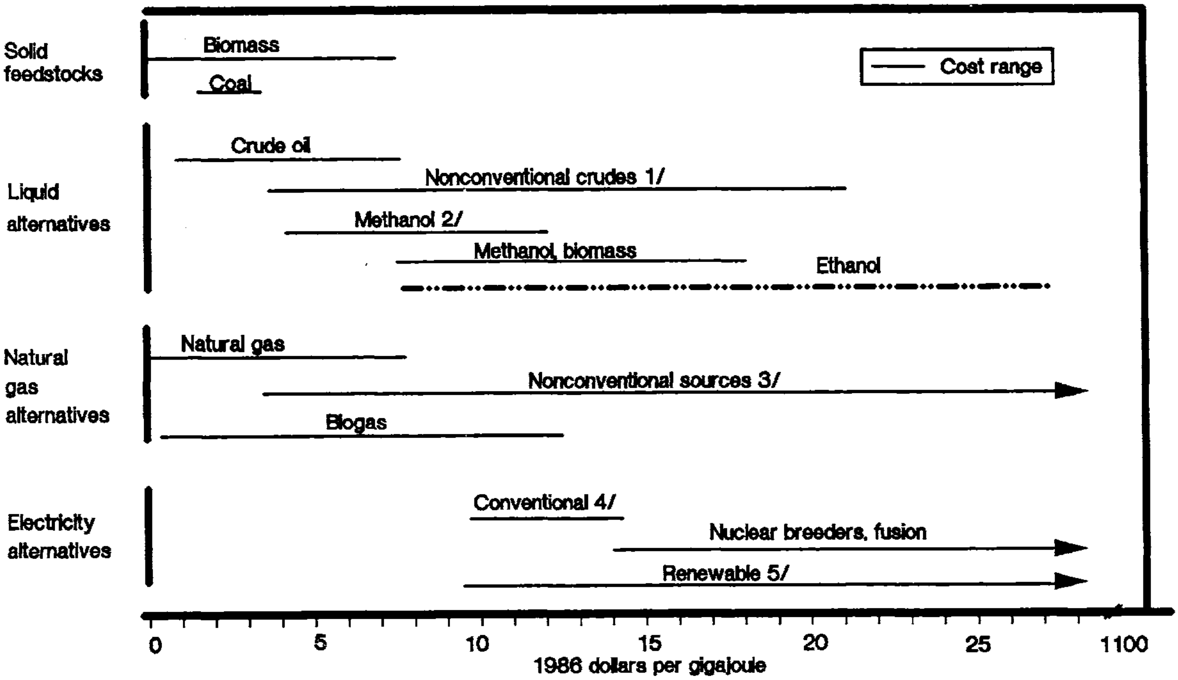
Figure 10

Cost and scarcity of energy resources



Source: Edmonds and Reilly, 1985.

Figure 11
Costs of fuel alternatives



1/ Enhanced oil recovery, shale oil, coal liquefaction.
2/ Natural gas, coal, shale as feedstocks.
3/ Tight gas, coal seam gas, devonian shale, coal gas, geopressured gas.
4/ Electricity generated from coal, nuclear, oil, or gas.
5/ Wind, ocean thermal electric (OTEC), thermal solar, photovoltaics low-head hydro.
Source: Adapted from Edmonds and Reilly, 1985.

Energy Subsidies and Fuel Ethanol Competitiveness

Public-sector support for the ethanol industry depends, not on the fuel's market price, but on national interest in producing and using the fuel. Supporters of ethanol point out however, that the level of ethanol subsidies should be compared with the level of subsidies received by competing fuels. Fuel prices are, however, set by worldwide supply and demand conditions. Domestic U.S. policies have a negligible effect on world prices making ethanol's price competitiveness as a fuel a separate issue from subsidies for other fuels.4/ Domestic subsidies, however, support a domestic industry with the presumed intent to foster energy security.

The Federal Government has provided large subsidies for development of all energy resources. Available estimates for 1977 and 1984 are reported in table 8. The major source of energy industry subsidies are tax incentives rather than direct budget outlays. The accelerated cost recovery system (ACRS) and the investment tax credit (ITC) which were available to all industries were a major component of the subsidies estimated for 1984. The subsidy effect is greater for the more capital-intensive energy industries, especially nuclear and hydroelectric power production. Tax incentives for investment have changed dramatically for 1987 and beyond with passage of the Tax Reform Act of 1986, eliminating the ITC and the ACRS.

4/ The Treasury Department emphasized this result in its published comments on the GAO analysis (GAO, 1984, pp. 66-69).

Table 8 -- Energy incentives and production (1986 dollars)

Energy resource/technology	1977 Incentives	1977 Production	1984 Incentives	1984 Production
	Million dollars	Quadrillion Btu's	Million dollars	Quadrillion Btu's
Crude oil and NGL	21,307	17.315	496	20.957
Natural gas	-1,467	21.907	4,953	17.750
Coal	1,843	15.926	3,664	19.696
Synthetic fuels	1/	0	692	0
Nuclear	2,820	.856	17,013	1.11
Fusion	1/	0	651	.0
Electricity 2/	8,101	7.247	7,689	6.002
Hydroelectric	610	.752	2,823	1.096
Other renewable resources 3/	ND	0	1,822	2.929
Energy conservation	ND	ND	928	ND

1/ Not separately identified.

2/ There are some differences in the 1977 and 1984 categories. For 1984, electricity broken down by fuel, including nuclear, hydroelectric, and fossil. For 1977, specific nuclear- and hydro-related expenditures are identified.

3/ Including ethanol.

ND = Not defined.

Source: Cone and others, 1980; Heede, 1985.

More direct energy subsidies include intangible drilling expenses and depletion allowances for oil, coal, and gas; various guaranteed loan programs for energy development; Federal involvement in power generation; the alternative energy investment tax credit (EITC) for energy production facilities other than oil, coal, gas, nuclear, or conventional hydroelectric power; and residential energy conservation and renewable tax credits. Most of these have been eliminated or are being phased out as a result of tax reform.

Federal and State motor fuel excise tax exemptions make up the bulk of tax subsidies for ethanol (table 9), although the tax treatment of depreciation and investment has provided significant subsidies. The investment credits are one-time credits on a plant that may operate for 30 years, whereas the excise tax exemptions are annual subsidies to production as long as the exemptions are allowed. The ACRS benefits also represent the discounted value of the benefit over the asset's life, making the reported figures comparable to the investment credit incentives. Tax reform eliminated ITC and ACRS tax incentives for ethanol plants as it did for other energy industries. The energy investment tax credit for alcohol fuels was kept through 1987, but eliminated thereafter. The Federal

Table 9 -- Estimated ethanol industry tax expenditure

Year	Investment credits and accelerated cost recovery schedule (ACRS) 1/: Added capacity	Investment tax credit (ITC)	Energy investment tax credit (EITC)	ACRS over economic depreciation	Motor fuel excise tax exemption: Federal	State	Total	Domestic production: Volume	Energy content
	Million gallons	Million dollars						Million gallons	Quadrillion 2/ Btu's
1979	60	9.6	9.6	17.5	-	-	36.7	20	0.002
1980	120	19.2	19.2	35.1	32.0	28.0	133.5	40	.003
1981	200	32.0	32.0	58.5	34.0	29.8	186.3	75	.006
1982	215	34.4	34.4	62.9	63.6	81.9	307.2	210	.018
1983	105	16.8	16.8	30.7	210.0	155.1	412.6	375	.032
1984	140	22.4	22.4	40.9	284.0	198.5	568.2	430	.036
1985	40	6.4	6.4	11.7	476.0	277.6	778.1	625	.053
1986	220	35.2	52.8	64.3	480.0	280.0	912.3	750	.063

1/ Assumptions: Capital investment costs of $2 per installed gallon, 80 percent of investment eligible for ITC and EITC, ACRS income tax advantage over economic depreciation calculated as the difference in the present value of tax treatment of depreciation assuming straight-line economic depreciation over a 30-year economic life and a 50-percent income tax rate.

2/ 1 Quadrillion = 10^{15}.

motor fuel exemption runs through September 1993 under current law. Thus, the primary subsidy for ethanol remains in effect.

Interpretation of relative subsidy levels is controversial. Direct comparison of the total industry subsidy and comparison of the subsidy per unit of energy produced are major alternatives. If the subsidy is viewed as a means of demonstrating the viability of the technology, the level of the subsidy per current energy production is irrelevant. For example, no energy was produced from nuclear fusion or synthetic fuels in 1977 and 1984 because funds were spent for only research and development. Comparisons of crude oil, coal, and nuclear fission appear straightforward, but these aggregate categories mask R&D projects that had little or no attributable output in the year the funds were spent. Ethanol subsidies fit between the categories of R&D funds and direct subsidy. The industry contributes to current energy supplies, but remains a very young industry.

