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16. Abstract

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Evaluation and Analysis of Texas Biofuel Supply Chains Originating in The United States Midwest and Brazil

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ABSTRACT

This 2009 study, funded by the Southwest Region University Transportation Center, investigates competing ethanol supply chains terminating in the State of Texas. Midwest corn ethanol and Brazilian sugarcane ethanol constitute two sources of the biofuel necessary for synthesis of the ten percent ethanol, ninety percent gasoline fuel blend, commonly referred to as E10. The updated 2007 Renewable Fuel Standard passed by Congress and signed into law by President George W. Bush in December 2007, promotes national availability of E10. As a follow up to the 2008 Bioenergy and Alternative Fuels Scoping Study, this report discusses the requisite equipment, time, and costs to transport ethanol to the Lone Star State from its Midwestern or Latin American sources. Federal biofuels policy along with new transportation technology, such as pipeline movement of renewable fuels, will largely determine whether domestic or international ethanol is more economically competitive in six Texas fuel markets. If Congress chose to repeal the $0.54 per gallon domestic ethanol offset tariff, sugarcane ethanol pipelined inland from the coast could be more competitively priced than the corn variety as far west as the El Paso metropolitan area.

EXECUTIVE SUMMARY

Former President Bush's strategy for reducing petroleum consumption called for expanding renewable fuel sources. The U.S. renewable fuel standards (RFS) represented the centerpiece of this plan. In December 2007, the RFS were significantly increased and now stipulate 20.5 billion gallons of renewable fuel by 2015 and 36.0 billion gallons by 2022. The bioenergy and alternative fuel scoping study conducted for the Southwest Region University Transportation Center during FY 2008 cited biofuels as the most commercially viable renewable energy alternative during the next decade. Corn ethanol currently dominates the U.S. biofuels market but has significant drawbacks including:

- Scientific sources question whether ethanol derived from corn is truly energy positive. Studies suggest the energy required to synthesize the fuel exceeds the energy released when ethanol is combusted in vehicle engines.
- The Midwest corn ethanol industry exhibits significant market externalities. During the last two years ethanol conversion has come to demand up to 15 percent of the entire annual U.S. corn harvest. As a result, the supply of corn for human and animal feedstock has declined and inflated the commodity price of corn. As late as summer 2008, corn traded above $7 per bushel. Critics not only cite ethanol for raising the price of corn but also contributing to overall price inflation of food staples. The current 5-7 percent increase in food prices is causing economic hardship in the U.S. and potential food shortages in the industrializing world.
- Once manufactured, corn ethanol faces infrastructure problems that largely limit the fuel's availability outside the Midwest Corn Belt. These logistical issues have greatly impeded the development of a national biofuel industry capable of offsetting transportation petroleum consumption to even a small degree. Eighty percent of the U.S. populace resides in coastal regions and currently cannot fully benefit from E85 and other biofuel alternatives.

In addition to corn ethanol's drawbacks, the updated 2007 RFS caps corn ethanol's contribution to the overall renewable fuel mandates at 15.0 billion gallons after 2015. By 2022, at least 21.0 billion gallons must come from non-corn biofuel sources. Second generation biofuels, including cellulosic ethanol, represent promising alternatives but these bioenergy sources remain in a research and development phase. Current analysis suggests cellulosic ethanol remains at least a decade away from commercial viability.

Brazilian sugarcane ethanol currently represents the most promising alternative to the corn variety. A four-parameter comparison citing lifecycle energy output, carbon emissions, land use intensity, and production costs indicates sugarcane ethanol is superior to corn ethanol in all categories. After identifying sugarcane's advantages over corn in terms of ethanol synthesis the next step involves detailing a supply chain by which Brazilian biofuel imports can service the Southwest region. These infrastructure logistics can then be evaluated using the existing, limited Midwest export capacity to Texas as a benchmark.

This domestic and international biofuel supply chain analysis supplements the 2008 scoping study enabling a truer cost comparison between the corn and sugarcane ethanol alternatives. The narrative details specific costs and time durations associated with transporting sugarcane ethanol from Brazilian biorefineries to ports, shipping the fuel overseas to Texas, and then unloading the commodity and transferring it to ground transportation at the port.

