Ethanol Programs

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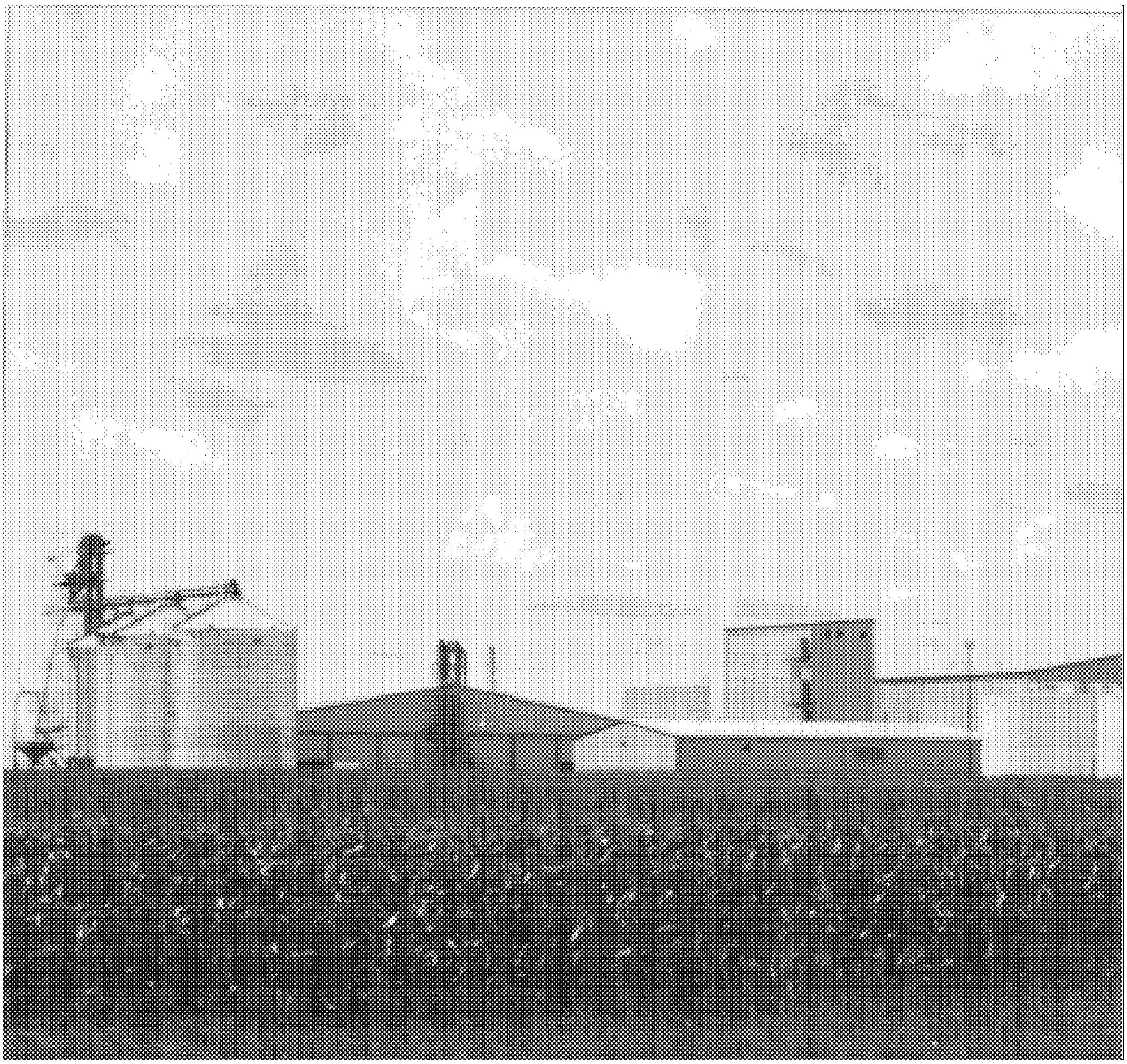
A Program Evaluation Report



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Office of the Legislative Auditor
State of Minnesota

Centennial Office Building, 658 Cedar Street, St. Paul, MN 55155 • 612/296-4708

STATE OF MINNESOTA
OFFICE OF THE LEGISLATIVE AUDITOR
CENTENNIAL BUILDING, 658 CEDAR STREET • ST. PAUL, MN 55155 • 612/296-4708 • TDD RELAY 612/297-5353
JAMES R. NOBLES, LEGISLATIVE AUDITOR

February 6, 1997

Members
Legislative Audit Commission

Minnesota has enacted several programs designed to promote the production and use of ethanol in automotive fuel. In May 1996, the Legislative Audit Commission asked us to evaluate the costs and benefits of these programs.

We learned that Minnesota's level of support for ethanol is substantially greater than that offered by any other state government. Minnesota's support includes a tax credit, a producer payment, subsidized loans, and the use of tax increment financing at the local level. It also includes a requirement that consumers use oxygenated gasoline, which in Minnesota is achieved by blending ethanol with gasoline. We estimate that, for fiscal years 1997-99, Minnesota's ethanol programs will cost about $25 million per year in state government spending and $42 million per year in higher consumer gasoline prices.

Minnesota's support for the ethanol industry has created significant economic benefits, both for the communities where ethanol plants are located and for the state as a whole. But Minnesota's ethanol industry faces future risks. First, for the foreseeable future the ethanol industry will continue to be dependent on federal and state subsidies. In addition, even with continued subsidies, there are prices for corn and ethanol at which the industry will not be profitable. Finally, we conclude that some of the claims that have been made for ethanol's environmental benefits cannot be substantiated scientifically.

Our report was written by Elliot Long (project manager) and Jared Creason, with the assistance of Lilja Dandelake. We received the full cooperation of the Minnesota Department of Agriculture and helpful assistance from the Pollution Control Agency, the Department of Public Service, and ethanol plant managers across the state.

Sincerely,

James Nobles
Legislative Auditor

Roger Brooks
Deputy Legislative Auditor

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MINNESOTA OFFICE OF THE LEGISLATIVE AUDITOR

Ethanol Programs

SUMMARY

In comparison to other midwestern corn-producing states, Minnesota has pursued an aggressive, multifaceted strategy to promote the production and use of ethanol as an automotive fuel. Since the mid-1980s, Minnesota has developed a sizable ethanol industry that, by October 1996, had the capacity to produce about 92 million gallons of ethanol per year. Additional production facilities are now in planning or under construction.

This study, requested by the Legislative Audit Commission, addresses the following questions:

- **How much do Minnesota's ethanol programs cost?**
- **Have the programs succeeded in promoting the establishment and growth of an ethanol industry?**
- **What are the economic and environmental benefits of ethanol production and use?**
- **What are the major risks to the future viability of ethanol production in Minnesota?**

In carrying out this study, we interviewed officials in the Minnesota Department of Agriculture (MDA) and other state agencies. We visited the six major Minnesota ethanol plants in operation during the summer of 1996 and talked to managers about their experiences in building and operating the plants. We also reviewed the national literature relating to environmental and economic issues of ethanol production and examined other states' ethanol programs.

Minnesota is one of the nation's leading corn producers. Most ethanol is produced from corn.

ETHANOL PROGRAMS

Over 95 percent of ethanol in Minnesota and in the nation is produced from corn. Minnesota is the nation's fourth leading corn producer, and like many major corn-producing states Minnesota promotes the use of ethanol as an automotive fuel through various activities. The state also operates a fleet of about 270 flexible-fuel vehicles that can use up to 85 percent ethanol mixed with gasoline.

Like some other states, Minnesota offers subsidized loans for development of ethanol production facilities. However, Minnesota goes beyond other states in the scope of its support of the ethanol industry. Minnesota currently provides a 5 cent per gallon tax credit, called the "blender's credit," to distributors of "gasohol" (ethanol mixed with gasoline at a concentration of 7.7 to 10 percent[1]), and it pays a subsidy of 20 cents per gallon for ethanol produced in Minnesota. Minnesota also requires the use of oxygenated gasoline year round in the Twin Cities area, and statewide starting next October.[2]

The production and use of ethanol is promoted through various state incentives and requirements.

Ethanol production has also been promoted through several subsidized loan programs, including economic recovery grants administered by the Department of Trade and Economic Development, and two programs administered by the Minnesota Department of Agriculture that provide loans to producers and to farmers who wish to purchase shares in ethanol-producing cooperatives. The largest state loans are those to producers through the Ethanol Production Facility Loan Program; this program provides low-interest loans of up to $500,000 per plant.

PROGRAM COSTS

The producer payment program pays ethanol producers 20 cents per gallon up to a maximum of $3 million per plant and a statewide limit of $30 million. The payments last until 2000 in some cases, and, in others, 10 years from the start of production or expansion of production. In fiscal year 1996, two plants reached the $3 million limit. Producer payments totaled $22.1 million in the three year period, fiscal years 1994 through 1996. The Minnesota Department of Agriculture estimates that annual producer payments will reach about $26 million in fiscal year 1999.

As the producer payment is expanded, the blender's credit is being phased out. The blender's credit cost $61.2 million in foregone tax revenue in fiscal years 1994 through 1996, but will end in October 1997, and is projected to cost $8.7 million in fiscal years 1997 through 1999.

The cost of the mandate to use oxygenated gasoline, which becomes a statewide requirement in October 1997, will be borne by consumers paying higher prices at the pump. The exact size of the premium is difficult to determine. Nevertheless:

- **We estimate that the retail price of gasohol will exceed the price of conventional gasoline by about 2 to 3 cents per gallon over the next several years.**

Our estimate of the higher cost of gasohol considers retail prices in October and December 1996 and January 1997, and wholesale prices 1994 through 1996.

1 The credit is 5 cents per gallon of pure ethanol, not per gallon of ethanol-gasoline mix.

2 The federal Clean Air Act requires the use of oxygenated gasoline in areas that are out of compliance with federal air quality standards. The Twin Cities Area is out of attainment with carbon monoxide standards and is required to use oxygenated gasoline from October through January. Ethanol is the only oxygenate currently in use in Minnesota.

Over this period, oxygentaed gasoline has generally cost at least 2 to 3 cents more than nonoxygenated gasoline nationally, regionally, and in Minnesota, as far as the numbers can be determined from available data.

Minnesotans use about 2 billion gallons of gasoline each year, so each penny of additional price is equal to $20 million in costs attributable to the oxygenated fuel requirement. But since the Twin Cities area (about half the state's population) is under a federal Clean Air Act requirement to use oxygenated gasoline from the first of October through January each year, the cost of the state requirement is only five-sixths of $20 million for each additional penny that oxygenated fuel costs. If we take this into consideration, and if we split the difference between two and three cents per gallon:

- **We estimate that the statewide requirement to use oxygenated gasoline will cost consumers about $42 million each year.**

The programs just described were designed to promote the production of ethanol in Minnesota, and the evidence suggests that:

- **Minnesota's ethanol industry has come into existence largely in response to Minnesota's ethanol programs, especially the producer payment. Very little production existed prior to 1987 when the producer payment was enacted.**

Minnesota has eight ethanol plants with a production capacity of about 92 million gallons per year.

As of September 1996, Minnesota had eight plants on line with a capacity of about 92 million gallons per year. One plant is a large "wet mill" that produces about 30 million gallons of ethanol, but could produce a lot more if it devoted more of the corn it grinds to ethanol production. [3] There are two small plants of around one million gallon capacity each. One produces ethanol from dairy whey, the other from food processing waste. The five remaining plants are "dry mills" of 8 to 15 million gallon per year capacity. Several plants are under construction and additional plants are being planned.

The total capitalization of a 15 million gallon per year dry mill ethanol plant is about $25 to $30 million. While the exact terms of each Minnesota project have varied, the sale of common stock financed about 40 to 50 percent of the cost of the four plants built between 1994 and 1996, and bank loans or other debt with a term of 7 to 10 years financed most of the remaining cost. All but one of Minnesota's major ethanol plants are farmer-owned cooperatives where ownership of a share of common stock requires delivery of one bushel of corn to the plant each year. In the case of each of the four dry mills, the plants received a low-interest Minnesota ethanol facility production loan of $500,000, as well as up to $1 million in tax increment financing.

Agriculture department officials, plant managers, and lenders all told us that the role of the producer payment was critical to financing the production facilities,

3 Wet mills separate the germ from the remainder of the corn kernel and can refine corn oil from the germ as well as ethanol and higher-value products from the starch content of the kernel. Dry mills grind the entire corn kernel and are limited to the production of ethanol and Distillers Dried Grain and Solubles (DDGS) an animal feed.

because it provides a secure revenue stream for ten years that is about equal to the cost of constructing the plant and starting production. A 15 million gallon plant receives $3 million per year (at 20 cents per gallon of ethanol production). Over ten years this provides $30 million which, as we have seen, is enough money to build the plant and capitalize the company. Banks have been willing to lend money for 7 to 10 years to finance about half the project costs. Under these terms bankers do not have to assume that the plant will be profitable over the long run.

ECONOMIC BENEFITS

Most of the communities in which ethanol plants are located, and the surrounding counties, are struggling with problems of limited economic diversity and declining populations. We found:

- **Construction and operation of ethanol plants are a boon to the communities in which they are located, and there are significant benefits for the state as a whole.**

Ethanol plants improve the economic climate in small cities by providing new job opportunities. Ethanol plants typically employ around 27 people and provide good wages and benefits.

Ethanol plants have a significant local and statewide economic impact.

In addition to jobs and tax revenue, small cities receive other benefits from ethanol plants. Most cities improved their roads or utility infrastructure as a part of ethanol plant development. All of the most recent plants have received tax increment financing, however, so local governments have subsidized these infrastructure improvements. Officials in these cities hope that these improvements will increase their ability to attract and retain other business ventures.

All but one of the major ethanol plants have been organized as farmer-owned cooperatives. The benefits of the cooperative structure are two-fold. First, any profits from ethanol production are distributed among the farmer-owners. This allows farmers to participate in the profits from processing the raw commodities they produce. Second, cooperatives may be better able to withstand periods of high corn prices, making them more stable forces in the community. Farmers can provide corn at below market rates during such periods.

Unlike local benefits, statewide impacts cannot be measured directly. We estimated the statewide economic impacts of ethanol production using a method called "input-output analysis." This method allows us to estimate the ripple effects that are created in the economy by a project such as the expansion of the ethanol industry in Minnesota.

In fiscal year 1997, the Department of Agriculture projects that the ethanol industry will manufacture 99 million gallons of ethanol. Using a long term average price for ethanol of $1.30, this represents about $129 million in revenue. We estimate an additional $41 million in revenue will come from sales of animal feed byproducts, again assuming average prices. The department projects producer payments will total $17 million in fiscal year 1997. Thus, industry revenues for fiscal year 1997 are expected to total to $187 million.

Economic Impact of Ethanol Production

Ethanol production has an overall economic impact that is greater than the value of plant revenues. Firms that supply goods and services to the plant, such as corn growers and trucking companies, receive benefits and local shopkeepers profit from increased economic activity. Input-output analysis uses the economic relationships between industry sectors in the overall economy to estimate the indirect and induced effects, for example, in the transportation and retail sectors.

We estimate the annual statewide economic impact of ethanol production to be $211 to $327 million, as shown in the accompanying table. The range of values represent different assumptions about the value added per bushel of corn by ethanol production over the market price for the raw commodity.

We also estimated the economic costs of public subsidies using the input-output method, in order to calculate net statewide impacts. Ethanol programs such as the producer payment and blender's credit have implications for the taxes paid by Minnesotans, while oxygenated fuel requirements in excess of federal requirements raise fuel prices for consumers.

Economic Impact of Ethanol Production and Use

		Output Impact (Millions)	Employment Impact (Jobs)	Personal Income Impact (Millions)
ANNUAL BENEFITS AND COSTS[1]				
Ethanol Industry		$211 - 327	1,132 - 1,618	$37 - $51
Producer Payment		(20)	(314)	(8)
Blender's Credit		(7)	(102)	(3)
Metro Area Summertime Use:				
Higher Fuel Cost[2]	2 to 5 cents per gallon	(16) - (39)	(246) - (633)	(6) - (15)
Lower Fuel Economy[3]	2.3 to 3.5 percent decrease	(24) - (36)	(373) - (575)	(9) - (14)
Total		$109 - $260	(492) - 583	$(3) - 25
ONE-TIME NET BENEFITS				
Construction Impacts:	1/2 Local Content	174	1,146	38
	2/3 Local Content	232	1,537	50
	3/4 Local Content	261	1,733	57

[1]All benefits and costs are based on fiscal year 1997 projections, except as noted.

[2]Assumes 667 million gallons annual consumption.

[3]Assumes 667 million gallons annual consumption and $1.30 per gallon fuel costs.

Economic Impact of Producer Payments

The Department of Agriculture projects producer payments to total $17 million in fiscal year 1997. We estimate the "cost" of this public expenditure by calculating the impact of an equivalent increase in middle income household spending. Input-output analysis uses data on past consumption patterns to estimate the economic impact of a spending change.

If the producer payments were not made, and instead taxes on middle income households were reduced by an equivalent amount, the impact would be a $20 million increase in statewide economic output, as shown in the table. In other words, paying the $17 million subsidy costs the state $20 million in consumer expenditure impacts.

Economic Impact of the Blender's Credit

The positive impacts from ethanol production are partly offset by the costs of ethanol incentives and requirements.

The impact of the blender's credit is also estimated as the impact of an equivalent increase in middle income household expenditures. The Department of Revenue projects the value of credits for fiscal year 1997 to be $6 million. As shown in the accompanying table, we estimate the total impact to be a cost of $7 million.

Economic Impact of Year-Round Ethanol Use

Consumers also incur costs as a result of the year-round oxygenated fuel requirement in the Twin Cities area. We assume that about 2 billion gallons of gasoline are used in the state, and about one-half of that total is used in the Twin Cities area. Federal law requires use of an oxygenate in four winter months in the Twin Cities, so only two-thirds of the annual costs associated with use are attributable to state policy.[4] Thus, about 667 million gallons are to be affected in fiscal year 1997. The effects of oxygenated fuel are measured in higher fuel prices and lower fuel economy.

We estimate oxygenated fuel costs at 2 to 3 cents more than conventional gasoline, but other estimates put this premium at 5 to 6 cents or higher. The impact of raising the price of this portion of gasoline by 2 cents per gallon, and alternatively, by 5 cents per gallon, are shown in the table. We estimate that year-round ethanol use in the Twin Cities costs the state between $16 and $39 million annually.

Furthermore, vehicles travel fewer miles per gallon of oxygenated fuel as compared with conventional gasoline. This results in 2.3 to 3.5 percent more gasoline being consumed, and (assuming a price of $1.30 per gallon) an annual loss of $24 to $36 million in statewide economic impacts.

4 Starting in October, 1997, oxygenated gasoline will be required statewide, increasing the cost factor to five-sixths.

Economic Impact of Ethanol Plant Construction

Construction of an industrial facility such as an ethanol plant has a large, but short-lived, impact on the state's economy. The impact on the state's economy of constructing ethanol facilities is presented in the table. This impact differs from the annual estimates just presented in that it represents a one-time boost to the state's economy.

Plant records indicate that construction of a dry milling ethanol production facility costs roughly $2 per gallon of production capacity. Using this figure, the cost to build the state's 99 million gallons of capacity was around $198 million. Assuming two-thirds of this total supports Minnesota construction firms, the total one-time output impact from facilities construction is estimated to be $232 million. The table also shows estimates derived under the assumptions of one-half and three-fourths local content of $174 million and $261 million, respectively.

Ethanol production generates economic activity each year of $109 to $260 million.

Net Benefits

Adding up the benefits and costs discussed above:

- **We estimate the ethanol industry generates a net annual impact of between $109 and $260 million, statewide. In addition, we estimate a one-time benefit of $174 to $261 million from plant construction.**

Employment and Personal Income Impacts

Our estimates also include the impacts of ethanol production on statewide employment and personal income. The sectors that gain employment directly from increased ethanol production are mostly manufacturing sectors. In general, these sectors are highly mechanized and levels of output per worker are high. Hence, a given change in output supports a relatively small number of jobs. In contrast, decreases in household spending due to the cost of ethanol programs affect workers mainly in the retail sectors, where output per worker is lower. Thus for a given transfer of income from households to the ethanol industry, more retail jobs are lost than there are jobs created in manufacturing. The net result depends on specific assumptions, but job impact estimates range from a loss of 492 jobs to a gain of 583 jobs for fiscal year 1997.

The ethanol industry has a net positive impact on total state personal income under all but the most unfavorable combination of assumptions. Estimates range from a negative $3 million to a positive $25 million.

ENVIRONMENTAL BENEFITS

Ethanol is one of two oxygenates commonly used as a gasoline additive to control carbon monoxide (CO) emissions during the winter. The Twin Cities area is one of 39 areas across the nation out of compliance with federal standards for atmospheric carbon monoxide. In such "non-attainment" areas, gasoline containing 2.7 percent oxygen (by weight) is required from October 1 to January 31 each year. We examined the scientific literature on the benefits of wintertime use of oxygenated gasoline. We asked whether ethanol use allowed Minnesota to meet federal carbon monoxide standards, and to what extent there are positive environmental benefits to summertime use of ethanol in Minnesota.

Wintertime Ethanol Use

From a review of scientific studies and interviews with state and federal pollution control officials, we learned:

- **While atmospheric carbon monoxide has declined dramatically over the last 25 years, much of the decline occurred prior to the start of the oxygenated fuel program in 1991.**

By 1990, CO emissions nationally had declined to about 30 percent of their 1970 levels.

The effect of oxygenated gasoline was examined in a recent report of the National Research Council (NRC).[5] The NRC is an operating agency of the National Academy of Sciences which was established under a congressional charter to advise the federal government on scientific and technical matters. Although their advice is not infallible, the NRC appoints distinguished panels to objectively assess scientific studies in areas of concern to policy makers.

The NRC report, which reviewed hundreds of studies on the use of oxygenates to reduce wintertime carbon monoxide, is far more comprehensive and authoritative than any review we could have conducted, and we relied heavily, but not exclusively, on its conclusions about the environmental effects of oxygenated gasoline. The NRC study concluded:

- **Most of the reduction in atmospheric CO in recent years has been due to improved vehicle emissions equipment. The use of oxygenated gasoline cannot be linked to a significant reduction in atmospheric carbon monoxide.**[6]

The National Research Council, reviewing other studies, concluded that little or no reduction in ambient CO levels is due to the use of oxygenated fuels in newer vehicles with properly operating emissions systems. The NRC reviewed studies

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5 National Research Council, *Toxicological and Performance Aspects of Oxygenated Motor Vehicle Fuels*, Washington, D. C., National Academy Press, 1996.

6 The following are direct quotes from the report: ". . . the effects of oxygenated fuels on reduction of ambient CO levels are small at best; in some locations, increases in ambient CO have actually occurred." ". . . the major problem is a lack of thorough, statistically defensible analys is of ambient data . . ." National Research Council, 1996, 40.

reaching divergent conclusions on the efficacy of oxygenated gasoline, and called for more and better research on key questions.[7]

Minnesota has not recorded any violations of United States Environmental Protection Agency (EPA) carbon monoxide regulations in recent years and, according to the EPA, there have been few violations anywhere in the country. EPA foresees the time that wintertime oxygenate use will only be required in a few problem areas rather than the 39 metropolitan areas in which it is now required.

The National Research Council was very critical of the lack of cold-weather tests of oxygenated gasoline in light of some studies that show big differences in the effectiveness of oxygenated gasoline in cold weather, and some studies that actually show increased CO emissions at low temperatures. The EPA tests oxygenated gasoline at 75 degrees, and this obviously limits the applicability of test results to Minnesota wintertime conditions.

Summertime Ethanol Use

There are serious concerns about the adverse effects of using ethanol in warm-weather months.

Minnesota now mandates year-round use of oxygenated gasoline at 2.7 percent oxygen content in the Twin Cities area and will require oxygenated gasoline statewide starting in October 1997. We found:

- **There is a serious question in the literature and among pollution control officials in Minnesota about the environmental benefits of summertime use of ethanol in areas, such as Minnesota, that meet federal ozone standards.**

Ethanol raises the volatility of the fuel with which it is mixed, and summertime use requires a waiver from the federal volatility standards that apply to the use of gasoline mixed with methyl tertiary butyl ether (MTBE), the most commonly used oxygenate across the country. Controlling the volatility of gasoline is important in the summer, since gasoline is naturally more volatile at higher temperatures, and gasoline contains harmful volatile organic compounds that cause human health problems directly and also lead to ozone (smog) formation.

The Minnesota Pollution Control Agency (PCA) was concerned with summertime pollution effects of ethanol and sponsored a consultant study which concluded that summertime ethanol use is neither beneficial nor harmful.[8] Ethanol reduces tailpipe emissions of CO and certain toxins, but increases the release through evaporation of other harmful compounds. Based on a review of this study and interviews with PCA and EPA, we conclude that:

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7 The Minnesota Department of Agriculture referred us to a January 1997 consultant study sponsored by the Oxygenated Fuels Association and the Renewable Fuels Association that purports to show a positive effect of oxygenated gasoline on atmospheric CO. (Systems Applications Inc., 1997.) This study and others in the future may cause the scientific consensus to change. Nevertheless, we think the NRC report is curently the most independent, authoritative document available to policy makers.

8 Whitten, Gary Z., Austin, Barbara S., and O'Connor Karina, *Ozone Impact of Year-Round Oxy-Fuel Program in Minnesota*, Systems Applications International, June 30, 1994.

- **The net environmental benefits of ethanol use are minimal or non-existent in the summer.**

OTHER ISSUES

Ethanol use has been viewed by some as the cause of a variety of engine performance problems in automobiles, recreational equipment, and various small engines. We reviewed the best and most recent studies and conclude:

- **There is no substantial evidence of mechanical problems in modern engines from the use of 10 percent ethanol blends, although in some cases, carburetted engines need minor modification for optimal performance.**

Ethanol contains a third less energy than gasoline. Use of ethanol blends reduces fuel economy 2.3 to 3.5 percent.

A gallon of ethanol contains about 33 percent less energy than a gallon of gasoline, and fuel economy directly reflects the energy content of fuel, so,

- **There is a 2.3 to 3.5 percent drop in fuel economy when motor vehicles are run on ethanol blends.**

The exact loss of mileage varies with the concentration of ethanol in the fuel and the density of gasoline used which varies with the season. Ordinarily the drop in fuel economy will not be noticed by drivers, because it is less than one mile per gallon in a car getting 25 miles per gallon, and is less than the tank-to-tank variation that occurs because of changing driving conditions. On a statewide basis, however, a 2.3 percent reduction in fuel economy translates to 46 million additional gallons of gasoline each year.

Advocates of ethanol use point out that ethanol substitutes for petroleum and does not contribute to global warming. Advocates also point out that imported petroleum use carries hidden costs in the form of spending on military protection and environmental cleanup of oil spills.