Some Federal actions favoring certain energy industries are difficult to measure and are traditionally not included in dollar estimates. Utility liability limits on nuclear accidents is one example. Estimating the subsidy value requires assessing the likelihood of a nuclear accident exceeding the liability limit. U.S. military costs in the Arabian Gulf are sometimes proposed as another such example since the U.S. military presence helps assure oil shipments. It is unclear how much of the U.S. military cost should be assigned as a subsidy of U.S. petroleum imports. The United States would likely be present in the gulf in any case to support our broader security interests, including our pledged support for allies who import petroleum from the region.

Even with the above caveats, ethanol is highly subsidized when compared with other fuels. Tax expenditures related to ethanol production were nearly $1 billion in 1986, surpassing R&D funding for synthetic fuels or nuclear fusion. The 1984 ethanol subsidy of nearly $15 per million Btu's compares with less than $1 per million Btu's for petroleum, natural gas, and coal. Subsidies for nuclear fission approach the ethanol subsidy level per unit of fuel produced.

ENVIRONMENTAL EFFECTS OF ALTERNATIVE FUELS

Renewed interest in alternative fuels has been in response to environmental concerns in many parts of the country. The ambient standards and approaching compliance deadlines of the amended Clean Air Act and a perception that using alcohol in vehicle engines may lead to "painless emission reduction" have created interest in alternative fuels.

The alternative fuels receiving the most attention are ethanol, methanol, and MTBE. Blended fuels are similar to straight gasoline which enables most vehicles to use them without modifying engine designs. However, blended fuels consist primarily of gasoline, which limits the potential benefits, both emission control and efficiency, of the additive.

The Clean Air Act, as amended, requires that concentrations of certain air pollutants not exceed the national ambient air quality standards set by the EPA. The act specifically identifies six pollutants: lead, sulfur dioxide, nitrogen dioxide, ozone, carbon monoxide, and particulate matter. The act requires States, in areas where concentrations of those six pollutants exceed the standards, to develop State implementation plans to control emission sources to meet the standards. Levels of lead, sulfur dioxide, and nitrogen dioxide are nearing the desired standards, but ozone and carbon monoxide are still serious problems in many areas (Wilson, 1987).

The link between motor vehicles and ambient levels of carbon monoxide and ozone is important because the use of alternative fuels will mainly affect motor vehicle emissions. EPA attributes 66 percent of all carbon monoxide emissions to imperfect combustion in motor vehicle engines (1987a). This percentage exceeds 80 percent in many urban areas. Motor vehicles also significantly increase the ambient ozone pollution.5/ The level of ozone-producing compounds emitted by vehicles varies considerably among cities, but the contribution of vehicles is important in determining the potential effect of fuel-based emission control programs.

The carbon monoxide standard, established in 1971, is 9 parts per million (ppm) average for an 8-hour period and 35 ppm average for a 1-hour period, not to be exceeded more than once a year. Some 81 areas of the country exceed this standard (EPA, 1987a). From 1976 to 1985, the national carbon monoxide levels declined 36 percent. The median rate of improvement has been about 5 percent per year, with 1984-85 decreasing about 10 percent (EPA, 1985). Carbon monoxide levels should continue to decline as the current Federal Motor Vehicle Control Program is implemented and as older vehicles are replaced by newer vehicles designed to emit less carbon monoxide.

5/ Ozone, although not emitted directly by motor vehicles, forms in the air by the reaction of photoreactive, volatile, organic compounds, such as hydrocarbons and nitrogen oxides in the presence of sunlight.

The ozone standard allows a maximum 1-hour level of 0.12 ppm, not to be exceeded more than three times in a 3-year period. Some 76 areas exceed this standard (EPA, 1987a). Ozone pollution is almost entirely a summertime problem, with about 96 percent of the violations occurring between May and September (EPA, 1987c). The 10-year trend for ozone levels has declined somewhat to about the mean level called for by the standard. Unlike the carbon monoxide trend, the ozone trend line is above the EPA goal throughout the 10-year period (EPA, 1985).

Carbon monoxide and ozone pollution is both a regional problem and a local problem. The principal areas with high carbon monoxide or ozone pollution levels (or both) are California (both), the Northeast corridor (both), and the high altitude/cold weather areas (carbon monoxide). EPA has implemented programs to reduce the relevant emissions (for example, the Emission Control Program for new vehicles and the New Source Performance Standards). States have also taken a number of steps to reduce emission levels. Most of these areas will probably fail to comply with the Standards' goals by the December 31, 1987, deadline, however.

Carbon monoxide and ozone levels constitute most of the pollution problem, but ozone pollution will be considerably more difficult to eliminate. The magnitude of the nonattainment problem is presently similar for both ozone and CO. Projections of attainment, however, differ. Carbon monoxide pollution is predicted by EPA to decline significantly through the end of this century as older vehicles are replaced, although there is not complete agreement on this prediction because of pollution control requirement maintenance problems. By 1995, about 80-90 percent of the urban areas currently exceeding the carbon monoxide goal should comply. Fewer than 50 percent of the urban areas now exceeding the ozone goal are expected to comply. Ozone pollution will probably worsen in the late 1990's. Emission controls on newer vehicles mainly reduce the levels of carbon monoxide, rather than ozone components. Vehicle miles traveled in urban areas will probably continue to increase, offsetting, and at some point exceeding, the reduction in the emissions of each car. Emissions of volatile organic compounds from stationary sources will also increase from general economic growth (EPA, 1987a).

Effects on Air Quality

Motor vehicle emissions are a function of the air/fuel ratio of an auto engine.6/ Gasoline-fueled cars are calibrated to operate at air/fuel ratios in which there is just enough air to combust all the fuels. The air/fuel ratio is selected to obtain the best overall emission level, efficiency, and drivability. As vehicles age, their air/fuel ratios tend to decrease and the engine uses more fuel than the optimal ratio, thereby increasing exhaust emissions (for example, carbon monoxide). Fueling a vehicle with an oxygenated blend increases the air/fuel ratio, decreasing the carbon monoxide and hydrocarbon emission levels and increasing the nitrogen oxide emission levels. This result is most apparent with pre-1981 vehicles.

Adding ethanol or methanol to gasoline increases fuel volatility and thus increases the amount of evaporative hydrocarbon emissions. At the blend levels considered (10 percent or less of ethanol or methanol), fuel volatility as measured by Reid vapor pressure (RVP) increases by 1-2 pounds per square inch (psi). Although neat (100 percent) alcohols are less

6/ Spark timing and intensity and combustion rate are also major factors. Pinging results from an improper combustion rate. Octane boosters reduce pinging by improving combustion rate.

volatile than gasoline, the presence of alcohol in the blend leads to more evaporation of gasoline components than when the gasoline is not blended. Average gasoline RVP is currently about 11 psi, depending on the season and the area in question.7/ Without compensating changes in fuel formation (such as using gasoline of lower than average RVP in the blending process), the widespread adoption of alcohol fuels would increase the evaporation problem and local ozone levels. MTBE does not create this same volatility problem when added to gasoline.

Tests conducted by EPA suggest ethanol blends are likely to reduce carbon monoxide emissions in a car by 10-30 percent depending on the car's fuel combustion technology. The potential improvement in CO emissions over straight gasoline is significant. However, ozone-equivalent VOC emissions show no clear benefit for blends sold at constant volatility. For higher volatility blends (1 psi higher), evaporative hydrocarbon emissions and nitrogen oxide emissions could increase, thereby heightening ozone problems (EPA, 1987b).

Current Alternative Fuel Programs

The New York State Energy Research and Development Authority has operated a neat methanol-powered Ford Escort since 1983 and has leased four flexible-fuel vehicles for the New York State Thruway fleet. Legislation mandating future use of methanol is pending in California's Senate and State Assembly. The State operates a small number of methanol vehicles.

The Colorado Air Quality Control Commission has adopted regulations to reduce ambient levels of carbon monoxide and particulate emissions. The regulations mandate winter use of oxygenated fuels. By limiting the program to the winter months, Denver's summer ozone pollution problem will not be worsened by increased fuel volatility from ethanol blends.

Colorado's mandated oxygenated fuels program is only one piece of a larger package of measures designed to reduce carbon monoxide pollution in the Front Range region. Other strategies include an improved motor vehicle inspection and maintenance program (leading to carbon monoxide reduction of 7 percent), a voluntary better air campaign to promote no-driving days (projected carbon monoxide reduction of 6 percent), improved mass transit systems (projected carbon monoxide reduction of 16 percent), and year-round daylight saving time (projected carbon monoxide reduction of 9 percent). Even with these innovative programs, Denver and the Front Range will probably not meet the EPA carbon monoxide standard (Herman, 1987).

Federal, State, and local agencies are considering the mandated use of oxygenates as a means to meet EPA's standard for ambient carbon monoxide levels. The use of blended gasoline may initially decrease carbon monoxide levels 3-10 percent at sea level and as much as 20 percent at high altitudes. Thus, several areas with significant pollution problems could soon meet the EPA standards. However, the rate at which carbon monoxide levels decline may slow as population and the number of vehicles grow, possibly reversing the improvement in air quality in these areas in the longer run.

