The Growth of Alternative Fuels: Minnesota and U.S. Perspectives

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Introduction

The last two years have witnessed a growth in interest in alternative liquid fuels of ethanol and biodiesel at state and national levels. In 2001 Minnesota production of ethanol for the first time surpassed the amount necessary to oxygenate the entire supply of gasoline sold in the state. Establishment of the fuel ethanol business in Minnesota grew from efforts to improve air quality in the Twin City area as required by the U.S. Environmental Protection Agency and from the desire of Minnesota farmers to participate in value-added enterprises. Ethanol production has been subsidized by state and federal funds, but its growth in MN has been possible only due to plentiful, low-cost corn supplies. The rapid expansion of fuel ethanol plants in Minnesota has continued to the point where production capacity for this fuel now exceeds state requirements by 40%. [1] Minnesota, formerly a state with few energy resources, is now exporting fuel. Other states, particularly in the Corn Belt, are participating in the expansion of ethanol derived from the dry milling of corn.

Coming about a decade behind the establishment of the ethanol processing industry as an important sector of agricultural processing, biodiesel is relatively speaking in its infancy. While human experience making ethanol pre-dates written history, production of methyl esters (biodiesel) has occurred only for the last 90 years, with most serious research for commercialization occurring in the 1990's. This paper offers perspectives on these two biofuels, which are poised for further expansion following passage of significant federal and state legislation.

Minnesota's experience in development of profitable farmer cooperatives and limited liability corporations have spurred interest in the further development of biodiesel from soybeans and yellow grease akin to that which occurred for ethanol derived from corn. Development paths of both fuels are being propelled by the interplay of the following three dominant influences:

1) Societal environmental quality concerns
2) Low agricultural commodity prices
3) Energy security concerns

Despite the excitement and interest in biofuels at this time, the three dominant influences favoring the use of ethanol and biodiesel are tempered by factors influencing the cost and availability of biofuels, including the following:

1) The changing technology of their production
2) The ability of these fuels to reduce emissions and enhance engine performance
3) The quantity of existing feedstocks that can be diverted to fuel production

National and State Consumption Levels and Trends of Gasoline and Diesel

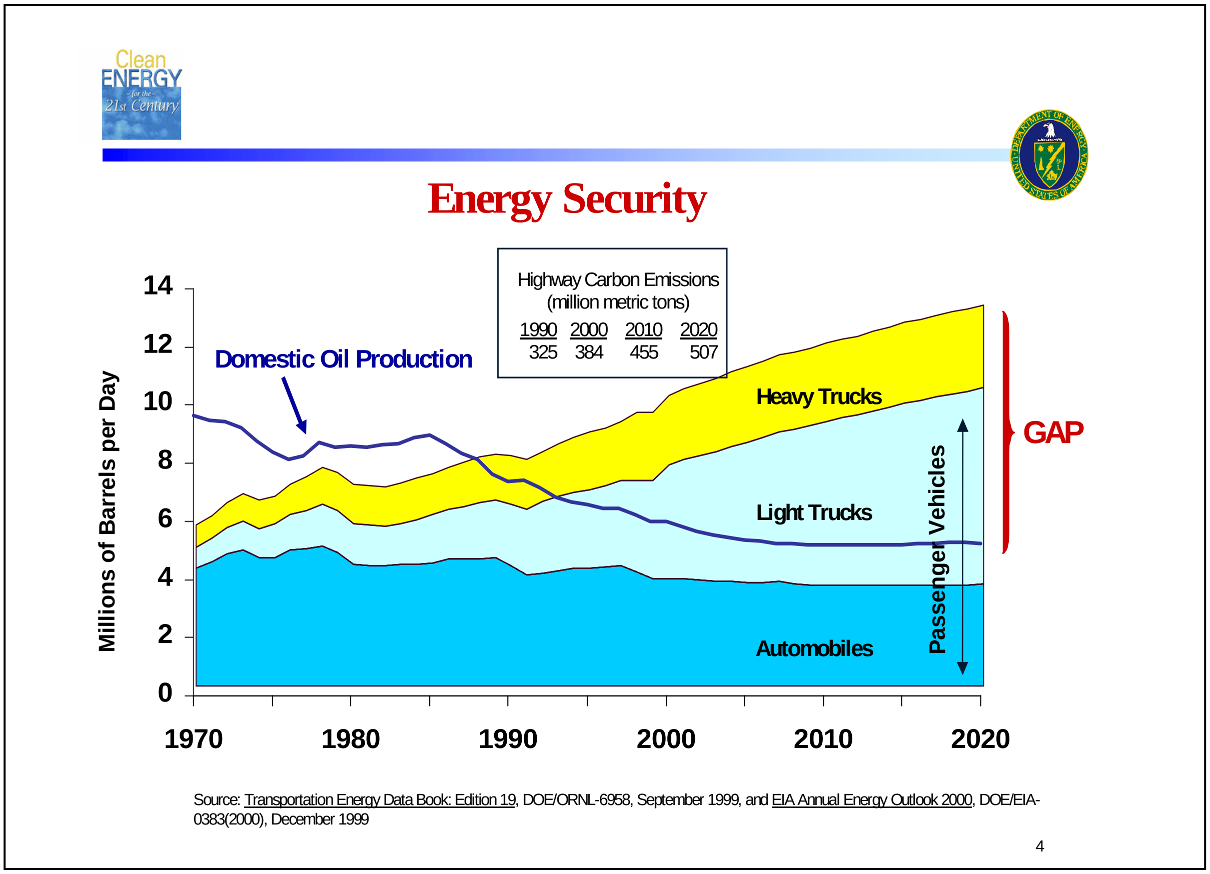
In 2001 U.S. usage of gasoline was 130 billion gallons, while the gasoline usage in Minnesota was just 2.5 billion gallons. U.S. usage of diesel was 37 billion gallons, while in Minnesota .8 billion gallons were used.[2] On a per capita national basis, these consumption figures work out to 460 gallons of gasoline consumed and 130 gallons of diesel. For the Minnesota population one can estimate 500 gallons of gasoline and 160 gallons of diesel per capita. When considering these numbers, at both the national and state level, use of diesel is roughly one-third the amount of gasoline. This is a situation peculiar to America, which consumes high amounts of gasoline in proportion to diesel.