Indeed, while burning ethanol puts CO2 into the atmosphere, the corn or other biomass from which ethanol is produced recently took this CO2 out of the atmosphere. On these grounds ethanol is preferable to fossil fuel; however, substantial energy, much of it derived from fossil fuel, is used in growing corn and producing and distributing ethanol.[9] Also,

- **Ethanol consumes about 7 percent of U. S. corn production and contributes a very small amount, about one-tenth of 1 percent, to United States energy consumption.**

There is no realistic scenario under which ethanol produced from corn or other grain can contribute much to independence from imported oil or contribute mean-

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9 Studies suggest that the net energy value of ethanol is 24 percent, meaning that ethanol contributes 24 percent more energy than is required for its production.

ingfully to reduction in greenhouse gasses in the atmosphere. About 39 percent of national energy needs are provided by petroleum. If ethanol were to contribute as much as 1 percent of national energy needs, it would use about 70 percent of United States corn production, and long before this happened food prices would increase unacceptably. Under any realistic ethanol scenario, oil imports will continue at substantial levels, so all the military and environmental costs associated with petroleum will continue.

RISKS TO FUTURE VIABILITY

We have seen that there are sizable local and statewide economic benefits to increased ethanol production. However, we urge policy makers to consider several risks to the future of the industry in Minnesota. The projected economic benefits of ethanol require an industry that can prosper under future conditions. The major contingencies include:

- **The risk that ethanol producers will not be able to make money at prevailing prices for corn and ethanol;**
- **The possibility that Minnesota plants will lose out in competition with larger, more efficient producers;**
- **The possibility that the federal government will withdraw all or much of its current 54 cent per gallon tax credit for ethanol.**

PROFITABILITY

The future profitability of ethanol production is subject to several risk factors.

The most fundamental question faced by any business is its profitability under conditions that will prevail in the future. The profitability of the ethanol industry depends chiefly on prices for corn, ethanol, distillers grains, and on the future of state and federal subsidies to ethanol production.

We collected production cost data from all the major operating ethanol plants in Minnesota, all but one of which are dry mills. We also reviewed published data on the same type of ethanol factories as the major dry mills currently operating in Minnesota. These sources allowed us to gain an accurate understanding of the economics of ethanol production and the range of prices for corn and ethanol under which production will be profitable.

We estimate that variable costs of ethanol production, excluding corn, are 37 cents per gallon and fixed costs are 29 cents. Variable costs include energy, water, supplies and certain employee payroll costs; fixed costs include management, insurance, depreciation and other expenses that do not vary with production. The price of corn is the biggest factor in determining the cost of ethanol, generally representing between one-half and two-thirds of total costs. Corn prices have varied widely in the last several years, and per-gallon corn costs have ranged from 73 cents to $1.77. (About 2.6 gallons of ethanol can be produced from a bushel of corn.) Our analysis shows:

- **Minnesota's ethanol plants will be profitable at long-term average prices for corn and ethanol, assuming continued federal subsidies.**

Average prices for corn and ethanol over the period 1988 through 1995 were about $2.25 per bushel and $1.30 per gallon respectively. At these prices, we estimate the net profit per gallon of ethanol production to be 40 cents. This corresponds to a return of about $1.00 per bushel of corn processed. At an ethanol price of $1.30 per gallon, the plants can break even with a corn price as high as $3.25 per bushel. Our analysis also shows:

- **Profitable ethanol production was possible (with the producer payment) at the prices prevailing in 15 of the 24 months ending October 1996. Without the producer payment ethanol production would have been profitable in 7 of 24 months.**

Prices in the corn and ethanol markets have been volatile in recent years. We looked at historical price data to reach conclusions about profitability under real-world conditions. Much of 1995 saw moderate corn prices coupled with below average ethanol prices, and 1996 saw near-record high prices for both. Corn prices were over $5.00 per bushel and peaked at $5.54 at the Chicago Board on July 12, 1996. The price of ethanol was also high during this period, around $1.60. At corn and ethanol prices of $4.75 and $1.60 respectively, the estimated per gallon profit is a negative 26 cents per gallon.

Risk factors include prices for corn and ethanol and continuation of state and federal ethanol subsidies.

As we learned during our plant visits during the summer of 1996, plants were losing money, although the ethanol co-ops' ability to pay less than full market price for corn (most try to make an initial payment of 80 percent of the market price) helped them to keep the factories going.

FEDERAL AND STATE SUBSIDIES

The federal government pays ethanol distributors 54 cents per gallon of ethanol in the form of a highway tax credit. Minnesota pays a 5 cent tax credit, and also pays producers 20 cents per gallon of ethanol. Our production model, presented in our full report, can be used to estimate the effect on ethanol plant profitability if all or part of these subsidies are eliminated. The producer payment is scheduled to be phased out by 2000 or ten years after the start of production. By itself,

- **The loss of the producer payment means that profits will be reduced 20 cents per gallon.**

Without the producer payment, the per-gallon profit of 40 cents at long term prices would be reduced to 20 cents. The "profit" of minus 26 cents during the high price environment of 1996 would be reduced to a minus 46 cents per gallon.

The possible loss of the 54 cent federal tax credit has to be calculated another way. The loss of the credit has the same effect as reducing the price of ethanol by 54 cents per gallon. If we do this using any realistic price assumptions for corn and ethanol, our model shows:

- **The loss of the 54 cent federal subsidy would be catastrophic to the ethanol industry, and Minnesota (and national) ethanol production would decline to near zero. Ethanol plants cannot make money if the price of the product declines by 54 cents under any realistic price assumptions.**

The federal tax credit expires in 2000 and a vote by Congress will be necessary to renew it. The Minnesota ethanol producers we talked to cite the possible loss of the federal credit as the biggest risk to their future profitability that they can see. The nation's largest ethanol producer is Archer Daniels Midland whose four plants have an annual production capacity totaling 750 million gallons per year, or half the nation's total production capacity. Archer Daniels Midland has recently paid a $100 million fine for conspiring to fix the price of two products it produces from corn, and opposition to corporate subsidies, and to the ethanol subsidy, appears to be growing in Congress. This is not to say we think it is likely that the entire credit will disappear. A reasonable speculation is that it will be reduced. Minnesota policy makers need to consider the risks to further public investment in the Minnesota ethanol industry under these circumstances.

Minnesota's ethanol plants face competition from larger, more efficient dry mills, and from wet mills that can produce a wider variety of products.

COMPETITION

A key risk to the Minnesota ethanol industry which consists mainly of dry mills under 15 million gallon capacity is:

- **Smaller plants have higher average production costs than larger plants, and dry mills produce a narrower and less valuable mix of products than do wet mills. The size and adaptability of wet mills may enable them to be profitable under conditions where dry mills cannot survive.**

- **The highly concentrated ownership of ethanol production may also pose risks for Minnesota producers.**

Minnesota producers face competition from large companies with large plants. One of Archer Daniels Midland's plants produces twice as much ethanol as all Minnesota producers put together. The top five companies produce nearly 75 percent of the nation's ethanol. This concentrated ownership means that large producers can set a price for ethanol that smaller companies might have to take.

Dry mills produce only ethanol and animal feed while wet mills can produce a variety of higher value products including corn oil, corn syrup, high fructose corn syrup and other products. An analysis prepared by the Minnesota Department of Agriculture shows that dry mills can produce as much ethanol from a bushel of corn as wet mills, but that a wet mill can add much more value to a bushel of corn than a dry mill. At April 1996 prices, MDA estimates that a dry mill produces products worth $5.12 from corn priced at $4.80. The wet mill can produce mixes of products with values ranging from $5.04 (if they produce only ethanol and animal feed) to $8.42 if they maximize high fructose corn syrup production.

This illustration suggests that wet mills can be profitable under a wider range of market conditions than dry mills. When ethanol prices are low, corn syrup prices could be high, for example. The advantage held by dry mills is that they are significantly cheaper to build, about $2 per million gallon capacity for a 10 to 15 million gallon per year factory. A wet mill costs several times this amount.

According to our interviews with plant managers, Minnesota's dry mills are not efficiently-sized in terms of staffing requirements. A substantial increase in production in these mills would require little or no increase in employees. Minnesota's cap on the producer payment at 15 million gallons of annual production may be partly responsible for limiting the size of recently-built plants. Some plants are attempting to achieve greater economies of scale through cooperative marketing agreements. An important issue is whether Minnesota producers can compete with larger dry mills and large wet mills in an environment where the large companies can set the price for ethanol and could underprice Minnesota producers if they needed or chose to do so.

Finally, there are other risks to the future of corn-based ethanol production. The federal government, for example, is funding a major research effort on production of ethanol from cellulose sources such as grasses and fast-growing trees. Commercial application of this technology could threaten Minnesota's corn-based production facilities. Minnesota's investment in ethanol is considerable compared to its other economic development programs. Given the risks to future profitability discussed above, we think that:

- **Policy makers should consider whether so much of Minnesota's rural economic development effort should go to one industry.**

Minnesota's ethanol programs should not be based on the premise that profitable ethanol production is a sure bet. There are plausible scenarios for both success and failure.

Introduction

Minnesota is a major corn producer. A bushel of corn converted to ethanol can be sold for more than the raw commodity.

Ethanol production complements Minnesota's agricultural economy because Minnesota, one of the nation's leading corn producing states, exports most of its corn as a raw commodity. Although ethanol can be commercially produced from various materials, over 95 percent of fuel ethanol production in the nation and in Minnesota uses corn as the raw material.

In 1995 Minnesota was the fourth largest corn producer among the states, with 6.70 million acres planted, and 6.15 million acres harvested. The value of the corn harvested for grain in Minnesota was $2.1 billion in 1995. Between 1988 and 1995, Minnesota produced an average of 655 million bushels annually. For the same period, U. S. average annual production was 7.6 billion bushels. Thus, during this eight-year period, Minnesota produced 8.6 percent of the nation's corn.

In 1993, according to Minnesota Department of Agriculture estimates, about 62 percent of the corn grown for grain in Minnesota was exported out of the state as a raw commodity. About 33 percent was fed to livestock and 5 percent was processed into other products including ethanol. It is a goal of economic development policy to process a greater share of the state's agricultural products within the state in order to add value to raw products and improve the state's economy, especially the rural economy. A bushel of corn converted into ethanol and co-products can be sold for more than the corn itself, so ethanol production is one way to add value to the grain that would otherwise be sold at a lower price.

Minnesota has enacted a set of programs designed to promote the production and use of ethanol. Minnesota's ethanol programs are based on the sound assumption that the state as a whole, and the corn-growing regions of Minnesota in particular, will benefit if a profitable ethanol industry is established. As we will see, taken together these programs represent a level of effort that exceeds that of any other state. These programs have succeeded in fostering the growth of ethanol production capacity that has grown from almost nothing in the mid-1980s to 92 million gallons per year in 1996. The state has supported the industry through subsidized loans, producer payments, tax credits, and a requirement to use oxygenated gasoline that will become a statewide, year-round mandate in 1997. As a result, Minnesota has a sizable investment in the future of the industry.

Ethanol subsidies are a controversial issue nationally and in Minnesota, and questions have been raised about the benefits of ethanol use and the need for continued taxpayer support. The Minnesota Legislature heard some testimony questioning ethanol subsidies last year, and the Legislative Audit Commission asked the Office of the Legislative Auditor to carry out a study that would look further into the costs and benefits of the state's ethanol programs.

This report asks:

- **What are Minnesota's ethanol programs and how much do they cost?**
- **To what extent have the programs succeeded in promoting the establishment and growth of ethanol production facilities in Minnesota?**
- **What are the economic and environmental benefits of ethanol production and use?**
- **Are ethanol plants profitable at current prices? At what future prices of corn and ethanol will the Minnesota ethanol industry be profitable? Will continued state and federal subsidies be required for future profitability?**
- **What are the major risk factors affecting the future viability of ethanol production in Minnesota?**

To answer these questions, we reviewed the history of Minnesota's ethanol programs and discussed the programs with officials in the Minnesota Department of Agriculture responsible for administering them. We also visited six Minnesota ethanol plants and talked to plant managers about their experience in building and operating the facilities. We obtained production and financial data from each plant in order to put together a composite picture of production costs. In many cases we talked to public officials and others in the communities we visited who were involved in the effort to build or locate a plant in the community.

We reviewed the national literature and past Minnesota studies relating to the environmental and economic issues connected to ethanol use and production. We interviewed experts in several state and federal agencies on various technical questions, and in order to carry out the economic analysis reported here, we obtained data and specialized software that allows an estimate of the direct and indirect economic impact of an expanded ethanol industry.

Our report is organized in four chapters. Chapter 1 provides background information on Minnesota's ethanol programs, including data on ethanol production and the cost of each major program. Chapter 2 presents our analysis of the state and local economic benefits of ethanol production. Chapter 3 presents a review of scientific findings on the environmental benefits of ethanol use, along with an examination of studies of ethanol's effect on fuel economy and mechanical performance. Chapter 4 is a discussion of major risks to the future profitability of the ethanol industry in Minnesota.

Minnesota's Ethanol Programs

CHAPTER 1

Many midwestern states promote the production and use of ethanol by offering low-interest loans and by various promotional activities. What sets Minnesota apart from other states is the scope and variety of its programs, including a broad mandate to use oxygenated gasoline, a producer payment of 20 cents per gallon, and a highway tax credit for ethanol blends.

Minnesota promotes the production and use of ethanol through a variety of programs.

This chapter asks:

- **What are the incentives and requirements for ethanol production and use in Minnesota?**
- **How much do the programs cost?**
- **How do Minnesota's ethanol programs compare with programs offered by other major corn-producing states?**
- **What are the federal policies governing ethanol production and use in Minnesota?**
- **What is Minnesota's ethanol production capacity and how has it grown in recent years?**
- **To what extent have these programs succeeded in promoting the creation and expansion of the ethanol industry in Minnesota?**

MINNESOTA ETHANOL PROGRAMS

In the following sections we will describe each of Minnesota's ethanol programs, and present cost data on each. We will also take a look at ethanol programs in other states. Finally, we will present some information on the ethanol industry in Minnesota and the United States, and examine the question of whether Minnesota's ethanol industry owes its existence to the state ethanol programs.

Oxygenate Mandate

Starting in October 1997, oxygenated gasoline will be required statewide.

The 1990 amendments to the federal Clean Air Act require the use of oxygenated gasoline between October 1 and January 31 in federally designated carbon monoxide non-attainment areas. [1] During this period, gasoline must contain 2.7 percent oxygen by weight, and this is achieved with a mixture of about 7.7 percent ethanol (by volume) in gasoline. A 10 percent concentration of ethanol achieves a concentration of oxygen of approximately 3.5 percent. In Minnesota, the 10 county Twin Cities metropolitan area is included in the carbon monoxide (CO) non-attainment area.[2] This federal requirement was put into effect in October 1992.

In 1991, Minnesota enacted a year-round requirement that gasoline sold for motor vehicle use in air quality non-attainment counties must have a minimum oxygen content of 2.7 percent. This requirement went into effect in the Twin Cities area in October 1995 and is scheduled to become effective statewide in October 1997. [3] Thus,

- **Minnesota has significantly extended the geographic area and the time period in which oxygenated gasoline is required over that required by federal law.**

Ethanol is the only oxygenate currently used in Minnesota although about two thirds of the oxygenate used nationwide is methyl tertiary butyl ether, (MTBE) produced from methanol.

Producer Payment

Minnesota pays ethanol producers 20 cents per gallon.

The state of Minnesota pays ethanol producers 20 cents per gallon up to a per plant limit of $3 million and a statewide limit of $30 million for all plants. In general, payments last 10 years from the start of production. The producer payment was enacted in 1986 (Laws of Minn., Ch. 1) and payment rates and maximums (as well as actual payments) have increased over time. Table 1.1 presents a summary of legislative adjustments to the producer payment over the years. From 1986 to 1995, the rate per gallon increased from 15 cents per gallon to 20 cents and the maximum rose from $10 million to $30 million per year. [4]

The significance of changes in limits on the producer payment, of course, depends on whether actual production reaches these limits. In the aggregate, the producer payment can now pay 20 cents per gallon on 150 million gallons of ethanol production statewide. In the past, when the statutory cap in the producer payment appeared to be inhibiting investment in ethanol production facilities, the payment

1 These are areas that are out of attainment with U. S. Environmental Protection Agency standards governing atmospheric concentration of carbon monoxide.

2 The Duluth area was originally designated a CO non-attainment area, but was redesignated by the EPA as complying with CO standards in 1993.

3 *Minn. Stat.* 239.791, Subd. 1.

4 In 1994 the rate and per plant maximum were higher, but the law was changed before these provisions went into effect.

Table 1.1: Producer Payment History

Minnesota Legislation		Effective Dates	Payment Rate[1]	Annual Maximum (in millions) Single Plant	All Plants
1986 Special Session	Ch. 1	FY 1987	$0.15		$0.20
1986 Special Session	Ch. 1	FY 1988-92	.20	$3.00	10.00
1991	Ch. 302	FY 1992-00	.20	3.00	4.50
1992	Ch. 513	Through FY 2000	.20	3.00	8.50
1994	Ch. 632	FY 1994-95	.20	3.00	20.00
1994	Ch. 632	FY 1996-00	.25	3.75	20.00
1995	Ch. 220	Until 2000[2]	.20	3.00	30.00

Source: Minnesota Department of Agriculture.

[1]Full payment is for pure anhydrous alcohol. Payment is reduced for wet alcohol.

[2]*Laws of Minnesota*, 1995, Ch. 220 provides for payment until 2000 or 10 years after the start of production, whichever is later.

cap was increased. While the current statewide maximum has not been reached and probably will not be reached in the next five years, two plants have already reached the $3 million dollar cap on payments to a single plant.

Blender's Credit

The blender's credit has been the state's largest ethanol subsidy, but it is scheduled to end in October 1997.

The blender's credit provides a tax credit to wholesalers or retailers of ethanol-blended gasoline, so that gasohol is exempt from part of the tax due on straight gasoline. In 1994 and 1995 the Legislature enacted changes that will phase out the blender's credit by October 1997. [5] The credit was 20 cents per gallon (of pure ethanol) until October 1994, 15 cents until October 1995, 8 cents until October 1996, and 5 cents per gallon until October 1997. The decision to phase out the blender's credit was made in conjunction with the decision to expand the amounts paid and payable through the producer payment. Some form of the blender's credit dates back to the early 1980s. [6]

The blender's credit has been the state's largest ethanol subsidy in recent years. According to the Minnesota Department of Revenue which administers the blender's credit, the credit totaled $11.9 million in fiscal year 1992, $20.2 million in 1993, $24 million in 1994, $22.9 million in 1995, and $13.7 million in 1996. The blender's credit will reach zero for fiscal year 1999.

5 *Laws of Minnesota*, 1994, Ch. 632, and *Laws of Minnesota*, 1995, Ch. 220.

6 *Laws of Minnesota*, 1980, established a 4 cent per gallon tax exemption, Laws of Minnesota,1983, Ch. 17, established a 2,4, and 8 cent per gallon tax exemption applicable to different time periods and for different purposes. In 1985, the Legislature established a 40 cent per gallon tax credit to distributors of fuel grade alcohol blended with gasoline and an 80 cent per gallon tax credit to distributors of fuel grade alcohol blended with gasoline and sold in bulk to government or for school transportation.

Loan Programs

The Minnesota Department of Agriculture (MDA) administers two loan programs designed to assist the financing of ethanol plants, the Ethanol Production Facility Loan Program and the Value-Added Agricultural Processing Loan Program also known as the Stock Loan Program. Ethanol plants are also eligible for economic recovery grants through the Minnesota Department of Trade and Economic Development and tax increment financing through local units of government.

Minnesota offers several loan programs designed to assist in the financing of ethanol plants.

The Ethanol Production Facility Loan Program was established in 1993 to help finance ethanol plants with low-interest loans of up to $500,000 per plant.[7] The purpose of the program, as explained by MDA, is to encourage private lenders through a demonstration of state commitment and interest and to fill in gaps in the financing arrangements that ethanol plant developers are able to put together. The 15 million gallon per year plants recently built cost $18-25 million for construction and $25-30 million in total capitalization, so a loan of $500,000 can only supplement other financing sources. Generally the state's security interest is subordinate to that of other lenders. The exact details of each loan contract vary; the term of the loan is 7 to 10 years and the interest rate is 6 percent per year. As we discuss later in this chapter, the Minnesota producer payment involves much more money (up to $3 million per year per plant), and is essential to obtaining bank financing for most of the recently built ethanol plants. The production facility loans play a lesser role because of the small size of the subsidy (reduced interest on a maximum of $500,000).

Production facility loans are administered by the Agriculture Finance Division of the Minnesota Department of Agriculture. The production facility loans are financed through the Ethanol Development Fund. Appropriations to the fund totaled $1 million in 1993, $1,475,000 in 1994 and $350,000 in 1995. Repayment of the loans is deposited back into the Ethanol Development Fund to be used for further ethanol production facility loans.

As of the end of fiscal year 1996, loans had been issued to most of the operating ethanol plants in Minnesota, specifically the plants located in Benson, Winnebago, Winthrop, and Morris. In addition, loan commitments had been made to plants in Claremont, Buffalo Lake, and Little Falls. As of March 31, 1996 the uncommitted balance of the Ethanol Development fund was zero. According to agriculture department officials, repayment of all loans is current.

The Value-Added Agricultural Product Loan Program, also known as the Stock Loan Program, was enacted to help farmers finance the purchase of stock in a cooperative proposing to build or purchase and operate a facility to process agricultural crops.[8] The loan can be used to finance the purchase of stock in various farmer owned cooperatives, including ethanol plants. The program was funded by 1994 and 1995 appropriations totaling $450,000 to the Value-Added Agricultural

7 *Laws of Minnesota* 1993 Chapter 342, *Minn. Stat*. 41B.044.

8 *Laws of Minnesota* 1994 Chapter 642.

Product Revolving Fund.[9] The program is also administered by the MDA's Agriculture Finance Division. Interest and principal payments return to the fund and are available for further loans.

The loans provide 45 percent of the loan principal to a maximum of $24,000 to farmers applying for a loan through local lenders. The lender applies for state participation on qualifying loans. Loans are for a maximum of eight years, and loan payments of interest only are permitted for up to two years, with a fully amortized repayment schedule calculated for the remaining years. Interest on the state's portion of the loan is 4 percent or one-half of the lender's effective rate at the time of closing, whichever is lower. At the end of fiscal year 1996, a total of $466,191 in loans had been made, most of these to purchase stock in ethanol plants.

Ethanol plants also qualify for economic recovery grants administered by the Department of Trade and Economic Development. Morris Ag Energy, Corn Plus in Winnebago, and Heartland Corn Products in Winthrop each received $150,000, and Al-Corn in Claremont received $85,000.

Finally, most of the operating ethanol plants have received tax increment financing.[10] In 1993, the Legislature enacted a tax increment financing provision that sets a limit of $1,000,000.[11] Ethanol plants were also exempted from certain statutory provisions providing for reduction in state education and local government aids.[12] The TIF limit was raised to $1,500,000 in 1995 and broadened to include all agricultural processing facilities.[13]

COST OF MINNESOTA PROGRAMS

This section summarizes the cost of the major ethanol programs described above. The producer payment, the blender's credit, and the oxygenate mandate have cost implications many orders of magnitude greater than all three state loan programs put together. Adding in the value of the subsidized loans would not materially affect our estimate of the total cost of ethanol programs.

The costs of the three major programs are borne in three different ways. The producer payment is financed through an appropriation, the blender's credit is a tax expenditure, (it reduces revenues that would otherwise accrue to the trunk highway fund), and the cost of the oxygenate mandate is due to the fact that ethanol costs more than gasoline and causes an increase in the cost of gasoline to the consumer.

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9 In 1995 the appropriation totaled $1,000,000, but part was earmarked for use as an incentive to locate a large processing plant or for use in an interest buy-down program that was never implemented.

10 These include the plants in Benson, Claremont, Winnebago and Winthrop in recent years.

11 *Laws of Minnesota*, 1993, Chapter 250.

12 *Minn. Stat*. 273.1399 Subd. 3-4.

13 *Laws of Minnesota*, 1995, Chapter 264.

We calculate:

- **The producer payment cost $22.1 million in the three years 1994 to 1996. It will cost about $66.1 million in the next three year period, 1997 through 1999 according to MDA projections.**

- **The blender's credit cost $61.2 million between 1994 and 1996, and is projected to cost about $8.7 million from 1997 to 1999.**

Together, the blender's credit and the producer payment have cost an average of $27.8 million per year over the last three years (fiscal years 1994-96) in direct expenditures and foregone tax revenue. In the future the producer payment will continue to increase while the blender's credit is phased out. Together, the programs will still total $24.9 million per year in fiscal years 1997 to 1999.

As Table 1.2 shows, a total of about $39 million has been spent on the producer payment since 1987. The producer payment totaled $10.8 million in fiscal year 1996, and $22.1 million in fiscal years 1994-96. Based on MDA projections, ethanol production will increase in the future as additional plants begin operating and existing plants expand their output. MDA currently projects that ethanol production will reach 159 million gallons per year and the cost of the producer payment will climb to $26 million by fiscal year 1999.

Table 1.2: Producer Payments and Ethanol Production, FY 1987-96 with Projections, FY 1997-2001

Fiscal Year	Payment	Ethanol Produced (millions of gallons)
1987	$215,777	1.0
1988	493,175	8.0
1989	2,009,057	10.0
1990	2,197,123	11.0
1991	3,357,706	17.0
1992	4,950,454	35.0
1993	3,599,545	38.0
1994	4,796,247	41.0
1995	6,460,215	51.0
1996	10,799,192	69.5
Total Spent 1987-96	$38,878,491	281.0
PROJECTIONS		
1997	$16,910,000	99.1
1998	23,550,000	140.8
1999	25,660,000	159.2
2000	26,530,000	171.2
2001	23,200,000	177.8

Source: Minnesota Department of Agriculture.

The cost of the blender's credit is calculated by the Minnesota Department of Revenue. As we show in Table 1.3, the tax credit was worth $13.7 million in fiscal year 1996. For fiscal years 1994-96, the total was $61.2 million. Although the blender's credit is in the process of being phased out, residual tax credits will still accrue through part of fiscal year 1998.

Table 1.3: Blender's Credit, in Millions of Dollars

Fiscal Year	Amount
1992	$11.85
1993	20.21
1994	24.63
1995	22.92
1996	13.68
1997	5.92
1998	2.75
1999	0

Source: Minnesota Department of Revenue.

EXTRA COST OF OXYGENATED GASOLINE

Gasoline containing ethanol generally costs more than straight gasoline.

Minnesota's requirement to use gasoline with 2.7 percent oxygen year-round will cost consumers an amount that should be considered a cost of the program. Exact calculation of this cost is somewhat difficult because a federal oxygenated gasoline requirement is in effect for the Twin Cities area for one-third of the year, and because the state year-round requirement is being phased in over time, and the schedule of the phase-in does not correspond either to calendar years or the state's fiscal years.