Benefits gained by reducing carbon monoxide emission levels would be associated with increased nitrogen oxide emissions and, in many cases, increased hydrocarbon emissions. The reaction of nitrogen oxide and hydrocarbons in the presence of sunlight yields ozone

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7/ EPA has proposed a requirement that gasoline refiners reduce the volatility of their summertime commercial fuels.

which is a more difficult pollution problem to treat than is carbon monoxide. This effect may not matter in the colder months when ozone formation from hydrocarbon and nitrogen oxide is not significant, but it could matter in the warmer months in most parts of the country, almost all year in southern California, and most of the year in parts of Arizona and the Gulf Coast States. Even if hydrocarbon emissions do not increase because of the more volatile gasoline-alcohol blends, the higher nitrogen oxide emissions will increase ozone formation.

The use of alcohol-blended gasolines will not solve the carbon monoxide pollution problem in all areas in the United States, but judiciously used blended fuels can contribute to many regional and local strategies for improving air quality. Colorado's mix of programs to reduce emissions may be an example of an effective way to attack pollution. Colorado will require the use of blended fuels only during the winter months, thereby minimizing ozone formation from blended fuels.

ETHANOL AND AGRICULTURE

How important ethanol production is for agriculture depends on commodity market conditions, the nature of farm programs, and the size of the ethanol industry. With favorable market conditions for corn, higher levels of ethanol production would have a greater effect on commodity prices and production than when market conditions are soft (low prices and large stocks). In times of low export demand, ethanol takes on added importance as an alternative demand for corn. In such cases, an expanded grain demand by the fuel ethanol industry can partially substitute for more traditional agricultural programs which have relied on price supports, supply control, and grain reserve programs to reduce excess domestic supplies.

Because the agricultural sector is complex, a statistical model was used to assist in the analysis of the effect of ethanol production on agricultural production, prices, and income.8/ The model generated results on prices, production, and income similar to other models used for analyzing ethanol impacts. Counterintuitive or uncertain results or results which differ markedly from other analyses are highlighted.

The Agricultural Setting

Although predictions are uncertain, the farm economy is expected to continue its adjustment to economic conditions experienced in the early 1980's.9/ Additional adjustments are expected as the 1985 Food Security Act shifts agriculture toward a greater reliance on market forces. Greater reliance on market economics means lower loan rates and changes in target prices to make U.S. farm products more price competitive in international markets.

8/ The model selected, AGSIM, is a set of econometrically estimated equations linking national grain and oilseed market demands with regional crop supply and a national livestock market. Specific crop demands include barley, corn, cotton, hay, oats, sorghum, soybeans, and wheat. Crop supply is composed of planted or harvested acres for 11 regions.

9/ Agricultural production and prices are difficult to predict because domestic and international farm policies are uncertain and weather is variable. Any assessment of long-term agricultural market conditions suffers from uncertainty.

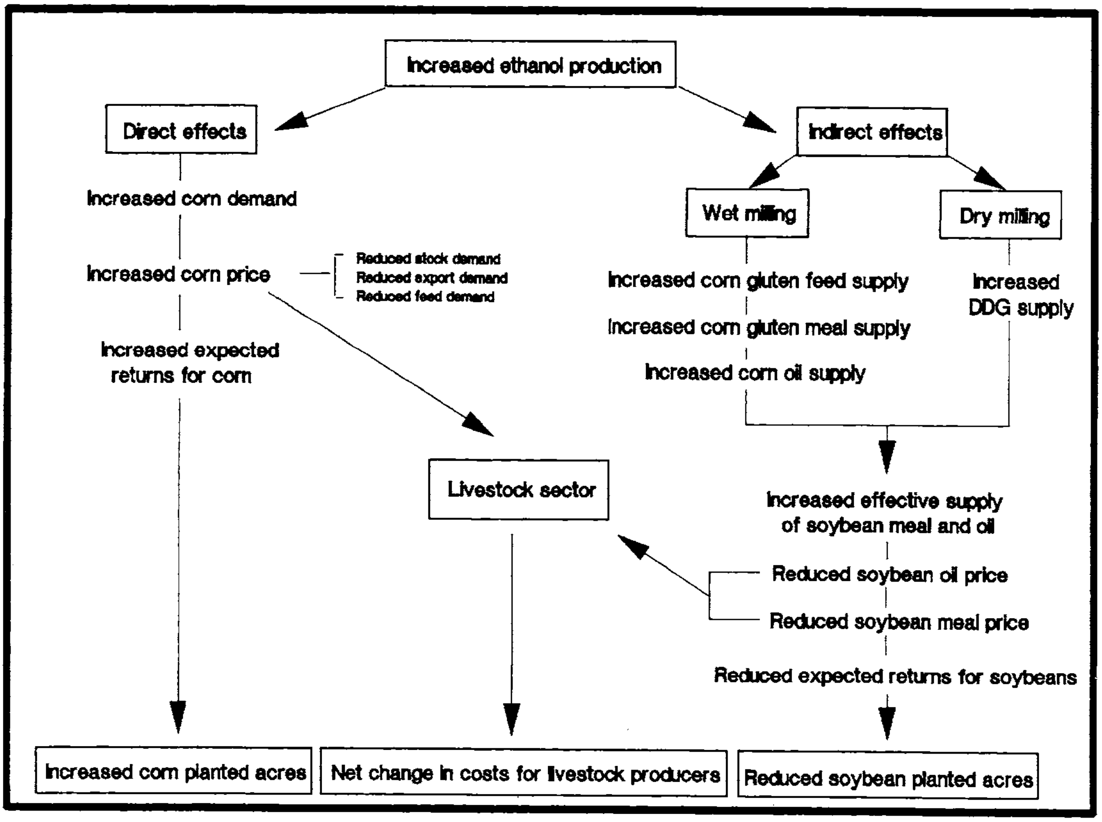
The 1985 Food Security Act, combined with a declining international value of the dollar on international currency exchanges, has improved the international competitiveness of U.S. farm products and reversed the erosion in the U.S. market share for several commodities. The volume of U.S. farm exports is expected to rise over the next several years, following 6 years of decline. Current assessments suggest volume increases of around 3-4 percent a year over the next several years.

A modest increase in export demand, however, will be insufficient to alleviate chronic agricultural excess capacity. During the next decade, demand growth from increases in population and per capita income is expected to be insufficient to overcome current agricultural excess capacity considering the likelihood of productivity increases of 1.5-2 percent per year. Given these conditions, real prices for corn, wheat, and soybeans might decline by as much as 20 percent during the next decade. Productivity increases, of course, translate into lower production costs for producers. If the provisions of the 1990 farm bill are similar to present legislation, farm income would remain relatively stable or fall slightly.

Effects of Ethanol Production

Ethanol production affects both the demand and supply for grain (fig. 12). The demand for corn increases because ethanol production creates an additional market outlet for corn. Ethanol production also increases the supply of high-protein animal feeds. Dry milling produces about 18 pounds of distillers dried grains (DDG) for every bushel of corn converted to ethanol. The wet milling of corn for starch, sweetener, or ethanol produces 2.5 pounds of gluten meal (60 percent crude protein), 12.5 pounds of gluten feed (20-21 percent crude protein), germ which is converted to 1.6 pounds of corn oil, and carbon dioxide.