In America diesel is the fuel of industry, while in Europe 35-40% of the automobiles are diesel-powered.[3]

Gasoline and diesel are derived from the same portion of mid-level distillates in a barrel of crude oil. It has been the policy of European governments and the frugality of European consumers to prefer diesel-powered cars over those powered by gasoline. There are some technical advantages for using diesel fuel in a passenger car, such as greater energy efficiency. In general diesel engines are able to extract 40% more of the potential energy in their fuel than gasoline engines. Furthermore, diesel requires less processing at the refinery because diesel consists of longer chains of hydrocarbons.[4] In the course of processing crude oil into gasoline, 26% of the energy is lost, reflecting an energy balance of 0.74 . Diesel fuel's energy balance is .83 due to the need for less refinery energy.[5] American drivers have shown a preference for gasoline in their cars and light trucks that probably stems from convenience, preferences for less smell and noise, winter fuel management issues, and outdated concepts of more rapid acceleration from gasoline. Today's modern diesels have great efficiency and performance as witnessed by the fact that many of the high performance cars sold in Europe are turbo-charged diesels.

Graph 1, appearing below, was produced by the U.S. Department of Energy, and [6] contains historical and projected data on vehicular fuel use in America from 1970 through 2020. The quantities of fuel consumed by automobiles, light trucks (pick-up and sports utility vehicles) and heavy trucks are shown as well as the level of domestic oil production. The graph shows the growing gap in crude oil supplies in coming years as domestic crude oil production falls and total petroleum usage climbs. A major contributor to this growing gap is the American preference for large vehicles for personal use with poor mileage in the light truck category, including vans, pickups and sport utility vehicles (SUV's).

Graph 1.



The U.S. Congress in 2002 considered and passed bills encouraging a National Renewable Standard for fuels used in America. At this time the final version of the bills hasn't emerged from conference committees. The goal of this legislation is to increase U.S. production and use of renewable fuels of ethanol and biodiesel from 1.2% in 2002 to 4% by 2016. It is estimated that 85% of the renewable fuels will be ethanol and 15% biodiesel. The overall effect sought is to reduce U.S. crude oil imports from 70%

projected in 2016 to 65%. According to A.U.S. Consulting this boost in renewable fuel production is expected to raise corn prices $.28 per bushel and soybeans by $.68 per bushel, while cutting government payments to farmers, creating 300,000 jobs, and increasing investment in rural areas by $10.5 Billion. [7] A combination of circumstances contributed to passage of this historic legislation:

1) Societal environmental quality concerns
2) Low agricultural commodity prices
3) Energy security concerns

In the succeeding sections of this paper, discussions of first ethanol and then biodiesel will occur, followed by observations concerning development of both fuels will be presented.

ETHANOL

Ethanol Review

Using ethanol to fuel automobiles in an old idea. Henry Ford considered ethanol to be an excellent fuel for his early automobiles as he expressed concern for adequate supplies of gasoline to fuel the millions of cars he planned to sell. Today ethanol is blended with gasoline for a variety of reasons. Foremost is that the molecular oxygen of ethanol supports more complete burning of gasoline. As an oxygenate, it can readily substitute for methyl-tertiary-butyl-ether (MTBE). This oxygenate that has been used for approximately fifteen years in California in efforts to reduce emissions from automobiles in that state. Ethanol can also be an octane enhancer and improve the performance of otherwise unsatisfactory gasoline. Octane is the numerical attribute to reduce premature ignition in gasoline engines. Ethanol has an octane number of 113, while gasoline is typically 87.

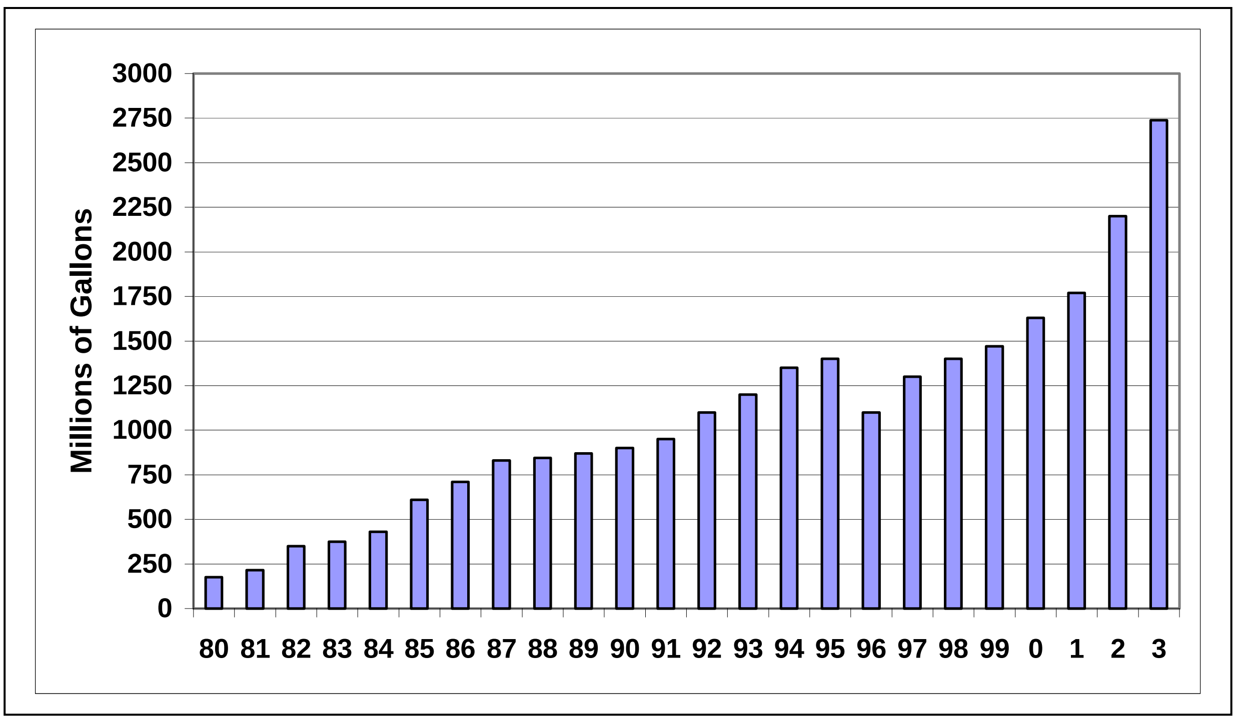
In Minnesota fuel ethanol is produced by the dry milling and wet milling of corn as well as from whey recovered at cheese plants. State law requires that virtually all gasoline sold in the state contains 10% ethanol. In 2001 Minnesota ethanol production was 250 million gallons, enough to oxygenate the 2.5 billion gallons of gasoline used in the state. By the end of 2002 ethanol production capacity will exceed that amount by 40%.[8] Expansion of existing plants and the building of new plants are occurring throughout the Midwest in other states such as South Dakota, Nebraska, Wisconsin, and Iowa.[9] These ethanol producers anticipate expansion of the market for fuel ethanol, particularly as the use of MTBE is phased-out in the United States due to its extreme toxicity and mobility to water supplies. E.P.A. air quality standards will increase the need for ethanol by consumers in California and many eastern U.S. cities.