In addition, the exact method of calculation can be debated. Nevertheless, for reasons explained below:

- **We estimate that the retail price of gasohol will exceed the price of conventional gasoline by about 2 to 3 cents per gallon over the next several years.**

Our estimate of the higher cost of gasohol considers retail prices in October and December 1996 and January 1997, and wholesale prices 1994 through 1996. Over this period, oxygenated gasoline has generally cost at least 2 to 3 cents more than nonoxygenated gasoline nationally, regionally, and in Minnesota, as far as the numbers can be determined from available data. It also considers the cost of ethanol mixtures based on wholesale prices for ethanol and gasoline.

Retail Prices

Data from the United States Department of Energy compare the price of gasoline in carbon monoxide (CO) non-attainment areas, such as the Twin Cities, ozone non-attainment areas, and areas governed by neither of these requirements. CO non-attainment areas must use a mixture of ethanol or another oxygenate containing 2.7 percent oxygen, while ozone non-attainment areas must use "reformulated gasoline" (RFG) that contains 2.0 percent oxygen.

The retail price of oxygenated gasoline exceeded the price of conventional gasoline by 2 to 9 cents in the Midwest in late 1996 and early 1997.

Between October 7 and October 28, 1996, the difference between the national average retail price of conventional gasoline and oxygenated gasoline varied by about 8 to 11 cents. Between December 23, 1996 and January 20, 1997, this difference varied between 1.8 and 2.5 cents. Table 1.4 shows these prices, along with the price of reformulated gasoline which contains less oxygenate and is intermediate in price between conventional and oxygenated gasoline. For example, on October 28, 1996 the national average retail price of gasoline in oxygenated areas was $1.323 per gallon and in conventional areas it was $1.247, a difference of 7.6 cents. The difference on October 7 was 11.2 cents. The price of reformulated gasoline was intermediate to prices in conventional and oxygenated areas, 6.4 cents more than conventional areas on October 7, and 2.5 cents more on October 28.

Table 1.4 also presents retail gasoline price data for a large multi-state region that includes Minnesota and 14 other midwestern states from Oklahoma to the Canadian border.[14] In this region, however, Minnesota is the only state with an oxygenated gasoline requirement, so the prices for oxygenated gasoline for the region are the Minnesota prices. The prices for other types of gasoline are for all RFG areas or conventional areas in the region.

Table 1.4: 1996-1997 Retail Gasoline Prices, All Grades

	Oct. 7	Oct. 14	Oct. 21	Oct. 28	Dec. 23	Dec. 30	Jan. 6	Jan. 13	Jan. 20
NATIONAL PRICE DATA									
Conventional Areas	$1.216	$1.230	$1.233	$1.247	$1.267	$1.263	$1.259	$1.276	$1.276
Oxygenated Areas[a]	1.328	1.317	1.315	1.323	1.292	1.281	1.280	1.300	1.300
RFG Areas[b]	1.280	1.280	1.273	1.272	1.295	1.295	1.300	1.311	1.314
Amount Price Exceeds Conventional Gasoline									
Oxygenated Areas	$0.112	$0.087	$0.082	$0.076	$0.025	$0.018	$0.021	$0.024	$0.024
RFG Areas	0.064	0.050	0.040	0.025	0.028	0.032	0.041	0.035	0.038
MIDWEST PRICE DATA									
Conventional Areas	$1.194	$1.219	$1.216	$1.244	$1.247	$1.240	$1.232	$1.266	$1.264
Oxygenated Areas	1.282	1.275	1.300	1.290	1.308	1.307	1.299	1.291	1.287
RFG Areas	1.277	1.290	1.292	1.309	1.352	1.345	1.338	1.348	1.344
Amount Price Exceeds Conventional Gasoline									
Oxygenated Areas	$0.088	$0.0567	$0.084	$0.046	$0.061	$0.067	$0.067	$0.025	$0.023
RFG Areas	0.083	0.071	0.076	0.065	0.105	0.105	0.106	0.082	0.080

Source: U.S. Department of Energy, Motor Gasoline Price Survey, Form EIA-878.

[a]Oxygenated Areas are those in which a gasoline mixture containing 2.7 percent oxygen is required.

[b]RFG (reformulated gasoline) areas are those in which 2.0 percent oxygen is required.

14 This region is one of five Petroleum Administration for Defense (PAD) districts, and it includes Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, Oklahoma, South Dakota Tennessee, and Wisconsin.

The premium for oxygenated gasoline ranged from 8.8 cents on October 7 to 4.6 cents on October 28. For the five-week period ending January 20, 1997, the regional price difference ranged from 6.7 cents to 2.3 cents.

Wholesale Price Differences

We also looked at wholesale oxygenated and conventional gasoline prices (net of taxes) for the nation, the region in which Minnesota is located, and for Minnesota for 1995. Table 1.5 shows that there is little difference between the large 15 state region in which Minnesota is located and the nation as a whole, but while oxygenated gasoline is about the same price in Minnesota as in the nation as a whole, conventional gasoline prices are higher in Minnesota, and the difference between oxygenated and non-oxygenated gasoline prices is lower. In 1995, the wholesale price of regular grade gasoline in Minnesota was 60.0 cents in conventional areas and 62.4 cents in oxygenated areas, for a difference of 2.4 cents. The difference is 2.2 cents for all grades of gasoline in Minnesota compared to a difference of 5.4 cents nationally and 4.8 cents in the region. One possible reason for the smaller difference in Minnesota is that the comparison between oxygenated and non-oxygenated areas in Minnesota is also a comparison between gasoline prices in the Twin Cities area and the balance of the state. Gasoline prices may be higher outside the Twin Cities because distribution costs are higher and there is less retail competition.

In 1995, the wholesale price of oxygenated regular grade gasoline was 2.4 cents higher than conventional gasoline in Minnesota.

Table 1.5: Comparison of Prices for Conventional, Oxygenated, and Reformulated Gasoline, 1995

	Cents Per Gallon		
Wholesale Prices	U.S.	Midwest	Minnesota
REGULAR GRADE			
Conventional	57.2¢	57.0¢	60.0¢
Oxygenated	63.0	62.5	62.4
RFG	61.0	61.0	NA
Price Differences			
Oxy minus Conventional	5.8	5.5	2.4
RFG minus Conventional	3.8	4.0	NA
ALL GRADES			
Conventional	59.2	58.5	61.1
Oxygenated	64.6	63.3	63.3
RFG	63.5	62.9	NA
Price Differences			
Oxy minus Conventional	5.4	4.8	2.2
RFG minus Conventional	4.3	4.4	NA

Note: Oxygenated gasoline (oxy) contains 2.7 percent oxygen. Reformulated gasoline (RFG) contains 2.0 percent oxygen. See text for definition of the Midwest Region.

Source: U.S. Department of Energy, *Petroleum Marketing Annual 1996*, Tables 32, 33, 34, 44.

Weighted Average Estimates

We also estimated the price difference between oxygenated gasoline and conventional gasoline by taking an average of the wholesale price of ethanol and gasoline, and calculating the price of a 10 percent mixture. The wholesale cost of regular gasoline has averaged 56 to 58 cents per gallon in 1994 and 1995, and averaged 65 to 67 cents in 1996. The cost of ethanol has averaged about $1.22 per gallon in 1994 and 1995, and averaged $1.51 in 1996. The 54 cent federal tax credit and the 5 cent Minnesota blender's tax credit now bring down the cost of ethanol a total of 59 cents per gallon, although the blender's credit will disappear in October 1997 and should be ignored in looking to the future.

We can estimate the additional cost of gasohol mixed at 10 percent ethanol or at some other concentration if we specify prices for both ethanol and gasoline net of the tax credits we want to include. [15] Table 1.6 shows that at a price of ethanol of $1.51 and a price of gasoline of $.67, (average 1996 prices) a 10 percent mixture of ethanol and gasoline costs 75 cents a gallon rather than 67 cents for straight gasoline. If we net out the federal credit of 54 cents from 1.51, the effective ethanol price is $0.97, and as the table shows, the price difference for gasohol is 3.0 cents. If we net out the 5 cent blender's credit and the federal credit, the difference is 2.5 cents.

If we choose a lower price for ethanol, the premium for an ethanol mixture is less. For example, using 1994 and 1995 average prices of $1.22 for ethanol and $.58 for gasoline and current federal and state credits, the price difference is one-half of one cent per gallon.

Table 1.6: Effect of Ethanol on Gasoline Prices

	Price Per Gallon					Price Difference (in Cents)	
	Ethanol	Gasoline		10 Percent Mix		10 Percent Mix	
	Twin Cities[2]	Twin Cities[2]	Midwest Region[3]	Twin Cities	Midwest Region	Twin Cities	Midwest Region
1996 AVERAGE PRICES[1]							
No Tax Credits	$1.51	$0.67	$0.65	$0.75	$0.74	8.4	8.6
Less State 5 cent credit	1.46	0.67	0.65	0.75	0.73	7.9	8.1
Less Federal 54 cent credit	0.97	0.67	0.65	0.70	0.68	3.0	3.2
Less Federal and State credits	0.92	0.67	0.65	0.70	0.68	2.5	2.7
1994-95 AVERAGE PRICES							
No Tax Credits	1.22	0.58	0.56	0.64	0.63	6.4	6.6
Less State 5 cent credit	1.17	0.58	0.56	0.64	0.62	5.9	6.1
Less Federal 54 cent credit	0.68	0.58	0.56	0.59	0.57	1.0	1.2
Less Federal and State credits	0.63	0.58	0.56	0.59	0.57	0.5	0.7

[1] 1996 averages represent the period January to October only.

[2] Source: Minnesota Department of Agriculture.

[3] Source: U.S. Department of Energy, *Petroleum Marketing Monthly*, January 1997, Tables 32 and 33.

15 The term gasohol refers to a mixture of alcohol and gasoline, usually around 7-10 percent ethanol.

We have not separately counted the 54 cent federal tax credit for ethanol in previous discussions of ethanol program costs, although Minnesotans pay a share of the cost of this credit as a federal tax expenditure. The rough cost is 54 cents per gallon times the number of gallons of ethanol consumed annually in Minnesota. When oxygenated gasoline use becomes mandatory statewide, Minnesota ethanol consumption will be about 200 million gallons, and the federal tax credit on Minnesota consumption will equal about $108 million each year.

Oxygenated gasoline costs more even considering its value as an octane enhancer.

Ethanol contains about 33 percent less energy than gasoline, and proportionally less mileage is obtained from ethanol mixtures. Mixed at 10 percent, ethanol lowers mileage by about 3 percent. This effect is not specifically considered in the weighted averages calculated in Table 1.6, although this can be done by reducing the price of gasoline by about 30 percent and recalculating the numbers. If we counted the fact that a gallon of ethanol contains 30 percent less energy than a gallon of gasoline, we would add about 2 cents to our estimates of the difference in fuel costs per gallon between gasoline and a 10 percent ethanol mix.

There is one factor that works in the opposite direction, however. Ethanol has an octane rating of about 115 and raises the octane value of the fuel with which it is mixed. Under some circumstances, ethanol has value as an octane enhancer. Ethanol can be blended with a cheaper, lower grade of gasoline and the resulting product meets higher octane specifications.

We talked to representatives of the three refiners serving the Minnesota market. One company says they do not blend ethanol with a special low-octane blend in order to get regular-grade gasoline. (Regular gasoline accounts for about 70 percent of gasoline sold.) Two refiners said they did blend lower octane gasoline with ethanol for the Twin Cities, but not the outstate market. The lower-octane gasoline costs .5 to 1.25 cents less than regular grade, but induces additional storage and handling costs.

Where oxygenated gasoline is required, and with state and federal tax credits that lower the cost of ethanol, ethanol blends have a value of .5 to 1.25 cents per gallon as an octane enhancer (ignoring additional storage costs). However, if we take account of the octane enhancement value and the energy content factor, both of which are left out of our weighted average calculations, the 2 to 3 cent estimate we have been using is increased a penny per gallon or so. Still, for the purpose of subsequent cost analysis, we stay with a conservative estimate of 2 to 3 cents per gallon.

About 2 billion gallons of gasoline are consumed each year in Minnesota. Each penny per gallon is equivalent to $20 million in the cost of fuel to consumers.

Roughly 2 billion gallons of gasoline are consumed each year in Minnesota. For each penny that the ethanol mixture costs over straight gasoline, the cost of fuel consumed goes up $20 million per year. As noted, starting in October 1997, the use of oxygenated gasoline will be required statewide for the entire year, but before October 1995, the only legal requirement was the federal requirement for wintertime use in the Twin Cities area. Part of the extra cost of oxygenated gasoline before October 1997, therefore, is due to the federal mandate, not the state requirement and should be subtracted from our calculation of the cost of using gasohol.

The federal government requires oxygenated fuel use in the Twin Cities area for four months per year. If one half the vehicle miles traveled in Minnesota annually take place in this area, and four months represents one-third of the year, then only five sixths of the total 20 million should be counted as extra cost induced by the state oxygenate mandate.

Our estimate, therefore, is that after October 1997, when the oxygenated gasoline requirement is in force statewide,

- **Minnesota consumers will pay $33.3 to $50 million (five-sixths of $40 to $60 million) more for gasohol than they would pay for straight gasoline each year, and this equals about $100-$150 million over a three year period, assuming annual consumption of 2 billion gallons of fuel. Taking the mid-point of this range yields an estimate of nearly $42 million per year or $125 million over the three years.**

These numbers are based on a 2 to 3 cent premium price for oxygenated gasoline which is lower than other estimates of the premium price of oxygenated gasoline, including the October 1996 retail prices from the Department of Energy quoted above. It is also lower than the price difference of 3 to 5 cents quoted this summer by an official of the Minnesota Department of Agriculture. [16]

Table 1.7 summarizes the cost of the major ethanol programs. These estimates do not include the cost of subsidized loans and grants received by ethanol plants. Together, the cost of these loans is much less than the cost of the major programs. If the 6 percent interest rate charged by these loans is half of the market rate that would otherwise have to be paid, each of the $500,000 production facility loans constitutes a subsidy of about $30,000 per year for 7 to 10 years. [17] Adding all the loans and grants together might add a few hundred thousand dollars to our estimate of the total cost of ethanol programs assuming that all the loans are paid back. Since the estimates presented above can not be calculated to this level of precision, these amounts are left out of the total.

In the future, the blender's credit will be phased out but the producer payment and consumer costs will increase. The producer payment is projected by the MDA to increase to about $25 million in fiscal year 1998 and $26 million in fiscal year 1999. The total cost of the major ethanol programs will continue to increase for several years. However, the producer payment expires for the earliest participants in the program in 2000, and it is scheduled to expire for others 10 years after production begins. As Table 1.2 showed, MDA estimates that total payments through the producer payment program will decline after fiscal year 2000.

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16 Ralph Groschen, MDA quoted by Lee Egerstrom, "The Ethanol Gap," St. Paul Pioneer Press, Tuesday, July 31, 1996. This estimate is in line with our data for this period.

17 Six percent of 500,000 is worth $30,000 each year.

We estimate that ethanol programs will cost about $67 million per year in the next three years.

Table 1.7: Ethanol Program Cost Summary (Dollars in Millions)

	1994-96	Annual Average	1997-99	Annual Average
Producer Payment	$22.1	$7.4	$66.1	$22.0
State Oxygenate Mandate	NA[a]	NA	125.0[b]	41.7
Blender's Credit	61.2	20.4	8.7	2.9
Total	$83.3	$27.8	$199.8	$66.6

Note: NA = Not Applicable.

Source:

[a]Starting in October 1995 the Twin Cities area, with about half the state's drivers, was governed by a year-round oxygenate requirement. The cost of this requirement equals one-half (of the drivers) times two-thirds (of the year) time 2-3 cents (the premium price of gasohol) time 2 billion, the statewide amount of gasoline consumed. This yields an estimate of $6.67 million to $10.0 million per year starting October 1995.

[b]The cost of the mandate is computed as though it were in effect year round and statewide. This will not occur until October 1997. Other costs are computed for fiscal years.

PROGRAMS IN OTHER STATES

We looked at the ethanol incentives offered by other states and found:

- **Minnesota's approach to promoting the production and use of ethanol is far-reaching and comprehensive compared to the ethanol incentives offered by other midwestern corn-producing states.**

We looked in some detail at programs offered in a number of midwestern states: Illinois, Indiana, Iowa, Nebraska, North Dakota, South Dakota, and Wisconsin. This group of states includes most major corn producers and most major ethanol producers.

As Table 1.8 shows, all the states listed promote ethanol use through the state department of agriculture or another office. A number of states, including Minnesota, operate a fleet of ethanol-powered or flexible fuel vehicles. Minnesota is unique among this group of states in that it mandates oxygenated fuel use beyond the time period and geographic area required by federal regulations that apply in CO or ozone non-attainment areas. There is no state-mandated oxygenate or ethanol use in the other midwestern states we examined.

Of the states listed on Table 1.8, only Iowa and Minnesota offer a subsidized loan program specifically for ethanol production facilities. In Minnesota and presumably some other states, ethanol plants qualify for loans through other state or local economic development programs.

Table 1.8: Ethanol Programs in Selected States

State	Federally Mandated Use[1]	State Mandated Use	Producer Payment	Maximum Producer Payment	Blender's Credit	Subsidized Loan Programs	Ethanol Promotion Activities	Number of Ethanol Plants
Minnesota	Ozone - No CO - Yes	Year round in CO nonattainment areas	20 cents per gallon	$30 million	8 cents per gallon	Yes	Minnesota Department of Agriculture	8
Illinois	Ozone - Yes CO - No	Government vehicles only	No	NA[2]	No	No	Illinois Department of Commerce and Community Affairs	4
Indiana	Ozone - Yes CO - No	No	No	NA	No	No	Indiana Lt. Governor's Office	1
Iowa	Ozone - No CO - No	Government vehicles only	No	NA	No	Yes	Iowa Department of Agriculture	7
Nebraska	Ozone - No CO - No	Government vehicles only	20 cents per gallon	$25 million	No	No	Nebraska Ethanol Development Board	7
North Dakota	Ozone - No CO - No	No	40 cents per gallon	$5 million[3]	No	No	North Dakota Agricultural Products Utilization Commission	2
South Dakota	Ozone - No CO - No	Government vehicles only	20 cents per gallon	$10 million	2 cents per gallon	No	South Dakota Corn Utilization Council	4
Wisconsin	Ozone - Yes CO - No	Government vehicles only	No	NA	No	No	Wisconsin DOA[4] Energy Office and the Wisconsin Department of Agriculture	2

Source:

[1]In either ozone or carbon monoxide nonattainment areas.

[2]Not applicable.

[3]Dependent on date plant went into operation and amount of ethanol produced.

[4]Department of Administration.

Only Minnesota and South Dakota offer a blender's credit, but several states in addition to Minnesota offer a producer payment of 20 cents or more per gallon. Nebraska has a producer payment of 20 cents per gallon, as does South Dakota. North Dakota pays producers 40 cents per gallon, but payments under this program are capped at $5 million. The Nebraska cap is $25 million, close to Minnesota's limit of $30 million; South Dakota's maximum annual producer payment limit is $10 million. Several states, including Illinois and Iowa, do not offer major production incentives or tax credits, but are nevertheless the locus of major ethanol production facilities.

ETHANOL USE IN MINNESOTA AND THE NATION

In this section we look at statistics on ethanol use and production in Minnesota and the United States. A look at this information shows:

Minnesota leads the nation in the percentage of gasoline that contains ethanol.

- **In 1994, even before the state requirement to use gasohol became effective, Minnesota led the nation in the percentage of gasoline mixed with ethanol.**

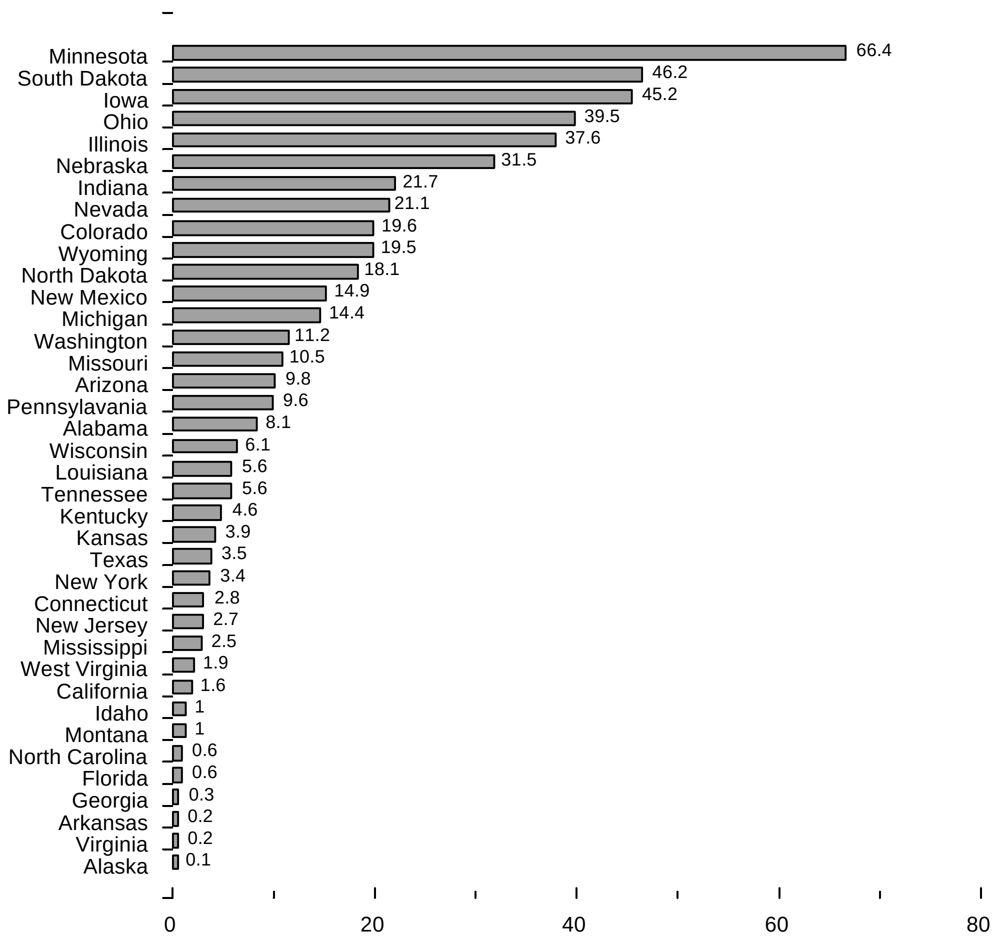
As Figure 1.1 shows, in 1994, before any state requirement for ethanol use was in place, 66 percent of the gasoline for highway use in Minnesota was mixed with ethanol. This percentage led the nation in 1994, the most recent year for which we have this information. Over 45 percent of the gasoline in Iowa and South Dakota was mixed with ethanol. Other midwestern corn-producing states use a high proportion of gasohol, including Ohio, Illinois, Nebraska, and Indiana. In Wisconsin, though, only about 6 percent of gasoline was mixed with ethanol.

Table 1.9 shows that in 1994 over one billion gallons of ethanol was used in gasoline nationwide. In fact, as the table shows:

- **In 1994, Minnesota was the third highest user of ethanol, at over 125 million gallons. Only Illinois and Ohio, states with much larger populations, used more ethanol in gasoline.**

As a generalization, the states that use a lot of ethanol are the same states with a significant ethanol production capacity. In the next section, we look at ethanol production facilities in Minnesota and the United States.

Figure 1.1: Gasohol as a Percent of Gasoline for Highway Use, 1994



Source: U.S. Department of Transportation Highway Statistics, 1994.

ETHANOL PRODUCTION IN MINNESOTA AND THE UNITED STATES

Figure 1.2 shows the location of ethanol plants in the United States. The plants owned by the largest producers are concentrated in Illinois, Iowa, Nebraska and Indiana. According to data compiled by the Renewable Fuels Association, as of January 1996 United States ethanol production capacity was about 1.5 billion gallons per year.

Table 1.9: Estimated Use of Gasohol, 1994

State	Total Ethanol Used in Gasohol (In Thousands of Gallons)	Total Gasohol (In Thousands of Gallons)
Alabama	14,385	143,850
Alaska	26	260
Arizona	7,073	80,708
Arkansas	278	2,783
California	27,497	482,396
Colorado	19,998	234,571
Connecticut	3,729	37,590
Delaware	--	--
District of Columbia	--	--
Florida	3,595	35,950
Georgia	1,093	10,926
Hawaii	--	--
Idaho	551	5,514
Illinois	174,741	1,747,412
Indiana	59,762	597,625
Iowa	62,773	627,730
Kansas	4,655	46,546
Kentucky	8,755	87,546
Louisiana	10,563	105,626
Maine	--	--
Maryland	--	--
Massachusetts	--	--
Michigan	63,119	631,188
Minnesota	125,280	1,431,263
Mississippi	3,343	33,428
Missouri	29,240	292,398
Montana	--	--
Nebraska	18,489	184,894
Nevada	--	--
New Hampshire	--	--
New Jersey	3,215	40,125
New Mexico	5,192	55,525
New York	6,956	79,284
North Carolina	10,114	107,993
North Dakota	5,893	58,935
Ohio	186,690	1,866,896
Oklahoma	--	--
Oregon	--	--
Pennsylvania	18,882	192,703
Rhode Island	--	--
South Carolina	--	--
South Dakota	18,333	183,326
Tennessee	28,560	285,603
Texas	12,605	126,969
Utah	--	--
Vermont	--	--
Virginia	9,400	100,403
Washington	76,215	882,104
West Virginia	1,629	16,287
Wisconsin	13,312	133,124
Wyoming	6,011	60,113
TOTAL	1,041,952	11,009,594

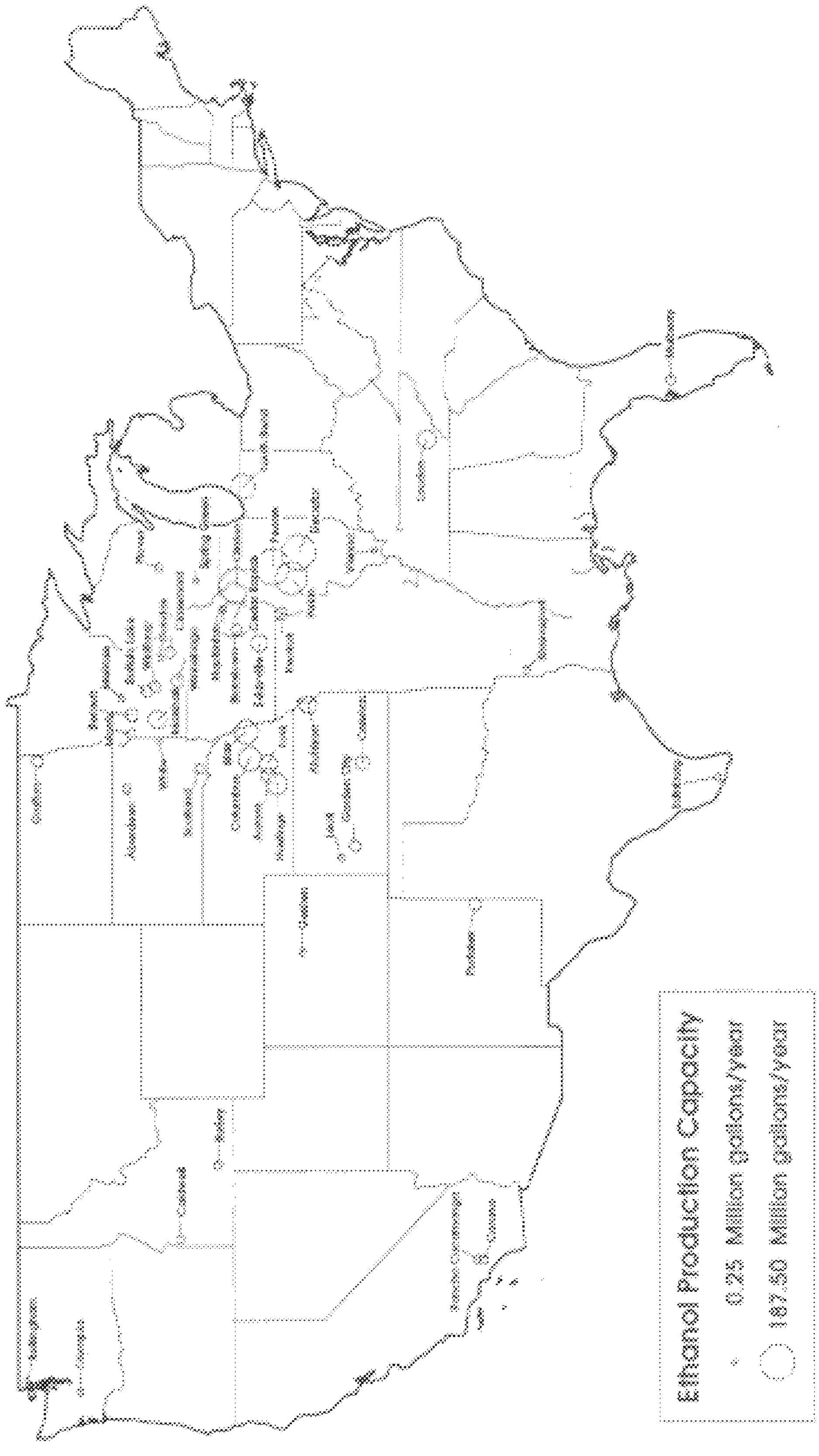
Source: Federal Highway Administration, *Highway Statistics 1994.*

Ethanol production is highly concentrated, and most ethanol production is carried out in a few large plants. As Table 1.10 shows, Archer Daniels Midland can produce 750 million gallons per year in its four plants, which accounts for about half of total U.S. capacity. The five largest producers on the list own about 1.156 billion gallons of annual production capacity or about 74 percent of the total.