Figure 12
Change in grain and oilseed demand from additional ethanol production



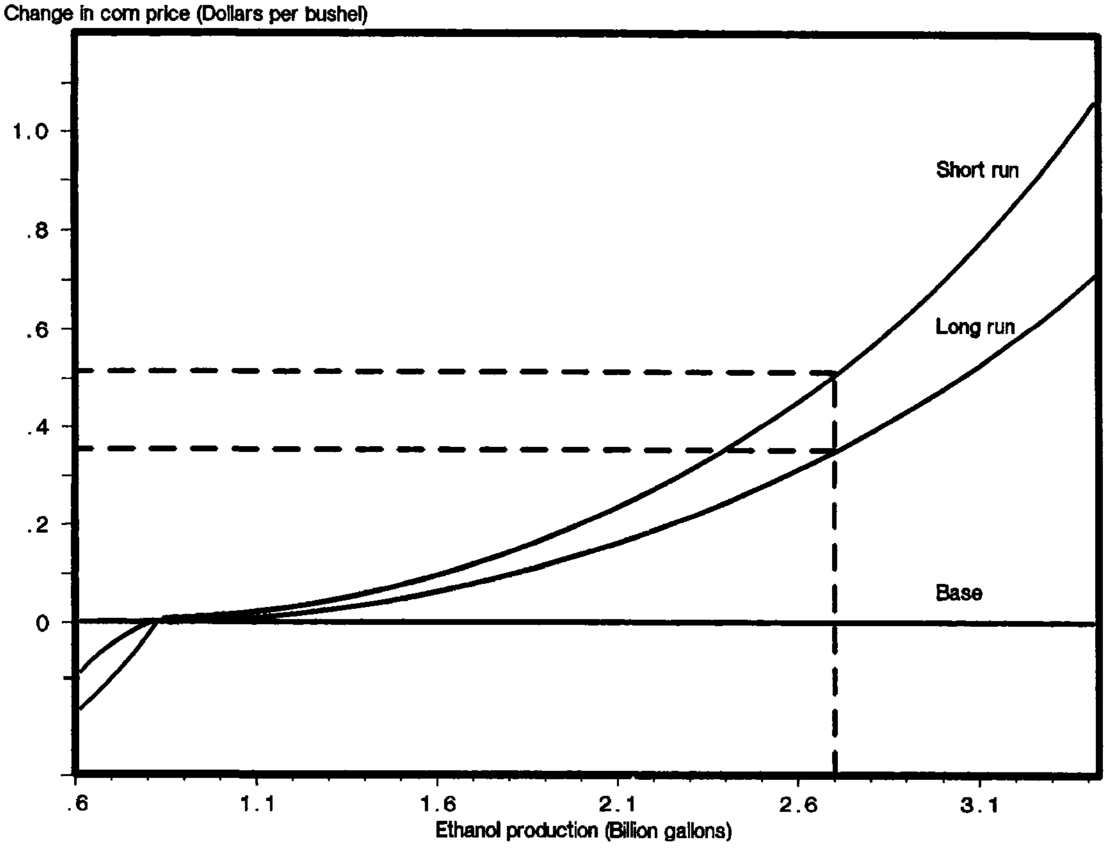
Corn Market Effects

The primary effect of increased ethanol production is to increase corn prices. The size of the increase depends on how much corn is demanded by ethanol producers (the amount of ethanol produced) and the ability and willingness of farmers to shift idle acreage and land used for competing crops into the production of corn. Depending on the market price of corn and the set of government incentives in place, farmers would be expected to increase their planting of corn at the expense of soybeans. Farmers will make the shift for two reasons. First, expanded ethanol production increases the price of corn. Second, ethanol byproducts (DDG, corn gluten feed and meal, and corn oil) reduce the demand for oilseeds including soybeans, cottonseed, and sunflower seeds. Falling prices for these crops further enhance the relative profitability of corn.

Crop production response would initially be centered in the Corn Belt. This region contains the cropland best suited to corn production. About 50-60 percent of U.S. corn is produced in this region where soybeans are the primary competitor for cropland. To the extent that prime cropland there is fully utilized, a substantial increase in acreage devoted to corn production would require a reduction in soybean acreage. High levels of alcohol production and the resulting rise in corn prices could also induce acreage shifts between corn and other crops outside the Corn Belt. Corn could replace sorghum and wheat and land not presently cropped could be brought into production.

The magnitude of the corn price increase directly depends on the level of ethanol production and the amount of corn demanded by the ethanol industry (fig. 13). Given

Figure 13
Ethanol expansion and change in corn market price



current ethanol industry expectations of financial losses after the expiration of the Federal excise tax exemption in 1993, there exist economic incentives for only minor capacity expansion. These expansion plans will likely lead to an output level of 1.1 billion gallons of ethanol production within the next few years. Production will decline without significant changes in oil prices or other factors affecting industry profitability. Additional corn demand of 140 million bushels from the modest expansion will have a negligible effect on corn prices.

If the favorable profit conditions for producing ethanol that have existed during 1987 were assured of continuing through the year 2000, the ethanol industry could expand to a production level on the order of 2.7 billion gallons by 1995. The additional corn demand of nearly 800 million bushels could increase corn prices 50 cents per bushel in the near term with the price effect moderating to 35 cents as corn production and the agricultural sector adjust. Arguments for smaller price effects because corn stocks are at historically high levels cannot, however, be discounted.

An intense ethanol development program spurred by additional incentives, mandates, or other government actions might achieve an ethanol production level on the order of 3.4 billion gallons by 1995. In such a case, the corn price effect could be as much as $1.10 per bushel in the short run, moderating to 70 cents in the long run. High levels of development would stretch the ability of ethanol producers to expand and would require significant financial incentives to justify marshalling the necessary investment resources.

Legislation is pending in Congress that would increase corn demand by the ethanol industry by billions of bushels. For example, H.R. 2052, Ethanol Motor Fuel Act of 1987, would require that one-half of the motor fuels sold by U.S. refiners be blended with 10 percent ethanol by 1992. The Durbin bill would increase corn use by the ethanol industry to between 3 and 4 billion bushels and require a tenfold increase in the production of ethanol in as little as 5 years.

Effects on Oilseeds and Protein Meal Markets

Oilseed and protein market prices are negatively affected by increased ethanol production as greater quantities of protein feeds (DDG, corn gluten feed and meal) and corn oil are supplied. Ethanol production of 2.7 billion gallons means 5 million tons of ethanol byproducts, measured on a soybean meal protein-equivalent basis, and 831 million pounds of corn oil are generated.10/ Current production of soybean meal is about 25 million tons and domestic oil production is about 12 billion pounds.

The potential impact on oilseed and protein markets is offset by the reduction in supply as farmers switch to more profitable corn production. Under conditions where acreage in the Corn Belt is straining to meet feed and food demand, soybean prices could increase. However, given expected acreage requirements in prime corn producing areas during the next decade, increases in soybean prices are unlikely. For large increases in ethanol production, soybean market prices might initially decrease by 20 percent. However, as farmers substitute corn for soybean acreage, soybean supply would shrink and offset the fall in soybean prices. Corn prices relative to soybean prices would ultimately move back toward their long-term relationship which reflects relative production costs.

10/ Calculation assumes 50 percent of ethanol production is wet milling.

Byproduct Markets

Domestic feed markets could absorb all the ethanol byproducts from a large ethanol program, but market prices would reflect the energy rather than the higher valued protein content of the byproduct. These lower prices would increase ethanol production costs by reducing byproduct credits against the price of grain. If the byproducts are to maintain their value as protein substitutes, then unrestricted export markets are needed. The likelihood that byproduct feeds would receive a protein-equivalent price decreases significantly if export opportunities were restricted and ethanol production expands significantly.

The European Community (EC) is the largest foreign market for gluten feeds. The United States is the largest supplier of gluten feed to the EC, accounting for over 95 percent of its imports. Corn gluten feed currently enters the EC free of tariffs and duties and is, therefore, priced at the world market price. By contrast, corn in the EC costs about $5 per bushel because of prevailing tariffs and duties. Recent GATT sessions indicate a restrictive mood in the EC and the possibility of placing duties on byproduct feeds is being discussed. In October 1984, the EC's Commission proposed to limit annual imports of corn gluten feed to 3 million metric tons, compared with current annual U.S. exports of about 4 million metric tons. By restricting corn gluten feed imports, the EC Commission hopes to limit the availability of inexpensive feeds to livestock and dairy producers. Limits on imports would support the demand for grains produced in the Community. The effect on the United States would be to reduce the value of ethanol byproducts and reduce the profitability of producing ethanol.

Other Effects

Ethanol production mainly affects the corn and soybean markets. However, because agricultural production decisions are tied by interrelated markets, ethanol affects other crops as well as livestock production. The effects are, however, generally minor. For example, market prices of protein meals and grain affect the cost of feeding livestock. The use of traditional soybean meal feeds and ethanol byproducts in livestock rations is determined by nutritional and economic relationships. Direct feeding of grains is supplemented by high-protein feeds to achieve a balance between energy and protein in the feed ration. The digestive systems of various livestock species limit opportunities for substitution among protein feeds. Within ration limitations, substitution is governed by the relative prices of protein supplements.

Annual ethanol production below 3 billion gallons would not likely cause significant changes in livestock production or prices since increases in corn prices would be largely offset by decreases in protein supplement prices. Although the total change in consumption is not great, increases in corn price and the arrival on the feed market of high-protein feed from the ethanol industry have differential effects on livestock feeding patterns. When ethanol production increases, the aggregate use of corn and sorghum for feed decreases and use of high-protein feeds composed of soybean and cottonseed meal and ethanol byproducts increases. For moderate levels of ethanol production, 2.7 billion gallons by 1995, feed utilization of corn and sorghum would decrease about 5 percent. But high-protein feeds, measured in soybean meal protein-equivalents, would increase 5 percent.

Changes in livestock production reflect how easily ethanol byproducts substitute for higher priced corn in the rations of animals. If substitution possibilities are limited, higher total feed costs decrease profits and production. When ethanol production approaches and then exceeds 3 billion gallons, byproduct amounts are large and the first significant effects on livestock occur. Since cattle are relatively efficient users of byproducts, fed beef producers would benefit by increased supplies of ethanol byproducts. With an additional 2.7 billion gallons of ethanol produced, beef production would increase by 6 percent while pork and poultry production would decrease by 4 and 3 percent. Milk production is virtually unaffected.11/

Farm prices for livestock would generally change little, even for large levels of ethanol production. Farm prices for beef would likely decrease by only 5 percent even when ethanol production exceeds 4 billion gallons.12/ For lower levels of ethanol production, 2.7 billion gallons, farm prices for beef would decrease only 3 percent.