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CHAPTER 1. PERILS ASSOCIATED WITH CONTINUED RELIANCE ON PETROLEUM

The American transportation sector's overwhelming reliance on petroleum presents a host of serious issues that will require resolution over the coming decade. Oil's risks fall into three general categories: climactic/environmental, demand exceeding supply, and geopolitical security. Significant debate in recent years has focused on how significantly the burning of fossil fuels contributes to global warming. In 2007 the United Nations Framework Convention on Climate Change (UNFCCC) published its fourth in a series of reports that make a case that carbon dioxide (CO_2) and other greenhouse gases (GHG), contribute to the warming of the earth. Rising levels of CO_2 in the atmosphere and increasing temperature have spurred many nations to consider policies that curb emissions as a way of lessening further release of anthropogenic carbon into the air. The transportation of people and freight through the burning of petroleum in traditional catalytic converter engines represent a major source of GHG emissions and one that the UNFCCC argues is difficult to control.[1]

The Kyoto Protocol of 1997 represented the first global accord designed to reduce the annual amount of greenhouse gases emitted to the atmosphere. The United Nations Framework Convention on Climate Change (UNFCCC) designated countries of the world either as Annex I or Non-Annex I nations through the Kyoto Agreement. Annex I nations are the developed world, namely Europe, North America, Japan, and Australia. The industrializing countries in Latin America, Africa, and Asia constitute the bulk of Non-Annex I nations. The Kyoto Protocol establishes different requirements on Annex I versus Non-Annex I countries. On average Annex I states are required to reduce their emissions five percent below their respective 1990 levels during the first commitment period (2008-2012) or face emissions penalties. In contrast Non-Annex I countries only have to report their respective emissions.[2]

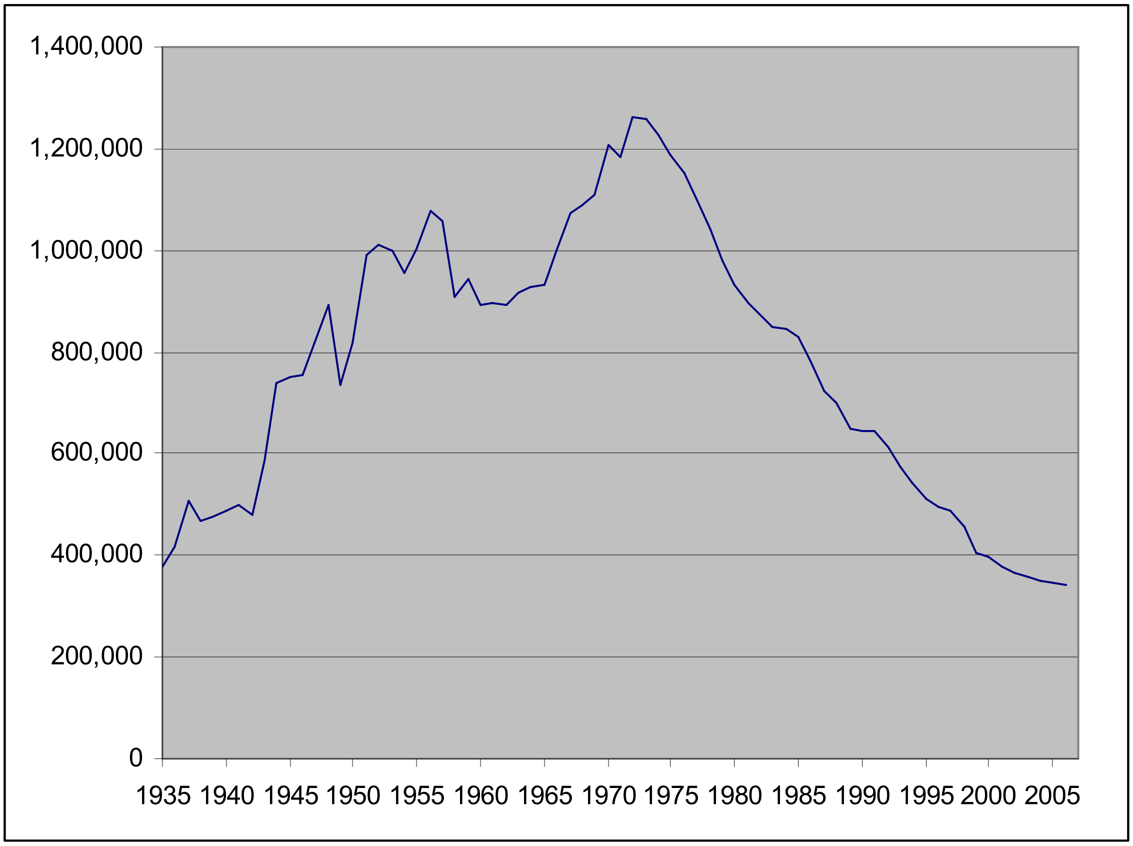
The United States is the last Annex I country to sign but not ratify the Kyoto Protocol.[3] Citing flawed science, negative economic impacts, and a strong opposition to the exemptions given to developing nations, particularly India and China, President George W. Bush declared that the U.S. would work outside the protocol to decrease greenhouse gas emissions by making voluntary reductions in GHG intensity.[4] Kyoto critics within the U.S. have argued that not only would the accord negatively affect the economies of Annex I nations but its failure to curtail third world emissions would mean that increased GHGs from Non-Annex I nations would likely dwarf any GHG reductions by Annex I states. When the agreement came into force in February 2005, thirty-six Annex I countries had signed and ratified the document; Australia and the United States had signed but not ratified the document.[5] Australia has since ratified the protocol. The United States' decision not to ratify Kyoto almost a decade ago implies the U.S. need not comply with mandatory international agreements dictating reductions in net greenhouse gas emissions during the Kyoto Phase I period, 2008-2012. Despite the United States' reluctance not to adhere to the terms and conditions of the original Kyoto Protocol, the U.S. has begun to move toward compulsory carbon reduction. Signs include a more proactive American delegation helping to draft Kyoto Phase II guidelines at the December 2007 UN Climate Conference in Bali, Indonesia, as well as agreements like the Regional Greenhouse Gas Initiative (RGGI), an accord among northeastern states to cut carbon emissions. Energy sector participants suspect the new administration of President Barack Obama may have the moral capital to institute carbon reduction schemes, such as a cap-and-trade system.