Most of the large plants, but not all, are "wet mills" that can separate the germ from the corn kernel and permit the refinement of a wide variety of corn products including corn oil, corn syrup, and high fructose corn syrup. Minnesota has one moderately sized ethanol refinery that is part of a large wet mill owned by Minnesota Corn Processors in Marshall. This company also owns a plant in Nebraska. "Dry mills" can produce ethanol and animal feed as well as efficiently as wet mills, but cannot produce corn oil, corn sweeteners, and certain other products.

Figure 1.3 presents a map showing the location of Minnesota's operating and planned ethanol plants. Total capacity of the plants in operation is about 92

Figure 1.2: U.S. Ethanol Plants, 1996



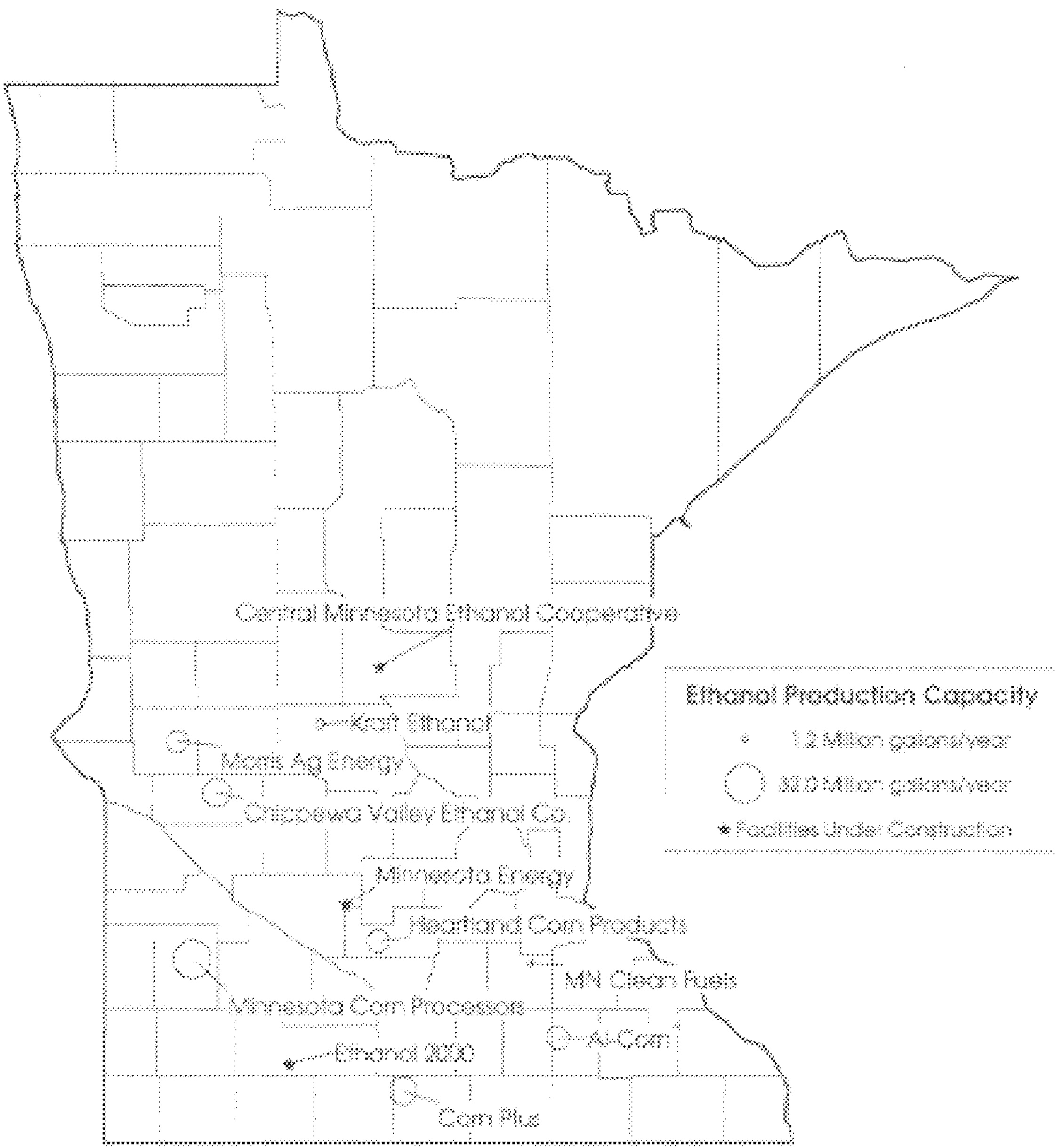
Note: The circles for Pokin, IL and Hastings, NE each represent two plants.

Table 1.10: U.S. Ethanol Production Capacity

Company	Location	Million Gallons per Year
A.E. Staley	Louden, TN	42.0
AGP	Hastings, NE	30.0
Ag Power of Colorado	Golden, CO	1.4
Alchem	Grafton, ND	10.5
Al-Corn	Claremont, MN	10.0
Archer Daniels Midland	Decatur, IL	--
	Peoria, IL	--
	Cedar Rapids, IA	--
	Clinton, IA	--
	Total	750.0
Arkenol	Mulberry, FL	6.5
Broin Enterprises	Scotland, SD	7.0
Cargill	Blair, NE	110.0
	Eddyville, IA	
Chief Ethanol	Hastings, NE	30.0
Corn Plus	Winnebago, MN	15.0
CVEC	Benson, MN	15.0
ESE Alcohol	Leoti, KS	1.1
Farm Tech USA	Spring Green, WI	.5
Georgia-Pacific Corporation	Bellingham, WA	7.0
Giant Industries	Portales, NM	13.5
Golden Cheese of California	Corona, CA	2.7
Heartland Corn Products	Winthrop, MN	10.0
Heartland Grain Fuel	Aberdeen, SD	4.0
High Plains Corporation	York, NE	40.0
	Colwich, KS	20.0
J.R. Simplot	Caldwell, ID	3.0
	Burley, ID	3.0
Jonton Alcohol	Edinburg, TX	1.1
Kraft, Inc.	Melrose, MN	1.5
Kor Ethanol	White, SD	0.25
Midwest Grain Products	Pekin, IL	60.0
	Atchison, KS	30.0
Minnesota Clean Fuels	Dundas, MN	1.2
Minnesota Corn Processors	Columbus, NE	76.0
	Marshall, MN	32.0
Minnesota Energy	Buffalo Lake, MN	10.0
Morris Ag Energy	Morris, MN	7.5
Nebraska Energy	Aurora, NE	25.0
New Energy Company of Indiana	South Bend, IN	85.0
Pabst Brewing	Olympia, WA	0.7
Parallel Products	Rancho Cucamonga, CA	3.0
Pekin Energy Company	Pekin, IL	100.0
Permeate Refining	Hopkinton, IA	1.5
Reeve Agri-Energy	Garden City, KS	9.0
Reyncor Industrial	Shreveport, LA	2.5
ROI	Plover, WI	2.0
Roquette America	Keokuk, IA	14.5
Sunrise Energy	Blairstown, IA	9.0
Vienna Correctional	Vienna, IL	0.5
TOTAL		1.5 Billion

Source: Renewable Fuels Association. Minnesota data from Minnesota Department of Agri culture.

Figure 1.3: Minnesota Ethanol Plants, 1996



million gallons per year, not counting the plant in Buffalo Lake which is about to start operations. Fiscal year 1996 production was close to 70 million gallons. Minnesota plant capacity is now about 6 percent of national ethanol production capacity, and this number will presumably move up as operating plants expand and new plants come on line.

Minnesota is a significant ethanol producing state and, as we will see, almost all this production capacity has been developed since the mid 1980s. All but one of Minnesota's major ethanol plants are dry mills of 8-15 million gallon capacity. To put the matter into perspective, however, Minnesota's total ethanol production capacity is only about equal to one-half of one of Archer Daniels Midland's large factories. We will discuss in Chapter 4 the risk for Minnesota producers of competition from larger, more efficient producers.

USE OF CORN FOR ETHANOL

About 7 percent of the nation's average annual corn production was used to make ethanol in 1995.

As Figure 1.2 shows, ethanol production is concentrated in the midwest corn-producing region of the country. Table 1.11 presents data on corn production in Minnesota and the United States between 1988 and 1995. In 1995, for example, about 732 million bushels of corn were produced in Minnesota. In the U. S. as a whole, 7.37 billion bushels were produced in 1995. Minnesota's production averaged 8.6 percent of the nation's production from 1988 to 1995.

As we noted, in the United States, total annual ethanol production was approximately 1.5 billion gallons in 1995. About 95 percent of this ethanol was produced from corn. Since about 2.5 gallons of ethanol can be produced from a bushel of corn, about 532 million of 7.645 billion bushels were used in the process.[18] Nationally, this amounts to just under 7 percent (6.96 percent) of the nation's annual average corn production between 1988 and 1995. In Minnesota 28 million bushels of corn were consumed in making 70 million gallons of ethanol. This is equal to about 4.3 percent of Minnesota's average corn crop between 1988 and 1995.

EFFECTIVENESS OF ETHANOL PROGRAMS

One important objective of our study was to learn whether Minnesota's ethanol programs have accomplished their primary goal--to promote the development of an ethanol industry in Minnesota. Prior to the mid-1980s, before the enactment of the producer payment and expansion of the blender's credit, there was very little ethanol production in Minnesota. Thus, the timing of the construction of the ethanol industry in Minnesota strongly suggests that the programs were important, but to explore the issue further, we looked at how each of the ethanol plants that have come on line in recent years was financed, and we discussed the development of

18 The yield of 2.5 gallons per bushel of corn is the national average most often used. Minnesota's newer plants are more efficient, and we use a yield of 2.6 gallons for Minnesota's dry mills.

Table 1.11: Corn Production, Minnesota and United States

	Corn for Grain					
	Thousands of Acres				Annual	
Minnesota	Planted	Harvested	Yield	Bushels (thousands)	Average Price	Value (thousands)
1988	5,700	4,700	74	347,800	$2.40	$834,720
1989	6,200	5,600	125	700,000	2.27	1,589,000
1990	6,700	6,150	124	762,600	2.17	1,645,842
1991	6,600	6,000	120	720,000	2.22	1,598,400
1992	7,200	6,500	114	741,000	1.91	1,415,310
1993	6,300	4,600	70	322,000	2.26	727,720
1994	7,000	6,450	142	915,900	2.23	1,923,390
1995	6,700	6,150	119	731,850	2.90	2,122,365
Total	52,400	46,150	888	5,241,150	$13.69	$11,856,747
Average 1988-95	6,550	5,769	111	655,144	$2.28	$1,482,093
	Millions of Acres				Annual	
United States	Planted	Harvested	Yield	Bushels (millions)	Average Price	Value (millions)
1988	67,717	58,250	84.6	4,929	$2.54	$12,661
1989	72,322	64,783	116.3	7,532	2.36	17,897
1990	74,166	66,952	118.5	7,934	2.28	18,192
1991	75,957	68,822	108.6	7,475	2.37	17,864
1992	79,311	72,077	131.5	9,477	2.07	19,723
1993	73,235	62,921	100.7	6,336	2.60	16,032
1994	79,175	72,887	138.6	10,103	2.26	22,158
1995	71,245	64,995	113.5	7,374	3.21	23,597
Total	593,128	531,687	912.3	61.160	$19.69	$148,124
Average	74,141	66,461	114	7,645	$2.46	$18,516
Percent Minnesota				8.5696%		

Source: USDA National Agriculture Statistics Service; Minnesota Department of Agricult ure, Minnesota Agricultural Statistics.

the ethanol industry with officials in the Minnesota Department of Agriculture. We also visited each major ethanol plant operating in the summer of 1996 and talked to plant managers, board members, local public officials, and others knowledgeable about how each project was developed. We also talked to a representative of one of the two banks responsible for most Minnesota ethanol plant financing. Based on what we learned, we conclude:

- **The programs are directly responsible for the development of a sizable ethanol production capacity in Minnesota.**

Minnesota has developed a significant ethanol industry since 1987 when the producer payment program started. Table 1.12 presents information on all currently operating plants as well as those proposed and under construction. Before the mid-1980s there was almost no ethanol production in Minnesota; of those currently operating, only the Kraft plant with about one million gallon annual production was in operation. Now, as Table 1.12 shows, there are eight plants operating with a total capacity of 92 million gallons per year. Three more plants are under construction. One of these, the Minnesota Energy Plant in Buffalo Lake, is due to start operation in the fall of 1996. There are additional plants in some stage of planning.

Minnesota's ethanol plants were built because of the state's ethanol programs, especially the producer payment.

A case-by-case examination of the history of each major operating plant leads us to conclude that the plants were built because of the state's ethanol programs, especially the producer payment. Below, we go over the history of each of the major plants to learn how Minnesota's programs aimed at encouraging ethanol production influenced the decision to build the plant.

Minnesota Corn Processors

The Minnesota Corn Processors (MCP) plant in Marshall is a wet mill that began operating in 1982, producing various products including corn syrup and sweeteners and began producing ethanol in 1987. MCP is organized as a farmer-owned cooperative with about 5,000 shareholders, 4,000 of them in Minnesota. It operates ethanol plants in Minnesota and Nebraska. According to plant managers, the state of Minnesota approached MCP 1986 and asked the company to develop an ethanol refining capacity, promising a producer payment of 20 cents per gallon as an incentive.

The MCP plant in Marshall is a large factory that grinds more corn than all the other Minnesota ethanol plants put together. Ethanol is not its main product, but the plant still produces about 32 million gallons per year, about twice as much ethanol as any other plant, as Table 1.12 shows. This plant is expanding its corn-grinding capacity and, when complete, it will grind 160 thousand bushels of corn per day, or about 58.4 million bushels per year. In comparison, a 15 million gallon dry mill grinds about 6 million bushels of corn each year. If the Marshall plant converted all its corn starch to ethanol, it could produce about 146 million gallons of ethanol per year. This level of production would make it one of the nation's largest plants.

The producer payment reaches a maximum of $3 million per plant at 15 million gallons of annual production. MCP produces around twice this amount of ethanol and has reached the maximum payment under Minnesota's program. MCP recently built an ethanol plant in Nebraska. Nebraska also has a producer payment of 20 cents per gallon, and this may have been a factor in MCP's decision to expand outside of Minnesota.

Recently Built Dry Mills

Four plants started up between 1994 and 1996 are dry mills of 10 to 15 million gallon per year capacity. These are the mills in Benson, Claremont, Winnebago, and Winthrop. All of these are farmer-owned cooperatives. In these companies, each share of common stock obligates the shareholder to deliver one bushel of corn to the plant per year. Typically, the co-op member receives 80 percent of the prevail-

Table 1.12: Minnesota Ethanol Plants Operating, Under Construction, and Proposed, September 1996

	Location	Start Up	Capacity	FY 1996 Production
OPERATING				
Chippewa Valley Ethanol Co. (CVEC)	Benson	1996	15	2,459,240
Al-Corn	Claremont	1996	10	1,043,148
Minnesota Corn Processors (MCP)	Marshall	1987	32	29,610,255
Morris Ag Energy	Morris	1990	7.5	6,347,166
Kraft Ethanol	Melrose	Early 1980s	1.5	1,482,869
Minnesota Clean Fuels	Dundas	1992	1.2	805,188
Corn Plus	Winnebago	1994	15	15,871,592
Heartland Corn Products	Winthrop	1994	10	11,858,349
Total Operating			92.2	69,477,807
UNDER CONSTRUCTION				
Minnesota Energy	Buffalo Lake	1996	10	--
Central Minnesota Ethanol Cooperative	Little Falls	1997	15	--
Ethanol 2000	Bingham Lake	1997	12.5	--
Total Under Construction			37.5	
PROPOSED				
RDO	Park Rapids	--	15	--
Exol-So. Central MN Agrifuels Co-op	Albert Lea	--	30	--
Cornerstone	Luverne	--	15	--
Renewable Oxygenates, Inc.	Madison	--	15	--
Dawson Project	Dawson	--	20	--
South East MN Ethanol Co-op (SEMEC)	Preston	--	10	--
Total Proposed			105	
GRAND TOTAL			234.7	

Source: Minnesota Department of Agriculture.

ing market price at the time of delivery and later receives an additional amount and, potentially, a share of the profits. Typically the minimum initial investment is 5,000 shares. In some companies, non-farmers are allowed to purchase shares, but they, too, have to supply corn each year.

The total capitalization of a 15 million gallon per year ethanol plant is about $25 to $30 million. In a $30 million plant, roughly $8 million goes to construction, $10 million to equipment, $6 million in engineering and design, and $6 million in working capital for the start up of operations. While the exact terms of each Minnesota project are different, the sale of common stock financed about 40-50 percent of the cost of building these four plants, and bank loans or other debt with a term of 7 to 10 years financed most of the remaining cost. In the case of each of the four dry mills built between 1994 and 1996, the plants received a Minnesota ethanol facility production loan of $500,000 at 6 percent interest, and up to $1 million in tax increment financing.[19]

19 Benson, $1 million; Claremont, $657 thousand; Winnebago, $556 thousand, and Winthrop, $525 thousand.

The Morris Ag Energy plant in Morris is owned by the Milsolv Corporation, an ethanol marketing company headquartered in Milwaukee. Unlike all the other operating plants discussed so far, the company is not a cooperative nor is Milsolv a publicly-owned company. The Morris plant was moved to Minnesota from Illinois and began operations in 1990. According to the plant's general manager, Milsolv went into ethanol production to assure a steady supply of the product they were marketing. Building on this marketing expertise, Morris Ag Energy markets the ethanol for two other plants, CVEC in Benson and Al-Corn in Claremont. According to MDA, Morris has plans to expand production from about 6 million gallons in fiscal year 1996 to 12 million in 1999, and more in future years.

Small Producers

Two of the plants listed in Table 1.12 are small producers of about 1 million gallons per year capacity. The Kraft plant in Melrose is an adjunct to a cheese making operation and uses dairy whey as a feedstock. The Minnesota Clean Fuels Plant in Dundas uses starch that is a waste product of a Twin Cities food processing operation. Together these plants account for about 2-3 percent of Minnesota ethanol production. We did not visit these plants or study their financing or operations. The Kraft plant was in operation before the state ethanol incentives were enacted. The plant has plans to expand ultimately to about twice its current output, and these plans may be related to the existence of state programs.

In summary, as of September 1996, the Minnesota ethanol industry consisted of eight operating plants with a total production capacity of about 92 million gallons per year. All but one of the major plants (Morris Ag Energy) is a farmer-owned cooperative. All the plants use corn as a feedstock except for two small plants with a combined capacity of less than 3 million gallons per year. One plant is a wet mill (MCP) with a corn-grinding capacity well in excess of all the others put together. Ethanol production is an important part of their operation, but not the major part. Five plants are medium sized (8-15 million gallons per year) dry mills that have come into existence since 1990. About five of the currently operating plants have plans to significantly increase production, and as noted earlier, counting these plans and projections of new plants coming on line, MDA forecasts that ethanol production will increase from about 69 million gallons in fiscal year 1996 to 159 million gallons in 1999 and 178 million gallons in 2001.

A key question about the Minnesota programs designed to promote the development of an ethanol industry is whether the industry would have come into existence or have these expansion plans without the state programs. We discussed the history of each project with plant managers and in many cases we talked with local officials who were involved in the process. Considering the four medium sized dry mills and the wet mill in Marshall, we conclude that:

- **The producer payment was critical to the construction of the ethanol industry in Minnesota and much less ethanol production would exist in its absence.**

The producer payment is limited to 15 million gallons of production per year. It is not coincidental that all recently built plants have a capacity of 15 million gallons or less.

Agriculture department officials, plant managers, and lenders all pointed to the crucial role of the producer payment in providing a secure revenue stream for ten years that is about equal to the cost of constructing the plant. A 15 million gallon plant receives $3 million per year (at 20 cents per gallon of ethanol production) Over ten years, this provides $30 million which, as we have seen, is enough money to build the plant and capitalize the company.

Banks have been willing to lend money for 7 to 10 years to finance about half the project costs. Under these terms, bankers do not have to assume that the plant will be profitable. In fact, the loans are likely to be repaid even if the ethanol plant is an economic failure since state requirements assure the continuation of local demand for ethanol, state producer payments subsidize the cost of production, and shareholder equity can cover operating losses for a time.

In our view it is not a coincidence that all recently built ethanol plants in Minnesota are dry mills of under 15 million gallons per year capacity. Dry mills are cheaper to construct than wet mills, and the size of the plants reflects the fact that the producer payment is limited to 15 million gallons of production per plant each year.

In quite a few cases among the successful projects we studied, it was not easy to put together a financing package, and project developers were required to cobble together loans from diverse sources and to reduce plant capacity below what was originally planned for. In one case, the engineering firm that designed and built the plant had to take a sizable ownership interest in the plant as well as on-going operational responsibility. In other cases, higher-interest loans had to be obtained to complete the financing package. In most cases local tax increment financing was a key factor in the location of the plant.

FEDERAL ETHANOL PROGRAMS AND REQUIREMENTS

One point needs to be kept in mind when looking at ethanol programs in Minnesota or other states.

- **Given the cost of production, little ethanol would be used as automotive fuel without the 54 cents per gallon (of ethanol) federal subsidy now in place.**

The wholesale price of ethanol averaged $1.27 between 1987 and 1995. [20] The wholesale price of unleaded regular gasoline was less than half of this price (between 50 and 60 cents per gallon August 1995 to August 1996). In late summer 1996, ethanol prices were strong, around $1.60 per gallon. Unless mandated or subsidized, little ethanol would be used as an automotive fuel at these prices. The analysis reported in Chapter 4 of this report suggests quite strongly that Minne-

20 Computer Petroleum Corp. cited in MDA Economic Impact of the Ethanol Industry in Minnesota, May 1996.

sota's ethanol plants would go out of business without the 54 cent per gallon federal tax credit.

The federal government tax credit for ethanol of 54 cents per gallon of ethanol brings the ethanol price to the point where it is more competitive with gasoline. Subtracting 54 cents from $1.27 yields a price of 73 cents for ethanol compared to 50-60 cents per gallon. As we have seen, ethanol still adds at least 2 to 3 cents per gallon to the cost of automotive fuel, but this has not met with a lot of consumer resistance. An issue facing ethanol producers for the future and potential ethanol plant lenders now is that the federal tax credit may not be extended beyond 2000.

The ethanol industry depends on the federal tax credit of 54 cents per gallon.

The federal government also mandates the use of oxygenated gasoline in 39 CO non-attainment areas and 9 ozone non-attainment areas. At 73 cents per gallon with the 54 cent per gallon tax credit, ethanol is competitively priced as an oxygenate. The other oxygenate in widespread use, methyl tertiary butyl ether (MTBE), costs around 79 cents per gallon on the gulf coast (August 1996 price), 83 cents per gallon in New York, and 87 cents in Los Angeles. MTBE is manufactured from methanol produced from natural gas as a by-product of oil refining. Comparing oxygenate costs in Minnesota means we have to add shipping costs since little MTBE is produced here. It costs 15 to 20 cents per gallon to ship MTBE to the midwest from the Gulf Coast.

A 15 percent mixture of MTBE in gasoline achieves the same level of oxygen as a 7.7 percent mixture of ethanol. So ethanol (with the 54 cent credit) is competitive with MTBE in Minnesota, even at 1.60 per gallon.[21] Ethanol is the oxygenate of choice in Minnesota and other midwestern states where little MTBE is produced and a lot of ethanol is produced. It would be even more competitive at lower ethanol prices such as the average 1987-95 wholesale price of $1.27. There are some advantages to using MTBE over ethanol in the summer that could potentially affect the competition between the two oxygenates, however. This issue is discussed in Chapter 3.

MTBE is cheaper to produce than ethanol, however, and is used more widely than ethanol around the country, especially in the vicinity of oil refineries. As shown elsewhere, very little ethanol is mixed in gasoline in Texas, New York, and California, states which nevertheless have large populations living in CO and ozone non-attainment areas.

In summary, federal air quality standards and a 54 cent per gallon ethanol tax credit make it possible for ethanol to compete with MTBE as an oxygenate and to be added to gasoline without increasing the price of gasoline so much that there is significant consumer resistance. Ethanol could not be profitably produced in Minnesota without the federal subsidy, and loss of all or part of this subsidy is the biggest concern of many of the ethanol producers with whom we talked.