Changes in livestock prices translate into changes in retail prices of meat and dairy products. Changes in prices for a moderate sized ethanol industry would be small. Even small changes in prices, however, can result in significant changes in consumer expenditures when millions of pounds of meat and dairy products are consumed. A 2.7-billion-gallon program would cost consumers an additional $150 million per year in food expenditures. A 3.4-billion-gallon program might cost consumers as much as $350 million. In either case the increments represent small changes to consumer food expenditures of $100 to $200 billion.

The primary effects of changes in ethanol production are played out in the adjustments between the production and use of corn and soybeans and the raising of livestock. Large-scale production of alcohol fuels could, however, have implications for other crops which compete directly with corn and soybeans as alternative animal feeds or indirectly as competitors for cropland.

The general expansion of corn acreage and higher feed costs tend to increase the price of grain sorghum. Even for large levels of ethanol production, however, price increases for grain sorghum would likely be less than 5 percent. Given the expected small price increases for sorghum, increased ethanol production would not greatly affect sorghum acreage or production decisions. Similarly, although wheat acreage would be affected, the effects would be small. Price effects would be less than 1 percent.

Mirroring domestic consumption, increases in the export volume of protein products would be offset by decreases in corn exports. Changes in the volume of farm exports would closely follow from expected changes in commodity prices. Because corn prices would increase and protein product prices would decrease, changes in export demand would be offsetting. Export demand for other crops would increase as other countries substitute for higher priced corn. Increased demand for other crops would be minor. The net effect depends on the relative responsiveness of export demand to corn and protein supplement price changes and

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11/ Results from other analyses suggest even fed beef production might decrease because lower protein supplement prices do not fully offset higher corn prices in cattle diets (Gavett, 1986). Although there is disagreement, any effect on livestock is likely to be small because of the offsetting effects of ethanol byproducts. Additional research into the use of ethanol byproducts by livestock is necessary before any conclusive statements can be made.

12/ Ethanol production of 4 billion gallons implies production of 8 million tons of soybean meal protein-equivalent byproducts.

how much corn and protein supplement prices change due to ethanol production. Export demand is generally expected to display limited responsiveness to price changes.13/

If 2.7 billion gallons of ethanol were produced, the volume of corn exports would be expected to decline in the range of 5-7 percent or about 150 million bushels. Increases in protein supplement exports would be slightly greater and in the range of 7-10 percent. This assumes, however, that ethanol byproducts could be easily exported. Although the volume of corn exports declines, corn prices increase. The value of aggregate exports increases less than $1 billion by 1995.

Farm Income

Farm commodity programs buffer effects of changes in market prices on farm income. Higher market prices received by farmers are offset by lower deficiency payments. When market prices are low relative to target prices and program participation among farmers is high, modest changes in commodity prices have little effect on farm income. In such a situation, ethanol production would have significant income effects for farmers who do not participate in farm programs. Significant changes in aggregate income for grain producers who participated in farm programs occur only when the market price for their commodity approaches and then exceeds the target price.14/

In addition to the buffering effects of farm programs, changes in total farm income are moderated by differential effects among grain, oilseed, and livestock producers. Although increased demand for corn by ethanol producers increases corn prices, the generation of high-protein byproducts decreases the price of soybeans and other oilseeds. As a group, grain producers may increase their income, but livestock producers, who must pay higher grain prices, may lose. Income effects are likely to vary even among livestock producers. Those producers who avoid higher corn prices by substituting relatively less costly feeds, particularly ethanol byproducts, could increase their incomes.

The operation of government commodity programs and offsetting effects among crop and livestock producers suggest moderate levels of ethanol production would have relatively small effects on aggregate farm revenue and income. Market prices for corn would be unlikely to exceed target prices before 1994 or 1995 and perhaps only for ethanol production levels approaching 3-4 billion gallons. The prices of other feed grains would also register modest gains. By 1995, annual gross receipts (production multiplied by price) from crop production could increase by $1-$2 billion for 2.7 billion gallons of ethanol production and about $6 billion for high levels.15/ The largest gains would be made by corn (16 percent under moderate growth) and wheat (13 percent). The largest losses would be attributable to soybeans (5 percent). Because different crop producers gain and lose, increased ethanol

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13/ There is, however, growing concern that large increases in commodity prices experienced during the 1970's have encouraged some importing countries to increase their domestic production capability. The ability to increase domestic production would make demand from these countries more responsive to changes in farm export prices.

14/ If increased demand for corn is met by reducing set-aside requirements, total deficiency payments and income can increase for participants, even with market prices below target prices.

15/ These calculations assume continuation of farm programs as described under the Food Security Act of 1985. Target prices for corn in 1995 are assumed to be $2.75 per bushel.

production implies interregional income shifts. The largest changes would occur in the Corn Belt (10-percent increase) and the Delta (5-7-percent decrease). The Delta produces soybeans and cotton. Delta farmers cannot, therefore, take advantage of increasing corn prices by substituting corn acreage for soybeans.

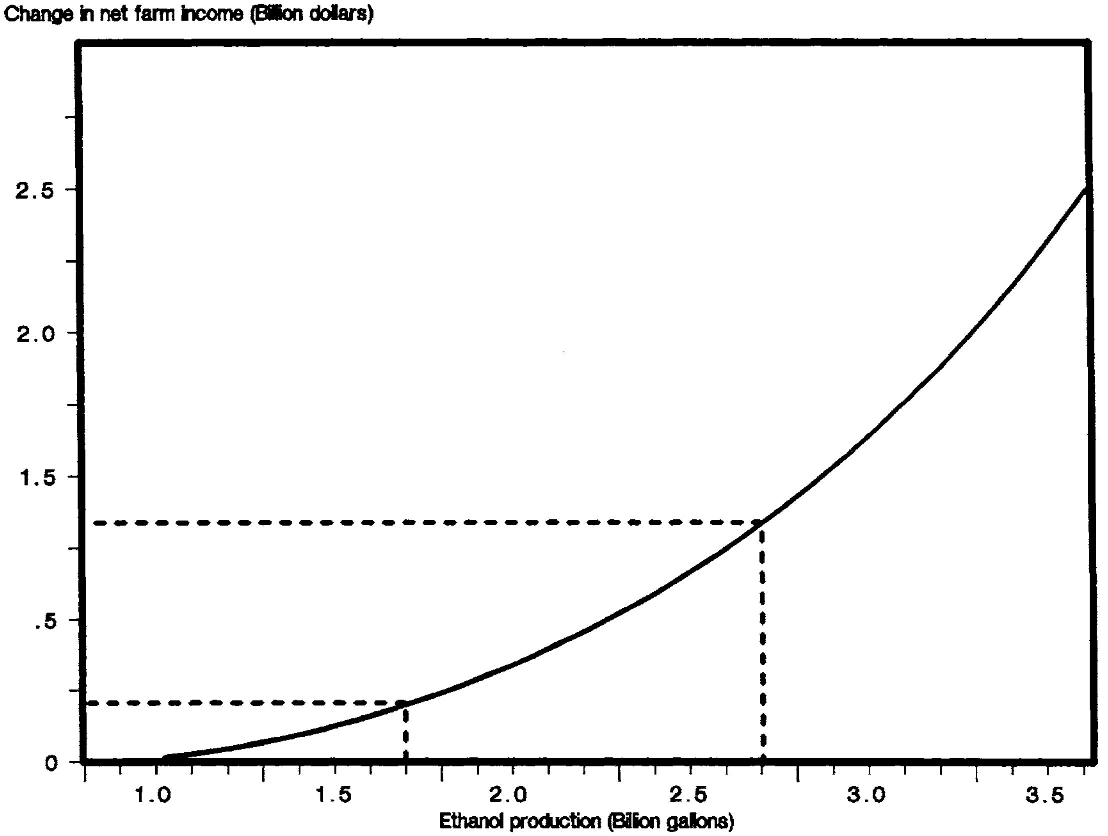
In the aggregate, expenditures for crop production inputs would change less than 5 percent. Increases in corn production would be largely offset by decreases in soybean production. In addition, most farm costs are associated with fixed payments for land and capital. Fixed costs would change little because of current excess production capacity. Net income (gross receipts less costs) derived from crop production would closely follow changes in gross receipts. Net income increases under moderate ethanol growth would be slightly over $1 billion.

Changes in crop prices also affect revenue and net income for livestock producers. Revenue and income would be different for different animals, though the changes are minor for all animals. In the aggregate, net income to livestock producers would decline by about $1-$2 billion dollars for high levels of ethanol production and less than $1 billion for moderate growth.