While fossil fuel combustion has negative environmental consequences, the depletion of easily accessible oil reserves worldwide may be the underlying factor that eventually mandates transition to an alternative fuel economy. The rampant economic growth of the People's Republic of China (PRC) over the past twenty years largely explains the significant price increase of not just petroleum but most raw materials since 2000. During the first decade of the twenty-first century, the PRC has adopted a strategy of sustaining economic growth at all costs to stave off prospects of social revolt. Perhaps the mightiest challenge China must overcome concerns resource security. As of 2007, the PRC boasted the fourth-largest economy in terms of nominal gross domestic product, behind that of the United States, Japan, and Germany. The amount of energy required to spur continued growth is enormous. Despite its expansive land area, China does not have a wealth of fossil fuels to support its huge population of 1.3 billion people. China's oil and natural gas deposits in per capita terms (i.e., barrels of oil produced domestically per person) amount to only 8.3% and 4.1% of global averages, respectively.[6] Until 1993, China's domestic reserves had been sufficient to fuel its economy. However, the PRC's rapid economic expansion during the following decade caused China to surpass Japan as the world's second-largest oil consumer in 2003. In that year, total Chinese petrol consumption equated to 5.56 million barrels per day (mbd). More importantly, the PRC imported approximately two-thirds of this amount, totaling 3.4 mbd as of April 2004. Analysts forecast oil imports to grow to approximately 8.8 mbd by 2020.[7]

China and other developing nations are increasingly competing with the United States for a finite petroleum supply. The majority of the world's crude oil is derived from the sedimentation of algae that thrived in ancient seas during periods of excessive global warming between 90 and 150 million years ago.[8] These reserves will eventually be depleted given rates of petroleum extraction far exceed the millions of years required for the geologic transition from organic matter to oil. "Peak oil" is the point in time when the maximum rate of global petroleum production is reached, after which the rate of production enters its terminal decline. If global consumption is not mitigated before the peak, an energy crisis may develop because the availability of conventional oil will drop and prices will rise, perhaps dramatically. M. King Hubbert first used the theory in 1956 to accurately predict that U.S. oil production would peak between 1965 and 1970. His model, now called Hubbert peak theory, has since been used to predict the peak petroleum production of many other countries, and has also proved useful in other limited-resource production domains. According to the Hubbert model, the production rate of a limited resource will follow a roughly symmetrical bell-shaped curve based on the limits of exploitability and market pressures. Currently, much debate concerns when the world's peak oil will occur. Optimistic longer-term projections cite the 2020s or 2030s, while more dire forecasts point to the 2010 to 2015 timeframe.[9]

The post-peak oil period generally features both declining revenues for private industry, as well as a shrinking of tax income for municipality, state, and national governments that have come to rely on the region's commodities. The Lone Star State particularly understands the hardships that can ensue following peak oil. Beginning with the discovery of oil at Spindletop in 1901, technological improvements enabled Texas to increase its oil production for nearly three-quarters of a century as shown in Figure 1. However, after peaking in 1972 at 1.26 billion barrels annually, oil output steadily declined due to an exhaustion of crude deposits.[10] By 2006, oil production had plummeted 73% to less than 341 million barrels.[11] Declining oil production equates to reduced oil industry contributions to the Texas economy. Indeed, Texas' reliance on petroleum production and sales as its primary tax revenue stream forced the state government to weather several years of severe economic downturn in the early 1980s.[12] Alternative fuel proponents advocate Texas investment in renewable energies would benefit the state economically given the existing petroleum cash flow is tied to oil output, which will continue to shrink in the coming years.