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21 At a wholesale price of $1.60, the subsidized cost is 54 cents less, $1.06 per gallon. One gallon of ethanol adds as much oxygen as 1.5 gallons of MTBE so MTBE at 79 cents with 15 cents shipping equals 84 cents and this sum times 1.5 equals $1.26 compared to ethanol at $1.06.

Economic Impact of Minnesota's Ethanol Industry

CHAPTER 2

At current capacity, the ethanol industry in Minnesota has annual revenues of about $150 million from sales of ethanol and its animal feed coproducts. Ethanol producers spend most of this money locally, purchasing corn, labor, and other inputs to the production process. In addition, plant construction adds a one-time economic boost to each locality.

This chapter discusses the local and statewide economic impacts of fuel ethanol production. In particular, we address the following questions:

- **What is the local and statewide economic impact of the fuel ethanol industry?**
- **What are the projected economic impacts of further ethanol development?**
- **How do these impacts compare with those of alternative economic development projects?**
- **What effect does ethanol production have on the price of corn?**
- **What are the implications of ethanol development for our dependence on imported oil?**

The first part of this chapter addresses the local effects. We interviewed plant managers at all of the major operating plants. We also interviewed local economic development officials in communities with ethanol production facilities. The second section focuses on economic impacts at the state level. We calculated estimates of statewide economic impacts and reviewed estimates published by the Minnesota Department of Agriculture. Finally, we discuss other statewide and national impacts, such as the strategic importance of ethanol as an alternative to imported oil.

We found that the ethanol industry has a significant impact in the state's economy, and important benefits for the small towns where plants are located. However, we also found that the programs designed to support the ethanol industry have a substantial cost. Overall, we find that the net impact on the state's economy is positive, but there are transfers of income from taxpayers and consumers of gasoline to the ethanol industry that also merit consideration.

LOCAL ECONOMIC IMPACT

Minnesota's ethanol plants are located in communities with populations ranging from 530 in Claremont to over 12,000 in Marshall.[1] Most of the cities and counties in which plants are located are struggling to grow economically. Ethanol plants promise increased employment and tax revenues for small cities, as well as benefits to farmers through cooperative ownership and potentially higher prices for the corn crop. This section considers these issues in turn.

Jobs, Tax Revenue, and Other Growth

Ethanol plants of 5 to 15 million gallons per year capacity can change the face of small cities such as Winthrop, Winnebago, Claremont, and others. A number of indicators show that:

- **Ethanol plants are an economic boon to the communities in which they are located.**

Ethanol plants have created jobs in rural Minnesota.

As Table 2.1 shows, Minnesota ethanol plants typically have become one of the larger employers in the cities where they have been built. Moreover, the plants offer relatively high-paying jobs. The plants we visited employ about 27 people on average and operate around the clock. Most plants have four shifts, with two or three process operators per shift, one boiler operator per shift, four or five maintenance people, plus office staff, and equipment operators. The hourly wages for these jobs range from about $9 to $14.[2] The jobs also provide health insurance and other benefits and are considered good jobs in the community.

Table 2.1 also shows unemployment statistics for the cities and counties where major plants are located. Unemployment in these predominantly rural areas ranged from 3.4 percent to 5.4 percent in 1995.[3] For comparison, unemployment in the metro area in 1995 averaged 2.8 percent. We learned in our interviews, however, that skilled labor markets in these small rural towns are very tight. Often, plants have to bring people in from other communities or even other states. This fact tends to limit local employment effects of ethanol plants, but small towns still benefit from increased population and activity. Table 2.1 also shows that the small cities and rural counties where the plants are located have experienced declining populations in recent years.

In addition to jobs and tax revenue, small cities may receive other benefits from ethanol plants. Most cities improved their roads or utility infrastructure as a result of ethanol plant development. The city of Winthrop updated its water main system for the ethanol plant, and the expanded service may make the area more attractive for other development in the future. In Winnebago, prior to the plant's construction, the city had built a wastewater treatment facility with excess

1 Minnesota Department of Trade and Economic Development, *Community Profiles* (1993).

2 Wage estimates are approximate, but representative. We did not collect detailed payroll data.

3 Minnesota Department of Economic Security, *Local Area Unemployment Statistics Files* (1996).

Table 2.1: Population and Employment Data for Cities and Counties with Ethanol Plants

		1990 Census Population		Population Change 1980-90		1995	1995	Largest Employer-City		Ethanol Plant	
Plant Location	County	City	County	City	County	County Employment	Average Unemployment	Employer	Number of Employees	Number of Employees	Rank in City
Claremont	Dodge	530	15,731	-9.56%	6.46%	8,588	5.40%	Ethanol Plant	30	30	1
Winnebago	Faribault	1,565	16,937	-16.27	-14.09	8,008	5.00	Nursing Home	110	45	5
Winthrop	Sibley	1,279	14,337	-7.06	-7.53	6,489	5.20	Assembly & Packaging	230	30	6
Benson	Swift	3,235	10,724	-11.52	-17.00	4,982	4.60	Fertilizer Applicator Equipment	215	28	6
Morris	Stevens	5,613	10,634	4.58	-8.09	5,166	3.40	Univ. of MN-Morris	385	28	*
Marshall	Lyon	12,023	24,789	7.72	-1.68	14,114	3.40	Food Products	372	178	7
Melrose	Stearns	2,561	118,791	8.31	8.83	69,824	4.10	Turkey Processing	800	n.a.	n.a.

Source: Minnesota Department of Economic Security; Department of Trade and Economic Development Community Profiles.

*Not in top 13 in the city.

capacity. City officials believe that the facility now runs more cost effectively. These communities and others feel that plant development has increased their potential for further industrial development and thereby conveys benefits that are hard to quantify.

Local Ownership and Co-op Structure

All but one of the major ethanol plants have been organized as farmer-owned cooperatives.[4] Ethanol cooperatives differ from other corporations (and from some other agricultural cooperatives) in that shareholders are required to deliver a bushel of corn for each share of stock owned. Typically, farmers must purchase a minimum of 5,000 shares to become a member, and unlike other corporations, each member holds one vote, no matter how many shares are held.

About half of the financing for the typical Minnesota ethanol cooperative has been raised through sale of shares. Shares initially cost between $2.00 and $2.50 each with a minimum purchase of 5,000 shares, for a minimum investment of $10,000 to $12,500. Most cooperatives have over 500 members, and most of those members live within 40 miles of the plant.

Most Minnesota ethanol plants are organized as cooperatives.

Generally, the plants try to pay 80 percent of the market price for corn at the time of delivery, although the specific language in delivery agreements allows for less to be paid in some cases. Members that fail to perform on delivery agreements forfeit their shares, which can then be sold by the company to recoup the cost of corn. The market price difference at time of delivery is to be paid at the end of the quarter, although this payment may be retained by the plants under some conditions. In addition, the plants are expected to return a value-added dividend to the members whenever possible. In understanding Minnesota's ethanol industry, it is useful to keep in mind:

- **All but one of Minnesota's major ethanol plants are organized as cooperatives, bearing several profit- and risk-sharing benefits.**

The benefits of cooperative structure are essentially two-fold. First, any profits from ethanol production are distributed among the farmer-owners. This allows producers to participate in the profits of processing the raw commodities they produce. Second, as shown in Chapter 4, cooperatives may be better able to withstand periods of high corn prices, making them more stable forces within the community. The delivery agreements allow cooperatives to pay less than the market price for corn at the time of delivery, giving them a competitive advantage over plants that must buy grain on the open market in times of high corn prices. The summer of 1996 saw corn prices reach record highs, yet two new cooperative plants opened and development activities on other projects continued. This record is in contrast to a number of plants across the country, which curtailed or stopped fuel ethanol production.

4 Some of the cooperatives allow non-farmers to buy shares, but each share still requires annual delivery of a bushel of corn.

Corn Prices

Corn is a uniform commodity traded actively on the world market. The prices in effect at rural elevators reflect events taking place in the world's major grain exchanges, including those in Minneapolis and Chicago. We examined price data over a period of weeks for rural elevators near and remote from ethanol production facilities. Many people in the plants and communities that we interviewed believe that corn prices are a few cents higher in the immediate vicinity of ethanol plants. However, we found that:

- **At current production levels, ethanol plants have little discernible effect on the local price of corn.**

There is no consistent evidence that would indicate a permanent price "bubble" in the immediate vicinity of ethanol plants, with the possible exception of the wet milling facility at Marshall. The reason appears to be that, again with the exception of the Marshall plant, the mills grind a small fraction of the region's corn.

Ethanol producers process about 5 percent of Minnesota's corn crop.

Table 2.2 shows that existing plants have the capacity to convert about 5 percent of Minnesota's corn crop to ethanol. We obtained production statistics by county and estimated each plant's grinding capacity as a percentage of the corn grown in surrounding ring of counties. These estimates were in the 4 to 7 percent range, with the exception of the Marshall plant, which grinds, on average, about 12 per-

Table 2.2: Corn Production and Use in Ethanol Plants

	Bushels (in Millions)	Percent
MCP feedstock requirement	12.80	12%
Production: Lyon County and 6 surrounding counties	103.08	
Heartland feedstock requirement	3.85	5
Production: Sibley County and 6 surounding counties	82.97	
Corn Plus feedstock requirement	5.77	5
Production: Faribault County and 5 surrounding counties	115.69	
Al-Corn feedstock requirement	3.85	4
Production: Dodge County and 6 surrounding counties	101.84	
CVEC feedstock requirement	5.77	7
Production: Swift County and 6 surrounding counties	78.15	
Morris feedstock requirement	3.00	5
Production: Stevens County and 6 surrounding counties	59.23	
Minnesota Total feedstock requirement	35.03	5
Production: Minnesota Total	686.15	
US Total Feedstock Requirement	600.00	7
Production: US Total	8,153.00	

Notes: Feedstock Requirements are based on current capacity. Corn production data are 1991-1995 averages.

Source: Minnesota Agricultural Statistics, Renewable Fuels Association.

cent of the region's corn for ethanol production. Nationwide, about 7 percent of average annual corn production is converted to ethanol.

Although a 5 percent change in supply might be sufficient to put upward pressure on prices, the change would be unobservable under actual market conditions. For comparison, the 1995 corn crop was 20 percent smaller than the 1994 crop, due primarily to weather patterns. Other recent year-to-year changes are even larger and such changes overshadow the impact of small changes in current demands from ethanol production. We conclude that the effect of ethanol production on corn prices at current production levels is too small to be observed. Therefore, we assume that food prices are not affected, and the benefits to corn growers do not extend outside of the membership of the cooperatives.

At current capacity, ethanol has a small effect on the price of corn.

Producing 200 million gallons per year, however, would require about 80 million bushels per year, assuming an efficiency of 2.5 gallons per bushel.[5] This could represent over 11 percent of the state's average corn crop. At this level of ethanol production, corn prices in rural areas, especially areas serving one or more ethanol plants, might be pushed upwards. This would benefit corn growers, but Minnesota livestock producers will not profit from higher corn prices.

STATEWIDE ECONOMIC IMPACT

Ethanol production has an overall economic impact that is greater than the value of plant revenues. Firms that supply goods and services to the plant, such as corn growers and trucking companies, receive benefits and local shopkeepers profit from increased economic activity. The total economic impact is not directly measurable, but it can be estimated. This section summarizes our estimates of the impact of the ethanol industry in Minnesota and compares our estimates to those of the Minnesota Department of Agriculture.

New businesses hire workers, purchase raw materials and other inputs, pay taxes, and generate profits. These are termed "direct" impacts. What we think of as "ripple effects," caused by increased demand for everything from office products to haircuts, are divided into "indirect" and "induced" categories.

- "Direct" effects are equal to the value of sales.
- "Indirect" economic impacts are defined as those that come about through better opportunities for suppliers at all levels, in this case primarily corn growers.
- "Induced" effects are those brought about through increased disposable income of new employees, for example, the purchases of ethanol plant workers.

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5 National average over dry and wet milling processes.

The total economic impact is the sum of the direct, indirect, and induced effects, and is almost always greater than the direct effect alone, but measurement can be complicated.

Input-Output Analysis

We analyzed direct and "ripple" effects in the economy.

Indirect and induced effects can be calculated through survey research, but the costs of such surveys are high and errors are magnified by the level of detailed information required. An alternative to the survey method is to conduct an "input-output" analysis, using data from sources published regularly by the federal government and other sources to estimate direct, indirect, and induced effects. This method is appealing because it is less costly and can be used to evaluate potential projects as well as completed ones. Input-output analysis was pioneered in the 1930s by Wassily Leontief, who received the Nobel Prize for his contribution to economics.

It is widely understood that the effects of plant closings and openings have repercussions throughout the economy. Input-output analysis provides a way to estimate these effects.

Within this framework, the ability of an industry to create significant economic impacts is summarized in the concept of a "multiplier." Multipliers show how estimated statewide economic output will change with a given change in industry output. According to economists, multipliers typically range in value from just above one (for a project with few indirect or induced effects) to about 2.5. Multipliers for a sampling of Minnesota industry sectors are listed in Table 2.3, which shows that the multiplier for the ethanol industry, excluding corn impacts, is 1.44. Thus, for a $1 increase in ethanol production, statewide economic output goes up $1.44.

In general, the statewide economic impacts are greater in industries with higher multipliers. It is not possible, however, to rank industries based on their multipliers alone. Industries must "fit into" a region in ways that are too varied to summarize here before meaningful comparisons can be made. As shown in Table 2.3, the multiplier associated with ethanol production is not as high as some alternatives, but may be as high or higher than most economic opportunities with wide-spread applicability for rural areas.

Advantages and Limitations

Input-output analysis is a convenient way of estimating the direct and ripple effects through a region's economy. The structure of the accounts provides a framework for investigating questions that are inherently complex. Input-output analysis can be used to investigate alternative future development proposals. Furthermore, the analysis results in a numerical estimate that is easily understood and can be readily compared.

Table 2.3: Selected Minnesota Industrial Sectors and Their Multipliers

Sector	Multiplier
Dairy Farm Products	1.54
Poultry and Eggs	1.45
Ranch Fed Cattle	1.55
Hogs, Pigs, and Swine	1.83
Feed Grains (including corn)[a]	1.53
New Industrial and Commercial Buildings	1.83
Ethanol (dry milling, not including corn impacts)[a]	1.44
Wet Corn Milling	1.73
Commercial Printing	1.69
Boiler Shops	1.80
Sheet Metal Work	1.66
Pipe, Valves, and Pipe Fittings	1.72
Machine Tools, Cutting Metal Types	1.81
General Industrial Machinery	1.59
Electronic Computers	1.67
Surgical and Medical Instruments	1.75
Wholesale Trade	1.73
Miscellaneous Retail	1.81
Security and Commodity Brokers	1.90
Elementary and Secondary Schools	2.24
State and Local Government - Non Education	1.98
Middle Income Household Spending[a]	1.18
Ethanol Plant Construction[a,b]	1.76

Note: Data is from 1993.

Source: Minnesota IMPLAN Group.

[a]Used in the impact analysis.

[b]Multiplier for a combined project including the following sectors: new industrial and commercial buildings; boiler shops; pipe, valves, and pipe fittings; general industrial machinery; and computers.

On the other hand, there are several known sources of bias "built in" to the way impacts are estimated in input-output analysis. The careful analyst can assess the severity and compensate for many of them on a case-by-case basis.

Economic impacts need to be interpreted cautiously.

For example, in the case of a specific industrial development project, the input-output results would be calculated under the assumption that all new employees represent net additions to the labor force, and all inputs to the production process must be created from raw materials. Sometimes, this is an accurate assessment of expected outcomes. For the case at hand, it presents a problem; ethanol was intially proposed as an alternative use for surplus corn. We do not anticipate ethanol production at proposed levels to have an expansionary effect the number of acres planted to corn. Our analysis, therefore, omitted this expansionary effect..

It is important to recognize that analyzing economic impacts is difficult and sometimes controversial. Credible results depend heavily on careful specification of events. Even with reasonable assumptions, it is difficult to judge the accuracy of the results.

FISCAL YEAR 1997 ESTIMATES

At current capacity, ethanol programs produce net benefits.

Estimates of the net economic impacts of current ethanol industry development and public support measures are presented in Table 2.4. Our analysis indicates that current levels of industrial development generate $269 million in economic activity, not including the impacts arising from profits or losses of corn producers. Impacts from corn profits range from a possible loss of $58 million to a gain of the same amount. However, we estimate that the producer payment, the blender's credit, higher fuel costs, and lower fuel economy cost the state between $67 and $102 million annually in foregone household spending. Overall, we estimate the net annual impact to be between $109 and $260 million. This section details our assumptions, beginning with benefits.

Economic Impact of Ethanol Production

In fiscal year 1997, the Minnesota Department of Agriculture projects that the ethanol industry will manufacture 99 million gallons of ethanol. Using the 1989-96 average price for ethanol of $1.30, this represents about $129 million in revenue. We estimate an additional $41 million in revenue will come from sales of animal feed byproducts, again assuming 1989-96 average prices. The department projects producer payments will total $17 million. Thus, industry revenues for fiscal year 1997 are expected to sum to $187 million. Table 2.3 shows the multiplier for ethanol (excluding corn impacts) to be 1.44, so the total annual output impact is estimated to be $269 million, as shown in Table 2.4.

Table 2.4: Net Economic Impact of Ethanol Programs, Current Capacity

		Value	Output Impact (Millions)	Employment Impact (Jobs)	Personal Income Impact (Millions)
ANNUAL BENEFITS AND COSTS[a]					
99 Million Gallons Ethanol Production		$187	$269	1,375	$44
Corn Profits[b]	+$1.00 to -$1.00 per bushel	38 - (38)	58 - (58)	243 - (243)	7 - (7)
Producer Payment		17	(20)	(314)	(8)
Blender's Credit		6	(7)	(102)	(3)
Metro Area Summertime Use:					
Higher Fuel Cost	2 to 5 cents per gallon	13 - 33	(16) - (39)	(246) - (633)	(6) - (15)
Lower Fuel Economy	2.3 to 3.5 percent decrease	20 - 30	(24) - (36)	(373) - (575)	(9) - (14)
Total Annual Benefits and Costs			$109 - 260	(492) - 583	$(3) - 25
ONE-TIME NET BENEFITS:					
Construction Impacts	1/2 Local Content	99	174	1,146	38
	2/3 Local Content	132	232	1,537	50
	3/4 Local Content	149	261	1,733	57

Source:

[a]All benefits and costs are based on fiscal year 1997 projections, except as noted.

[b]Corn profits from ethanol production is the value added per bushel over the market price for the raw commodity.

Economic Impact of Corn Profits

Corn growers profit if the price paid by ethanol plants exceeds the overall market price for corn. Corn prices and ethanol plant profits are highly variable, so we present a range of potential values. The projected 99 million gallons of ethanol output will require about 38 million bushels of corn. If the growers receive $1.00 per bushel in value added through ethanol production, then the total value is $38 million. Table 2.3 shows the multiplier for the feed grains sector to be 1.53, so the total output impact associated with a $1 per bushel dividend is $58 million.

Alternatively, if the growers receive just 50 cents per bushel, then the impact is likewise reduced by half. Similarly, if the farmers lose money, we estimate a negative statewide economic impact. Impacts for $1 per-bushel profits are shown in Table 2.4, together with impacts for losses of $1 per bushel. Overall, we estimate statewide economic impacts from corn profits may range from $58 million to a loss of the same amount.

Economic Impact of the Producer Payment

Minnesota's Department of Agriculture projects producer payments to total $17 million in fiscal year 1997 (see Table 1.2 in Chapter 1). We estimate the cost of this public expenditure by calculating the impact of an equivalent increase in middle income household spending. The multiplier for household spending, listed in Table 2.3, is 1.18.[6] If the producer payments were not made, and instead taxes on middle income households were reduced by an equivalent amount, the impact would be a $20 million increase in statewide economic output, as shown in Table 2.4.

Economic Impact of the Blender's Credit

Until it is completely phased out in October of 1997, the blender's credit reduces revenues accruing to Minnesota's Trunk Highway Fund. As with the producer payment, we estimated the costs of the blender's credit by calculating the impact of an equivalent increase in middle income household expenditures. The Department of Revenue projects the value of credits for fiscal year 1997 to be $6 million. If middle income households spent this money, using the multiplier of 1.18, we estimate the total economic impact to be $7 million, as shown in Table 2.4.

Economic Impact of Metro Area Summertime Ethanol Use

Consumers also incur costs as a result of the year-round oxygenated fuel requirement in the Twin Cities area. We assume that about 2 billion gallons of gasoline

6 Household spending multipliers for the state are small relative to those for producing sectors because a small proportion of consumer goods are made in Minnesota. The expenditures of middle income households are used as representative of all households, but this does not affect the results appreciably. Because the household spending multiplier is relatively small, our estimate of the cost impacts may be considered conservative.

are used in the state, and about one-half of that total is used in the Twin Cities area. Federal law requires use of an oxygenate in four winter months in the Twin Cities, so only two-thirds of the annual costs associated with use are attributable to state policy. Thus, about 667 million gallons are to be affected in fiscal year 1997. The costs of the oxygenated fuel requirement can be measured in higher fuel prices and lower fuel economy.

In Chapter 1, we estimated that oxygenated fuel costs consumers 2 to 3 cents more per gallon than conventional gasoline. Table 2.4 shows the impact of raising the price of 667 million gallons of gasoline by 2 cents per gallon and alternatively, by 5 cents per gallon. Assuming a 2 cents per gallon premium, year-round ethanol use costs Twin Cities area residents over $13 million, and at the higher premium of 5 cents per gallon, the total is over $33 million annually. Were these amounts not spent on gasoline, other expenditures would generate between $16 and $39 million in economic activity. In other words, year-round ethanol use in the Twin Cities costs the state between $16 and $39 million, annually.

Furthermore, fuel efficiency in terms of miles per gallon is reduced with oxygenated fuel as compared with conventional gasoline. As explained further in Chapter 3, this results in 2.3 to 3.5 percent more gasoline being consumed, and (assuming a price of $1.30 per gallon) an annual increase in fuel costs of about $20 to $30 million for Twin Cities residents. This corresponds to a loss of $24 to $36 million in statewide economic impacts, as shown in Table 2.4.

Economic Impact of Ethanol Plant Construction

Plant construction brings one-time benefits.

Construction of an industrial facility such as an ethanol plant has a large, but short-lived, impact on the state's economy. The impact on the state's economy of constructing ethanol facilites is presented in Table 2.4. This impact differs from others in Table 2.4 in that it represents a one-time boost to the state's economy.

The size of the impact depends on what percent of construction costs are paid to Minnesota firms. In most plant construction projects, some equipment was purchased secondhand and engineering services were contracted to out-of-state firms. Out-of-state purchases must be subtracted before estimating the construction impact.

Plant records indicate that construction of a dry milling ethanol production facility costs roughly $2 per gallon of installed capacity. Using this figure, the cost to build the state's projected 99 million gallons of capacity is $198 million. Our interviews with plant managers suggested that about two-thirds of construction costs went to Minnesota firms. Using this assumption, the total value is $132 million. The multiplier of an ethanol plant construction project was shown in Table 2.3 as 1.76. Thus, the total one-time output impact from facilities construction is $232 million. Table 2.4 also show estimates derived under the assumptions of one-half and three-fourths local content of $174 million and $261 million, respectively.

Net Benefits

Summing the benefits and costs discussed above, Table 2.4 shows that:

- **The ethanol industry generates a net annual impact of between $109 and $260 million, statewide. In addition there is a one-time benefit of $174 to $261 million from plant construction.**

Statewide job impact of current plant capacity is unclear.

Employment and Personal Income Impacts

The previous section focused on impacts measured in changes to the value of the state's economic output. The input-output model we used also calculates impacts in terms of employment and personal income. As shown in Table 2.4, we estimate that on an annual basis, employment impacts range from a loss of 492 jobs to a gain of 583 jobs. The reason that employment impacts may be negative is because of differences in labor patterns between the sectors where job gains and losses occur.

The sectors that gain employment directly from increased ethanol production are mostly manufacturing sectors. In general, these sectors are highly mechanized and levels of output per worker are high. Hence, a given change in output supports a relatively small number of jobs. In contrast, decreases in household spending affect workers mainly in the retail sectors, where output per worker is lower. Thus, for a given transfer of income from households to the ethanol industry, more retail jobs are lost than there are opportunities created in manufacturing. Our analysis indicates that:

- **Statewide employment gains are less significant than increases in the value of economic output, and reduced household spending due to the cost of ethanol programs may result in a net loss of jobs.**

As shown in Table 2.4, we estimate that 1,375 jobs are supported annually by an ethanol industry with 99 million gallons of production capacity. Changes in farm profits potentially affect a number of jobs in the wider economy ranging from a loss of 243 jobs to a gain of the same amount.[7] However, our analysis shows that the producer payment, blender's credit, and year-round oxygenated fuel requirements in the Twin Cities raise costs to taxpayers and consumers of motor fuel. Reduced household expenditures in other areas decrease state employment by between 1,035 and 1,624 jobs.

In terms of total personal income in the state, our analysis again shows less significant impacts than for the value of total state economic output. Unlike the employment results, however, the range of personal income impacts stays largely above zero. As shown in Table 2.4,

7 Although the model predicts that changes in corn grower's profits will directly lead to similar changes in farm employment, we believe that this is unlikely. Our estimates, therefore, do not include the employment changes directly affecting the corn growing sector, although indirect and induced effects on the wider economy are included.

- **The ethanol industry has a net positive impact on total state personal income under all but the most unfavorable combination of assumptions.**

We estimate that statewide personal income increases by about $44 million due to the direct, indirect, and induced effects of ethanol production. To the extent that corn growers earn profits or losses, personal income impacts may be adjusted up or down by up to $7 million. However, the costs of the producer payment, blender's credit, and oxygenated fuel requirements for the Twin Cities reduce statewide personal income by $22 to $35 million. [8] The net personal income gain is between negative $3 million and positive $25 million.

FUTURE ETHANOL DEVELOPMENTS

Table 2.5 shows estimated economic impacts associated with projected future industry growth, as well as those resulting from extending the oxygenated fuel requirement statewide.

Table 2.5: Net Economic Impact of Ethanol Programs, Fiscal Year 2001

		Value	Output Impact (Millions)	Employment Impact (Jobs)	Personal Income Impact (Millions)
ANNUAL BENEFITS AND COSTS[a]					
178 Million Gallons Ethanol Production		$329	$472	2,426	$78
Corn Profits[b]	+$1.00 to -$1.00 per bushel	68 - (68)	104 - (104)	444 - (444)	12 - (12)
Producer Payment		(23)	(27)	(436)	(11)
Subtotal: 178 million gallons of production			$341-549	1,546-2,434	$55-79
Statewide Year-Round Use:					
Higher Fuel Cost	2 to 5 cents per gallon	(33) - (83)	(39) - (99)	(633) - (1,608)	(15) - (38)
Lower Fuel Economy	2.3 to 3.5 percent decrease	(50) - (76)	(59) - (89)	(954) - (1,118)	(23) - (26)
Subtotal: Statewide Year-Round Use			$(188) - (98)	(2,726) - (1,587)	$(64) - (38)
Total Annual Benefits and Costs			$153 - 451	(1,180) - 847	$(9) - 41
ONE-TIME NET BENEFITS					
Constuction Impacts	1/2 Local Content	178	313	2,078	68
	2/3 Local Content	237	417	2,781	90
	3/4 Local Content	267	470	3,134	102

Source:

[a]All benefits and costs are based on fiscal year 2001 projections, except as noted.