Another source of increased demand for ethanol may be flexible-fuel vehicles, which can utilize blends with 85% ethanol. These vehicles work by having a computer chip that dynamically detects the percentage of fuel ethanol in the fuel just before ignition. Government fleets are highly encouraged to offer flex-fuel vehicles, which have the potential of reducing tail pipe emissions by 25% and greenhouse gas emissions by 40%. Automobile owners are encouraged to purchase flex-fuel vehicles by air quality authorities in metropolitan areas suffering poor air quality. E-85 (Ethanol at 85%) typically sells for $.12 to $.20 per gallon cheaper than gasoline.[10]

Government subsidies at the federal and state levels have encouraged the production of ethanol from grain (especially corn in Minnesota and the U.S.). Minnesota ethanol plants receive $.20 per gallon for the first 15 million gallons of ethanol produced each year for the first ten years of production. In addition, a federal Blender's Credit pays $.54 per gallon of ethanol. On the typical gallon of gasoline blended with 10% ethanol purchased by a Minnesota motorist, subsidies of $.074 have been paid. This is about 5% of the recent retail price of gasoline including federal and state taxes. In Minnesota, the state subsidy rules caused many plants to be built at the 15 million gallon per year capacity. Minnesota has fourteen ethanol plants, twelve of which are farmer-owned. Of the fourteen plants, there is one corn wet-mill, one whey plant, one brewery, and eleven dry mills, which have simpler processes and lower overhead costs.[11]

U.S. ethanol production has grown from 0.2 Billion gallons in 1980 to 2.3 Billion gallons in 2002**.** **Graph 2.,** which follows, shows the expansion U.S. ethanol production.[12] As fast as U.S. ethanol production has grown in recent years, it still remains 38% less than ethanol production of Brazil with 3.18 billion gallons compared to 2.3 billion gallons in the U.S. In Brazil 40% of the cars run on 100% ethanol, while the remaining 60% of the cars run on 22% ethanol blends.[13]

Graph 2.



Ethanol Production

Mankind has been making ethanol from prehistoric times with fruits and grains. The key is to have sugars that yeasts can work on to create ethanol. When ethanol levels reach a certain level, yeast activity ceases and the yeast die.

In the typical dry-milling plant producing fuel ethanol, the following activities occur:

1) Bushels of corn (56 pounds) are ground
2) Water is added to form mash
3) Mash is cooked to kill bacteria and expose the starch
4) Enzymes are added to convert the starch to sugar
5) Yeasts are introduced to convert the sugar to ethanol
6) Carbon dioxide is collected
7) Ethanol is separated and distilled
8) Distillers dried grains and soluble are dried
9) Ethanol is denatured with gasoline

There are three major products from ethanol production from the most common dry-mill plants. From a 56 pound bushel of shelled corn, one obtains from 2.5-2.8 gallons of ethanol. Substantial energy is expended to remove water from the ethanol; and then 5 percent gasoline is added to denature the alcohol to prevent its diversion to unauthorized fashions. Because only the starch portion of the corn kernel is used, 18-20 pounds of a residual by-product called distillers dried grain and solubles (DDGS) remains after the ethanol is removed from the mash. The DDGS are dried and sold as livestock feed, typically containing 26% crude protein, 10% crude fat, and 12% crude fiber. In addition, most Minnesota ethanol plants collect and sell carbon dioxide for use in food preservation.[14]

Ethanol Plant Revenues

The following table reveals aspects of revenue for typical corn dry-mill plants in southern Minnesota over a five-year period. In the last five years dry mill ethanol plants have largely been profitable, helped in part by the $.20 per gallon Minnesota Production Credit, which only applies to the first 15 million gallons of production per year for ten years. This subsidy has been very important in assuring lenders of the financial viability of these enterprises. Ethanol sales can be volatile, but because ethanol is a substitute for gasoline, ethanol prices are closely correlated with gasoline prices. When prices for corn are high, ethanol prices typically rise to levels necessary to supply oxygenates required in local fuel supplies of the air sheds identified by the U.S. Environmental Protection Agency. When gasoline prices are high, the opportunity to blend ethanol reduces the price of blended fuel while raising octane. Although sales of DDGS represent 17% of the revenue, this is an important aspect of ethanol plant profitability. Carbon dioxide sales are a minor item representing 1% of the revenue stream**.** **Table 1.** shows percentages of the revenue associated the different products and the Minnesota Production Credit recorded by a Minnesota dry mill ethanol plant over a five-year period.[15]

Table 1.

Dry Mill Revenue Categories (5 yr.)

