Bioenergy – Agricultural Issues and Outlook

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INTRODUCTION

Global interest in bioenergy production and consumption has surged over the past five years. While Brazil (ethanol) and Germany (biodiesel) have relatively more mature biofuels markets, there are other countries such as the United States, Canada, China, and India that have recently elevated bioenergy production and consumption in terms of national importance. For example, in the United States, bioenergy has gone from initially drawing support from a small number of commodity groups and some environmentalists to being counted on to:

- help lessen reliance on foreign oil imports;
- increase farm commodity prices thereby reducing commodity program expenditures;
- enhance the perception of being more environmentally conscious by using more environmentally friendly fuels; and
- enhance rural development through a dispersed bioenergy industry.

Governments around the world have enacted policies designed to encourage bioenergy production and use, and to protect bioenergy producers from international competition. Some countries, such as the United States, have policies in place to do all three for the ethanol industry. In the short-run, it can be argued that some encouragement is needed to develop a new industry through government policies, as well as policies that are designed to protect a new industry from international competition. However, in the

Table 3.1: 2006 ethanol production for all uses for selected countries.

	Millions of liters	Millions of gallons
Brazil	16,998	4,491
US	18,376	4,855
China	3,849	1,017
India	1,900	502
France	950	251
Russia	647	171
South Africa	386	102
UK	280	74
Saudi Arabia	197	52
Spain	462	122
Thailand	352	93
Germany	765	202
Ukraine	269	71
Canada	579	153
Poland	250	66
Indonesia	170	45
Argentina	170	45
Italy	163	43
Australia	148	39
Japan	114	30
Pakistan	91	24
Sweden	114	30
Philippines	83	22
South Korea	61	16
Guatemala	79	21
Cuba	45	12
Ecuador	45	12
Mexico	49	13
Others	1124	297
Total	51,056	13,489

Source: Renewable Fuels Association.

long-run, the cost of production will determine whether or not bioenergy can be viewed as a viable energy alternative.

Bioenergy production is generally perceived in a positive light by the public. However, there are many industry observers who wonder whether the industry will crumble if the price of oil declines or if the government reduces/eliminates the blenders' tax credits. The answer is – it depends. Knowing what the price of oil is only gives you part of the information needed to address this question. One also needs to know the bioenergy costs of production, especially feedstock costs. For example, in May 2006 the price of corn in the US was roughly one-half of the May 2007 price – nearly $4 per bushel. There will likely be combinations of low and high oil prices and feedstock costs that result in profits or losses for the bioenergy sector, with or without government support. This chapter attempts to shed some economic insight into these questions for the NAFTA countries and other important countries in the Americas. To understand the likely economic consequences, we first provide some background on the two primary biofuels[1] (ethanol and biodiesel).

STATUS OF ETHANOL AND BIODIESEL

Ethanol

Table 3.1 presents annual ethanol production data for 2004 to 2006 (for all uses, not necessarily transportation fuel) of the major producers in the world. Brazil and the United States are by far the largest producers while Canada and Mexico have been minor players up to this point. Before addressing the current situation in the NAFTA countries, it may be helpful to have a better understanding of the situation in the country with the most advanced ethanol industry in the world – Brazil.

Brazil While most of the world is initiating new ethanol research and development programs, Brazil already has a long and successful history with biofuels. This experience started in 1975, after the first oil shock, with the establishment of a National Ethanol Program or Programa Nacional do Alcool (Proalcool) for the particular purpose of reducing oil imports. Brazilian ethanol production has been based on sugarcane processing with coordinated efforts between the cane and biofuels sectors. These were the primary determinants of the program until the mid 1980s when 95 percent of the automobiles sold in the country were exclusively fueled by ethanol.[2] Brazil managed to establish an efficient and coordinated production and consumption system. This was not a trivial task since it involved a harmonic development of appropriate engine technology, increased sugarcane and ethanol production capacity, and the very challenging task of establishing a continental infrastructure and logistics system for distribution.

However, the convergence of three factors: 1) dropping oil prices in the international market; 2) the end of tax incentives for producing and purchasing vehicles that run on ethanol; and 3) the ethanol supply crisis of 1989, led consumers to switch back to vehicles powered by gasoline.

[1] Biofuels are fuel for transport derived from biological sources (e.g., agricultural).

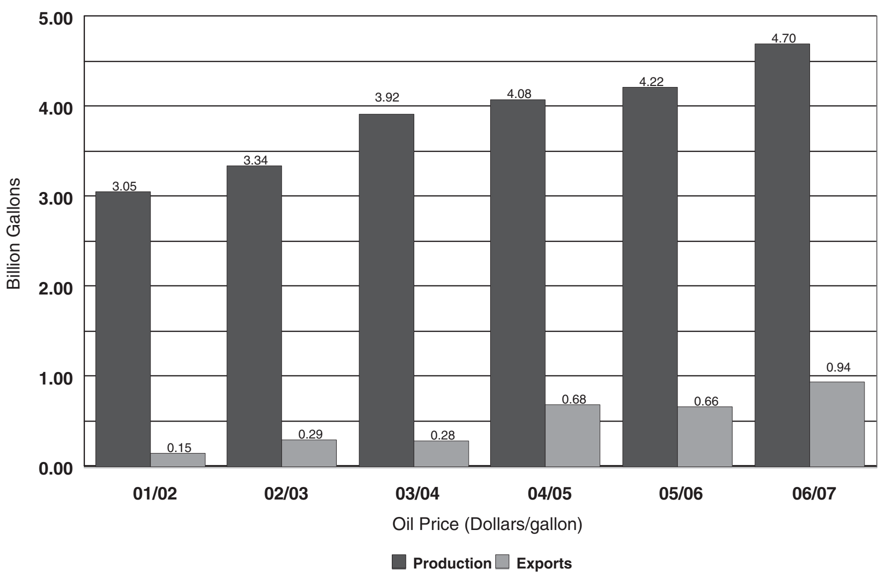
[2] Brazil produces two types of ethanol: 1) hydrated ethanol which is used in cars adapted to be fueled exclusively by ethanol; and 2) anhydrous ethanol which is mixed with gasoline to obtain gasoline C, which can contain a maximum of 25 percent of anhydrous ethanol.