[b]Corn profits from ethanol production is the value added per bushel over the market price for the raw commodity.

8 These impacts were estimated by calculating the change in employment and income associated with changes in household spending.

Economic Impact of Ethanol Industry Expansion

In fiscal year 2001, the Minnesota Department of Agriculture projects that the ethanol industry in Minnesota will manufacture 178 million gallons of ethanol. Using the same prices for ethanol and feed byproducts as in the estimates above, this represents $231 million in revenue from ethanol and an additional $75 million in revenue from sales of animal feed byproducts. The department projects producer payments will total $23 million in fiscal year 2001. Thus, industry revenues sum to $329 million. Table 2.3 showed the multiplier for ethanol production to be 1.44, so the total annual output impact is estimated to be $472 million in fiscal year 2001, as shown in Table 2.5.

It is important to note that the input-output method assumes that capacity will be added by increasing the number of facilities and keeping the average plant size constant. Increasing ethanol plant capacities would mean more cost-efficient operation and hence, smaller economic impacts. We acknowledge that the estimate for the year 2001 is biased upwards, but the extent of this bias is unknown. We present it as an upper bound to the range of possible true impacts.

Economic Impact of Corn Profits

Manufacturing the projected 178 million gallons of ethanol would require about 68 million bushels of corn. If the corn growers receive $1.00 per bushel in value added through ethanol production, then the total value is $68 million. Table 2.3 shows the multiplier for the feed grains sector to be 1.53, so the total output impact at this increased capacity is $104 million. Table 2.5 shows this estimate, along with those for other potential profit margins. Overall the impacts from corn profits may range from $104 million to a loss of the same amount.

Economic Impacts of the Producer Payment

The Minnesota Department of Agriculture projects producer payments to total $23 million in fiscal year 2001 (see Table 1.2 in Chapter 1). We estimate the cost of this public expenditure by calculating the impact of an equivalent increase in middle income household spending. The multiplier for household spending, listed in Table 2.3, is 1.18. If the producer payments were not made, and instead taxes on middle income households were reduced by an equivalent amount, the impact would be a $27 million increase in statewide economic output.

Summing production benefits and subtracting the costs of the producer payment, we find:

- **The projected level of output in 2001 of 178 million gallons per year will generate an estimated $341 to $549 million in annual statewide economic benefits. Actual impacts will probably be smaller, depending on the actual increases in efficiency.**

Economic Impact of Statewide Year-Round Ethanol Use

Statewide ethanol use adds significant costs for consumers.

Consumers will also incur costs as a result of the year-round oxygenated fuel requirement. We assume that about 2 billion gallons of gasoline are used in the state. Federal law requires use of an oxygenate in four winter months in the Twin Cities metro area only, so about five-sixths of the annual costs associated with use are attributable to the state policy requiring oxygenated fuel statewide and year-round. Thus, about 1.67 billion gallons are affected under statewide oxygentated fuel requirements sceduled to take effect in October, 1997. The costs of oxygenated fuel use are measured in higher fuel costs and lower fuel efficiency.

Table 2.5 shows the impact of raising 1.67 million gallons of gasoline by 2 cents per gallon and, alternatively, by 5 cents per gallon. Assuming a 2 cent per gallon premium, this amounts to over $33 million in extra fuel costs. At the higher estimate of 5 cents per gallon, the costs total over $83 million. Were these amounts not spent on gasoline, other middle income household expenditures would generate between $39 and $99 million in economic activity.

Furthermore, vehicles travel fewer miles per gallon of oxygenated fuel as compared with conventional gasoline. This results in 2.3 percent to 3.5 percent more gasoline consumed, and (assuming a price of $1.30 per gallon) $50 to $76 million is extra fuel costs. In terms of household expenditures, this represents an annual loss of $59 to $89 million in statewide economic impacts.

Totalling these results, we estimate:

- **Statewide, year-round ethanol use will cost consumers $83 to $159 million, with statewide economic impacts of $98 to $188 million annually.**

Economic Impact of Ethanol Plant Construction

Using the cost assumption of $2 per gallon of installed capacity, the total cost to build the state's projected 178 million gallons of capacity is $356 million. Assuming two-thirds of this total supports Minnesota construction firms, the total value is $237 million. The multiplier of an ethanol plant construction project was shown in Table 2.3 as 1.76. Thus, the total one-time output impact from facilities construction is $417 million. Table 2.5 also show estimates derived under the assumptions of one-half and three-fourths local content of $313 million and $470 million, respectively.

Combining the above impacts, we estimate that:

- **The net annual impact of future ethanol developments is estimated between $153 and $451 million in economic output. In addition,**

one-time ethanol plant construction benefits are estimated to grow to a cumulative total of $313 to $470 million.

Employment and Personal Income Impacts

Expansion of current plant capacity will have mixed impacts on jobs and personal income.

Table 2.5 also shows the impacts of 178 million gallons of annual production and statewide, year-round ethanol use measured in terms of employment and personal income. For the same reasons explained above, employment impact estimates at this greater level of production and use show a trade off between jobs in the ethanol sector and jobs supported by household spending, which are mainly in retail sectors. The net impact depends on the specific assumptions, but estimates range from a loss of 1,180 jobs to a gain of 847 jobs. The direction of personal income impacts is also dependent on assumptions, but the estimates on Table 2.5 range from a loss of $9 million to a gain of $41 million.

Like any impact analysis, these estimates rely on projections of current economic patterns and little is known about the accuracy of such models. Without careful specification the models can overstate impacts. Our analysis has made every effort to properly account for costs as well as benefits.

The Department of Agriculture's Estimates

The Minnesota Department of Agriculture has published estimates of the impact of ethanol on the Minnesota economy. These estimates include "balance of trade effects," total value of output, total economic impact, job creation, and fiscal impacts. The department's analysis examines three scenarios for ethanol production: 25 percent market share (50 million gallons per year), 50 percent market share (100 million gallons per year) and 100 percent market share (200 million gallons per year). Overall,

- **The Department of Agriculture's estimates of economic impact focus on the benefits of ethanol production while ignoring the costs of state programs.**

The department's balance of trade analysis is based on the value of ethanol as a direct substitute for gasoline, which is "imported" from other states. The department claims that replacing 10 percent of all gasoline sold in Minnesota (200 million gallons, at $0.50 per gallon) with ethanol would improve the balance of payments by $100 million. This analysis greatly oversimplifies the balance of payments effect and overstates the potential benefit by singling out one of the potential benefits of ethanol, and none of the associated costs. A more thorough analysis of the impact on the balance of trade would include the lost "exports" of raw corn or alternative products, and the "import" of people and capital to build and operate the plants.

We also think that the arguments concerning balance of trade effects are largely out of place in an economic impact analysis. Reduced imports mean a loss of jobs and income at some level, if only in the importing sector. More likely, the changes will have repercussions in many areas of trade. We do not think it is acceptable to count reductions in imports as a category of economic benefits alongside increases in income and output. While we acknowledge the desirability of fuel supply as a national security issue, our analysis examines this issue separately.

To estimate economic impacts, the department uses input-output analysis as we have done in this chapter. The department's estimates are much higher than ours, primarily because they do not consider the economic impacts of public support, higher fuel costs, or reduced fuel economy. For example, the department's estimate of the total impact resulting from 100 million gallons of ethanol production is $301 million.[9] We estimated the net impact of 99 million gallons of ethanol production, excluding corn impacts and all forms of cost, to be $269 million. With corn impacts and costs included, our estimate falls to between $109 and $260 million (see Table 2.4).

Comparing the estimates of the annual economic impact of ethanol production alone, we believe our estimates are essentially similar to those of the department. Our estimates benefited from a more recent data set than that used by the department, and we think our estimates better account for some of the inherent biases of the input-output method. However, the numerical benefit estimates are close; the major difference is the lack of cost impacts in the department's analysis.

The Department of Agriculture's estimates consider benefits but not costs.

The department's analysis of fiscal impacts balances the cost of producer payments against estimates of payroll tax, taxes on cooperative member's dividends, and property taxes. This, too, is oversimplified. As outlined elsewhere, there are many other forms of state assistance, and a more complete analysis would also include the costs to local infrastructure and municipal services.

Furthermore, the department's analysis assumes a property tax rate of 7 to 8 cents per gallon of capacity installed, and therefore forecasts an increase in tax revenues whenever output increases. Our data suggests that the sum total of all taxes amount to less than 2 cents per gallon of capacity for a small plant and much less for larger facilities. Moreover, many of the plants have secured tax increment financing, whereby they can reduce their net property tax exposure.

By the department's own analysis, the ethanol subsidies will create a net drain on government revenues up until the industry reaches a 90 percent market share. The only factor limiting the loss is the $30 million spending cap. We believe, however, that net fiscal impacts are tangential to the question of economic impacts. The ethanol programs were designed to transfer funds to a fledgling industry, and cost containment measures such as the spending cap and the 10 year limit were enacted by a Legislature cognizant of the potential fiscal impacts involved.

9 Su Ye, *Economic Impact of the Ethanol Industry in Minnesota* (St. Paul: Minnesota Department of Agriculture, May, 1996).

STRATEGIC VALUE OF ETHANOL

In addition to the economic benefits described above, Minnesota's ethanol industry may have a strategic value stemming from ethanol's partial substitutability for gasoline. In 1993, the United States imported about 2.5 billion barrels of crude oil, almost 40 percent of our consumption, and imports are increasing in volume and percentage terms. More than half of oil imports come from members of the Organization of Petroleum Exporting Countries, and there is lingering concern about the power of the OPEC cartel. This section summarizes strategic value by looking first at the amount of petroleum used to produce ethanol, followed by strategic values to the nation, and finally, the state of Minnesota.

Net Energy Value

For ethanol to play a role in energy security, it must have a positive net energy value, meaning that it must contain more energy than is used in the ethanol production and distribution process. Although in earlier years this was a valid criticism of ethanol production technology, more recent studies indicate that:

Ethanol production is energy efficient.

- **Ethanol contains more energy than is used to manufacture it.**

The most recent and best study indicates a national average gain in energy value of about 24 percent, including values for coproducts.[10] This study also includes some state level estimates, from which we infer even higher net energy values in Minnesota. Compared to other major corn producing states, Minnesota uses less nitrogen fertilizer and less irrigation, both of which are energy intensive. We therefore consider the national estimates conservative from the state's perspective.

A related measure of energy value considers petroleum fuels only. This ratio balances the energy content of ethanol against only the petroleum used to manufacture ethanol. The USDA reports that ethanol contains 7.24 times the energy in the petroleum used in the production and distribution process. Put another way, producing one Btu of ethanol energy requires 0.14 Btu of petroleum energy.

The Cost of Gasoline and the Strategic Value of Ethanol

There is little doubt that the total costs to society of petroleum use are greater than the prices paid by consumers. A recent study suggested that the "true" cost of gasoline was 32 cents higher than the average retail price.[11] Most of this difference (19.2 cents per gallon) is attributable to military expenditures. Environ-

10 Hoesin Shapouri, James Duffield, and Michael Grabowski, *Estimating the Net Energy Balance of Corn Ethanol* (Washington, D.C.: USDA Economic Research Service, 1995).

11 Jenny Wahl, *Oil Slickers: How Petroleum Benefits at the Taxpayers' Expense* (St. Paul: Institute for Local Self Reliance, 1996).

mental and health costs are also important, adding 11.5 cents. Finally, the tax breaks enjoyed by the oil industry cost 1.45 cents per gallon of gasoline.

We think that this pricing problem is not relevant to an evaluation of the ethanol industry. From a national perspective, ethanol is a minor energy source. In 1994, ethanol fuels accounted for 0.1 percent of total energy consumption, whereas petroleum supplied about 39 percent. Ethanol consumption could triple from these levels and still represent less than half of 1 percent of total energy consumed, and less than 1 percent of the nation's consumption of petroleum energy. Thus:

- **Ethanol replaces a tiny fraction of imported petroleum, and cannot be credited with any national energy security benefits.**

Furthermore, there is no plausible scenario under which ethanol can meet expected increases in petroleum demand. Crude oil imports are projected to grow almost 30 percent by the year 2000 on an energy content basis.[12] This amount translates to over 44,000 times as much ethanol as is currently produced in the US. Expanding ethanol production to meet these increased petroleum demands would require over 2,000 times as much corn as is grown in the US in an average year.

The United States is committed to being a large petroleum importer for the foreseeable future, with or without ethanol production. To this end, military expenditures, human health costs and environmental costs will likely remain at or above current levels. The effect of ethanol on energy security is no more than symbolic, and may be counterproductive if more effective strategies exist to reduce our reliance on imported oil.

Octane and Replacement Value

Ethanol currently replaces a tiny fraction of imported oil.

Even without national security benefits, ethanol can have value to the state as a gasoline additive.

This may come about through simple substitution, with ethanol replacing a quantity of gasoline with equal energy content. Ethanol contains 33 percent less energy than an equal volume of gasoline. Using this factor, the 69 million gallons produced in Minnesota in fiscal year 1996 replaced 46 billion gallons of gasoline. This represents 2.3 percent of statewide gasoline consumption. In terms of its replacement value,

- **A gallon of ethanol replaces 0.67 gallons of gasoline.**

Ethanol may also have a value in use stemming from its high octane content. Cheaper, lower octane gasoline formulations can be used in ethanol blends, since the octane in ethanol will bring the oxygenated fuel up to specification. Of course, to take full advantage of this refiners must expand their systems to include tankage and handling capability for another grade of gasoline.

12 *Statistical Abstract of the United States* (Washington, D.C: US Bureau of the Census, 1995).

We spoke with representatives from two major refiners that produce gasoline with an octane rating of about 84. This fuel is not sold as is, but is used exclusively at the refinery to produce oxygenated unleaded regular gasoline with an octane rating of 87. This pre-blended fuel is distributed exclusively in the Twin Cities area, because tankage and handling capacity in the remainder of the state can not accommodate an additional grade of fuel. A third refiner we spoke with said that due to handling and capacity problems, they did not produce any sub-grade gasoline for ethanol blending.

However, even the refiners that take fullest advantage of the octane benfits of ethanol acknowledged that there are cheaper octane enhancers available to them. Without the oxygenate mandate, and the tax benefits associated with ethanol, they said they would use very little ethanol.

SUMMARY

Minnesota's ethanol industry conveys significant net economic benefits for the small cities where the plants are located, and also for the state as a whole. Most of the recent development in ethanol production has been focused on small rural cities, which gain benefits in terms of economic diversification, job growth, and improved economic environments. In addition, ethanol plant development has brought improvements in small cities' infrastructure, which may improve future prospects for additional growth.

The industry generates significant statewide net economic benefits as well. Subtracting the cost impacts from the annual production impacts, we estimate that the present level of development has had a net impact of $109 to $260 million, depending on which assumptions about corn growers profits and fuel costs are used.

The projected level of output in the year 2001 of 178 million gallons per year would generate an estimated $341 to $549 million in statewide economic benefits, net of costs of subsidy, assuming the industry maintains the current level of efficiency. Actual impacts will probably be smaller, however, as planned expansions of the current plants should make them operate more efficiently.

Implementation of the statewide, year-round oxygenated fuel requirement will increase Minnesota's fuel costs by increasing fuel prices and decreasing average fuel economy. We estimate the annual costs to be between $83 and $159 million. Were these costs not imposed, other household spending would generate between $98 and $188 million in annual statewide economic activity.

We found other potential benefits, such as energy security, to be unsubstantiated. Comparatively, ethanol constitutes a tiny fraction of petroleum demand, and arguments based on national energy security or the "true" costs of oil are symbolic at best. There is simply no plausible scenario under which ethanol derived from corn can lessen our dependence on imported petroleum.

Environmental and Performance Effects of Ethanol Use

CHAPTER 3

The Twin Cities metropolitan area is required by federal law to use oxygenated gasoline from October through January.

The 1990 amendments to the federal Clean Air Act require wintertime use of oxygenated gasoline in 39 carbon monoxide (CO) non-attainment areas across the nation. These are areas where EPA air quality standards had not been met in the late 1980s. In Minnesota, the 10 county Twin Cities metropolitan area is a federally designated carbon monoxide non-attainment area. The Twin Cities is the only CO non-attainment area in the midwest.

The law also requires year-round use of reformulated gasoline (RFG) which contains a lower concentration of oxygenates in 9 severe ozone non-attainment areas. Minnesota does not have any ozone non-attainment areas, although a large part of the eastern seaboard from Maine to Virginia, much of California, and metropolitan areas closer to Minnesota including Chicago and Milwaukee are so classified. Both carbon monoxide and smog, which is produced by ozone and other pollutants, cause health problems, especially among people with respiratory or cardio-vascular disease.[1]

Ethanol is one of two oxygenates commonly in use. The federal and state laws governing wintertime oxygenate use in Minnesota require a concentration of 2.7 percent oxygen (by weight), but they do not require the use of a particular compound. The requirement can be met with about a 7.7 percent mixture of ethanol (by volume) in gasoline. A 10 percent mixture of ethanol yields 3.5 percent oxygen content. Data from the Minnesota Department of Public Service shows that gasoline samples taken over the last several years actually contain an average of about 3.2 percent oxygen which corresponds to about 9.1 percent ethanol by volume. For economic reasons, ethanol is the only oxygenate currently used in Minnesota, although ethanol constitutes less than a third of the oxygenates used nationally.

While incentives for ethanol production and use are designed primarily as economic development programs, the federal oxygenated fuel program is designed to reduce pollution and improve human health. The Minnesota program that extends the federal oxygenated gasoline requirement both in time and geographic coverage has implications for the economic health of the industry, but also needs to be evaluated in terms of environmental, health, and performance effects. Toward this end, we addressed the following questions:

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1 A few areas are out of attainment for both CO and ozone. Also, starting in June 1996, the entire state of California is required to use its own reformulated gasoline that is similar to the Federal Phase II fuel that is due to replace Federal Phase I reformulated gasoline in 2000.

Minnesota law will require the use of oxygenated gasoline statewide and year round starting October 1997.

- **Has wintertime ethanol use allowed Minnesota to meet federal carbon monoxide standards? Does the use of oxygenated fuel lower tailpipe emissions and atmospheric CO levels?**
- **Are there environmental benefits from summertime use of ethanol?**
- **Are there significant health effects of ethanol use?**
- **Does ethanol affect engine mechanical performance or fuel economy?**

In order to study the environmental benefits of ethanol use in Minnesota, we reviewed the literature and previous analyses of the impact of oxygenated gasoline on ambient CO concentrations. We interviewed officials in charge of the air quality program at the Minnesota Pollution Control Agency (PCA), and reviewed research sponsored by PCA. We also interviewed the Director of Atmospheric Modeling in the Environmental Protection Agency's Office of Mobile Sources. While federal requirements remain for wintertime use of oxygenated gasoline in CO non-attainment areas, according to EPA there are few violations of the EPA carbon monoxide standard nationwide, and there is a growing belief that the standards could be achieved in most places without the use of oxygenated gasoline.

CARBON MONOXIDE ABATEMENT

About 70 percent of CO emissions are produced by highway vehicles, according to the Minnesota Pollution Control Agency (PCA). The United States Environmental Protection Agency (EPA) regulates carbon monoxide concentrations through its National Ambient Air Quality Standards, and the Duluth and Twin Cities areas were judged to be out of compliance on the basis of measurements made in 1988-89 when initial measurements were taken.[2]

Oxygenated gasoline is designed to help lower the concentration of carbon monoxide in the atmosphere.

Requiring the use of oxygenated gasoline in winter months is part of a multifaceted strategy for reducing CO. Minnesota and some other states also check tailpipe emissions during annual vehicle inspections. Transportation planners seek improvements in traffic flow that can lower CO levels in problem areas. Finally, modernization of the automobile fleet has a positive effect, since newer cars with oxygen sensors and computerized fuel injection emit less CO than the vehicles they replace.

Nationally and in Minnesota, ambient CO levels have been declining for many years. By 1990, when Congress established the oxygenated fuel program, CO emissions had already declined nationally to about 30 percent of their 1970 level. By 1995 they had declined even further, to about 20 percent of the 1970 level. These declines were achieved in spite of greatly increased vehicle miles traveled. There is considerable discussion in the literature and among scientists advising federal regulatory agencies about how much of this decline can be attributed to oxygenated gasoline versus the other strategies.

2 Duluth was subsequently classified as in attainment.

Our review of the literature and interviews with experts suggests:

- **Most of the reduction in atmospheric CO in recent years is due to improved vehicle emissions equipment. It is not clear that the use of oxygenated gasoline can be linked to a significant reduction in atmospheric carbon monoxide. Scientists say that little or no reduction in ambient CO levels can be expected from the use of oxygenated fuels in newer vehicles with properly operating vehicle emissions systems.**

Minnesota has not recorded violations of CO standards in recent years.

According to data reported by the Minnesota Pollution Control Agency (PCA), Minnesota has not recorded any violations of CO levels over the last several years. Air quality is monitored continuously at various places including busy traffic intersections that are known to be trouble spots. If CO readings exceed the state standard of 30 parts per million (ppm), or the federal standard of 35 ppm on an hourly basis, or 9 ppm on an eight hour basis, an "exceedence" is recorded. A "violation" is defined as two exceedences per year. In recent years, Minnesota has recorded occasional exceedences, but they have not occurred often enough to cause a violation of state or federal air quality standards for CO. The federal and state hourly standards have not been violated since 1984, and the 8 hour standards have not been violated since 1991.[3] According to the EPA, only a few violations have been recorded anywhere in the country in recent years.

Measurement of compliance with the national ambient air quality standards by the EPA involves the use of a predictive ambient air quality model as well as atmospheric measurement. The model considers the age of the vehicle fleet, miles driven, vehicle inspection, use of oxygenated fuel, and other factors. According to PCA, it is possible that we would meet EPA carbon monoxide standards without the use of oxygenated fuel, given the modernization of the vehicle fleet that has occurred since the last violations were recorded.

Two recent government-sponsored studies have been conducted that address questions about the efficacy and safety of oxygenated gasoline: a report by the White House Office of Science and Technology Policy (OSTP), and a review of the OSTP by the National Research Council.[4] The Office of Science and Technology Policy directed the preparation of an interagency report on the effects of oxygenated gasoline including toxicological and performance effects. This study was carried out by working groups comprised of technical and scientific experts form several federal agencies as well as representatives of state government industry and environmental groups. The preamble to the study describes it as "...a scientific state-of-understanding report of the fundamental basis and efficacy of the EPA's winter oxygenated gasoline program."[5]

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3 Minnesota Pollution Control Agency, Minnesota Air: Air Quality and Emission Trends 1974-1994, Draft Report September 23, 1996.

4 National Research Council, *Toxicological and Performance Aspects of Oxygenated Motor Vehicle Fuels*, (Washington, D. C.: National Academy Press, 1996.)

5 National Research Council, 152.

While the interagency report was intended to include a full risk assessment and cost-benefit analysis of oxygenated gasoline use, the Interagency Steering Committee guiding the research concluded that such an analysis was not possible in all areas because of research and data limitations. Where evidence was lacking, the report identified research that would allow a more thorough assessment of health and environmental effects. A draft of this report was issued for review in March 1996, but it has not yet been published except for its preamble and executive summary which appear in the National Research Council report.[6]

The National Research Council published a review of scientific studies of oxygenated fuel in 1996.

We have used the published summary of the original report and the National Research Council review to gain a sense of whether a national scientific consensus exists on the beneficial or harmful effects of oxygenated gasoline, specifically the effectiveness of oxygenated gasoline in reducing ambient carbon monoxide. The focus of the Interagency Report and the National Research Council review is on use of oxygenates in winter to reduce atmospheric carbon monoxide, not on summertime use of a lower level of oxygenates in reformulated gasoline which is required in ozone non-attainment areas. We will discuss summertime use of oxygenates later, since Minnesota has enacted a statewide year-round mandate for oxygenated gasoline, and there are different issues involved in warm-weather use of ethanol.

The draft Office of Science and Technology Policy report and the National Research Council both point to the reductions in ambient CO concentrations over 20 years and agree that vehicle emission controls have been a major factor in the reduction. Cars now carry one or two oxygen sensors that measure the oxygen content of the exhaust and adjust the engine to achieve complete combustion of fuel. The National Research Council report notes the weaknesses of data on the amount of the reduction that can be attributed to oxygenated fuels. It points out that the predictive EPA ambient air quality model currently in use overestimates the oxygenated fuel effect on CO emission reductions by a factor of two and calls for further study.[7] Because of improved pollution control equipment on newer vehicles, the report concludes:

> "For current and future vehicles,...only small changes in CO and NOx (Nitrous Oxide) emissions can be expected when using oxygenated fuels."[8]

Further, the report says:

> "...the federal (Interagency) report should better characterize the uncertainty about the extent to which oxygenated fuels have contributed to this reduction. The com-

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6 The National Research Council was organized by the National Academy of Sciences in 1916, and has become the principal operating agency of the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The National Academy of Sciences is a private, non-profit research organization, chartered by congress in 1863 with a mandate to advise the federal government on scientific and technical matters. While the NRC is not infallible, its committees are composed of leading experts and its reports are considered quite authoritative. It is often called on to review evidence in situations where conflicting research results are introduced into the policy debate.

7 National Research Council, 4.

8 National Research Council, 31.

> mittee believes that it has not been established that oxygenated fuels have been a major factor in this reduction. "[9]

Thus, while wintertime use of oxygenated fuels enables Minnesota to meet technical air quality standards, there is a surprising amount of uncertainty about the efficacy of oxygenated gasoline for reducing ambient CO levels.

The National Research Council found a lack of scientific evidence on the oxygenated fuel program's effectiveness.

The uncertainty over the efficacy of oxygenated gasoline goes beyond its effectiveness relative to other abatement strategies, it concerns the limitations of laboratory and on-road tests of vehicles and fleets for predicting real-world changes in tailpipe emissions. The CO data in the interagency report were largely collected using the Federal Test Procedure that specifies an ambient temperature of 75 degrees Fahrenheit. Until 1994, EPA test procedures collected CO emissions data only at 75 degrees, even though the federal CO oxygenated fuels program involves wintertime regulations and requires wintertime use of oxygenated gasoline. The interagency report reviewed some research data taken at 35 degrees and 50 degrees, but high emitting vehicles were not included in these tests, and high emitting vehicles are largely responsible for the atmospheric CO problem. The 1990 Clean Air Act called for model year 1994 and later vehicles to be tested at 20 degrees as well as 75 degrees. CO emissions data are lacking for temperatures less than 20 degrees for both dynamometer and on-road tests.