Figure 1 – Annual Oil Production in Texas (in Thousands of Barrels)



Adapted from: Railroad Commission of Texas[13]

Although peak oil may be several years to decades away, petroleum needs force the United States to already become embroiled in the more volatile regions of the globe, namely the Middle East. With over one-fifth of U.S. supplies coming from the Persian Gulf region and traveling by tanker through the critically narrow, thirty-five mile wide Strait of Hormuz between Iran and Oman, any act of aggression towards an oil installation has the potential to inflate petroleum prices on international commodities markets. For example, a pirate-initiated rocket attack on a Japanese oil tanker off the coast of Yemen on April 21, 2008 caused crude oil futures to spike to a record $117.40 per barrel and the price of regular, unleaded gasoline to rise to $3.50 per gallon in the United States.[14] The growing risk of maintaining transportation sector reliance on oil incentivizes a migration to clean, alternative fuels within the United States. Texas' energy tradition suggests the state can develop a leadership role in more sustainable fuels analogous to the Lone Star State's connection to oil and gas.

CHAPTER 2. FEDERAL POLICIES TO REDUCE PETROLEUM CONSUMPTION

The risks associated with continued reliance on fossil fuels have spurred numerous federal policies aimed at reducing demand of these non-renewable resources. Legislation has promoted a variety of solutions, from enhanced fuel economy to solar power tax credits. Desired economic impacts differ depending on whether a given policy targets producers or consumers. Producer credits or subsidies intend to reduce the upstream costs associated with manufacturing more efficient vehicle engines or synthesizing new, alternative fuels. In contrast, consumer tax breaks help shield customers from higher downstream prices generally associated with newer types of technology.[15] Given the scope of this report, those policies encouraging biofuel development within the transportation sector are emphasized.

During the latest period of high oil prices that abruptly ended due to the deepening of the worldwide economic crisis in late summer 2008, the majority of legislation seeking to reduce the transportation sector's fossil fuel dependence has focused on biofuel development. Biofuels, which include ethanol and biodiesel, substitute geologic hydrocarbons with energy derived from plant matter. Fuel ethanol is produced from the fermentation and distillation of simple sugars whereas biodiesel is derived from vegetable oil, grease, and other organic solvents. From a national perspective, recent ethanol interest has primarily targeted six policy categories: alcohol fuel tax incentives, the renewable fuel standard, specialized or "boutique" fuels, ethanol imports through Caribbean Basin Initiative (CBI) countries, flex-fuel vehicles, and the significance of biofuels in the 2008 Farm Bill reauthorization.[16]

The energy crises of 1973 and 1979 helped to spur the development of the corn ethanol industry, centered in the Midwestern states of Illinois, Iowa, Minnesota, and Nebraska. However, with the collapse of world oil prices in 1986, petroleum remained dominant among transportation fuels and corn ethanol output grew modestly for the remainder of the twentieth century. Prior to the escalation of oil prices in 2003, domestic corn ethanol production in 2002 totaled 2.5 billion gallons, less than 3% by volume of motor vehicle gasoline supplies in the United States.[17] Before the Energy Policy Act of 2005, most federal ethanol programs popularized this biofuel for emissions reasons. The Volumetric Ethanol Excise Tax Credit (VEETC) provides a tax credit of up to 51 cents per gallon for "ethanol blended with petroleum up to 10%" to help areas meet local air standards as directed by the Clean Air Act of 1990.[18] Automobiles currently manufactured in the U.S. market are capable of running on a mixture of 90% petroleum and 10% ethanol, known as E10.[19] The goal is to "increase the oxygenation of gasoline," thereby reducing emissions from combustion.[20] Ethanol demand rose significantly in 2006 when twenty-seven states, including California and New York, replaced synthetic methyl tert-butyl ether (MTBE) with ethanol as an oxygenate fuel additive.[21]

Section 932 of the 2005 Energy Policy Act created a biofuels program to encourage the transportation sector to use biofuels and reduce consumption of oil as a carbon-intensive fossil fuel. The Energy Policy Act of 2005 mandated use of ethanol and other biofuels by establishing a renewable fuel standard (RFS). The RFS required the use of at least 4.0 billion gallons of renewable fuel in 2006, rising to 7.5 billion gallons in 2012.[22] Reinvigorated by new federal government incentives, the corn ethanol industry exceeded the mandate during the next two years, synthesizing 4.8 billion gallons of fuel in 2006.[23] To further promote biofuel development, the Energy Independence and Security Act of 2007, signed by President Bush on December 19, 2007, increased the RFS, calling for 9.0 billion gallons of renewable fuel in 2008, steadily rising to 36 billion gallons by 2022 as reflected in Table 1. It is worth mentioning the current deepening U.S. recession has reduced American consumption of gasoline. The ten percent of gasoline by volume ceiling imposed on U.S. ethanol calls into question whether producers will attain the higher RFS ethanol targets for 2009 and 2010.[24]