As a consequence of the relative price change, the Brazilian ethanol fuel program underwent a major setback in the 1990s. By 2001, the production of vehicles fueled only by ethanol was almost completely phased out and consumers were back to vehicles fueled by gasoline.

Despite all of these changes, ethanol fuel consumption was sustained in Brazil through a 1994 law that mandated all gasoline in the country should contain 20 to 25 percent anhydrous ethanol. This kept Brazilian cane producers from redirecting all of their production to sugar. In March 2003, flex-fuel vehicles that run on either ethanol or gasoline (or a combination of these) started to be produced and sold to Brazilian consumers. This was the cornerstone of a new phase for the Brazilian fuel ethanol program. With flex-fuel cars, Brazilian consumers have the ability to choose the fuel combination that offers a relatively better price. More specifically, consumers are allowed to choose between filling their car with hydrated ethanol or with gasoline C, composed of 25 percent anhydrous ethanol, or a combination of the fuels, according to their relative fuel prices.

Although ethanol is currently distributed throughout Brazil, applied research has shown that in general, ethanol consumption has been concentrated near production units, particularly in the State of Sao Paulo, which is the most important producer of the Center South region

Figure 3.1: Brazilian ethanol production and exports, 2001/02 – 2006/07.



Source: UNICA (2007).

(Agencia Nacional de Petroleo). In addition, research conducted to better understand Brazilian domestic markets and fuel consumption of flex fuel car owners has indicated that there is still not a very well defined pattern in fuel usage (Ibope). Only 17 percent of flex-fuel car owners use a mix of ethanol and gasoline. About 25 percent alternate between using gasoline or ethanol and 57 percent use only one type of fuel.

Despite its peculiarities, domestic consumption of Brazilian ethanol is much higher than its exports. Figure 3.1 shows that in 2006/07 about 80 percent of total ethanol production was consumed internally.

The capacity of the market to absorb fuel ethanol in the coming decades will determine Brazil's potential to maintain its current advantages, both in domestic and foreign contexts. So far, the domestic market has absorbed a much higher portion of ethanol production than foreign markets. In fact, building global markets for ethanol has been one of the greatest challenges for Brazilian producers and policy-makers involved in cane, sugar, and ethanol production.

The participation of flex-fuel vehicles in total car sales has increased substantially and gained extra strength, particularly after the 2005 international oil price increase. Car producers in Brazil have indicated that since 2005, for every ten vehicles sold in the country, seven were flex-fuel (Unica 2005). Sales of flex-fuel cars were 82 percent of the total number of vehicles sold in the country in 2006, and are expected to increase to 88 percent in 2007 and 90 percent between 2007 and 2013. In addition, it is important to note that 90 percent of flex-fuel vehicles are located in states where the price parity between ethanol and gasoline favors the use of the former. It is expected that through time, 85 percent of flex-fuel vehicles in these states will exclusively use ethanol as fuel (Unica 2007).

Canada Canada has a small but growing ethanol industry of around seven plants with an annual production capacity near 599 million liters (158 million gallons). There are also two plants under construction that will boost production to 839 million liters (222 million gallons) by the end of 2007. The industry has a target output of 2.74 billion liters (0.72 billion gallons) by 2010. The Canadian ethanol industry utilizes corn and wheat as feedstocks in their plants. Ethanol costs of production in Canada are comparable to corn-based ethanol plants in the United States, and as such, their profits are currently being squeezed with the higher corn and wheat prices (AAFC 2006b). Canadian and US corn prices are almost identical, so their ethanol costs of production from corn should also be very close (AAFC 2007a). Canada is also home to Iogen, which makes ethanol from wheat straw in a cellulosic conversion process[3] in a demonstration plant.

The Canadian government recently announced C$2 billion in new incentives for renewable fuels consisting of C$1.5 billion over seven years for ethanol and biodiesel producers and a C$500 million fund for commercialization of next generation renewable fuels technologies. There is also a government regulation requiring five percent renewable content in gasoline and two percent renewable content in diesel fuel by 2010 (Canadian Renewable Fuels Association). The five percent regulation is expected to result in a medium-term increase in biodiesel output to a level of 300 to 400 million liters (79 to 106 million gallons) which is significantly higher than current industry output of 95 million liters (25 million gallons). There are federal excise tax exemptions of C$0.10/liter (C$0.38/gal.) of ethanol blended with gasoline and C$0.04/liter (C$0.15/gal.) for biodiesel. In addition, several provinces have fiscal incentives for renewable fuels (AAFC 2006a).

Mexico Mexico has just recently started examining and debating the merits of alternatives to fossil fuels. The Mexican Government has become increasingly interested in developing their biofuels capacity because they see it as a way to reduce political pressure related to a number of agricultural commodities, particularly corn and sugar, in light of the upcoming full implementation of NAFTA in 2008 (USDA FAS).

Mexico produced 80 million liters (13 million gallons) of ethanol (ethylic alcohol) in 2006 from sugarcane. Ethanol produced in Mexico is not presently used for fuel purposes but by the chemical, alcoholic beverage, and pharmaceutical industries. Currently Mexican consumption of ethanol for these uses is 165 million liters (44 million gal.), thus Mexico imports the remaining volume needed, mainly from the US, Brazil, and recently China (USDA FAS).

According to Mexico's Ministry of Energy, there is currently no specific biofuels promotion program in the country (F.O. Licht 2006). The National Energy Plan of 2001-2006 goes the furthest towards defining a national strategy by mandating that the state-run electricity generation firm, Comision Federal de Electricidad is to produce at least 1,000 mega-watts of energy from renewable sources by 2006.