The National Research Council study says that the effect of oxygenated gasoline is different at temperatures below 20 degrees, and even points to some evidence of *increased* CO emissions with oxygenated fuels at these temperatures.[10] But the main point of the National Research Council's review of the evidence in both dynamometer studies, and on-road studies is the absence of reliable studies at a range of temperatures, using suitable experimental controls.[11]

Tests of oxygentated fuel at wintertime temperatures are lacking, even though the federal program is a wintertime requirement.

The National Research Council is extremely critical of the fact that a wintertime program does not involve tests at a greater range of winter temperatures. The limitations of the EPA test requirements are hard to understand given that CO emissions vary greatly with temperature, and are a problem mainly at low temperatures. The EPA and some defenders of the EPA test procedure point out that many of the CO non-attainment areas are in places with fairly warm winter temperatures.[12] It goes without saying that winter temperature tests are especially important to understand the effect of oxygenated gasoline in Minnesota and other northern states. The EPA staff we talked to acknowledged the lack of winter temperature tests and pointed out the difficulty of standardizing test procedures at a wider range of temperatures. They did not have an effective rebuttal of the NRC

9 National Research Council, 49.

10 National Research Council, 35.

11 National Research Council, 37.

12 A letter to the Chair of the NRC Committee from University of California-Berkeley Professors Robert Harley, Civil and Environmental Engineering, and Robert Sawyer, Mechanical Engineering, is quoted in the August 16, 1996 *Ethanol Report* as defending 75 degree tests because "...nearly half of the non-attainment areas are in milder-winter locations where temperatures much below freezing are irrelevant."

criticism, however, and indicated that they would probably sponsor additional tests.

SUMMERTIME USE OF OXYGENATED FUEL

Ethanol increases the volatility of the fuel with which it is mixed. Evaporation causes harmful compounds in gasoline to be released into the atmosphere.

Minnesota will require oxygenated gasoline statewide starting in October 1997. There is a question in the scientific literature over the environmental benefits of summertime use of ethanol.[13] This question is of more than academic interest in Minnesota because of the requirement to use oxygenated gasoline year round. For this reason, we inquired about the summertime effects of ethanol use, and found:

- **The Minnesota Pollution Control Agency does not advocate summertime use of ethanol in order to reduce carbon monoxide. A study commissioned by PCA to address the question of whether summertime use of ethanol is harmful concludes that ethanol use is neither harmful nor beneficial.**

Gasoline is naturally more volatile during warm weather and, on top of this, gasoline mixed with ethanol is more volatile than straight gasoline. Evaporation causes harmful volatile organic compounds (VOCs) contained in gasoline to be released into the atmosphere. These VOCs along with oxides of nitrogen and carbon monoxide cause atmospheric ozone levels to increase.

Many parts of the country are designated as ozone non-attainment areas and are required to use "reformulated" gasoline in warm-weather months. The Twin Cities has an ozone problem, but not one that brings it to formal non-attainment status.[14] Even in areas where reformulated gasoline is not required, gasoline is required to have lower volatility in the summer than in the winter in order to work properly. Lower volatility is not the only specification that reformulated gasoline must meet, but it is responsible for most of its ability to reduce VOC emissions. About 13 percentage points of the 15 percent VOC reduction that reformulated gasoline is required to achieve come from lower volatility.

The use of ethanol in gasoline was the subject of controversial decisions by Congress and the EPA in the early 1990s. The 1990 Clean Air Act provided a one pound per square inch waiver, as measured by the Reid Vapor Pressure scale, for gasoline mixed with 10 percent ethanol. Ethanol would have been excluded from summertime use without the waiver for reasons presented above. MTBE, the other oxygenate in common use nationally, does not increase the volatility of gasoline and could have been used in the absence of the waiver. The waiver for ethanol was vigorously opposed by oil industry representatives, environmental groups, and some state government officials who wanted to enforce stricter state volatility standards, but a compromise was reached that permits ethanol's use.

13 Ethanol is the only oxygenate used in Minnesota according to Department of Public Service Division of Weights and Measures.

14 The Twin Cities ozone level would be in violation of existing California standards.

The Minnesota Pollution Control Agency (PCA) continues to advocate wintertime use of oxygenated gasoline, but says it has never advocated year-round use. Year-round use is, however, included in the contingency plan submitted to the EPA by Minnesota. (EPA requires state agencies to indicate additional steps they will take if atmospheric monitoring shows CO violations.) PCA says year-round use was included in the contingency plan only because Minnesota was already doing it

A study of summertime use of ethanol found it to be neither beneficial nor harmful.

In response to concerns about summertime use, PCA sponsored a study of the impact of year-round oxygenated fuel use in Minnesota.[15] Because Minnesota's levels are fairly close to applicable federal standards, Minnesota presumably cannot afford to increase the emission of organic compounds that produce ozone. Motor vehicles release fuel vapors from leaks and from venting of the fuel system. As noted, ethanol causes the fuel with which it is mixed to become more volatile and release volatile organic compounds which cause ozone readings to increase. Ethanol itself is not a problem; it is its effect on the volatility of gasoline which causes an increase in evaporative emissions.

The study found that a 10 percent ethanol mixture tends to increase evaporative VOC emissions while lowering exhaust emissions. The amounts of exhaust and evaporative emissions per mile vary according to driving speeds. The report estimates that the use of ethanol blends reduces summer ozone from zero to 3 percent, depending on the speed of the vehicle. The most favorable ratio is obtained at low or high speeds tested (20 MPH and 60 MPH) and the "worst case" measurements were at 30-50 MPH.

PCA does not argue that oxygenated fuel is needed to reduce CO levels outside the October through January period, but concludes from the Whitten study that ethanol does not cause additional pollution. PCA does not offer the study as definitive, however, and points out that reasonable scientists disagree about the effects of summertime ethanol use and ozone formation. The issue was supposed to be the focus of a National Academy of Sciences study this year, but this study has not been carried out. Further research sponsored by authoritative national scientific bodies that will illuminate or settle the issue is needed.

As matters stand, gasoline wholesalers and retailers sell gasoline with more ethanol in the warm weather months (between May 1 and September 15) than in the winter because federal regulations permit a one pound per square inch waiver from vapor pressure standards between May and mid-September. The waiver is not triggered, however, unless fuel mixtures contain 9 to 10 percent ethanol rather than lesser amounts that still would be sufficient to meet the 2.7 percent oxygenate requirement.[16] According to our calculations of data from the Minnesota Department of Public Service Weights and Measures Division, ethanol concentration was higher in the Twin Cities in the June 1 to August 8, 1996 period than the period February 1, 1996 to May 31, 1996. Ethanol was mixed at an average of 3.07 percent oxygen from January through May, and 3.36 percent oxygen from June to early August. We do not have data past August 8, 1996. (1996 was the first sum-

15 Whitten, Gary Z., Barbara S Austin, and Karina O'Connor, *Ozone Impact of Year-Round Oxy-Fuel Program In Minnesota*, Systems Applications International, June 30, 1994.

16 About 7.7 percent ethanol achieves the required 2.7 percent oxygen level.

mer period in which oxygenated fuel use was mandated. The warm weather months are the season when volatility is of greatest concern and ozone levels are highest.)

Summertime use of ethanol was made possible by a federal waiver of Clean Air Act requirements.

This waiver is a perverse response to complex environmental regulations at the state and federal levels and makes little sense in relation to either carbon monoxide or ozone abatement objectives. State law requires year-round use of oxygenated gasoline in the Twin Cities starting in 1996 and statewide starting October 1997. But the state requirements co-exist with a federal requirement to achieve a lower volatility of gasoline between May and September 15. Adding just 3 or 4 percent ethanol raises volatility enough to exceed the federal volatility standard of 9 pounds per square inch (on the Reid Vapor Pressure scale), but adding 9 to 10 percent ethanol qualifies the mixture for a one pound per square inch waiver of the federal requirement, so that the fuel can meet the vapor pressure standard at 10 pounds per square inch.

OTHER EFFECTS

Mandated use of oxygenated gasoline has engendered controversy around the country. There have been numerous complaints of adverse health effects, and adverse effects on fuel economy and mechanical operation. In this section we briefly examine the evidence on toxic effects of oxygenates on human health, and the effects of oxygenates on engine performance.

HEALTH EFFECTS

In recent years, many articles have been published on the health and performance effects of oxygenated gasoline in refereed scientific journals. In part these have been prompted by complaints of health effects by users of oxygenated gasoline, most of which is mixed with MTBE, not ethanol. Since the major reason for adding oxygenates to gasoline is concern about adverse health effects of CO and ozone levels in the atmosphere, the oxygenated gasoline needs to be as safe as non-oxygenated gasoline if the program is to be judged beneficial in terms of the purpose it was designed to serve. Agencies of the federal government have recently been active in reviewing the scientific evidence on the health effects of oxygenated gasoline.

The National Research Council reviewed a report by the Health Effects Institute (HEI) on the health effects of oxygenated fuels that was part of the Interagency report on oxygenated fuels discussed above. The HEI report says:

> "The potential health effects from exposure to gasoline containing MTBE include headaches, nausea, and sensory irritation in some, possibly sensitive, individuals based on reports after exposure to oxygenates... "[17]

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17 National Research Council, 126.

However the same report goes on to say:

There are no adverse health effects associated with the use of ethanol in gasoline.

> "Adding oxygenates is unlikely to substantially increase the health risks associated with fuel used in motor vehicles; hence, the potential health risks of oxygenates are not sufficient to warrant an immediate reduction in oxygenate use at this time. However, a number of important questions need to be answered if these substances are to continue in widespread use over the long term."[18]

Ethanol, of course, is widely ingested in alcoholic beverages, and there are adverse health effects noted in the literature, but none that are associated with the low levels of ethanol exposure that occurs as a consequence of its use as an automotive fuel.

Our conclusions as a result of a brief review of the human health issue are:

- **Low level exposure to ethanol is not associated with the same effects linked to MTBE, including nausea, headaches, and disorientation. The complaints of users of oxygenated fuel in states where MTBE is used have some scientific support.**

- **The national scientific bodies that have conducted major reviews of the evidence conclude that MTBE-containing fuels do not pose permanent health risks substantially different from those associated with nonoxygenated fuels.**

Concern about adverse health effects could conceivably undermine support for the use of oxygenated fuel, including ethanol, in the future even though the adverse health effects are associated with MTBE, not ethanol. Advocates of ethanol point out its advantages in this regard along with the fact that MTBE has an unpleasant odor while ethanol is essentially odorless.

CARBON DIOXIDE

Ethanol is a renewable fuel, and unlike fossil fuels, ethanol use does not add carbon dioxide (CO2) to the atmosphere. Ethanol produces CO2 when it burns but the corn or other raw material used to produce the ethanol had recently removed this CO2 from the atmosphere. Greenhouse gasses such as CO2 are associated with the threat of global warming. Ethanol is clean-burning compared to gasoline, and if pure ethanol were used as fuel it would not cause a variety of pollution problems caused by burning fossil fuels.

Ethanol would hold promise of significant environmental benefits if it could be used in substitution for a significant amount of gasoline, especially if it could be manufactured without using fossil fuel or other polluting processes. Currently, 95 percent of ethanol is produced from corn. Some environmental groups such as the Sierra Club and the Environmental Defense Fund are opposed to ethanol production from corn because of concern about adverse environmental effects. The Envi-

18 National Research Council, 127.

ronmental Defense Fund says that ethanol produced from corn increases greenhouse gas emissions 25 percent above gasoline because fossil fuels and nitrogen fertilizers are required to grow the corn.[19] The Sierra Club recommends that "...federal and state subsidies for gasohol from grains should be replaced by an energy conservation program of comparable magnitude."[20] In any case, a substantial amount of energy is used in ethanol production, and this is mostly fossil fuel used in growing corn, producing fertilizer, and distilling alcohol.

Ethanol accounts for one-tenth of one percent of U.S. energy consumption.

Still, assuming that ethanol use has a positive environmental benefit, it needs to be kept in mind that under any realistic scenario, ethanol will supply an extremely small fraction of U. S. annual energy consumption. In looking at the data, we found:

- **Ethanol's potential to contribute to the problem of atmospheric CO2 is extremely limited.**

Ethanol is quite a small fraction even of renewable energy. Ethanol accounts for 2 to 3 percent of total biomass energy consumed in the U. S. annually between 1990 and 1994. By far the largest biomass source is wood, which has supplied around 79 to 82 percent of biomass energy in recent years. However, as Table 3.1 shows, all biomass sources including ethanol, wood and waste supplied only a little over 3 percent of U. S. energy in the period 1990 to 1994. Ethanol itself supplied about one-tenth of 1 percent of U. S. energy compared to fossil fuels which supplied around 85 percent. In order to contribute meaningfully to a solution of the problem of CO2 accumulation in the atmosphere, ethanol has to substitute for fossil fuel. Not only does ethanol contribute very little to U. S. energy needs, it takes nearly three quarters of the energy contained in a gallon of ethanol to manufacture that amount.

Ethanol production at 1995 levels consumes close to 7 percent of the U. S. average corn crop in recent years. If national ethanol production were increased tenfold, ethanol would supply about 1 percent of U. S. energy needs, but take 70 percent of the U. S. corn crop. Long before this happened, food prices would have increased unacceptably, so in the absence of new production technology, this level of ethanol production is unlikely using corn or other high-value agricultural commodities. On the basis of this reasoning, we conclude that ethanol production from corn can have, at best, a very small effect on atmospheric accumulation of CO2.

FUEL ECONOMY AND PERFORMANCE EFFECTS

Ethanol has been widely used for more than a decade, and engines manufactured since the early 1980s are designed to use up to a 10 percent ethanol mix. Very few

19 Environmental Defense Fund Letter Vol. XXIII, No. 3 June 1991.

20 Sierra Club Policy Code 3.2.3, Adopted January 30-31, 1982.

Table 3.1: United States Energy Consumption by Energy Source, 1990-94

	Quadrillion BTUs					Percentage Distribution				
	1990	1991	1992	1993	1994	1990	1991	1992	1993	1994
RENEWABLE										
Biomass										
Wood	2.155	2.151	2.249	2.228	2.266	2.558%	2.560%	2.639%	2.561%	2.560%
Waste	0.395	0.426	0.460	0.468	0.488	0.469	0.507	0.540	0.538	0.551
Ethanol	0.082	0.065	0.079	0.088	0.098	0.097	0.077	0.093	0.101	0.111
Total Biomass	2.632	2.642	2.788	2.784	2.852	3.124	3.144	3.271	3.200	3.222
Solar Energy	0.067	0.068	0.068	0.069	0.069	0.080	0.081	0.080	0.079	0.078
Conventional Hydro	3.113	3.196	2.871	3.156	3.037	3.695	3.804	3.369	3.627	3.431
Geothermal	0.327	0.331	0.349	0.362	0.357	0.388	0.394	0.410	0.416	0.403
Wind Energy	0.024	0.027	0.030	0.031	0.036	0.028	0.032	0.035	0.036	0.041
Total Renewable	6.163	6.264	6.106	6.403	6.350	7.316%	7.455%	7.165%	7.359%	7.174%
FOSSIL FUELS										
Coal	19.101	18.770	18.868	19.430	19.541	22.674%	22.338%	22.140%	22.331%	22.076%
Coking Coal	0.005	0.009	0.027	0.017	0.024	0.006	0.011	0.032	0.020	0.027
Natural Gas	19.296	19.606	20.131	20.841	21.156	22.905	23.333	23.622	23.952	23.900
Petroleum	33.553	32.845	33.527	33.841	34.653	39.829	39.089	39.340	38.893	39.148
Total Fossil Fuels	71.955	71.231	72.553	74.129	75.373	85.414%	84.772%	85.133%	85.196%	85.150%
Nuclear Electric	6.161	6.579	6.607	6.519	6.830	7.313%	7.830%	7.753%	7.492%	7.716%
Hydroelectric Pumped	-0.036	-0.047	-0.043	-0.041	-0.035	-0.043	-0.056	-0.050	-0.047	-0.040
TOTAL ENERGY CONSUMPTION	84.243	84.027	85.223	87.010	88.518	100.000%	100.000%	100.000%	100.000%	100.000%

Source: United States Department of Energy, *Renewable Energy Annual, 1995*, Table 1.

manufacturers continue to complain about adverse effects of 10 percent blends in recently manufactured equipment. There are, of course, many complaints about mandatory use of ethanol and the limited availability of gasoline that does not contain ethanol.

Ethanol contains 33 percent less energy per gallon than gasoline; use of ethanol results in lower gas mileage.

Fuel Economy

Ethanol contains about 33 percent less energy per gallon than gasoline; therefore, the use of ethanol results in fewer miles per gallon. When ethanol is mixed at up to 10 percent, the effect is small enough that it is unlikely that individual consumers can detect a difference between gasohol and conventional gasoline, but the effect is big enough to be significant on a statewide basis.

At a theoretical level, miles per gallon is directly related to the energy content of fuel as measured in Btus.[21] The National Research Council concludes after reviewing 13 research studies: "There is agreement based on data from a wide variety of sources that if a given level of an oxygenate reduces the energy content per gallon of a formulated gasoline by 1.6 percent, for example, the expected reduction in fuel economy is also 1.6 percent."[22] We reviewed studies that cited a range of values for the energy content of conventional gasoline and ethanol. Table

21 One Btu (British Thermal Unit) is the amount of heat energy required to raise one pound of water one degree Fahrenheit.

22 National Research Council, 47.

3.2 also shows this information and also the energy content of oxygenated fuels made by blending gasoline with ethanol at specified rates. These calculations show a 2.3 to 3.5 percent decrease in the energy content of oxygenated fuels compared with conventional gasoline, depending on the blend. On the basis of these data, we expect:

- **There will be a 2.3 to 3.5 percent drop in fuel economy when motor vehicles are run on gasoline blended with ethanol.**

Table 3.2: Energy Content of Gasoline, Ethanol, and Ethanol Blends

	DAI, Inc.	GAO	USDA-ERS
Btu Content of Ethanol[1]	76,100	76,100	83,961
Btu Content of Gasoline	108,500-117,000[2]	114,000	1252,073
Energy Reduction with 7.7% Blend	2.3%-2.7%[2]	2.6%	2.53%
Energy Reduction with 10% Blend	3.0%-3.5%[2]	3.3%	3.29%

Source: Downstream Alternatives, Inc., *Changes in Gasoline III,* 1996 Update; U.S. General Accounting Office, 1996; U.S. Department of Agriculture.

[1]British Thermal Unit is a standard unit for measuring the quantity of heat energy equal to the quantity of heat required to raise the temperature of one pound of water by one degree Fahrenheit.

[2]Lower numbers refer to higher-volatility, wintertime gasoline blends.

Effects of this magnitude are difficult to detect in ordinary driving. A vehicle that gets 25 miles per gallon would be expected, (assuming a 3.5 percent reduction in fuel economy), to get over 24 miles per gallon on oxygenated fuel. Variations of this magnitude can easily be caused by normal, tank-to-tank changes in driving conditions, traffic patterns, or fill levels when refueling.

Different engines respond differently to oxygenated fuels. Older engines, especially those without fuel injection and/or computer controls commonly are tuned to run slightly rich, that is, with a higher-than-necessary fuel to air ratio.[23] These vehicles may benefit from the extra oxygen carried by oxygenated fuel, and the reduction in fuel efficiency may be lessened or even reversed by more efficient combustion for these vehicles. Modern engines with computer controls are able to adjust to differing operating conditions and therefore optimize performance. These engines tend to experience the largest reductions in fuel economy from use of oxygenated fuels.

Although individuals are not likely to notice reduced fuel economy, these effects are significant at the state or national level. Moreover, Minnesota has a vehicle fleet that is, on the whole, newer than the national average. Considering the state's annual gasoline consumption of roughly 2 billion gallons, even a 2.3 percent fuel economy reduction requires the use of 46 million additional gallons of fuel. This amount should be considered when the cost of ethanol to consumers or ethanol's contribution to energy security are considered.

23 This is because the loss in performance is much greater for running too lean than too rich, and changes in temperature and atmospheric pressure change the amount of oxygen the engine can take in.

Mechanical Performance

Much of the legislative debate in recent years has focused on the fuel requirements of small engines, watercraft, and antique automobiles. In addition, there are claims and counterclaims concerning ethanol's contribution to fuel system problems in modern automobiles. It is beyond the scope of this report to present detailed findings on each of the reported problems in each type of engine application, but we did review the arguments and available literature. We found:

- **There is no substantial evidence of mechanical problems in modern engines from use of 10 percent ethanol blends, although in some instances engines need minor modification.**

This is not to say that the types of problems mentioned have not existed or do not exist. They may, however, be attributable to other factors such as ethanol blends in excess of 10 percent, use of methanol or other alcohols (used in the early 1980s), engines manufactured before the early 1980s, or operator errors.

Few engine performance problems are caused by oxygenates in gasoline.

Historical problems attributed to ethanol fuels in general are poorly documented, and often do not consider other sources of performance problems. Some of these problems pertain to equipment manufactured before the early 1980s, before the introduction of alcohol-resistant elastomers and plastic parts. Once such machines have been upgraded, problems relating to materials compatibility do not persist. Current research reviewed by the White House Office of Science and Technology Policy (OSTP) concluded, and the National Research Council concurred, that except for possible drivability problems due to enleanment, performance problems due solely to the presence of oxygenates in gasoline are not expected.

Enleanment is a potential problem only for certain types of engines. A few snowmobile manufacturers and makers of marine and recreational equipment recommend relatively minor modifications of carburetted engines to offset the enleanment effects of oxygenated gasoline. Overblending oxygenates in gasoline can add to this enleanment effect. Fixing the problem requires installing a shim kit and rejetting the carburetor and is estimated to cost about $100. Minnesota has over 254,000 registered snowmobiles, but most of these machines will not need modification.

SUMMARY

The Twin Cities area has not recorded any violations of national air quality standards since the wintertime use of oxygenated gasoline became mandatory. However, most of the reduction in ambient carbon monoxide levels is due to improved vehicle emissions equipment. State law will require year-round use of oxygenated gasoline starting in October 1997, however, state and federal pollution control officials do not argue that there are environmental benefits for summertime use of gasohol in Minnesota.

There are no adverse health effects associated with ethanol use as a fuel additive, although there are some concerns about another oxygenate, MTBE, but these are hard to distinguish from the effects of straight gasoline which also causes some health problems. Ethanol blends cause minor engine performance problems in some marine and recreational equipment with carburetted engines. From the perspective of statewide costs, the most significant factor is the reduction in fuel economy of 2.3 to 3.5 percent due to the lower energy content of ethanol compared to gasoline.

Risks Facing Minnesota's Ethanol Industry

CHAPTER 4

We saw in Chapter 2 that there are significant economic benefits to a profitable ethanol industry, both to the communities in which the plants are located and the state as a whole. But, there are a number of risks facing the ethanol industry in the future:

- **The possibility that ethanol plants will not be able to make money at prevailing prices for corn and ethanol.**
- **The possibility that Minnesota plants will lose out in competition with larger, more efficient producers.**
- **The possibility that the federal government will withdraw all or much of its current 54 cent per gallon tax credit for ethanol, or its requirement that oxygenated gasoline be used in certain areas.**
- **The possibility that new technologies of ethanol production will become commercially viable and compete with corn-based production.**

On the other hand, there are some future scenarios that would tend to sustain the ethanol industry. If the price of oil goes up, ethanol will become a more competitive energy source.[1] If the national market for ethanol expands for any reason, Minnesota's producers will tend to prosper. We are unable to foresee the future, but each of these possibilities is worth thinking about given the size of Minnesota's public and private investment in ethanol.

PROFITABILITY

The most fundamental question faced by any business is its future profitability at prevailing prices for its products and the costs of raw materials. The profitability of the ethanol industry also hinges on the future of state and federal subsidies to

1 The annual world oil price projections by the Energy Information Agency (EIA) of The United States Department of Energy (DOE) made in 1996, project a price of $23.70 per barrel in 2010 (in 1994 dollars) and $25.43 in 2015. Other projected prices quoted in this source are lower ranging from $16.02 to $22.11 for 2010. United States Department of Energy, Energy Information Administration, *Annual Energy Outlook* 1996, 53 and 244. This compares to the 1995 composite (average domestic and imported) price to refiners of $15.59 per barrel in 1994 and $17.23 in 1995. U. S. DOE, EIA, *Petroleum Marketing Annual* 1995, 2.

ethanol production. This section looks at price and policy risks that could jeopardize the plants. Our analysis in this section pertains to ethanol production in dry mills, since all but one of Minnesota's plants are dry mills, and since we obtained good information on production costs from Minnesota's dry mills. In a later section of this chapter we discuss the issue of competition from wet mills.

We collected production cost data from the major operating ethanol plants in Minnesota. We obtained data on construction, operating costs, and financial performance where available. We also reviewed the data in the literature, although only the most current references are comparable to the type of dry mills represented in Minnesota. These sources allowed us to construct an accurate picture of the economic fundamentals of ethanol production in a dry mill. In this section, we first describe production costs, then use historical price data to examine economic performance of the plants under conditions that prevailed in recent years. Following this analysis, we look at profitability under the assumption that long term average prices will prevail in the future.

Economic Fundamentals of Ethanol Production

We examined production costs of Minnesota's dry mills.

This section describes a representative dry milling plant of 10-15 million gallon capacity. Revenue and production cost data for a typical mill are summarized in Table 4.1. Ethanol plant revenues come from sales of ethanol and distiller's dried grains with solubles (DDGS), as well as the state producer payment.[2] The cost data used (except for corn) are averages representing Minnesota's major dry mills.[3] The plants use similar processes and all face this same basic cost pattern.

As shown in Table 4.1, variable inputs (except for corn) cost an average of $0.37 per gallon. Fixed costs average $0.29 per gallon. The price of corn is the biggest factor determining the cost of ethanol, generally representing between one-half and two-thirds of total costs. The cost of corn per gallon of ethanol can be calculated by dividing the market price of corn by 2.6, the average number of gallons of ethanol that are produced from a bushel of corn in the dry mill process. For example, if corn costs $3 per bushel, then the cost per gallon is about $3 divided by 2.6 or $1.15 per gallon of ethanol. Corn prices have varied widely in recent years. The per-gallon cost of corn ranged from about 73 cents in November 1994 to $1.79 in July 1996.

The eight year (1988-1995) average prices for corn and ethanol were $2.30 and $1.27, respectively. As shown in the last line of Table 4.1, at these prices, the net profit per gallon is $0.35. This corresponds to a return of about $0.91 per bushel of corn processed. Thus:

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2 Producers may receive the 20 cent per gallon payments up to a limit of $3 million per year, corresponding to 15 million gallons of ethanol produced. There are no dry mills in Minnesota with more than 15 million gallons capacity, although one has produced slightly over 15 million gallons over the period of a fiscal year.

3 One dry mill also collects carbon dioxide for resale to the soft drink industry. Because only one plant sells CO2 and revenue from this source is minimal, we exclude it from this analysis.