The total effect of ethanol production on farm income is obtained by combining the effects on crops and livestock (fig. 14). Increased ethanol production would increase net farm income. Losses to livestock producers are offset by crop gains. Among crop farmers, those specializing in corn, sorghum, and wheat gain while those specializing in soybeans or those who combine cotton and soybeans lose. When ethanol production is about 4 billion

Figure 14

Ethanol expansion and change in net farm income



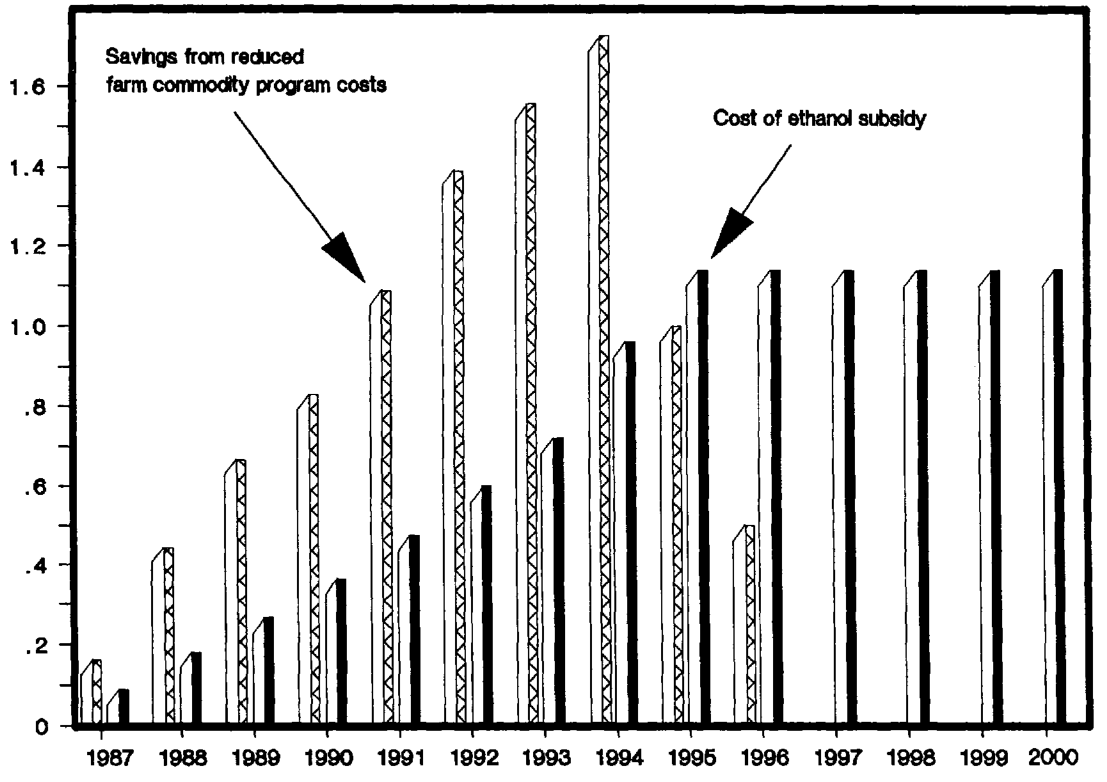
gallons by 1995, total farmer gains could reach $2-$4 billion but would be less than $1 billion dollars for a 2.5-billion-gallon ethanol production level.

Farm Program Costs

Increases in ethanol production decrease farm program costs by raising grain prices. Program costs are reduced in three ways. First, farmers in the program receive lower deficiency payments as the market price for the commodity is driven toward the target price. Second, fewer farmers default on CCC nonrecourse loans, thereby reducing CCC storage costs. Third, farmers' costs of participating in the program, in terms of foregone revenue from acreage set-aside requirements, increase as the market price increases. Therefore, the number of farmers participating in programs declines. Fewer participants, lower deficiency payments, and lower storage costs combine to reduce government costs.

Corn price increases cause all other grain prices to increase. The effect is to decrease program costs for wheat, sorghum, oats, and barley. Total decreases in government outlays for the period 1987 to 1995 (with 2.7 billion gallons of ethanol production by 1995) would approach $9 billion (fig. 15).16/ The largest decreases in government costs would come from corn. The possibility exists, however, for increases in CCC soybean stocks as high-protein ethanol byproducts compete in the animal feed market.

Figure 15
Yearly costs and savings to the Federal government
Billon dollars



16/ Sales of CCC stocks are valued at the market price. The cost to government of a commodity program, excluding storage costs, is calculated as the difference between the target price and the market price multiplied by the quantity produced by program participants.

These results depend on expectations about how commodity markets and government programs will look in the next decade. For the purposes of this analysis, we assume the 1990 farm bill will look similar to the current 1985 Food Security Act. The target price for corn, the most critical variable when calculating program costs, is assumed to be $2.75 per bushel beginning in 1990. Set-aside requirements are assumed constant. Movements in commodity prices are consistent with export growth of 3-4 percent a year and constant domestic demand. The market price of corn with no additional growth of the ethanol industry is $2.36 per bushel in 1995.17/ Although different assumptions suggest different agricultural cost savings, the general result that there would be net savings in the near term would likely remain unchanged.

Decreases in Federal outlays associated with farm programs are offset by tax losses associated with ethanol use. Under current law, Federal Highway Trust Fund revenues decline by 60 cents for every gallon of fuel ethanol consumed through September of 1993.18/ A level of annual ethanol consumption which increases gradually from 800 million gallons and reaches 2.7 billion gallons by 1995 would cost the Federal government an additional $5 billion in lost taxes. Moderate ethanol growth suggests, therefore, about a $4-billion net reduction (reduced farm payments less tax losses from ethanol) in Federal outlays would be realized over the period 1987 through 1995 (fig. 16).19/

If the analysis is extended past 1995, however, the net reductions in farm program outlays are overwhelmed by the added excise tax losses. Farm program savings are exhausted by 1997, eliminating any gains from added ethanol consumption. If ethanol consumption remains constant at 2.7 billion gallons, then by 1999 the entire pre-1995 gains from reduced farm program outlays would be offset. In addition, government savings from increased ethanol consumption before 1995 may be reduced if additional subsidies are necessary to promote the production and use of ethanol. Information from this analysis suggests, however, over 1.5 billion gallons of ethanol production capacity expansion would occur if the gasoline tax exemption were extended to the year 2000 and corn prices were about $2.50 per bushel.

Indirect Effects

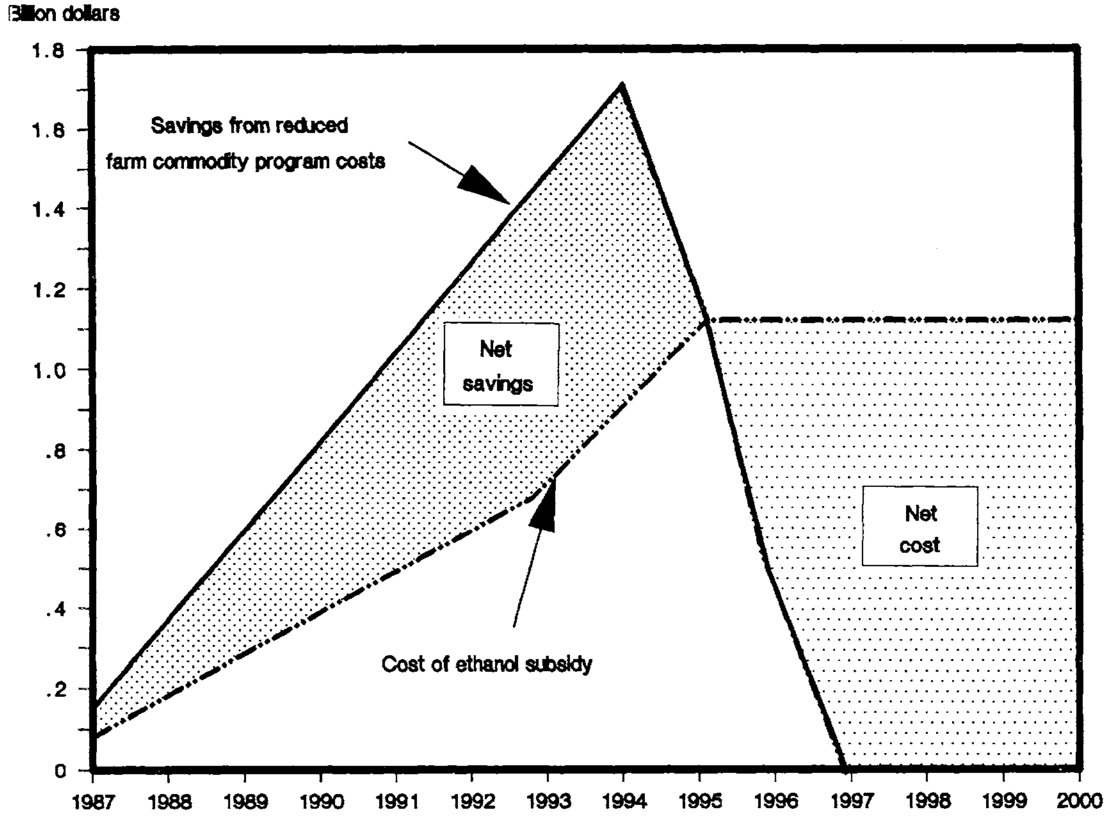
Ethanol production is linked to agriculture and the entire economy through a network of input purchases and product sales. Ethanol producers buy inputs such as equipment, energy, corn, labor, and financing from "upstream" industries. And they sell products to "downstream" sectors that store, process, transport, manufacture, distribute, retail, consume, or export the products. For example, corn germ is crushed into corn oil, sold as vegetable oil, added to other processed products, exported, or sold in retail stores. Other downstream linkages can be short, as with ethanol destined for retail sale which may only be transported to a central terminal or to a gasoline station.