Due to the recent interest in ethanol, the Mexican Government has decided to analyze the true potential of biofuels and other alternative sources of energy (F.O. Licht 2007). The Mexican Congress has also gotten involved

[3] Cellulosic or cellulose ethanol is identical in molecular structure to grain-based ethanol. The difference is that cellulosic ethanol uses the non-food portion of renewable feedstocks such as cereal straws and corn stover (Iogen Corporation 2005b).

in this debate. Two laws are proposed which would establish the legal framework under which the Ministry of Energy will define its strategy for biofuels and other sources of energy. The first is a law regarding the use of renewable sources of energy, which includes the creation of a trust fund that will allow renewable energy sources to reach eight percent of national electricity generation by 2012. The second is a law concerning the development and promotion of biofuels, which initially stated that gasoline should include a minimum of ten percent ethanol blend, but that was deemed by the petroleum industry as nearly impossible to comply with in the short-term. Thus, in the current version under discussion, the percentage requirement has been replaced with a "gradual phase-in" mechanism. Both of these proposed laws have been brought up for vote in Congress and are currently going through amendments.

According to Chavez, Nawn, and Martinez, the Mexican Customs Administration (Aduana Mexico) refers to traded ethanol as "ethyl alcohol." There is no equivalent to the US Harmonized Tariff Code (HTC) 9901.00.50, which defines ethyl alcohol or mixture of ethyl alcohol to be used as fuel or in producing fuel. Ethyl alcohol imports face a mixed tariff of 10 percent ad valorem plus $0.36 per kilogram.

Chavez, Nawn, and Martinez report estimates of total potential ethanol capacity of 7.95 billion liters (2.1 billion gallons), of which, 5.7 billion liters (1.5 billion gallons) would come from corn and the remainder from sugarcane. However, it is worth mentioning that this calculation which was meant for scientific purposes implies that all available resources would be devoted to ethanol production. This is, of course, not feasible for Mexico.

United States The US ethanol industry initially began to take shape in the late 1970s producing what was then called "gasohol" in response to a doubling of oil prices to nearly $30 per barrel. As a result of crude oil prices rising to nearly $40 per barrel in the early 1980s, the industry expanded rapidly and by the middle 1980s, there were an estimated 170 plants producing approximately 1.51 billion liters (400 million gallons) per year (Vander Griend). However, by July 1986, the price of oil retreated back to $10 per barrel and the gasohol industry collapsed as costs were not competitive with gasoline at lower oil prices. Few stayed in the industry, but those that did began focusing on decreasing production costs. By the late 1990s, the costs of production (primarily due to larger plants realizing scale economies, reduced enzyme costs, and higher corn to ethanol conversions) for ethanol were competitive with gasoline. It should be noted that the blenders' tax credit remained in place throughout the 1970s and 1980s, providing about the same amount of incentive now as was provided some thirty years ago.

Table 3.2: 2006 ethanol production for all uses for selected countries.

Country	Millions of litres	Millions of gallons
Brazil	1,641.6	433.7
Costa Rica	135.9	35.9
El Salvador	145.7	38.5
Jamaica	252.8	66.8
Trinidad & Tobago	93.9	24.8
Total	2,472.7	653.3

Source: Renewable Fuels Association.

There are well over 100 ethanol plants in operation in the United States, with around 50 more supposedly under construction. The US ethanol industry has been expanding as fast as plants can feasibly be built. Over the past year, as corn prices nearly doubled, some of the proposed ethanol plants have dropped their plans and/or put them on hold (Renewable Fuels Association). Most industry observers realize the Renewable Fuels Standard (RFS) contained in the Energy Policy Act of 2005 will not be a constraint since it will be reached ahead of schedule. There are a number of proposals in the US Congress that would significantly increase the mandated amount of ethanol used in the United States. These measures would provide additional growth signals for the industry.

Rest of the Americas Other than dehydration plants which operate under the Caribbean Basin Initiative (CBI), there is limited ethanol production in the rest of the Americas. The CBI allows a Caribbean country to dehydrate ethanol from Brazil and sell in the United States without paying the 14.27 cents per liter tariff ($0.54/gallon). Table 3.2 contains the imports into the United States, by exporting countries from 2002 to 2006. Discussed below are countries where there have been published reports of significant ethanol production activity and/or investments.

In Argentina, the Congress approved a biofuels law on 19 April 2006, aiming to promote the use and production of biodiesel, ethanol and biogas (Renewable Fuel News 2006b). Only small-scale biofuels suppliers are currently in production, but large suppliers are under development. A program of tax incentives, including a 15-year exemption from the country's tax on diesel fuel, is being offered to spur the development of the industry. Beginning 1 January 2010, the government will mandate five percent use of biodiesel and ethanol in all diesel oil and gasoline consumption. Currently, the addition of ethanol to gasoline is permitted by law up to a five percent blend without an indication at the pump and up to a 12 percent blend with indication at the pump (Renewable Fuel News, 2006b). Projected gasoline consumption in 2010 is 1.1 million liters (0.3 billion gallons) which would require 55,000 liters (14,500 gallons) of ethanol. Argentina produces ethanol mainly from sugarcane. Total ethanol production in 2006 was 170 million liters (45 million gal.) (table 3.1).

In Bolivia, small scale ethanol plants are currently in production using sugarcane as the feedstock (F.O. Licht 2006). In July 2005, the government approved a law allowing up to 25 percent ethanol blends in gasoline. The law is incrementally phased-in initially allowing ten percent blends, increasing to 25 percent blends over the next five years.

In Colombia there has been a mandated ten percent ethanol blend added to gasoline in metropolitan areas, which accounts for 60 percent total gasoline consumption (Renewable Fuel News, 2006a) since July 2005. Five sugarcane-based ethanol facilities are currently in production with an approximate total output of 367 million liters (97 million gal.).