Table 1 – Expanded Renewable Fuel Standard Requirements

Year	Previous RFS (billion gallons)	Expanded RFS (billion gallons)	Advanced Biofuel Mandate (billion gallons)[a]
2006	4.0		
2007	4.7		
2008	5.4	9.0	
2009	6.1	11.1	0.6
2010	6.8	12.95	0.95
2011	7.4	13.95	1.35
2012	7.5	15.2	2.0
2013	7.6 [b]	16.55	2.75
2014	7.7 [b]	18.15	3.75
2015	7.8 [b]	20.5	5.5
2016	7.9 [b]	22.25	7.25
2017	8.1 [b]	24.0	9.0
2018	8.2 [b]	26.0	11.0
2019	8.3 [b]	28.0	13.0
2020	8.4 [b]	30.0	15.0
2021	8.5 [b]	33.0	18.0
2022	8.6 [b]	36.0	21.0

a. The advanced biofuel mandate is a subset of the expanded RFS. The difference between the expanded RFS and advanced biofuel mandate, 15 billion gallons in 2015 onward, is an effective cap on corn ethanol.

b. Estimate

Adapted from: Congressional Research Service[25]

Perhaps more significant was the 2007 renewable fuel standard's declaration that only a percentage of the required biofuel would come from the traditional corn variety. Critics of corn ethanol, a "first generation" biofuel, had argued synthesis of this alternative fuel is energy neutral or even energy negative, meaning energy required to produce ethanol exceeds the energy gained through its use. The 2007 Energy Security Act declared by 2022 60% of the mandated biofuel would be of the second generation variety.[26] Much of the initiative focuses on the research and development of so-called "second-generation" biofuels. This category includes biodiesel (a cleaner, organic equivalent of higher mileage diesel fuel) and ethanol derived from cellulosic biomass such as switchgrass and other plant varieties that require less water and fewer soil nutrients. Laboratory tests suggest second-generation biofuels are decidedly energy positive and lower in net carbon emissions compared to corn ethanol, though cellulosic ethanol has yet to be commercially processed within the U.S.[27]

The relatively high financial price of developing corn ethanol further weakens this domestic fuel industry. Ethanol prices in other countries, namely Brazil, are significantly lower than in the United States due to lower production costs. In terms of international competition, the United States exerts a protectionist policy. The U.S. offsets its domestic ethanol tax incentives by subjecting ethanol imports to a 2.5% ad valorem tariff. In December 2006, Congress further regulated the market by adding a $0.54 per gallon duty on all imports, which has since curtailed significant expansion of the overseas biofuel trade. In essence, a loophole does exist since ethanol trade with the Caribbean Basin Initiative (CBI) countries of Costa Rica, Jamaica, and El Salvador enjoys duty-free status. Non-CBI nations like Brazil can take advantage of this opportunity if fuel originating within their borders undergoes dehydration, the final production step required to make ethanol usable as motor fuel, in a CBI state prior to shipment to the U.S.[28]

Automobile fuel standards in the U.S., known as Corporate Average Fuel Economy (CAFE) Standards, were enacted by the Energy Policy and Conservation Act (EPCA) of 1975. CAFE standards were originally conceived to reduce energy consumption. However, higher CAFE standards equating to reduced vehicle GHG emissions proved a subsequent benefit. The EPA and the National Highway Traffic Safety Administration (NHTSA) oversee the standards for light trucks and cars and determine the average fuel economy. Currently, the standard for passenger cars in the U.S. is 27.5 miles per gallon (mpg). This has been at the same level for over two decades. Standards for light trucks were recently tightened for vehicles made between 2005 and 2007, from 20.7 mpg to 22.2 mpg.[29] On December 19, 2007, President Bush signed legislation that would increase CAFE standards to an average of 35 mpg by 2020. New passenger cars are not subject to the updated standards until the 2011 models. Light trucks must average 24 mpg by 2011. Sport utility vehicles and passenger vans, currently not covered under the CAFE standards, will be subject to the new rules for the first time in 2011.[30] Specifically, by 2011, manufacturers will be required to meet new fuel efficiency standards based on the vehicles size or “footprint”, which is equal to the wheelbase times the track width. Vehicles with larger footprints will be required to meet higher targets and vice versa.[31]