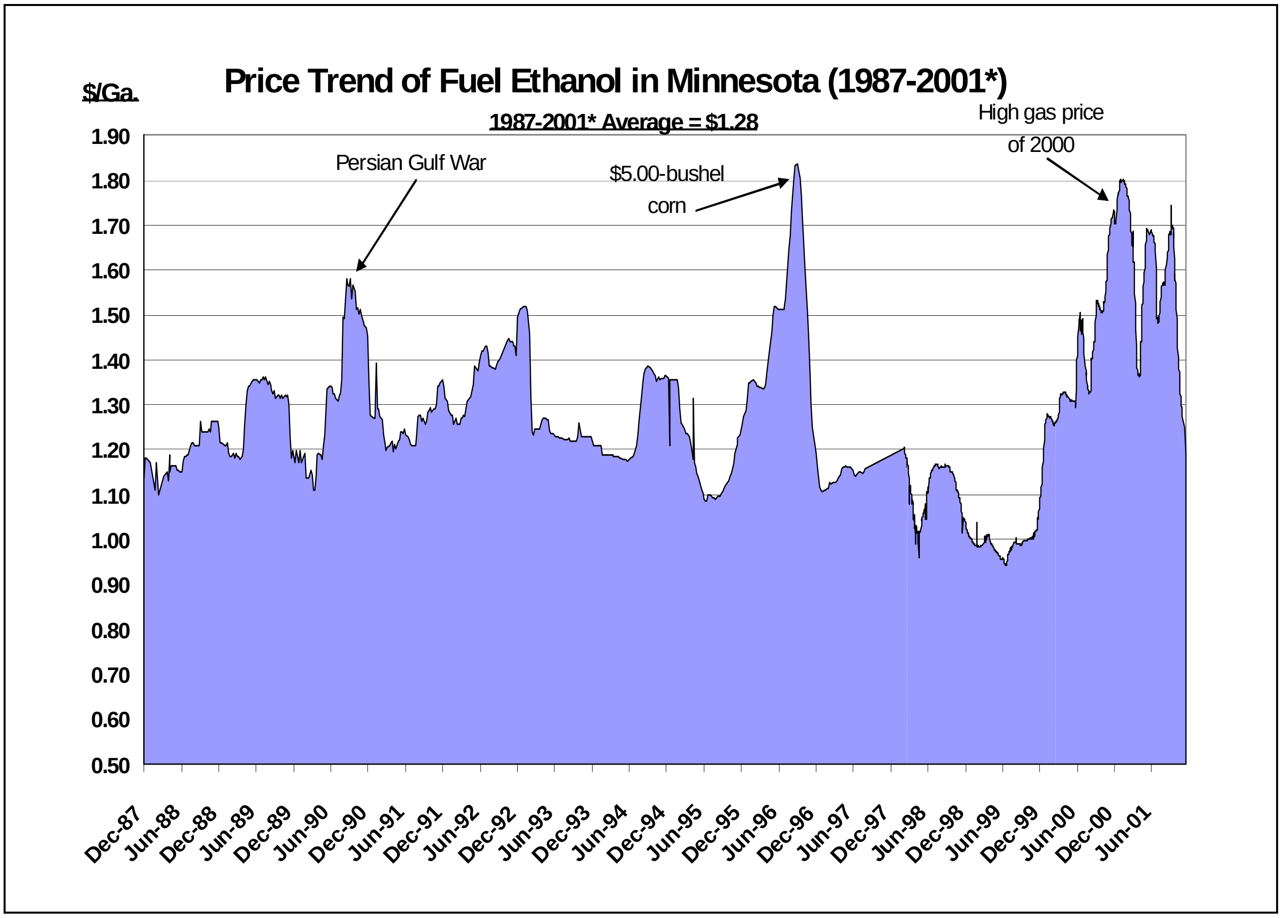
Ethanol Sales	70%
DDGS Sales	17%
CO_2	1%
MN Production Credit	12%
Total	100%

Improving Value of DDGS

DDGS is an excellent feed that is mid-level in protein, but deficient is certain amino acids, and lower in energy than corn, due to removal of starch. Anecdotal information reveals that it has taken considerable education and sales effort to convince dairy farmers in Minnesota and neighboring states how best to use this feed in their herds. At the University of Minnesota and other universities, nutritional research is being conducted with check-off funds raised by dry mill corn ethanol plants seeking to identify market niches for this feed. While dairy cattle are the biggest user, there is growing evidence that swine producers can typically replace .8 lb. of corn and .2 lb. of soybean bean with one pound of DDGS.[16] Some opportunities have been identified to utilize this feed in turkeys, but only at levels from 5-10% of the rations. The amino acid threonine is often found to be limiting when feeding DDGS to turkeys, resulting in lower standard breast meat quality and yield.[17] Because DDGS supply is plentiful and growing in abundance, dry- mill ethanol plants will face increased competition to market DDGS and price pressure on this co-product of ethanol production.

Graph 3., which follows, shows the volatility in price levels of ethanol sold in the state.[18] The timing of price spikes coincide with times of high gasoline prices as well as high corn prices. Ethanol plants are generally most profitable in times of low corn prices and high gasoline prices.

Graph 3.



Ethanol Production Costs

Table 2. shows the percentages of important cost categories of an ethanol plant over a five-year period, excluding the cost of the feedstock. Energy costs dominate. Natural gas is typically used to cook mash, to maintain proper temperatures for fermentation, to provide heat for distillation to drive off excess water, and to dry DDGS. Because 5% gasoline is added to ethanol for denaturing, the cost of gasoline is also

substantial. Very important are the enzymes, which convert the starch of the corn kernel to sugar and comprise 11.5% of costs. An active area of research is the search and development of more effective and lower cost enzymes. Electricity is used to move materials in the plants, grind the corn, and provide light.[19]

Table 2.

Important Cost Categories (5 Yr)

Cost Fuel (NG) + Denaturant	29.3%
Depreciation	19.0%
Labor & Management	11.7%
Enzymes	11.5%
Electricity	7.7%
Yeast	5.9%
Repair and Maintenance	5.8%
Interest	3.0%
Other	6.1%
Total	100.0%

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Discussion of Ethanol Energy Balance and Fuel Displacement

After considering all the energy expended in production of corn including the imbedded energy of fertilizer applied, direct fuel used, and energy used in processing, corn ethanol production in the U.S. can be considered to have an energy balance of 1.34 to 1. [20] This means that more energy is created in the process of making ethanol than consumed. The key to this remarkable situation is the storage of solar energy in starch molecules by the growing corn plants. An acre of Minnesota corn producing 150 bushels per acre can produce 405 gallons of ethanol per acre and 2700 pounds of DDGS.

In addition to the positive energy balance, corn-derived ethanol results in a six-fold displacement of liquid fuels. This means that every gallon of ethanol produced requires only one-sixth of a gallon of liquid fuels. This is due to the fact that corn production and ethanol processing utilize coal for electrical energy and natural gas for fertilizer production.[21]

Innovation and Emerging Trends in Ethanol

Most of the ethanol produced in America is made from corn, with most of the new capacity occurring in plants employing the dry-mill technology. Investigations are underway to cost-effectively increase the yield of ethanol from a bushel of corn by utilizing the cellulose contained in the corn kernel. Experiments in this area suggest that it may be possible to get as much as 3.0 gallons of ethanol per bushel versus the 2.5-2.8 gallons typically recovered. Exploiting the cellulose for ethanol would change the composition of DDGS and may adversely change its handling characteristics.