Paraguay has blended ethanol with gasoline since 1982 (Renewable Fuel News, 2006a). Currently, a maximum of 18 percent ethanol blend is permitted. A new law under consideration considers a mixture of five percent biodiesel content in diesel and 25 percent ethanol content in gasoline (Renewable Fuel News, 2006a). Paraguay's President Nicanor Duarte said that domestic ethanol production will reach 114 million liters (30 million gal.) in 2007, up from 53 million liters (14 million gal.) last year. State oil company Petropar will purchase 38 million liters (10 million gal.) of ethanol this year to mix with gasoline (Renewable Fuel News, 2006a).

Biodiesel

Table 3.3 presents the 2005 annual production of the major biodiesel producers in the world. Biodiesel production largely has been located in Europe, with Germany by far the largest producer in the world.

Canada Only three years ago, there was no Canadian biodiesel production or industry. As the industry develops, Canadian biodiesel plants will primarily use canola and soybean oil as their feedstocks. Canadian production of biodiesel is slowly coming on stream with annual production estimated to reach 95 million liters (25 million gal.) in 2006-2007 (AAFC 2006a). Agriculture and Agri-Food Canada indicates that to date, most of the biodiesel manufactured in Canada has been exported to the United States.

With limited supplies of yellow grease and tallow available in Canada, expansion of the biodiesel sector is going to be dependent on available supplies of canola and soybean oils. Just as in the United States, increased

Table 3.3: Biodiesel production for selected countries in 2005.

	Millions of liters	Millions of gallons
Germany	1,921	507
France	557	147
United States	284	75
Italy	227	60
Czech Republic	136	36
Austria	85	22
Spain	84	22
Denmark	80	21
Poland	80	21
United Kingdom	74	20
Brazil	70	18
Australia	57	15
Sweden	7	2
Other Countries	102	27
World	**3,762**	**994**

Source: F.O. Licht (2006).

oilseed production will happen if producer returns are higher for oilseeds than for feed or food grains. If the two percent mandate is put in place, it will create the demand for 360 million liters of biodiesel (95 million gal.) per year in Canada (AAFC 2006a).

Mexico Due to the recent interest by Mexico in biofuels, the biodiesel industry has not yet been developed. The only information currently available for biodiesel production is an agreement that ITESM University and Energeticos, a private fuel company signed to produce biodiesel from animal fats and oils and to use the resulting fuel in buses used by ITESM's student transport system (Masera et al.). In July 2005, a small plant with a potential output of one million liters (265,000 gal.) of biodiesel per month was inaugurated. This plant, whose products are still being tested, is currently producing between 492,000 and 606,000 liters (130,000 and 160,000 gal.) per month, and all the biodiesel produced is used in buses.

The potential biodiesel production in Mexico, if all available resources are used only for this purpose, is 281 million liters (74 million gal.) (Masera et al.). The main feedstock sources would be avocado (231 million liters or 61 million gal), coconut (26 million liters or seven million gal.), soybeans

(23 million liters or six million gal.), and sunflower (one million liters or 300,000 gal.).

United States The US biodiesel industry has been experiencing rapid growth increasing from only two million liters (500,000 gal.) per year in 1999 to 284 million liters (75 million gal.) in 2005. As of January 2007, there were 105 biodiesel plants in the US (National Biodiesel Board). Traditionally the industry was composed of relatively small plants (less than 39 million liters or ten million gallons per year). Over the past two years, there have been numerous announcements of larger plants (more than 114 million liters or 30 million gallons per year) to begin construction. The rapid growth experienced over the past the past eight years appears to be slowing as vegetable oil prices have increased significantly pressuring plant margins.

In the future, the pressure on plant margins is expected to intensify as relatively higher margins for corn production in the United States will continue to cause a decline in soybean acreage. There are a number of studies that indicate that plants will operate below capacity due to reduced profitability (FAPRI; Caldwell).

Brazil There are major differences between ethanol and biodiesel in Brazil. Besides being a relatively new priority (the National Program for the Production and Use of Biodiesel was only created in 2003), the industry has characteristics and objectives quite distinct from ethanol. In 2005, the Brazilian government implemented a law that established minimum percentages of biodiesel mix to diesel oil as well as the monitoring of the introduction of this new fuel in the market.

The law established three periods for market development:

1. 2005 to 2007: The law permits two percent of biodiesel to be added to all diesel oil consumed in the country. This represents a potential market of 840 million liters (222 million gal.) per year. However, it is not mandated.
2. 2008 to 2012: The two percent allowed in the first period becomes mandated, creating a market of 1 billion liters (264 billion gal.) per year for biodiesel.
3. Beyond 2013: The law establishes a mandated five percent addition of biodiesel to diesel consumed in the country. Expectations are that this will represent a market of 2.4 billion liters (635 million gal.) per year.

Currently, biodiesel production is not competitive with petroleum diesel in Brazil. It is believed that the establishment of some type of incentive such as federal tax incentives is needed.

Rest of the Americas Unlike ethanol production which has been concentrated in Brazil and the United States, biodiesel production is underway throughout the Americas. Listed below are several countries where there have been published reports of significant biodiesel production activity and/or investments.

In Argentina, biodiesel is produced primarily from soybeans. Argentina's ten biodiesel plants can produce up to 68 million liters (18 million gal.) per year. American firms Cargill and Bunge plan to invest an estimated $1.5 billion constructing biodiesel plants in Argentina. The Seattle, Washington based company, Imperium Renewables, will be building a 379 million liter (100 million gal.) plant (Stephens). Moreover, in early February of 2007, Argentine President Kirchner signed an executive order to create a national biofuel law designed to make Argentina a biodiesel exporter. Kirchner put a low five percent export tax on biofuels, compared with a 24 percent export tax on soybean oil.

Ecuador is a major producer of palm oil. EarthFirst Americas, Inc. has shipped palm oil-based biodiesel to the US since late 2005 (F.O. Licht 2006).

In El Salvador, Bio Energía S.A., a subsidiary of the state-controlled investment fund, Corporación Salvadoreña de Inveriones (Corsain), launched production at its $2.5 million biodiesel plant in the Valle de Zapotitlán. The plant, which has the capacity to handle 28,000 tons of raw materials per year, will initially process imported palm oil from Guatemala (F.O. Licht 2007).