17/ No additional growth means the ethanol industry demands about 320 million bushels of corn to maintain annual production of 800 million gallons.

18/ To induce significant expansion in the ethanol industry will likely require extension of the Federal fuel excise tax exemption at least until 2000. Thus, our consideration of Highway Trust Fund effects assumes the exemption or similar subsidy would be extended.

19/ This analysis focuses on Federal budget costs and savings. Twenty-eight States also exempt ethanol use from State gasoline sales taxation. The average tax exemption is valued at 2-3 cents per gallon of ethanol.

Figure 16
Net costs and savings to the Federal government



The ethanol industry contributes to rural areas mainly through the employment of workers for the construction and operation of ethanol plants. Wages paid to ethanol employees circulate within a community and encourage the expansion of other businesses. Furthermore, because the ethanol industry demands corn as a feedstock, regional agricultural income can be enhanced. Likewise, regional input suppliers and grain handlers may gain if increased acreage and input use are involved. Under current farm programs, there is limited potential for such regional impacts before the mid-1990's. Also, the national impacts would be small. An ethanol plant may increase the local farmer's corn price by 6-12 cents per bushel by eliminating the cost of transporting the grain to a far market and by reducing grain elevator charges because of the added year-round competition for grain.

No reliable estimates of the ultimate effect ethanol production would have on rural areas exist. Ethanol production is not labor intensive; a large plant employs only 50-150 permanent workers. Additional jobs, roughly equal to direct employment, may be created in the community to fulfill the plant's service requirements. Direct employment effects from the production of about 3 billion gallons of ethanol are in the range of 3,000-9,000 employees. It is possible, however, that employment and income gains made in rural areas from the production of ethanol could come at the cost of lost employment opportunities in oil refining as ethanol displaces gasoline. Little change in input purchases or employment is likely in agriculture. Because farmers respond to higher corn prices by reducing the acreage of other crops and because protein byproducts substitute for soybeans, ethanol production does not greatly affect either total crop acreage or farm income. With only small changes in total production and income, one expects only small changes in employment opportunities in agriculture.

ETHANOL AND NATIONAL POLICY GOALS

Ethanol contributes to broad national environmental, agricultural, and energy policy goals as they have been defined by Federal legislation over the past two decades. The broad national goals, secure sources of energy, a safe and healthy environment, and a strong rural economy, have remained largely unchanged over those years even though conditions have changed from agricultural and energy shortages to surpluses. While the goals have remained stable, perspectives on how best to achieve the goals have changed dramatically as research has improved our understanding of the problems as well as the range of technological options for addressing those problems.

That ethanol contributes to national policy goals is not at issue. Rather, the issue is how ethanol production and use compare to other alternatives. Ethanol blend fuels reduce carbon monoxide emissions from automobile exhaust but other oxygenates exist which reduce carbon monoxide without increasing hydrocarbon emissions. Ethanol is currently economically competitive in the role as a fuel blending agent because of the $0.60 per gallon Federal subsidy. Ethanol production offers an additional market for grain and can boost farm income and reduce government stock accumulation, but several alternatives exist including supply control, export enhancement, and conservation reserve programs. Finally, a variety of alternative strategies exist for enhancing energy security, including coal liquids, methanol, shale oil, and strategic fuel reserves.

Significant disagreement concerning the public role regarding ethanol arises from differing views of the appropriate level of agricultural supports and of how best to achieve energy security, environmental, and agricultural goals. Those who would benefit or lose from particular strategies have strong vested interests. With current agricultural policy and likely agricultural market conditions, a moderate increase in ethanol production will have little effect on farm income for several years. Increased ethanol production and the consequent rise in corn prices will simply shift the source of farm income from government programs such as deficiency payments to market price returns. While not directly helping farmers, a market-oriented approach to stabilizing corn prices would result in considerable savings in farm program costs to the U.S. Treasury. The increase in corn prices is, however, indirectly supported by the motor fuel excise tax exemption for ethanol blend fuels. Substantial increases in ethanol production are likely to be obtained only through extension of the Federal excise tax exemption through 2000. Such an extension is likely to result in net Federal budget costs of the program after 1995 that more than offset budget savings achieved in earlier years. Firms currently in the industry stand to gain considerably if ethanol subsidies are extended or new programs are initiated. If subsidies were eliminated before their scheduled lapse in 1993, however, the same firms would stand to lose as their substantial investment was rendered unprofitable.

Our study has investigated only how the ethanol industry fits into the current farm program environment. The distribution of impacts of an ethanol program depends on how the program is integrated with government policies. Promoting increased ethanol production by assuring favorable conditions through the year 2000 means stabilizing corn prices at relatively low levels and guaranteeing the gasoline tax exemption. Gains would accrue to ethanol producers. Corn producers and, up to 1995, taxpayers also benefit. Consumers who pay higher prices for farm products, soybean and other oilseed producers, and taxpayers after 1995 lose.

Other policy alternatives to maintaining the gasoline tax exemption exist. One option is to provide corn from current excess stocks at less than market prices to ethanol producers.

Reducing corn stocks directly decreases Federal outlays associated with storage costs. However, by providing stocks to the ethanol industry, the government reduces corn demand on a bushel-for-bushel basis while also generating high-protein ethanol byproducts which decrease the demand for soybean meal. By driving down both corn and oilseed prices, farm program costs would increase and farm income would fall. While taxes would be higher, consumers would gain through lower food costs. The ethanol industry would benefit from a direct income transfer from the U.S. Treasury.

Another alternative is to substitute expanded ethanol production for government involvement in farm programs. Such a program might be managed to maintain farm income at the same level it would have attained without the ethanol program. This approach would limit most impacts of the ethanol program to the Federal budget and taxpayers. The impact on the farm sector as a whole would be neutral by design although corn would benefit at the expense of oilseed crops. Farm program outlays would be decreased. Managed in this way, support for ethanol would be phased out as market prices overtake target prices. In principle, a program managed in this manner would avoid the negative effects on the Federal budget after 1995. In practice, however, it is unlikely that ethanol industry expansion can be induced without extension of the credit to 2000. Alternatively, additional current subsidies could be provided to offset expected industry losses after 1993 but the level required would likely turn near-term budget savings to budget losses.

The national debate on ethanol could be clarified if support for a higher level of farm sector support were separated from the debate on how best to achieve the support. It is beyond the scope of our effort to address overall farm policy. Because different views exist on the direction and level of existing farm policies, views on how ethanol can best be integrated into farm policy will differ considerably. How an ethanol policy is integrated with farm policy significantly affects how the gains and costs of the policies are distributed between the U.S. Treasury (taxpayers) and farmers, between farmers and consumers, within the farm sector, and among agencies within the Federal government.

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GLOSSARY

Anhydrous ethanol. Ethanol that has undergone final dehydration to remove the last 5 percent of water typically remaining after distillation.

Byproduct credit. The revenues obtained from selling byproducts from ethanol production. The revenues are treated as a credit against the cost of corn used in production.

Clarified substrate. The substrate produced in the wet-mill process: See Fermentable substrate.

Cogeneration. The process of supplying steam and electricity needs of an industrial plant using a single boiler.

Deficiency payment. Government payment made to farmers who participate in feed grain, wheat, rice, or cotton programs. The payment rate is per bushel, pound, or hundredweight, and is based on the difference between a target price and the higher of either the market price or the loan rate.

Dehydration. The process that removes the final 5 percent of water left in ethanol after distillation.

Distillation. The initial process for removing water from the beer resulting from fermentation. Distillation is capable of producing a liquid that is 95-percent ethanol and 5-percent water.

Dry milling. The process of grinding grain while it is dry. In reference to ethanol production, it is an ethanol plant where the grain is ground in a dry mill to produce a mash that is then mixed with water, processed, and fermented.

Fermentable substrate. The saccharified liquid mixture ready for fermentation. In the dry-mill process, the substrate includes the entire corn kernel as ground, cooked, and subjected to saccharification. In the wet-mill process, a clarified substrate is produced; that is, it does not contain the solid, nonstarch components of the corn kernel.

Fermentation. The use of yeast to produce alcohol from sugar.

Fermenter contamination. Uncontrolled growth of bacteria in the fermenter requiring it to be shut down, cleaned out, and restarted with new yeast and substrate.