Major research efforts are also underway seeking to develop better, cheaper enzymes to make ethanol out of fiber (cellulose). If break-throughs occur in this area, ethanol may be cost-effectively made from numerous sources of fibrous and woody biomass. The two major firms that market enzymes have each accepted $17 million U.S. Department of Energy grants with the goal of improving performance and/or cost of enzymes capable of reducing cellulose so that it can be fermented. If this research can be commercialized, then switchgrass, sugar cane bagasse, corn stover, wheat straw, and rice straw will be obvious feedstocks for ethanol production. In addition, certain forest wastes could also be utilized.[22] For the many dry-mill ethanol plants in Minnesota and the Midwest, break-throughs in enzyme technology may make their grain-based technology obsolete. However, there may be ways that MN ethanol plants can exploit the fibrous fractions of the corn plant in addition to the grain such as cobs, husks, and stalks.

Other research is occurring with bacteria as agents of fermentation. These organisms are more tolerant of environmental extremes and more resistant to infection than yeasts; however, to date bacterial fermentation has not proven as productive as yeast-based fermentation. Bacteria that have evolved in the hot springs of Yellowstone National Park are among the candidates for consideration as future fermentation agents, especially after a time of further testing and potential genetic manipulation.

BIODIESEL

Definitions and Production Methods

Biodiesel's development is in its infancy compared to ethanol, and its market will remain smaller than that of ethanol. Certainly, environmental standards and government incentives to encourage its use are critical for its further development, much as in the case with ethanol. In the pages ahead a discussion similar to that of ethanol will occur. At this time, no production of biodiesel occurs in Minnesota, although some amounts are used in the state. Factors favoring development of this fuel are in evidence in the state at this time. During the 2001 and 2002 Minnesota Legislative Sessions proposals to mandate the use of low blends of biodiesel were discussed. In 2002 a bill mandating the inclusion of 2% biodiesel in 2005 was passed and became law without the Governor's signature. In the event federal or state laws are passed that result in the reduction of costs of biodiesel or production of biodiesel exceeding 8.0 million gallons a year occurs, the mandate will be invoked sooner than 2005.[23]

The idea of using vegetable oils to fuel diesel engines is old. In fact Rudolf Diesel demonstrated his "new" engine at the 1900 World's Fair using peanut oil. Diesel engines are more energy efficient than gasoline engines and are 40% better at utilizing the energy contained in the fuel than gasoline engines. Diesel engines were first built and used in larger equipment like ships, trains, barges, and electrical generators due to their energy efficiency, mechanical simplicity, and durability. For these reasons diesel is considered the "fuel of commerce". As reported at the beginning of this paper, the U.S. used 37.0 Billion gallons of diesel fuel in 2001, which is equal to one third of the use of gasoline. Current U.S. production of biodiesel is estimated at 30 Million gallons, with existing plants producing other oleo chemicals also capable of producing biodiesel.[24]

Biodiesel is defined as methyl esters that are made from vegetable oils, animal fats, recycled cooking greases, tallow, and lard. The chemistry to make biodiesel is quite simple, although pre-treatment of feedstock oils and grease is crucial before processing. Testing after production is crucial in order to standardize and characterize the fuel. To make biodiesel one needs an oil feedstock, which is combined with mixture of an alcohol (generally methanol) and a common catalyst. Base catalysts like potassium hydroxide and sodium hydroxide are used when the feedstock oil is vegetable, while acid treatment with sulfuric acid is necessary when working with animal fats. The catalyst-alcohol mixture is combined with the correct proportion of fat or oil with the use of low heat, typically under sealed pressurized systems. The triglycerides that comprise the fat of oil are broken into individual chains with the products of biodiesel, glycerine, and the water–catalyst mixture separating by density. Biodiesel comprises the top layer in the tank. It is necessary to perform further processing to purify the glycerine and remove excess catalyst for recycling.

Experience with Biodiesel

The nations of the European Union have had more experience using biodiesel than those of North America. There are substantial biodiesel plants in Germany, Austria, and France. In 1991 Germany used 200 million gallons of biodiesel with consumption rising to 500 million gallons in 2001. Rapeseed, grown as a set-aside crop in Germany, is the typical feedstock with 3.7 million acres (1.5 million hectares) of rapeseed being grown in 2001.[25] European experience in biodiesel is also demonstrated by the fact that an Austrian company built the biodiesel plant for Griffin Industries in Kentucky.

In America, transit bus fleets have demonstrated the use biodiesel in cities in Illinois, Indiana, and Missouri. Numerous tour-boats serving whale watchers in Hawaii operate on biodiesel derived from recycled grease collected in the islands. In Minnesota snowplows and trucks of Hennepin County's Highway Department have run with biodiesel blends through several winters. The Center for Diesel Research at the University of Minnesota has conducted numerous studies on emission attributes of biodiesel blends at their lab and has participated in studies to model emissions control strategies using either biodiesel blends or filters in underground mines. Many U.S. National Parks have used demonstrated biodiesel in their trucks in various operating conditions and climates.

Operational Attributes of Biodiesel , Emissions

Biodiesel has a higher cetane number of 50 versus 40-45 typically recorded with petro-diesel. This attribute is analogous to octane in gasoline and characterizes a fuel's resistance to premature ignition. Fuels that hold their energy until the split-second of ignition have higher performance. Biodiesel has a higher flash point than #2 diesel at 131 C. versus 65 C. for #2 diesel. This attribute makes biodiesel a safer fuel when risk of explosion or fire is a consideration. Biodiesel's energy content as measured in BTU's is 121,000 BTUs per gallon, which is 7.6% less than #2 diesel and 4% less than #1 diesel.

It contains more oxygen than petro-diesel just like ethanol, which facilitates more complete combustion of the fuel. Biodiesel has greater lubricity than petro-diesel, which provides protection to the injection pumps of diesel engines, even at small blends. Biodiesel is slightly quicker to gel than petro-diesel at cold temperatures, which is a consideration in colder climates.[26] **Table 3.,** appearing below contains data on cold flow of diesel fuel of various grades blended with biodiesel at different percentages. At lower blends of 2% and 5% of biodiesel cold-flow measurements are minimal, especially in light of typical winter operating practice of blending #1 diesel.[27]

Table 3.