EPCA and subsequent amendments provide manufacturing incentives for alternative fuel automobiles, including flex-fuel vehicles (FFV), which can operate on a mixture of ethanol and gasoline up to 85% ethanol, known as E85. A manufacturer, such as General Motors or Ford, earns credits toward meeting CAFE standards with each alternative fuel vehicle produced.[32] As a result, the popularity of flex-fuel vehicles has grown markedly in recent years with 2007 estimates of approximately six million FFVs on American roads, primarily in the Midwest. Prior to the current recession, domestic auto makers anticipated increasing their numbers of FFVs to ten million by 2010 and having flex-fuel cars constitute 50% of their production lines by 2015.[33] Critics of FFVs complain that car companies receive credits for flex-fuel vehicles even though these dual fuel vehicles typically operate solely on gasoline due to the limited availability of E85 and other biofuel blends. The Energy Information Administration (EIA) supports these claims citing only about 2% of dual fuel vehicles currently use E85 on a regular basis. Motor companies contend the FFV CAFE incentives are necessary for the production of flex-fuel vehicles and that alternative fuel infrastructure will grow to meet the FFV demand over the coming decade.[34]

The 2008 Farm Bill Reauthorization, passed by the 110th Congress in May 2008, included provisions to expand and extend certain provisions associated with the development of cellulosic energy production in an attempt to transition from the older corn ethanol technology. In a related bioenergy program, the U.S. Department of Energy offered to subsidize construction of biorefineries nationwide, providing up to $100 million for a single refinery that manufactures transportation fuel substitutes for petroleum-based feedstock products.[35] Despite these incentives, development of the cellulosic ethanol market has stalled in early 2009 due to the severe recession.[36]

CHAPTER 3. TEXAS PETROLEUM REDUCTION TRANSPORT POLICIES

The State of Texas, unlike the RGGI and WCI states, has not established policies regarding global warming or the mitigation of greenhouse gases despite the fact Texas is the largest state source of greenhouse gases in the United States. Indeed, the Lone Star State emits more carbon dioxide than many countries, including Canada and the United Kingdom.[37] As of 2007, Texas' sole venture toward mitigation of GHG emissions in state transportation was a research and development plan still under investigation. The idea behind the research involves distance-based vehicle insurance, where car insurance payments would be based on the mileage that people drive versus a fixed rate determined by liability risks alone. In theory, increased insurance costs would discourage travel, thereby decreasing gasoline consumption and GHG emissions.[38]

With its traditional adherence to free market principles, Texas state government has been reluctant to embrace the tax credits and subsidies favoring producers, which are offered by other states as a way to court the biofuel industry. From a consumer standpoint, the state does exempt the biofuel portion of a diesel fuel blend from the fuel use tax. For example, biodiesel blends with diesel such as B20 (20% biodiesel) enjoy a reduction of 20% of the tax on a normal gallon of regular diesel fuel.[39]

Two attempts by the state legislature to increase the attractiveness of Texas as a location for biofuel companies are noteworthy. In response to the Energy Policy Act of 2005, the 77th State Legislature directed the State Energy Conservation Office (SECO) to accelerate the development of hydrogen fuel cells within Texas. Hydrogen fuel cells are electrochemical conversion devices that combine the elements hydrogen and oxygen into molecular water and in the process generate electricity. SECO's efforts created the Fuel Cell Initiative Advisory Committee (FCIAC) to further investigate the feasibility of hydrogen fuel. This initiative also included efforts to convince the U.S. Department of Energy to build one of two national biofuel research centers in Texas.[40] In April 2008, the Energy Department agreed to contract with Oak Ridge National Laboratory in Tennessee; the Great Lakes Bioenergy Research Center, led by the University of Wisconsin-Madison and Michigan State University; and the Lawrence Berkeley National Laboratory in California.[41]

Texas currently has one codified biofuel tax incentive program, but stopped funding the initiative in October 2007. The Texas biofuels incentive provided a subsidy of $0.20 per gallon for Texas biofuel producers. In order to participate in the program, producers were required to send $0.035 per gallon to Texas state government to ensure producers were not just profiteering off the subsidy, but were instead assisting in the long term development of a renewable biomass energy industry within Texas. This legislation resulted in a net gain of $0.165 per gallon for Texas biofuel companies. The Texas Department of Agriculture was the agency most involved in the evolution of the biofuels incentive. Ironically, administration of the subsidy was originally placed in the Governor's office under the Tourism Department. A bill passed during the 2005 legislative session moved the incentive program to the Agriculture Department, which had expressed enthusiasm toward developing and promoting biofuels. The biofuels incentive convinced a number of companies to proceed with plans to build biodiesel plants within Texas. Considering this subsidy was only funded for two years, the legislation did not factor as significantly with ethanol producers' strategic plans given the longer time horizons associated with ethanol plant development. The economies of scale explain why biodiesel developers were more numerous in Texas than ethanol manufacturers. An average ethanol plant can generate a fuel volume of 50 to 100 mega-gallons per year,[42] which is several orders of magnitude greater than a typical biodiesel refinery's annual capacity, generally around 8 mega-gallons.[43]