In Honduras, two biodiesel plants are currently in production with an output of 3.7 million liters (966,000 gal.) per year. African palm is the feedstock used by these plants. About 75 percent of production is self-consumed by producers, while the remainder is commercialized as automotive fuel for buses in the capital, Tegucigalpa. Biofuels specifications are being revised by the Central American Customs Union (CACU) (F.O. Licht 2007).

In Panama, Houston-based Texas BioDiesel is reported to have under construction a 379 million liters (100 million gal.) a year biodiesel plant. This plant is expected to use palm, mustard seed, and other vegetable products supplied by local farming cooperatives (F.O. Licht 2007) as feedstocks.

In Paraguay, the state oil company, Petropar, plans to invest three to four million dollars to produce 102,000 liters (27,000 gal.) of biodiesel (F.O. Licht 2007).

The Peruvian Cabinet recently approved a bill mandating a two percent biodiesel blend starting in 2009, being increased to five percent in the following year, and a seven percent ethanol blend mandate starting in 2010. The proposal will now be sent to a congressional commission before the final voting (F.O. Licht 2007).

ECONOMICS OF ETHANOL AND BIODIESEL

As indicated earlier, in the long-run, the relative costs of production between biofuels such as ethanol and biodiesel will determine whether they are legitimate alternatives to gasoline and diesel produced from petroleum oil. The following is a review of the latest cost of production estimates developed by the authors of this chapter, as well as those from other published research. It should be noted that the majority of the available research on costs of production is for plants operating in the United States.

Ethanol

The primary feedstocks used to produce ethanol are grains (corn, grain sorghum, and wheat) and sugar cane. The process of making ethanol from grains has evolved such that the grain (especially corn and grain sorghum) to ethanol conversion rate has risen while conversion costs have declined over the past decade.[4] Brazil has nearly perfected the process of converting sugar cane to ethanol over the past 30 years. Ethanol yields per acre are higher for sugar cane based ethanol than any other currently available feedstock. Around the world, scientists are racing to develop a low cost process to convert the cellulose from biomass to ethanol. While viewed as the future of ethanol production, it is discussed here because it will have a profound impact on the structure and viability of the current biofuels industry.

Grain Ethanol costs of production using grain will vary from country to country depending on variables such as grain transportation costs, natural gas prices, and the level of technology adopted. In the US, plant development has transitioned into a cookie cutter approach for new plants that are approximately 379 million liters (100 million gallons) per year dry mill plants. In other countries, such as Canada, the grain-based ethanol industry utilizes corn and wheat as feedstocks. Over the past few

[4] Those new to the area may wish to view the extensive set of presentations given at four conferences on bioenergy coordinated by the Farm Foundation at their website: www.farmfoundation.org.

months there has been an announcement of a grain-based ethanol plant for biofuels production potentially being constructed in Mexico, however, to the authors' knowledge, this has not happened.

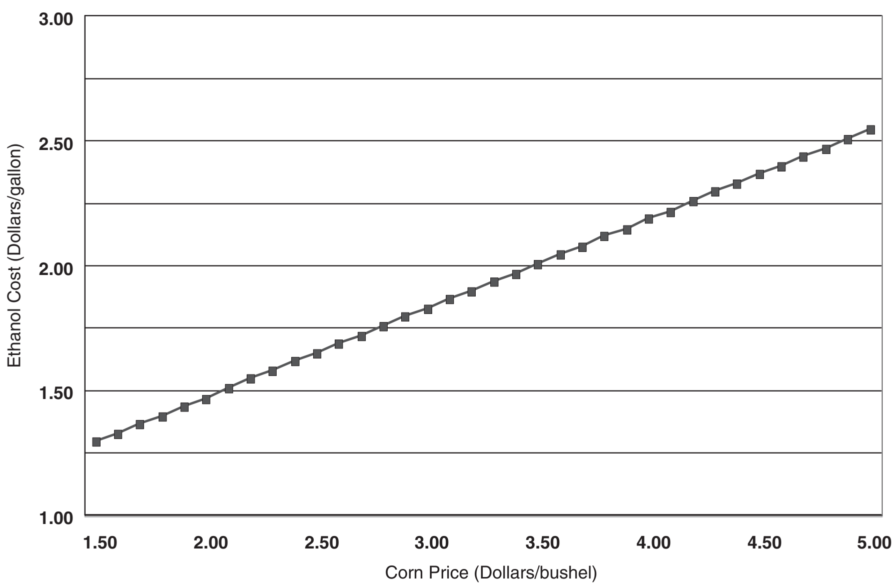
Figure 3.2 shows the estimated relationship between the feedstock cost in dollars per bushel of corn and the cost of ethanol produced in dollars per gallon. The cost of ethanol (measured on the vertical axis) does not reflect the credit for distillers dried grains with soluables (DDGS)[5] sales.

Table 3.4 contains a detailed breakout of per liter and per gallon costs of corn-based ethanol. As indicated, the price of corn makes up more than two-thirds of the cost of ethanol production. The other significant cost component is natural gas. The cost of ethanol increases around \$0.07 per liter or \$0.25 per gallon for each \$1 increase in the price of corn as long as DDGS prices maintain their normal relationship with corn prices (Eidman).

Richardson et al. estimate that the total costs of ethanol production are \$1.81 per gallon (\$0.48 per liter) in 2007 with a corn price of \$2.99 per

[5] Distillers dried grains with solubles is the product obtained after the removal of ethyl alcohol by distillation from yeast fermentation of a grain or a grain mixture by condensing and drying at least three-fourths of the solids of the resultant whole stillage by methods employed in the grain distilling industry (Iowa Corn).

Figure 3.2: Ethanol cost of production given changes in feedstock cost.



Source: Author's calculations.

Table 3.4: Estimated costs for a 50 million gallon per year dry mill ethanol plant, 2006.