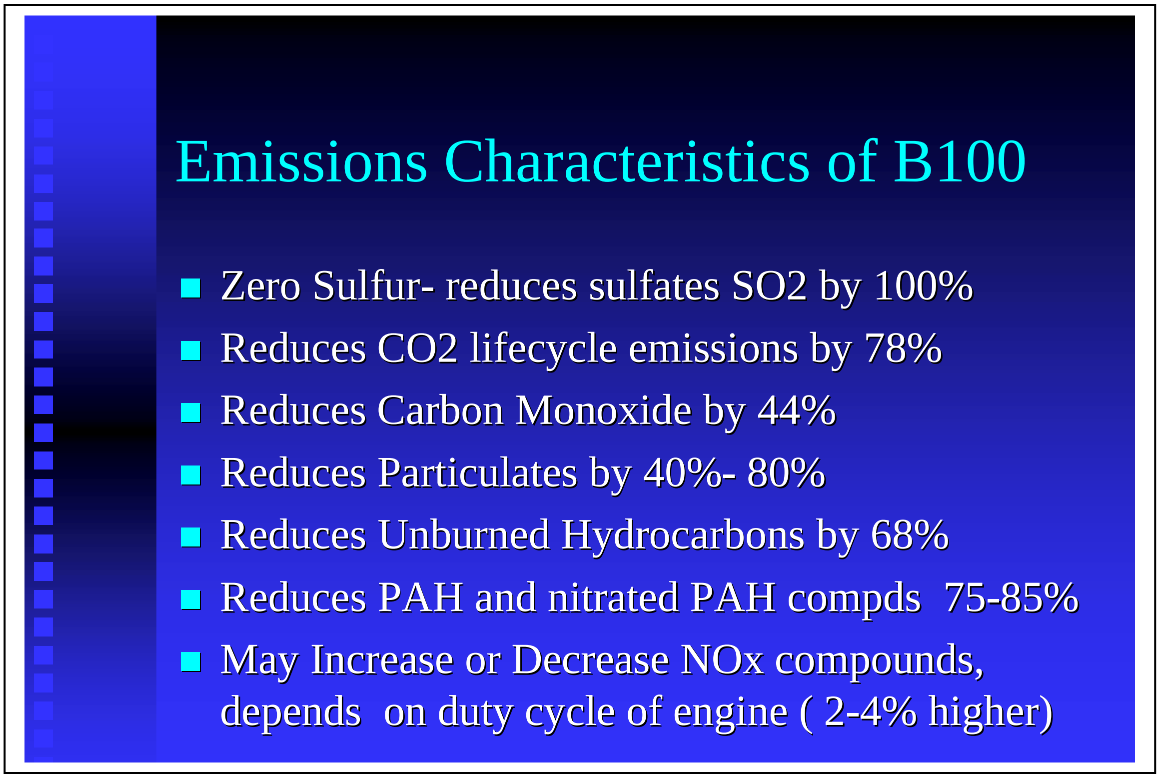
Minnesota
Cold Flow Data

Williams
Laboratory Services

Sample	Cloud* Point	Pour* Point	Cold Filter* Plugging pt.
#2 Diesel Fuel	4	-30	1
2% Soy in #2	6	-25	1
5% Soy in #2	8	-20	-1
50% #1 w/ 50% #2	-6	-45	-12
2% Soy in 50/50	-6	-40	-14
5% Soy in 50/50	-6	-40	-14

With respect to emissions, biodiesel produces significantly lower emissions than petro-diesel, especially at higher blend levels for all emissions except NOx compounds. NOx emissions from diesel engines run on biodiesel may be 2-4% higher than petro-diesel.[28] NOx emissions are noted because these chemicals in combination with other volatile organic compounds and hydrocarbons exposed to sunlight have the potential to create ozone in urban settings. Ozone alerts are associated with many more incidents of respiratory distress at local hospitals. NOx emissions may not be dangerous in all settings and depend upon the balance with hydrocarbon emissions in the atmosphere. Particulates are small particles that form in the exhaust stream of engines and boilers. Particulates of diesel engines have received special attention due to the existence of toxic substances that adhere to these microscopic particles, especially in congested urban settings and in underground mines. Biodiesel used in various machines in underground mines can reduce the mass emissions of the engines by 70%, a level achievable with disposable filters that require service every eight hours.[29] Recent research on diesel particulates includes a debate on whether size or mass of particulates plays a greater role in human health. **Table 4.** shows reductions in emissions that would occur with use of B100 or 100% biodiesel versus petro-diesel.

Table 4.



EPA Sulfur Standards and Lubricity

Major factors spurring the interest in biodiesel are the U.S. Environmental Protection Agency regulations that require that sulfur levels of diesel fuel be drastically lowered from 500 ppm to 15 ppm in 2006. This requirement sets the stage for after-treatment devices (catalytic converters and particulate traps) that will be required on over-the-road heavy-duty diesel engines in 2007. The efforts to reduce the emissions from heavy-duty diesel engines have been coming for some years since the major effort on urban air quality were first directed at automobiles. The additional processing of diesel fuel necessary to remove the sulfur will raise the cost of diesel fuel from $.05 to $.10 per gallon.[30]

When sulfur in removed from diesel fuel, lubricity is lost, which will result in accelerated wear of diesel injection pumps. Research conducted by Stanadyne Automotive Corporation shows that biodiesel blends of 2% (B2) will restore the lubricity lost by additional thermal processing. This is a key element in the interest of encouraging biodiesel production in Minnesota and other farm states.

Biodiesel Production, Factor Inputs and Products

To produce a typical Minnesota soybean acre yielding 45 bushels per acre or 2700 pounds requires about 7.4 gallons of diesel fuel and .9 gallons of gasoline.[31] When the soybean production from that acre is crushed into protein meal and oil, 540 pounds of oil and 2160 pounds of meal result. The 540 pounds of soy oil can be made into biodiesel using 108 pounds of methanol (and a small amount of catalyst). This will result in the production of 70.13 gallons of biodiesel and 43 lb. of glycerine, which can be used to make numerous products such as soaps, lubricants, and explosives.