The Texas biofuel incentive's source of funding largely determined its fate. Originally, money for the biofuels program was to come from "undesignated" funds within the general fund. If monies existed in the general fund that had not been earmarked for other ventures, those financial resources could be applied to the biofuels incentive up to predetermined limits. The program was authorized during the 2003 legislative session. Representative David Swinford of Amarillo, Texas was the primary proponent of the Texas biofuels incentive in the state legislature. The structuring of the program (i.e., writing of the rules) occurred early in the 2005-06 biennium, prior to the 2007 legislative session. Certain individuals believed it would be better to specify biofuel program funds via a budget line item incorporated into the Department of Agriculture's budget. The biofuels program became higher profile when viewed as a budget earmark for the Department of Agriculture. As a new item, the biofuels incentive increased Agriculture's prospective budget by millions of dollars fomenting critics to claim it was an unnecessary expense. Funding for the biofuels program became a victim of budget balancing efforts during summer and fall 2007. The increased attention garnered by the biofuels program as a potential budget item during the 2007 legislative session likely contributed to the incentive losing its popular support. The program was never "repealed" by a vote of the Texas state legislature. A handful of legislators in committee decided to cut the program's funding. The unfunded program still exists and monies could be reinstated at a later date.[44] However, prospects of the 2009 Legislature choosing to refund the mandate are essentially nonexistent given the state's projected \$3 to \$4 billion budget shortfall.[45]

Cutting off funding to the biofuels incentive may have jeopardized the Texas biofuels business climate for the longer term. Companies are not as willing to conduct operations in a state that appears capricious in its financial support of a particular industry. Biodiesel companies that had set up operations in Texas, when the incentive was actively funded and are now hurting because the subsidies have stopped, are less likely to conduct future biofuels transactions within the Lone Star State.[46]

CHAPTER 4. OVERVIEW OF BIOFUEL SOLUTIONS FOR PETROLEUM REDUCTION

Transitioning from a transportation sector fueled 96% by petroleum requires a portfolio solution. Currently, no alternative fuel or technology is sufficiently affordable or efficient to supplant oil on a one-for-one basis. A multi-faceted approach concentrating on demand management, vehicle technology innovation, and sustainable fuel generation may result in a post-2050 transport profile decidedly more heterogeneous than the monolithic, petroleum-car model of today.[47] Various studies, including an action plan developed by the University of Tennessee, stipulate renewable sources can provide 25% of the United States' energy needs by 2025 if intensive research and development efforts are made within the following four arenas: increasing renewable energy production; expanding the size of alternative energy markets; adhering to more stringent demand management and smart growth strategies; as well as increasing energy efficiency and productivity.[48]

Renewable Energy Production

Biofuel is the generic term applied to any solvent derived from organic matter that produces energy when combusted. Ethanol and biodiesel constitute the two primary biofuels commercially available.[49] Ethanol, also known as ethyl alcohol C_2H_5OH, is a clear and colorless liquid that can be readily produced by fermentation of simple sugars obtained directly from natural glucose (i.e., sugarcane) or converted from starch crops. In North America, the sugar for ethanol production is generally isolated from enzymatic hydrolysis of starch-containing crops, like corn or wheat. Although corn ethanol is an established industry in the American Midwest, the intermediate processing step required to convert corn starch to sugar makes fuel from corn less cost effective, less environmentally sustainable, and less energy efficient than ethanol techniques practiced in foreign markets like Brazil (see Chapter 5). Compared to traditional gasoline, ethanol is a clean-burning fuel because of its high oxygen content or high octane rating. Indeed, ethanol's elevated octane rating explains why the fuel first achieved popularity as a gasoline additive designed to improve emission quality of combustion engines. Since the abolition of methyl tert-butyl ether in most regions of the United States, ethanol blended up to 10% with conventional gasoline, known as E10, has become commonplace. Traditionally, ethanol-gasoline combinations higher than 10% ethanol have required special engine retrofits and therefore have not been commercially viable within the U.S. E10's restriction of ethanol volume to ten percent that of gasoline consumed essentially functions as an "ethanol wall" or upward limit for American demand of the biofuel.[50]