	$/liter	$/gallon
Corn [a]	4.13	1.09
Enzymes	0.15	0.04
Yeast and chemicals	0.08	0.02
Denaturant	0.19	0.05
Natural gas	1.06	0.28
Electricity	0.19	0.05
Labor	0.11	0.03
Maintenance and repairs	0.11	0.03
General services and administration	0.23	0.06
Depreciation	0.49	0.13
Interest	0.26	0.07
Total	7.00	1.85

Source: Urbanchuk.
[a] Corn costs $3.01/bu assumed.

bushel. With an average ethanol price estimated at over $2.10 per gallon ($0.55/liter) and a $0.35 per gallon ($0.09/liter) credit for DDGS sales, the plant has an expected profit of $0.64 per gallon ($0.17/liter) without any consideration of the blenders' tax credit. Other researchers have estimated similar ethanol costs, with the primary difference being the corn price at the time of the study (Eidman; Urbanchuk; Shapouri and Gallagher; Tiffany and Eidman).

There are limits to the amount of grain that can be used to produce ethanol. For example, if the entire US corn crop were used to produce ethanol, it would only represent 15 percent of US gasoline needs (Felmy). The feed and food industries, as well as our export customers, would be subjected to significant shortages and higher prices in the short-run. In the longer-run, the US would likely lose customers and nearly all of its cost advantages in livestock production. This is the primary reason most industry observers feel that, to make a meaningful dent in energy needs, cellulosic ethanol is what is needed.

Sugarcane Ethanol is being produced from sugar cane in a number of countries such as Brazil and India. Table 3.5 indicates Ribera et al.'s estimates of Brazilian and US ethanol production from sugar cane. Chaves stated that the cost of production in 2005 was $0.89 per gallon ($0.24 per liter) with the exchange rate of three Real per US dollar. However, due to the depreciation of the US currency against the Brazilian Real to around 2.20 Real per US dollar in 2006, the cost per gallon has increased to $1.22 ($0.32 per liter). The estimated total cost of production per gallon of ethanol from sugarcane in the US is $1.87 ($0.49 per liter) (Ribera et al.), assuming it costs $17/ton ($15.42 per metric tonne or MT) for cane.

Table 3.5: Estimated costs of production of sugarcane-based ethanol.

	Brazil[a]		US	
	$/liter	**$/gallon**	**$/liter**	**$/gallon**
Sugarcane cost	0.22	0.84	0.25	0.95
Administrative and processing costs	0.10	0.38	0.12	0.47
Capital and other costs			0.12	0.45
Total cost	0.32	1.22[b,c]	0.49	1.87

Source: Ribera et al.
[a] Chaves
[b] Excludes capital costs.
[c] Cost of production was $0.89/gallon ($0.24/liter) with an exchange rate of three Real/$ in 2005.

Due to the US sugar price support program, cane for sugar production is worth around $24/ton ($21.77/MT), thus making sugarcane-based ethanol unable to compete with sugar production.

The US numbers should be viewed with some care as there is currently no sugarcane-based ethanol in the United States. There are relatively few other estimates of cost of production for sugarcane-based ethanol. A recent USDA/LSU study showed the lack of economic feasibility to convert raw and refined sugar into ethanol in the US (Shapouri et al.). However, the costs of production cited above convert sugarcane juice and/or molasses into ethanol, not raw and/or refined sugar.

Cellulosic Depending upon who is being quoted, cellulosic ethanol is anywhere from three to ten years away from cost competitive commercial production (Khosla; Dale). Currently there is only one cellulosic ethanol plant in operation. Iogen Corporation (2005a) has a demonstration plant in Ottawa, Ontario that uses wheat, oat, and barley straw as its feedstock. The plant is designed to produce up to three million liters (793,000 gal.) of ethanol annually. As indicated earlier, a number of companies located in countries around the world are rapidly moving toward commercial-scale plants. For example, Abengoa which has grain-based plants located in Spain and the United States is reportedly going to begin producing cellulosic ethanol in Spain during 2007. In addition, Dedini, a Brazilian enterprise, which is one of the largest sugar mill and ethanol refinery builders in the world, has developed a process to convert bagasse into ethanol.

Current cost estimates of commercial-scale cellulosic ethanol production in the United States are in the neighborhood of $2.50 per gallon ($0.66 per liter) with the expectation that within five years, costs would decline to around $1.20 per gallon ($0.32 per liter) (Dale).

There are a number of scientific breakthroughs that are needed to bring down the cost of converting cellulose to ethanol. Other cost factors that get less attention but are equally important are the logistics and transportation costs associated with collecting, transporting, and storing the biomass feedstock. Considerable research is needed to reduce these costs and develop a workable system for handling large quantities of biomass. One alternative that seems to be getting some attention is module builder type equipment patterned after cotton handling equipment. Once the biomass has been harvested, modules could be built, like in cotton, for easy delivery to the ethanol plant.