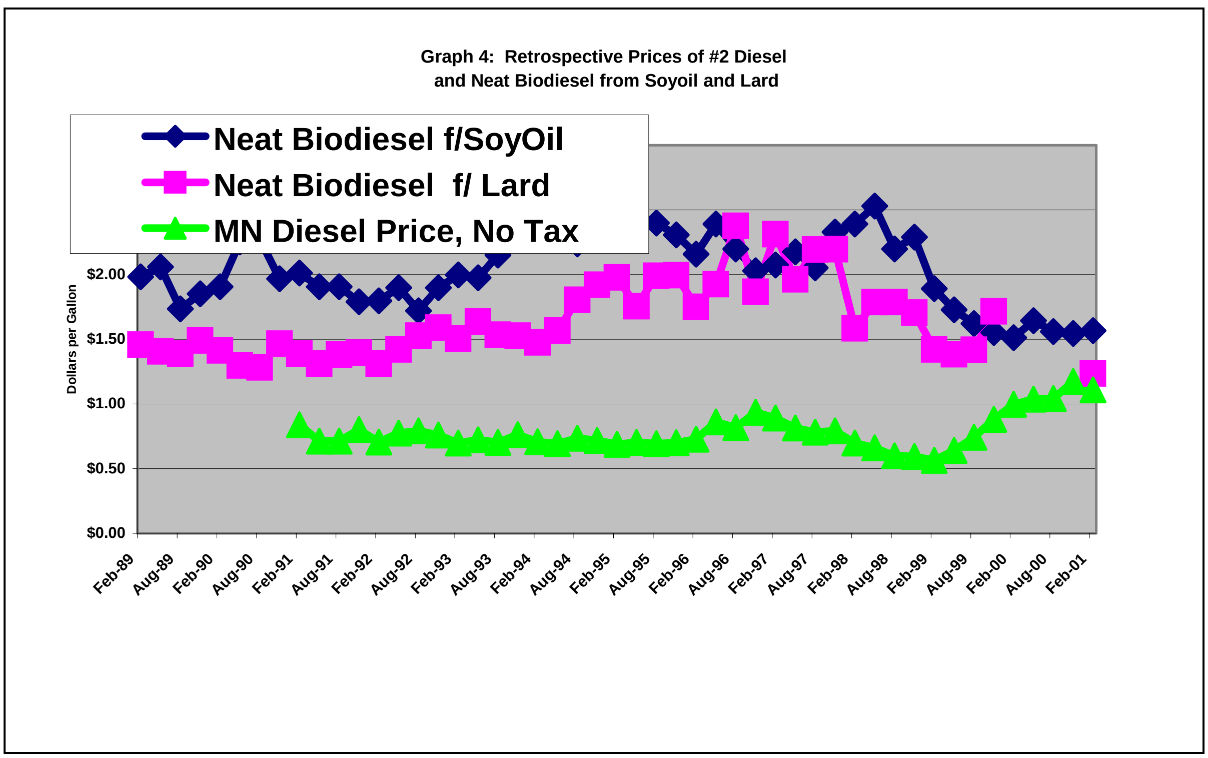
Sustainability, Energy Balance

The single acre example offers the view of the amount of liquid fuel that can be produced from the oil of an area of soybeans, a common sight in America. Of course, biodiesel can be made from numerous other feedstocks, including waste and recycled cooking grease and oils. A favorable factor in biodiesel's energy balance is the fact that the soybean plant produces long chains from sunlight and available nutrients. Energy is held in chemical bonds of molecules, most which stay intact in the processing to biodiesel. Considering all the energy used to grow soybeans, crush the soybeans, and transesterify the oil, biodiesel has an energy balance of 3.24 to 1.0.[32] This is one of the highest energy balances of any renewable fuel, and is excellent when compared to the energy balance of petro-diesel at .83.

Biodiesel Production Economics

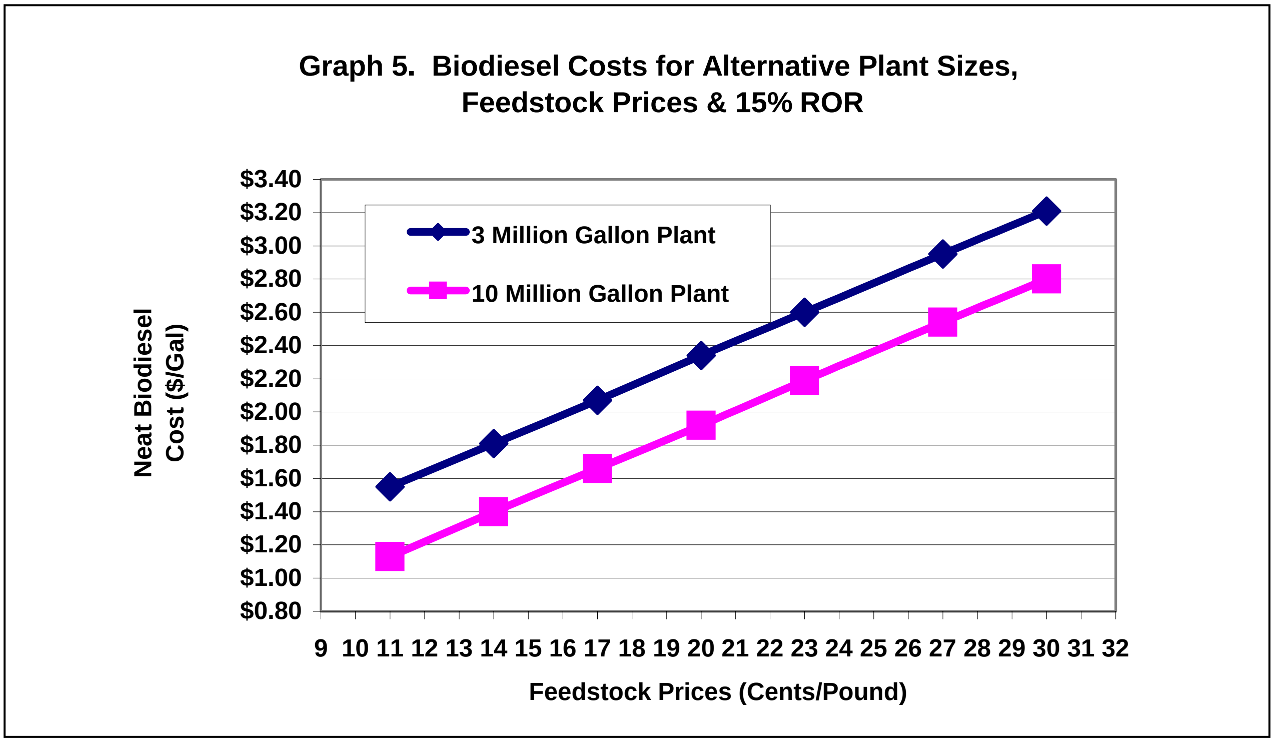
Processing costs to convert vegetable oil or recycled grease can range from $.15 per gallon to $.52 per gallon depending upon the feedstock and the scale economies of the facilities where processed.[33] Graph 3. , which appears below, retrospectively shows the cost of biodiesel derived from either soy oil or lard, assuming a net transesterification charge of $.35 per gallon as well as the price of Minnesota diesel fuel. **Graph 4.** shows the narrowing of gap between biodiesel and diesel that occurred with the low prices of soybean oil that prevailed from 1999 through the present.