Table 4.1: Economic Fundamentals of Dry Milling

	Dollars Per Gallon of Ethanol
COSTS	
Corn (1988-95 average)	$0.88
Variable costs (natural gas, electricity, water and sewer, miscellaneous supplies, employee payrolls), except for corn	0.37
Fixed costs (management payrolls, insurance, depreciation, general expenses)	0.29
Total	$1.54
REVENUES	
Ethanol (1988-95 average price)	$1.27
Average DDGS revenue	0.42
Minnesota producer payment	0.20
Total	$1.89
PROFIT MARGIN	$0.35

Source: Program Evaluation Division.

- **Minnesota's ethanol plants are profitable at long term average prices for corn and ethanol, assuming continued federal subsidies.**

At average price levels, Minnesota's dry mills can produce ethanol at a profit, assuming state and federal subsidies are continued.

At the long-term average price for ethanol of $1.27 per gallon, the plants break even at a corn price of $3.20 per bushel. At the long term average corn price of $2.30, the plants can break even with ethanol prices as low as $0.99 per gallon, assuming the continuation of state and federal subsidies.

State producer payments are scheduled to expire after ten years. Without the subsidy, revenues and profits per gallon would be 20 cents lower than shown in Table 4.1. Without the producer payment, the profit margin at average prices would be 15 cents per gallon of ethanol instead of 35 cents per gallon or about 39 cents per bushel of corn.

Historical Price Data

Average monthly corn prices are shown in Table 4.2, together with ethanol prices and the price of DDGS for the period January 1994 to October 1996. In addition, the last two columns of Table 4.2 show the resulting per gallon profit margins with and without the 20 cent producer payment.[4] The per gallon margins in Table 4.2 track a typical plant's economic performance over conditions experienced in the last three years. This period includes extremes of both low and high prices. Ethanol has ranged in price from $1.09 (June, 1995) to $1.81 per gallon (September 1996), and DDGS prices have varied from $93 (May, 1995) to $184 per ton (May,

4 The cooperative organization structure used by many of Minnesota's dry mills permits plants to pay members less than the market price of corn. Buying corn at a discount initially can increase profit margins over a short period.

Table 4.2: Ethanol Profits at Recent Prices

		Ethanol Price Per Gallon	DDGS Price Per Ton	Corn Price Per Bushel	Profit Per Gallon With 20 Cent Producer Payment	Profit Per Gallon Without Producer Payment
1994	January	$1.21	$126.60	$2.85	$0.06	$-0.14
	February	1.19	129.75	2.78	0.09	-0.11
	March	1.19	123.80	2.73	0.09	-0.11
	April	1.19	125.00	2.61	0.13	-0.07
	May	1.18	119.70	2.57	0.12	-0.08
	June	1.17	120.38	2.58	0.12	-0.08
	July	1.22	120.75	2.17	0.32	0.12
	August	1.36	118.70	2.15	0.47	0.27
	September	1.39	119.50	2.06	0.53	0.33
	October	1.36	120.50	1.96	0.54	0.34
	November	1.36	117.20	1.96	0.53	0.33
	December	1.36	110.50	2.04	0.48	0.28
1995	January	1.36	106.50	2.08	0.45	0.25
	February	1.29	96.90	2.00	0.38	0.18
	March	1.24	93.60	2.28	0.21	0.01
	April	1.19	93.10	2.40	0.11	-0.09
	May	1.13	93.10	2.47	0.03	-0.17
	June	1.09	96.90	2.61	-0.05	-0.25
	July	1.10	98.10	2.54	-0.02	-0.22
	August	1.09	101.50	2.51	0.00	-0.20
	September	1.11	114.75	2.70	-0.01	-0.21
	October	1.14	131.20	2.95	-0.02	-0.22
	November	1.20	140.10	2.98	0.06	-0.14
	December	1.26	138.60	3.06	0.08	-0.12
1996	January	1.34	141.50	3.14	0.14	-0.06
	February	1.34	143.50	3.40	0.05	-0.15
	March	1.34	147.90	3.73	-0.07	-0.27
	April	1.38	161.90	4.43	-0.25	-0.45
	May	1.50	184.38	4.85	-0.22	-0.42
	June	1.51	172.88	4.63	-0.16	-0.36
	July	1.57	159.50	4.65	-0.16	-0.36
	August	1.75	151.00	4.39	0.10	-0.10
	September	1.81	151.43	3.38	0.55	0.35
	October	1.60	140.75	2.75	0.55	0.35
Average 1989-96		$1.30	$128.20	$2.55	$0.28	$0.08

Source: Minnesota Department of Agriculture; Program Evaluation Division calculations .

1996). Long term average prices encompassing the period 1989 to 1996 are $1.30 per gallon for ethanol and $128 per ton for DDGS. Corn costs also show great volatility, ranging from $1.96 per bushel in November 1994 to $4.85 per bushel in May 1996, with an average price over this period of $2.55 per bushel.

Using our cost and revenue data, the average per-gallon profit margin over this period is 28.5 cents per gallon, including the 20 cent producer payment. Without this subsidy, margins would average 8.5 cents. Note also that there are periods of as long as 17 months in which the estimated profit margins are negative without the producer payment.

Table 4.3 shows estimates of the per-gallon profits of ethanol production at varying prices for corn and ethanol, holding the price of DDGS fixed at its long term average of $128 per ton. A range of corn prices is shown in the first column of Table 4.3, and a range of prices for ethanol is shown in the first row. The cell corresponding to each column and row shows the per-gallon profit from ethanol production. As noted earlier, the eight year (1988-95) average prices for corn and ethanol were $2.30 and $1.27, respectively. Rounding slightly, Table 4.3 shows a profit estimate of 40 cents per gallon. These estimates do not incorporate the effects of changes in the price of DDGS that might follow a change in corn prices. Thus, the per-gallon profit estimates are not projections, but rather illustrations of the relationship between the two largest factors affecting ethanol profits, corn prices and ethanol prices. This table can be used to examine several scenarios that illustrate the risks faced by Minnesota's dry milling industry.

Expiration of the Federal Gasoline Tax Credit

Later in this chapter we discuss the critical importance of the 54 cent federal gas tax credit to the ethanol industry. Since this subsidy is not paid directly to the plants, it does not show up in our analysis in the same fashion as the Minnesota producer payment. The effect of the federal credit is to increase the market price of ethanol. If the tax credit were reduced, the price of ethanol would have to fall

Table 4.3: Profit per Gallon of Ethanol Production

Corn	Ethanol Price											
Price	$0.70	$0.80	$0.90	$1.00	$1.10	$1.20	$1.30	$1.40	$1.50	$1.60	$1.70	$1.80
$5.00	-1.26	-1.16	-1.06	-0.96	-0.86	-0.76	-0.66	-0.56	-0.46	-0.36	-0.26	-0.16
$4.75	-1.17	-1.07	-0.97	-0.87	-0.77	-0.67	-0.57	-0.47	-0.37	-0.27	-0.17	-0.07
$4.50	-1.07	-0.97	-0.87	-0.77	-0.67	-0.57	-0.47	-0.37	-0.27	-0.17	-0.07	0.03
$4.25	-0.97	-0.87	-0.77	-0.67	-0.57	-0.47	-0.37	-0.27	-0.17	-0.07	0.03	0.13
$4.00	-0.88	-0.78	-0.68	-0.58	-0.48	-0.38	-0.28	-0.18	-0.08	0.02	0.12	0.22
$3.75	-0.78	-0.68	-0.58	-0.48	-0.38	-0.28	-0.18	-0.08	0.02	0.12	0.22	0.32
$3.50	-0.69	-0.59	-0.49	-0.39	-0.29	-0.19	-0.09	0.01	0.11	0.21	0.31	0.41
$3.25	-0.59	-0.49	-0.39	-0.29	-0.19	-0.09	0.01	0.11	0.21	0.31	0.41	0.51
$3.00	-0.49	-0.39	-0.29	-0.19	-0.09	0.01	0.11	0.21	0.31	0.41	0.51	0.61
$2.75	-0.40	-0.30	-0.20	-0.10	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70
$2.50	-0.30	-0.20	-0.10	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80
$2.25	-0.20	-0.10	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
$2.00	-0.11	-0.01	0.09	0.19	0.29	0.39	0.49	0.59	0.69	0.79	0.89	0.99

Note: Assumes DDGS price of $128 per ton, and 17 lbs. DDGS per bushel of corn; variable costs of 37 cents per gallon; fixed costs of 29 cents per gallon; 2.6 gallons of ethanol per bushel of corn; and a 20 cent per gallon subsidy.

Source: Program Evaluation Division calculations.

by an equivalent amount to maintain ethanol's competitiveness relative to MTBE and gasoline.

For example, a 20 percent cut in the 54 cent federal gasoline tax credit would reduce the price of ethanol by about 11 cents per gallon, or in Table 4.3, to approximately the previous column. Beginning from the corn price of $2.25 and an ethanol of, $1.30, (approximate 1989-95 average prices), this reduces per-gallon margins from 40 to 30 cents per gallon. Elimination of the credit would eliminate the possibility of profitable operation. [5]

Risk of High Corn Prices

The summer of 1996 saw very high corn prices relative to long term average values. For a time this summer, prices were over $5.00 per bushel, more than twice the 1988-95 average price of $2.30 per bushel. The price of corn at the Chicago Board of Trade peaked at $5.55 on July 12, 1996. While Minnesota plants cannot operate profitably at these prices,

- **At prices such as those of the summer of 1996, most plants were losing money even with the producer payment.**

- **The risk of high corn prices is somewhat reduced by the cooperative ownership structure. Minnesota's ethanol plants have found a "niche" which may result in better performance under high-price conditions of short duration.**

The cooperative ownership of Minnesota ethanol plants may reduce the risk of high corn prices.

To illustrate, we refer to Table 4.3. The average corn price for the month of July was $4.65, and ethanol averaged $1.57 per gallon. The cooperatives were able to use the clause in their delivery agreements and pay the members only 80 percent of the market price for corn, or $3.72. Table 4.3 shows that, at corn and ethanol prices of $3.75 and $1.60, respectively, the per-gallon profit is about 12 cents. Without the cooperative structure, and corn priced below the market, the mills would have experienced operating losses. At corn and ethanol prices of $4.75 and $1.60, respectively, the per gallon profit margin is a negative 26 cents per gallon.

Table 4.3 can also be used to evaluate the importance of the producer payment that pays 20 cents per gallon, up to $3 million total per plant, for a period of ten years. Without the subsidy, profits in Table 4.3 would be 20 cents lower in every cell. In the high price scenario just discussed, with corn at $3.75 per bushel and ethanol at $1.60 per gallon, margins would have been a negative 8 cents per gallon instead of 12 cents per gallon.

Risk of Low Ethanol Prices

Although ethanol prices reached record highs this summer and have remained at elevated levels, we only have to look back to 1995, a little over one year ago, to

5 The United States Department of Energy projects that ethanol production would decline to nearly zero without the 54 cent tax credit.

find a very different situation. In July of 1995, ethanol was priced at $1.09 per gallon, and corn cost $2.48 per bushel. Low ethanol prices present a risk for Minnesota's dry mills because they are relatively small, by industry standards, and unable to take advantage of economies of scale. Competitors in other states operate dry mills of 60 and 80 million gallons annual capacity and wet mills of up to 200 million gallons capacity. We discuss the risk of competition in the next section.

The case of low price ethanol can be examined using Table 4.3. Looking at the column corresponding to an ethanol price of $1.10 per gallon, we see that a typical plant requires continued subsidies or corn priced below long term average prices to remain a going concern. At corn prices approximating long-term averages, or $2.25 per bushel, the profit per gallon is 20 cents per gallon including the 20 cent per gallon Minnesota producer payment, or zero in absence of the producer payment. For these reasons, we conclude:

- **Minnesota's dry mills face a real risk from low ethanol prices, such as those of July 1995. Larger dry mills are more efficient and wet mills can manufacture a more diverse mix of products, making them more adaptive under a variety of circumstances.**

Competition from large national ethanol producers threaten small Minnesota plants.

COMPETITION

Ethanol production is concentrated in large plants owned by a few companies. Archer Daniels Midland (ADM) has the capacity to produce about 750 million gallons per year in four plants, which is about half of the nation's ethanol production capacity. The top five companies have about 74 percent of the nation's capacity. Most of the large plants are wet mills although ADM has one dry mill and New Energy Company of Indiana also operates a large dry mill. In contrast, Minnesota has one wet mill producing about 32 million gallons, six dry mills of between 8 and 15 million gallon capacity, and two small plants of about 1 million gallon capacity that do not use corn as a feedstock. All together, Minnesota's ethanol production capacity equals about half the capacity of one of ADM's four plants.

A key risk to Minnesota's ethanol industry is:

- **Smaller plants have higher average production costs than larger plants, and dry mills produce a narrower range of products and a less valuable mix of products than do wet mills. The size, and adaptability of large wet mills may enable them to be profitable under conditions where dry mills cannot survive. The highly concentrated ownership of ethanol production may also pose risks for Minnesota producers.**

An analysis prepared by the Minnesota Department of Agriculture (MDA) shows that dry mills can produce ethanol more efficiently than wet mills, in that their yields of ethanol per bushel of corn are as high or higher, but dry mills produce only ethanol and distiller's dried grains with solubles (DDGS), while wet mills can produce corn syrup, high fructose corn syrup (HFCS) corn starch, and corn oil as well as other products.[6] MDA's numbers shows that a wet mill can add much more value to a bushel of corn than a dry mill. Table 4.4 compares the value added to a bushel of corn by a wet mill and a dry mill at May 1995 and April 1996 prices.

At May 1995 prices, corn as a raw commodity sold for $2.52 while a dry mill produced ethanol worth $2.84 and DDGS worth $0.84 for a total of $3.68. A wet mill can separate corn oil from the corn kernel and take the starch content of corn and produce either ethanol, corn starch, HFCS, corn syrup, or some combination of these. Table 4.4 shows several alternative product mixes.[7] If the mill produced starch and the other products shown, it could produce products worth $5.17. If it produced high fructose corn syrup and other products, it could produce a mix of products worth $7.27. The second panel in Table 4.4 shows the same data at April 1996 prices. The dry mill produces products worth $5.12 from corn priced at $4.80. The wet mill can produce mixes of products with values ranging from $5.04 (if they maximize ethanol production) to $8.42 if they maximize HCFS production.

Wet mills produce a wide range of products and more stable returns.

Note that the wet mill does not produce more ethanol out of a bushel of corn than a dry mill; it actually produces a little less. But the co-products of a wet mill are worth much more than the co-products of a dry mill. This suggests that wet mills can be profitable under a wider range of market conditions than a dry mill. When ethanol prices are low, corn syrup prices could be high, for example. The advantage held by dry mills is that they are significantly cheaper to build, about $2 per million gallon capacity for a 10-15 million gallon per year factory. A wet mill costs several times this amount. As long as there is strong demand for ethanol, dry mills can stay in business because they can produce ethanol efficiently. However, under other conditions such as the high-price environment faced in the summer of 1996, plants lost money producing ethanol but could make money or minimize losses by producing other products. In the summer of 1996, wet mills could and did switch production away from ethanol.

Minnesota's dry mills have a capacity of less than 15 million gallons per year. According to our interviews with plant managers, this is not an efficiently-sized plant in terms of its staffing needs. A substantial increase in production would require little or no increase in employees. Indeed, several plants say they intend to expand in the future. We think Minnesota policy makers should consider whether it is better in the future if current plants expand, or whether ethanol production capacity should be added in additional small plants. The key issue is whether Minnesota producers can compete with larger dry mills and large wet mills in an environment where the large companies effectively set the price for ethanol and could underprice Minnesota producers if they needed or chose to do so. Thus it is

6 Minnesota Department of Agriculture, Market Development and Promotion Division, *Economic Impact of the Ethanol Industry in Minnesota: Present Situations and Future Opportunities*, May 1996, 26.

7 Table 4.4 provides a simplified view. There are various grades of corn sweeteners that can be produced from corn that are not shown and other high-value products such as lysine that major mills can produce. A given factory might not have all the refining capacity shown in Table 4.4 or it might have the ability to produce more or different products.

Table 4.4: Value of Corn, Raw Commodity and Value Added (Per Bushel of Corn)

		Value Added				
		Wet-Milling				Dry-Milling
				Sweeteners and Products		
Products	Corn Raw Commodity	Starch and Products	Ethanol and Products	Corn Syrup	HFCS	Ethanol and DDG
May 1995 Prices[1]						
Corn	$2.52					
Corn Oil		$0.41	$0.41	$0.41	$0.41	
Gluten Feed		0.43	0.43	0.43	0.43	
Gluten Meal		0.27	0.27	0.27	0.27	
Starch		4.06				
Ethanol			2.70			2.84
Corn Syrup				4.56		
HFCS					6.16	
DDG						0.84
Total Value	$2.52	$5.17	$3.81	$5.67	$7.27	$3.68
April 1996 Prices[2]						
Corn	$4.80					
Corn Oil		$0.43	$0.43	$0.43	$0.43	
Gluten Feed		0.69	0.69	0.69	0.69	
Gluten Meal		0.44	0.44	0.44	0.44	
Starch		4.73				
Ethanol			3.48			$3.66
Corn Syrup				5.26		
HFCS					6.86	
DDG						1.46
Total Value	$4.80	$6.29	$5.04	$6.82	$8.42	$5.12

Source: Minnesota Department of Agriculture.

[1]Computation based on the following:
Corn: $2.52/bushel cash price (Minneapolis Grain Exchange).
Corn oil: 1.6 lb./bushel, $0.26/lb. (Wall Street Journal).
Gluten feed: 10.9 lb./bushel, $78/ton, Illinois (USDA, Grain & Feed Market News).
Gluten meal: 2.6 lb./bushel, $210/ton, Illinois (USDA, Grain & Feed Market News).
Starch: 31.5 lb./bushel, $0.13/lb. (USDA, ERS).
Ethanol: 2.45 (wet-mill)/2.58 (dry-mill) gallons/bushel, $1.10/gallon (Minneapolis/St. Paul m arket, CPC).
Corn syrup: 40 lb./bushel, $0.11/lb. (Milling & Baking News).
HFCS: 33.3 lb./bushel 55% HFCS dry weight), $0.19/lb. (Milling & Baking News).
DDG: 18/lb./bushel, $93/ton (USDA, Grain & Feed Market News).

[2]Computation based on the following:
Corn: $4.80/bushel cash price (Minneapolis Grain Exchange).
Corn oil: 1.6 lb./bushel, $0.27/lb. (Wall Street Journal).
Gluten feed: 10.9 lb./bushel, $126/ton, Illinois (USDA, Grain & Feed Market News).
Gluten meal: 2.6 lb./bushel, $340/ton, Illinois (USDA, Grain & Feed Market News).
Starch: 31.5 lb./bushel, $0.15/lb. (USDA, ERS).
Ethanol: 2.45 (wet-mill)/2.58 (dry-mill) gallons/bushel, $1.42/gallon (Minneapolis/St. Paul m arket, CPC).
Corn syrup: 40 lb./bushel, $0.13/lb. (Milling & Baking News).
HFCS: 33.3 lb./bushel 55% HFCS dry weight), $0.21/lb. (Milling & Baking News).
DDG: 18/lb./bushel, $162/ton (USDA, Grain & Feed Market News).

the possibility of low ethanol prices that potentially holds the greatest danger for small, less versatile plants such as those that have recently been built in Minnesota.[8]

Minnesota's dry mill plants, together with the Minnesota Department of Agriculture, acknowledge these risk factors and have taken some steps toward addressing them. For example, many of the plants have entered into cooperative ethanol marketing agreements. Through these arrangements, they may be able to secure longer term contracts and higher prices for ethanol. Refiners see a cooperative arrangement as less risky, because if one plant is off line for a period due to contamination or some other production problem, other plants can still deliver ethanol on schedule. Cooperative marketing can also help the plants cut delivery costs.

Agriculture department officials told us that they were also working with industry officials to develop research and extension activities to link DDGS marketing with local livestock production. The plant managers we interviewed spoke of many different avenues for diversification that they were exploring, including the production and sale of industrial-grade ethanol, and carbon dioxide for the soft drink industry.

FEDERAL PROGRAMS

The ethanol industry cannot exist without continued federal support.

As our analysis at the beginning of this chapter shows, the loss of the 54 cent per gallon federal tax credit for ethanol would mean that ethanol could not be profitably manufactured in the Minnesota plants we have studied. The federal tax credit expires in 2000 and an affirmative vote by Congress will be necessary to renew it. A bill to eliminate the ethanol tax credit (HR 3345) introduced in Congress in 1996 attracted 50 co-sponsors. The Minnesota ethanol producers we talked to cite the loss of the federal credit as the biggest risk to their future profitability that they can see. Opposition to corporate subsidies appears to be growing in Congress, and the nation's number one ethanol producer, Archer Daniels Midland, has come in for a certain amount of unwanted publicity in recent months. ADM recently pleaded guilty and agreed to pay a $100 million dollar fine for conspiring to fix the price of lysine and citric acid, two products it produces from corn.

To some extent the economic prospects for ethanol production in Minnesota are also tied to the future of the federal oxygenated gasoline programs. As we have shown in Chapter 2, scientific support for the wintertime use of ethanol is weak, and the EPA foresees the time where the wintertime use of oxygenated gasoline will be limited to a couple of problem areas rather than the 39 metropolitan areas in which it is presently required. Minnesota has its own requirement for oxygenate use that will become statewide and year-round starting next October. It may be, however, that an end to the federal program will undermine support for a state requirement. In any case, we talked to officials at the Minnesota Pollution Control Agency and the U. S. Environmental Protection Agency and they do not believe

8 We do not imply that these plants are poorly managed. Actually, we were highly impressed by the competence and energy of the managers we met.

there is an environmental benefit for ethanol use in Minnesota in the summer. To the extent that summertime use of ethanol in Minnesota is based on a belief in its environmental value, the future of the requirement seems problematic. As in the case of the other risk factors considered in this chapter, however, we do not know what the future will hold. Minnesota policy makers need to consider where Minnesota's state-supported ethanol industry will be if the federal government withdraws all or part of the 54 cent tax credit or oxygenated fuel requirement.

As we saw in Chapter 1, however, that there is substantial use of ethanol in midwestern states that are major ethanol producers, including some, like Iowa, that do not have any requirement to use oxygenated gasoline. Also, ethanol has value as an octane enhancer and fuel additive, although not necessarily at a 10 percent concentration.

TECHNOLOGICAL DEVELOPMENTS

Corn is a valuable agricultural commodity that has numerous uses. Some analysts predict growing world demand for U. S. agricultural products, including corn and meat. As we have shown, there is greater potential profit in producing corn sweeteners and other food products from corn than there is from producing ethanol. In any case, a great deal of corn in Minnesota is fed to livestock and a material increase in the price of corn caused by demand from ethanol mills might adversely affect other agricultural sectors.

The federal government is spending millions on research and development of alternative feedstocks.

For these reasons and others, there is active interest in improving the technology of ethanol production from other raw materials, especially those that do not have to be grown on prime farm land, or for which there are many competing uses. The United States Department of Energy (DOE) is focusing most of its biofuels research effort on reducing the cost of growing and processing feedstocks such as grasses and fast-growing short-rotation trees. The feedstock production research is conducted at the Oak Ridge National Laboratory which is sponsored by DOE, and research on conversion of biomass feedstocks to fuel is conducted at DOE's National Renewable Energy Laboratory in Colorado. Total DOE funding for its transportation biofuels program was about $26 million for fiscal year 1995.[9]

The U. S. Agriculture Department (USDA) continues to work on improving ethanol production from corn and other agricultural feedstocks, but there has already been considerable improvement in the efficiency of ethanol production from these sources and, in any case, competing uses for corn greatly limit its availability as an ethanol feedstock. According to the GAO, a small component of USDA's program is also devoted to research on producing ethanol from cellulosic biomass and USDA is also sponsoring some research on energy crops such as short rotation trees and agricultural residues. Total USDA biofuels research and development funding for fiscal year 1995 was about $10 million.[10]

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9 General Accounting Office, Motor Fuels: Issues Related to Reformulated Gasoline, Oxygenated Fuels, and Biofuels, GAO/RCED-96-121, 8.

10 General Accounting Office, Motor Fuels, 31.

A recent symposium on fuels and chemicals from biomass sponsored by the Oak Ridge National Laboratory and the National Renewable Energy Laboratory (NREL) was held in Tennessee in May 1996. Various estimates were presented on the cost of ethanol production from lignocellulose. NREL estimated the current cost of ethanol production from lignocellulose to be $1.22 per gallon assuming a feedstock cost of $42 per ton, and a cost of 75 cents per gallon at zero cost for feedstock. Other estimates were higher. If these prices hold in commercial application, cellulosic feedstocks can compete with corn.

If production of ethanol from cellulose moves from the experimental stage to commercial application, Minnesota's ethanol plants located in corn-producing areas could face a difficult adjustment period. We have no idea how likely this is happen, although the federal government is putting some significant money behind research and experimentation. The corn-grinding part of an ethanol factory is a relatively minor part of a dry mill, and possibly some of the Minnesota plants could adapt to using other feedstocks, but it many also be the case that the factories would have to close or be moved to locations in closer proximity to a different feedstock.

CONCLUSIONS

With substantial help from the state and local governments in the form of subsidized loans, tax credits, producer payments, and requirements to use oxygenated gasoline, private companies have built a sizable ethanol industry in Minnesota. Each dry mill of 10-15 million gallon per year capacity cost $20 to $30 million to build and start up, about half of which represents the equity of (mostly) farmer-owners. The state producer payment over 7 to 10 years pays an amount of money sufficient to finance the construction and start-up of a typical plant. As a practical matter, policy makers have no real choice but to support these plants through a continuation of producer payments and by creating a hospitable environment in which they can operate.

In 1996 the plants produced nearly 70 million gallons of ethanol and their present capacity is about 95 million gallons per year. However, the state has a goal of developing an ethanol production of 220 million gallons which is approximately the amount that would be consumed in Minnesota if all automotive fuel consisted of a 10 percent mixture of ethanol in gasoline.[11] In light of what we consider to be significant risks to the future viability of the ethanol industry, we recommend:

- **The Legislature should reconsider its goal of producing 220 million gallons of ethanol each year in Minnesota.**

- **The Legislature should consider whether so much of its rural economic development effort should go to one industry. The size and variety of economic development programs supporting ethanol**

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11 *Minn. Stat.* 41A.09 Subd. 1a.

development dwarfs other efforts. In the face of uncertainty about the future, a more diversified approach holds significant advantages.

If the future economics of ethanol production are favorable, there is nothing to prevent growth in ethanol production in Minnesota to 220 million gallons per year with or without a state goal. However, we think there are reasons to doubt the wisdom of state support for one industry, especially one where there are significant risks to future profitability. One danger is that ethanol subsidies will drive out other opportunities for economic development in rural Minnesota. A substantial amount of private capital is invested in Minnesota’s ethanol plants, and when the state and federal governments ultimately withdraw their financial support as they are now scheduled to do within ten years, this private capital which could have gone to other local investments is put at risk.