Biodiesel

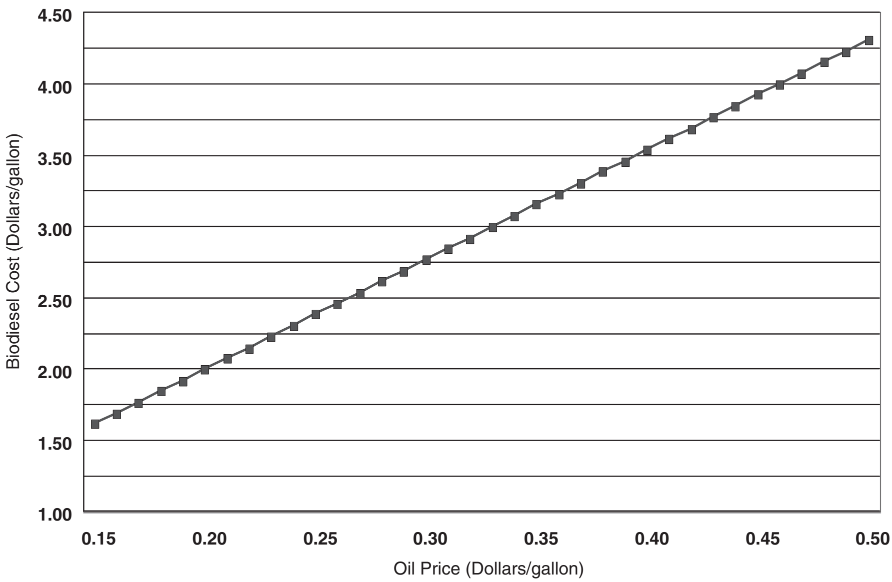
The primary feedstocks that are currently used to produce biodiesel are vegetable oils and animal fats such as chicken fat, beef tallow, and lard. Used cooking oil is also collected and processed into biodiesel and this activity has the added benefit of using a waste product to produce a biofuel rather than potentially becoming a biohazard if not disposed of properly. While the biodiesel industry is in its infancy in the Americas, it is a mature industry in Europe. The process of making biodiesel, which is called transesterification, is basically the same around the world. In the process, glycerin is separated from the fat or vegetable oil leaving behind methyl esters (the chemical name for biodiesel) and glycerin.

The primary differences in biodiesel production and costs from plant to plant are the costs of the feedstocks and the quality of the biodiesel from various feedstocks. Feedstock costs represent two-thirds of the cost of biodiesel production. Different feedstocks yield different biodiesel quality. For example, canola is believed to be a superior feedstock to other vegetable oils. Palm oil, which has been relatively inexpensive, has poor cold weather properties.

Unlike the ethanol industry, there does not appear to be as many areas where the costs of production can be greatly reduced with technology advancements. One major area of concern for biodiesel producers is the development of "renewable diesel" by oil refiners using refining-type technologies (hydrotreating) (Caldwell). The renewable diesel produced by hydrotreating can be produced in the same facilities that are producing petroleum diesel which give economies of scale and are fungible with petroleum-derived diesel. Currently, renewable diesel qualifies for the blenders' tax credit that was provided to biodiesel.

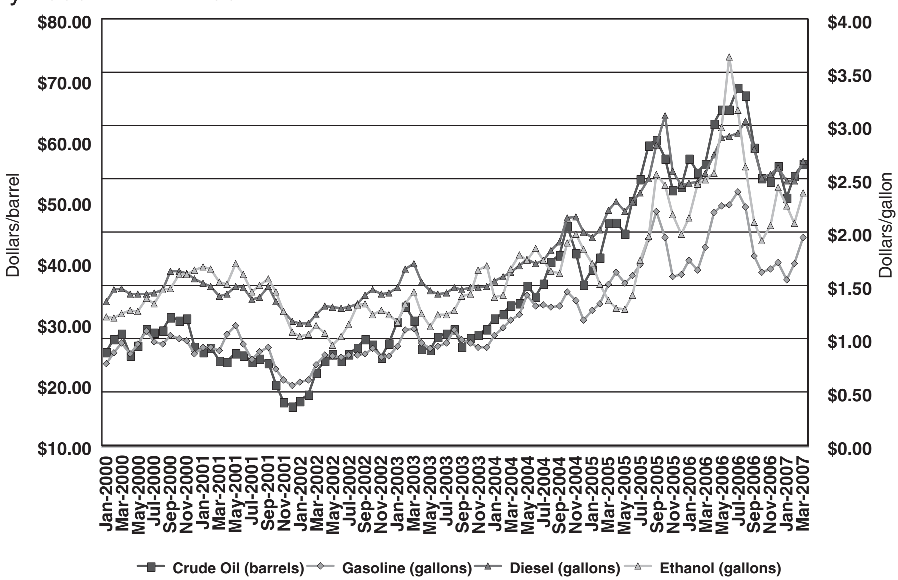
Oilseeds Canola, soybean oil, and, to a limited extent, cottonseed oil are the primary feedstocks in the NAFTA countries. It is estimated that close to 90 percent of the biodiesel processed in the United States uses

Figure 3.3: Biodiesel cost of production given changes in feedstock cost.



Source: Author's calculations.

Figure 3.4: US Prices of Crude Oil, Regular Gasoline, #2 Diesel, and Ethanol, Monthly, January 2000 - March 2007.



Source: U.S. DOE, EIA.

Table 3.6: Estimated costs for a ten million gallon per year biodiesel plant using soybean oil as the feedstock, 2006.

	$/litre	$/gallon
Soybean oil[a]		2.48
Catalyst		0.03
Methanol		0.12
Utilities		0.06
Labor		0.06
Transportation		0.05
Maintenance and repairs		0.01
General services and administration		0.05
Depreciation		0.06
Interest		0.02
Total		2.94

Source: Fortenbery.
[a] Soybean oil costs of $0.33/lb. assumed.

soybean oil as the feedstock. This primarily reflects availability and cost. When comparing vegetable oil prices, soybean oil has historically been the lowest cost and most available in the United States as it traditionally was a secondary product with the soymeal being the product with the greatest demand. The emerging biodiesel industry has increased the demand for vegetable oils in general which has led to higher soybean oil prices due to its use as a biodiesel feedstock. Vegetable oil prices have increased more than $0.10 per pound ($0.22 per kg) over the past year which has greatly reduced the economic viability of plants using vegetable oils as the feedstock.

Figure 3.3 shows the relationship between the feedstock cost in dollars per pound of oil and the cost of biodiesel in dollars per gallon. The estimated costs per gallon of biodiesel for a small scale plant are contained in table 3.6. Feedstock costs represent $2.48 per gallon ($0.65/liter) or 84 percent of the $2.94 per gallon ($0.78/liter) cost of production with a $0.33 per pound ($0.73/kg) soybean oil price. Again, other studies differ based on assumed feedstock costs but are generally in the same area (Eidman; Paulson and Ginder).