Graph 4.



Graph 5. shows the scale economies of biodiesel production plants of 3 million gallons per year and 10 million gallons per year with the costs of 100% (Neat) biodiesel calculated for various feedstock prices. This model was developed by Shaine Tyson of the National Renewable Energy Laboratory and requires an internal rate of 15% on assets[34]

Graph 5.



Projections released by Food and Agricultural Policy Research Institute (FAPRI) indicated a ten-year average price of soybean oil of $.17 per pound,[35] which would translate into a long-term cost of neat biodiesel of $1.66 per gallon. When produced in a 10 million gallon per year plant. When blended at a 2% rate with petro-diesel, additional costs to diesel fuel users would be approximately $.02 per gallon over a considerable range of soybean oil-petrodiesel prices.

Biodiesel Feedstocks: Near-Term and Beyond

Table 5. , produced by Shaine Tyson of the National Renewable Energy Laboratory identifies the sources of oil and fat that could be used in the near term to make biodiesel, totaling 5.6% of national diesel thirst. [36]

Table 5.

Near Term Biodiesel Feedstocks

Feedstock	Mil lbs	Mil gal	Percent
Soy	4,572	594	34
Brown grease	3,808	495	28
Inedible Tallow & Yellow grease	3,348	435	25
Corn	1,209	157	9
Everything else	684	89	5
Total	13,793	1,770	100
On-road Diesel Demand (mil gal/yr)		32,062	
Biodiesel supplies as a % Diesel Demand		5.6%	

Table 5. reveals that in the near-term, use of brown grease, inedible tallow, and yellow grease may be used to produce 53% of the biodiesel supply in the U.S. The opportunity

to utilize these low-cost feedstocks is evident, although yellow grease has proven to be a more easily standardized feedstock to begin the process of transesterification. While FAPRI estimates a ten-year average price of soybean oil at $.17 per pound, review of historical price data will find yellow grease, inedible tallow, and lard in the $.10-$12 per pound range. Future expansion of biodiesel will increase the price of yellow grease as more diverted from current uses to fuel production.

Cheap feedstocks for biodiesel production that the National Renewable Energy Lab is studying for production of biodiesel include vegetable oils derived from the mustard crops. A possible advantage of mustard crops arises due to the possibilities of producing the valuable co-product. Mustard meal has potential as a valuable organic pesticide, herbicide, and fungicide. The vast spectrum of species in the mustard genus demonstrates a broad range of adaptability as well as possibilities to be bred to various specifications. Mustard crops have demonstrated the potential to produce 4,000 pounds of seed per acre with 40% oil content. The oil of the mustard varieties is non-edible and easily extracted from the meal by mechanical methods. Production of mustards can readily occur in areas of the U.S. and other parts of the world where wheat is grown. These areas have less valuable land than those found in areas where corn and soybeans are grown. Mustards may prove to be a valuable crop in rotations in wheat country. Key to the development of mustards as a source of cheap vegetable oil for biodiesel is the development of a market niche for organic herbicides and pesticides from the mustard meal.[37]

Extreme Examples of Production Possibilities of Ethanol & Biodiesel

In physics and engineering, extreme examples are often formulated to help one recognize unique characteristics of a construction project. By considering extreme levels of alternative fuel production from existing feedstocks, perhaps one can gain some perspective on the potential place of alternative fuels to solving America's thirst for liquid fuels.

If the entire Minnesota corn crop of roughly 1.0 Billion Bushels were to be processed into ethanol, the state's current use of gasoline at 2.5 Billion Gallons could be replaced by ethanol. This is a useful picture to contemplate, especially when we realize that Minnesota is a top corn producing state with a relatively small population of 5.0 million people. In the same manner one could consider the situation of the entire U.S. corn crop being processed for ethanol. This extreme example would result in enough ethanol to replace 20% of U.S. gasoline consumption. It is hard to imagine the massive building of ethanol plants to accommodate such a severe change in usage patterns for the state and national corn crops.

Considering the extreme examples with biodiesel production, one should contemplate the entire Minnesota soybean crop having oil directed to production of biodiesel. In this case, roughly 50% of Minnesota's diesel fuel could be replaced by 100% (B100) biodiesel. The Economic Research Service of U.S. D. A. in 1998 estimated that if all U.S. vegetable oils, animal fats, and waste greases were converted to biodiesel, only 13.3% of the U. S. usage of biodiesel could be replaced.[38]

These extreme examples should alert the public that development of alternative, bio-based liquid fuels alone will not significantly reduce use of petroleum and attendant emissions of greenhouse gases. Government efforts to improve fuel economy standards, especially for the "light truck" category of petroleum consuming vehicles may be a much easier path to reducing American requirements for imported petroleum.

Conclusions Regarding Ethanol and Biodiesel

One should recognize from this discussion that the development of alternative fuels conforms to a long pattern of co-evolution in engine design and fuel characteristics. Both ethanol and biodiesel have attractive attributes in terms of emissions, and in the case of biodiesel, in lubricity. Lubricity became an issue in fuel characteristics when EPA decided to add after-treatment devices to diesel engines that required much lower levels of sulfur to keep catalytic converters working properly. Environmental concerns for air quality drove development of both fuels. Low prices for both corn and soybeans combined with farmers' plans to invest in value-added processing led to the development of substantial processing for ethanol. Biodiesel may soon follow. National energy security concerns, united with the first two influences in provided the necessary support to get the Renewable Fuel Standard legislation passed through Congress in 2002. It will be difficult for alternative fuels of ethanol and biodiesel to replace major portions of current petroleum usage; however, blends of both fuels can certainly help fuel supplies without the difficulties of siting and building further petroleum refinery capacity. The passage of the Renewable Fuel Standard confirms that national energy policy and agricultural policy are linked as never before, especially for the next 15-20 years before substantial price reductions in fuel cell technology can lead us to other plentiful and clean energy solutions.

Endnotes

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