Fluidized-bed combustion. A process for burning coal that removes many of the pollutants normally associated with coal burning including sulfur.

High fructose corn syrup. A sweetener produced from corn starch in the wet-mill process. It is widely used in soft drinks and other food products.

Immobilized yeast. A process where the fermentable substrate is passed through a membrane containing the yeast compared with the standard technology in which the yeast and fermentable substrate are mixed together.

Loan rate. The price per unit (bushel, bale, or pound) established by the government each year at which the Commodity Credit Corporation (CCC) will provide loans to farmers to enable them to hold their crops for later sale.

Market price (as defined for farm programs). The national weighted average market price for corn over the 5-month period immediately following a harvest.

MTBE (methyl tertiary butyl ether). A fuel-blending agent produced from methanol and isobutylene and used to enhance the octane of gasoline. The octane rating (R+M/2) of MTBE is approximately 106 at normal blending ratios.

Nonrecourse loans. Allows eligible producers to obtain a loan at the CCC-established loan rate by pledging crops in storage as collateral. Price support loans enable farmers to hold their crops for later sale. If the market price remains below the CCC loan rate, the producer can settle the loan by turning the stored commodity over to the government. The government has no recourse but to accept the commodity as complete settlement for the loan.

Paid land diversion. Gives producers a specific per-acre payment for each idled acre. Payment is made in addition to deficiency payment.

Saccharification. The use of enzymes to produce sugars from starch.

Severe refining. Oil refinery processes that go beyond simple distillation to alter the proportion of various refinery products and change their composition. More severe refining is an approach used to increase the octane of gasoline by increasing those components of gasoline that have higher octane, such as butane, xylene, and others.

Target price. A price level established by law for wheat, feed grains, rice, and cotton. The target price represents a gross return to a crop that supports income at an acceptable level. If the market price falls below the target price, an amount equal to the difference (but not more than the difference between the target price and the loan rate) is paid to participating farmers as a deficiency payment.

Wet milling. A process of grinding grain when it is wet that results in an essentially pure starch stream that has been separated from other ingredients of the corn kernel. In reference to ethanol production, it is an ethanol plant where grain is ground in a wet mill to produce starch which is processed and fermented.

Zymomonous mobilis. A bacteria capable of producing ethanol from sugars as a replacement for yeasts currently used.

LIST OF INDIVIDUALS AND ORGANIZATIONS CONTACTED

John Aird	J.R., Simplot Company, Director, Ethanol Marketing and Sales (Boise, Idaho)
Per Assarsson	St. Lawrence Reactors Limited, Executive Vice-President (Toronto, Ontario, Canada)
Daniel Beckman	U.S. Department of Energy, Deputy Director, Office of Alcohol Fuels (Washington, D.C.)
Jacqueline Broder	Tennessee Valley Authority, Project Engineer, Biomass Branch (Muscle Shoals, Alabama)
Paul Bucker	U.S. Department of Commerce, Deputy Director, Caribbean Basin Business Information Center (Washington, D.C.)
James Caldwell	U.S. Environmental Protection Agency, Enforcement Section Leader, Office of Mobile Sources (Washington, D.C.)
James Christensen	J.R. Simplot Company, Ethanol Plant Manager (Boise, Idaho)
Helena Chum	SERI, Manager, Chemical Conversion Research Branch (Golden, Colorado)
Jerry Crawford	U.S. Department of Agriculture, Agricultural Research Service, Leader, Biosynthesis Research Unit, Northern Regional Research Center (Peoria, Illinois)
Clarence Ditlow	Center for Auto Safety, Executive Director (Washington, D.C.)
Otto Doering	Purdue University, Department of Agricultural Economics (West Lafayette, Indiana)
Vernon Eidman	University of Minnesota, Department of Agricultural and Applied Economics (Minneapolis, Minnesota)
Joshua Epel	Denver Metropolitan Air Quality Council, State Implementation Plan Coordinator (Denver, Colorado)
David Feld	U.S. Department of Agriculture, Farmers Home Administration, Chief, Decision Support Branch (Washington, D.C.)
Richard Gadomski	PSI Systems Inc., President (Memphis, Tennessee)
George Graw	Centrico Inc., Vice-President of Engineering, Westphalia Corporation (Northvale, New Jersey)
Michael Hall	National Corn Growers Association, Executive Vice-President (Washington, D.C.)

Edward Harjehausen	Archer Daniels Midland, Ethanol, Vice-President, Marketing (Decatur, Illinois)
Ben Henneke	Energy Fuels Development Corporation, President (Portales, New Mexico)
Lawrence Hoboy	Technal Inc., President (Denver, Colorado)
Lawrence Hudson	New York State Energy Research and Development Authority (Albany, New York)
T. Jack Huggins	Pekin Energy Company, Vice-President, Finance and Administration (Pekin, Illinois)
Harlow Innman	U.S. Department of Agriculture, Farmers Home Administration, Analyst (Lincoln, Nebraska)
Curt Jones	Alltech Laboratories, Director of Research (Nicholasville, Kentucky)
Daniel Jones	U.S. Department of Agriculture, Interim Deputy Director, Office of Agricultural Biotechnology (Washington, D.C.)
Carroll Keim	Private Contractor (Stamford, Connecticut)
Nathan Kimpel	New Energy Corporation of Indiana, General Manager (South Bend, Indiana)
Michael Ladisch	Purdue University, Department of Chemical Engineering (West Lafayette, Indiana)
Lloyd Kreider	Small-Scale Ethanol Producer (Cochranville, PA)
Thomas Lareau	American Petroleum Institute, Senior Economist (Washington, D.C.)
Jerrold Levine	Amoco, Director, Corporate Studies (Chicago, Illinois)
David Lindahl	U.S. Department of Energy, Director, Office of Alcohol Fuels (Washington, D.C.)
Daniel Moenter	Marathon Petroleum Company, Manager, Industry and Corporate Affairs (Findlay, Ohio)
Richard Moorer	U.S. Department of Energy, Alcohol Fuels Program Manager, Biofuels and Municipal Waste Technology Division (Washington, D.C.)
John Murphy	Second National Building and Loan (Annapolis, Maryland)
William O'Brien	Tennessee Valley Authority, Technical Monitor, DOE loan guarantee program (Muscle Shoals, Alabama)

Douglas Parry	U.S. Department of Commerce, Industrial Specialist, Office of Energy (Washington, D.C.)
James Porterfield	American Farm Bureau Federation, Assistant Director, Natural and Env. Resources Div. (Chicago, Illinois)
Fred Potter	Information Resources Inc., President (Washington, D.C.)
Guy Pluche	Elf France, Substitute Fuels Coordinator (Paris, France)
Norman Rask	Ohio State University, Department of Agricultural Economics (Columbus, Ohio)
Ron Sanders	American Diversified Companies in Hastings, NE, Plant Manager (Hastings, Nebraska)
W. Robert Schwandt	Private Contractor (Decatur, Illinois)
Dennis Sharpe	American Soybean Association, Staff Vice-President (Washington, D.C.)
Linden Shepard	A.E. Staley Manufacturing Company, Manager, Refined Oil Division (Loudon, Tennessee)
Edgar Smith	U.S. Department of Agriculture, Farmers Home Administration, Chief, Loan Processing Branch (Washington, D.C.)
Kenneth Smith	California Energy Commission, Manager, Synthetic Fuels Office (Sacramento, California)
Todd Sneller	Nebraska Gasohol Committee, Administrator (Lincoln, Nebraska)
Joseph Somers	U.S. Environmental Protection Agency, Analyst, Mobile Sources Laboratory (Ann Arbor, Michigan)
Martin Sorkin	Consultant for Archer Daniels Midland (Washington, D.C.)
A.E. Stuenkel	Pekin Energy Company, President (Pekin, Illinois)
William Tallent	U.S. Department of Agriculture, Agricultural Research Service, Assistant Administrator, Office of Cooperative Interactions (Washington, D.C.)
Eric Vaughn	Renewable Fuels Association, President (Washington, D.C.)
Michael Voorhies	U.S. Department of Energy, Office of Alcohol Fuels (Washington, D.C.)
Jack Wade	South Point Ethanol, General Manager (South Point, Ohio)

Thomas Wallace	Gist-Brocades USA Inc., Applications Lab Manager, William Wells Biocom International Limited, Vice-President (Atlanta, Georgia)
Richard Wilson	U.S. Environmental Protection Agency, Director, Office of Mobile Sources (Washington, D.C.)
John Wright	Solar Energy Research Institute, Coordinator, Biochemical Conversion /Alcohol Fuels Program (Golden, Colorado)
W. Victor Wu	U.S. Department of Agriculture, Agricultural Research Service, Researcher, Northern Regional Research Center (Peoria, Illinois)
Charlie Wyman	Solar Energy Research Institute, Manager, Biotechnology Research Branch (Golden, Colorado)
Reno Zanussi	Grain Power Tucumcari Limited, Vice-President (Tucumcari, New Mexico)

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