Animal Fats and Waste Grease Animal fats and waste grease have historically been priced at roughly one-half the cost of vegetable oils. As vegetable oil prices have increased, so have the prices of animal fats and to a lesser extent, waste grease. Smaller-scale biodiesel plants tend to have more flexibility in shifting between feedstocks than larger plants. In light of recent soybean oil price increases, biodiesel producers have begun blending cheaper animal fats and waste grease (when available) with relatively high-priced vegetable oils to reduce feedstock costs.

RELATIONSHIP WITH THE BROADER ENERGY MARKET

In order to determine whether biofuel plants will remain profitable in the future, it is important to understand biofuel's relationship with the broader oil market. Figure 3.4 illustrates the strong positive relationship between gasoline, diesel, and ethanol prices (all measured on the right axis) and the acquisition costs of crude oil (measured on the left axis). One phenomenon that quickly jumps out is the large increase in ethanol prices during the summer of 2005 that is attributed to the unanticipated phase out of MTBE as a summer oxygenate. While the graph helps explain trends, a more meaningful analysis is needed to see the actual statistical relationship between prices. The following simple equations were estimated by the authors to provide more insight into the price relationships, but not to predict or forecast fuel prices because these relationships may not hold in the future.

(1) Monthly Ave. Price of Gasoline in $/Gal. = $0.0917 + 0.0311 * Price of Crude Oil/Barrel

(2) Monthly Ave. Price of Diesel in $/Gal. = $0.4499 + 0.0378 * Price of Crude Oil/Barrel

(3) Monthly Ave. Price of Ethanol in $/Gal. = $0.5206 + 0.0310 * Price of Crude Oil/Barrel

The R^2 goodness of fit measures for the US gasoline and diesel equations were 0.96 and 0.97, respectively. The R^2 for the estimated ethanol equation was 0.72 or roughly 72 percent of the variability in ethanol prices can be explained by the variability in crude oil prices. This indicates that there are other factors such as government policies (i.e., the Renewable Fuel Standard and tax credits) affecting ethanol prices other than its role as a gasoline extender. Using these simple equations, the estimated gasoline, diesel, and ethanol prices are presented in table 3.7 for a range of crude oil prices. Ethanol prices are higher than gasoline prices at all oil prices because in the US ethanol is not priced on a Btu basis, but as a gasoline additive to replace MTBE.

At current feedstock prices, even with the excise tax credit in the United States, biodiesel producers will not cover costs at crude oil prices much below $50 per barrel. There have been studies that indicate that ethanol is currently selling at a slight premium to gasoline in the United States on a Btu basis (Tokgoz et al.) and the economic situation is much better for ethanol. Ethanol will cover its cost of production given current feedstock prices with oil below $40 per barrel with the excise tax credit and around $50 per barrel without the excise tax credit. All this holds

Table 3.7: Estimated prices of gasoline, diesel, and ethanol for various crude oil prices.

Crude Oil	Gasoline		Diesel		Ethanol	
$/barrel	$/l	$/gal	$/l	$/gal	$/l	$/gal
30.00	0.27	1.03	0.42	1.58	0.38	1.45
40.00	0.35	1.34	0.52	1.96	0.46	1.76
50.00	0.44	1.65	0.62	2.34	0.55	2.07
60.00	0.52	1.96	0.72	2.72	0.63	2.38
70.00	0.60	2.27	0.82	3.10	0.71	2.69
80.00	0.68	2.58	0.92	3.48	0.79	3.00

Source: based on authors' analysis.

assuming that the price relationship between ethanol and gasoline doesn't change abruptly.

TRADEOFFS – FOOD, FUEL, AND FEED

As ethanol production began taking off over the past five years, livestock organizations in the NAFTA countries voiced their concerns that a short crop would cause their sector considerable economic difficulty. Their angst has increased considerably over the past eight months as feedgrain prices have nearly doubled. Most recognize that at least in the short-term there will be losses for livestock producers (Collins). However, there are representatives of the ethanol industry that feel there is no need for any policy changes that would result in slowing the rate of growth in the industry (Jennings).

FUTURE OF THE INDUSTRY IN 20 YEARS

The future for bioenergy in general and biofuels specifically appears bright. One reason for this optimism is that governments around the world are embracing ethanol and biodiesel as an initiative with the potential:

- to help lessen reliance on foreign oil imports;
- to increase farm commodity prices thereby reducing commodity program expenditures;
- to enhance the perception of being more environmentally conscious by using fuels that are generally referred to as more environmentally friendly; and
- to enhance rural development through a dispersed bioenergy industry.

The capacity to spread the advantages and gains expected from the bioenergy boom within a large number of countries is becoming one of the greatest concerns for policy-makers. Some countries do not have (and have strong restrictions to develop) the productive capacity required to benefit substantially from higher feedstock prices. However, consumers in these countries could benefit from lower fuel prices. Time will tell who the winners and losers will be. As with many technologies, early adopters will possibly reap the greatest benefits while those slow to embrace low-cost technologies will likely fall behind. It must be stressed, however, that those countries currently producing (and consuming) ethanol understand that the best strategy is to concentrate their efforts to stimulate fuel ethanol adoption within a large number of other economies. This would allow the consolidation of an international market for the product increasing the probability of gains by early adopters and those that already dominate the technology.

However, at this point there is no clear leader. Brazil has led in ethanol production and with a very low cost of production. Brazil might be able to maintain its competitiveness only if the new technologies and options for biofuel production introduced are compatible with its production process.

Currently, cellulosic technology seems to be the alternative with higher potential to come on line to increase biofuel production capacity. When this happens, the one thing that is certain is that those governments willing to invest in technologies will be giving their industries at least the advantage of being early adopters.

For Brazil, the introduction of cellulosic technology increases the potential to sustain its leading position, for several reasons. It has logistical advantages for exploring cheap feedstock at the mill. In addition, it has been identified as one of the few countries with the capacity to increase production due to land and water availability. This could further increase its competitiveness due to gains related to scale of production.

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