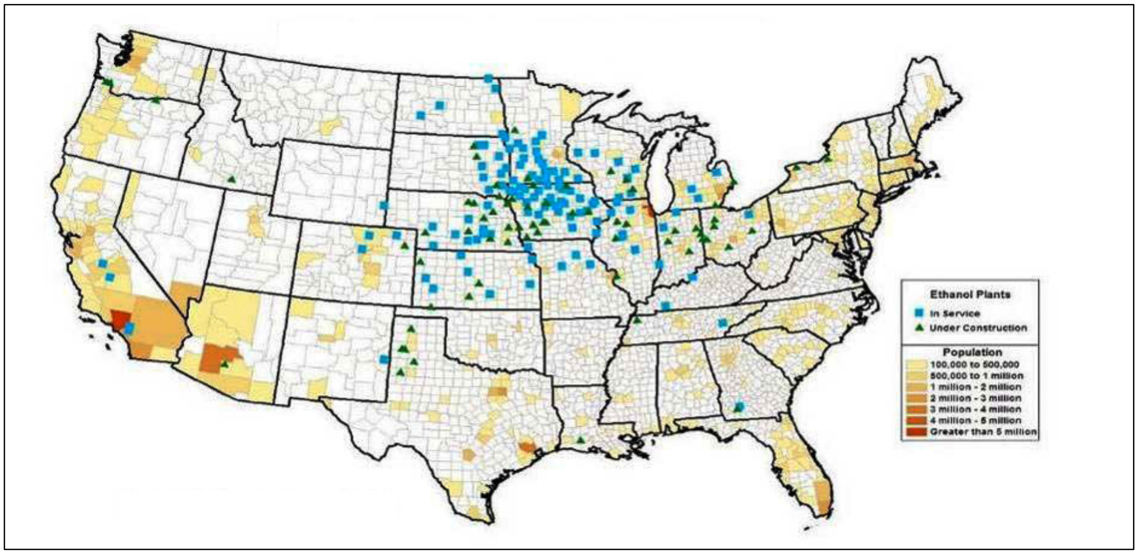
Biodiesel synthesis is accomplished by combining organically derived oils with an alcohol solvent, generally ethanol or methanol, in the presence of a catalyst to generate ethyl or methyl ester. A wide array of oils and fatty acids, including soybean oils and vegetable oil wastes (i.e., grease), can generate biodiesel. Once produced, biodiesel is blended with traditional diesel fuel in mixtures analogous to ethanol-gasoline combinations Typical blends commercially available in certain regions include B5, 5% biodiesel and 95% traditional diesel, as well as B20, 20% biodiesel and 80% regular diesel. Certain studies suggest regular diesel engines can operate on higher biodiesel blends when compared to regular combustion engines and ethanol concentrations. As a result, B20 is the commercially available biodiesel equivalent of E10. To date, the biodiesel scale of production is about an order of magnitude less than ethanol synthesis. Biodiesel's limited availability is due in part to a more complex production sequence that generally requires ethanol as an input. Additionally, supply and demand dictate diesel and biodiesel are available in limited quantities due to diesel vehicles accounting for only 10% of vehicles on American roads today.[51]

Renewable Energy Market Expansion

In order for alternative fuels to increase their market share both nationally and within Texas, the renewable energy market must undergo a significant expansion. In terms of ethanol, growing the market entails increasing the availability of biofuels beyond the Corn Belt states of the Midwest. During the first half of 2007, U.S. ethanol production totaled approximately 3 billion gallons, nearly one-third higher than the first half of 2006. As of September 1, 2007, 128 ethanol plants with a total annual capacity of 6.78 billion gallons were operating, and an additional 85 plants were planned or under construction. This figure remains the maximum capacity achieved by the ethanol industry since the economic downturn curtailed biofuel production and demand in 2008. Nearly all of the 85 biorefineries anticipated as of late 2007 have been indefinitely postponed.[52]

Figure 2 illustrates approximately 90% of production capacity is concentrated in an eight-state region encompassing Iowa, Nebraska, Illinois Minnesota, South Dakota, Indiana, Kansas, and Wisconsin. This crescent shaped area is geographically removed from population centers on the Atlantic, Gulf, and Pacific Coasts[53] accounting for roughly 80% of the country's 304 million residents.[54] Ethanol transport limitations, which will be further discussed in Chapter 6, necessitate the majority of ethanol be sold within one hundred miles of its production site. Figure 2 depicts four production sites will be located in the Texas Panhandle. The ethanol

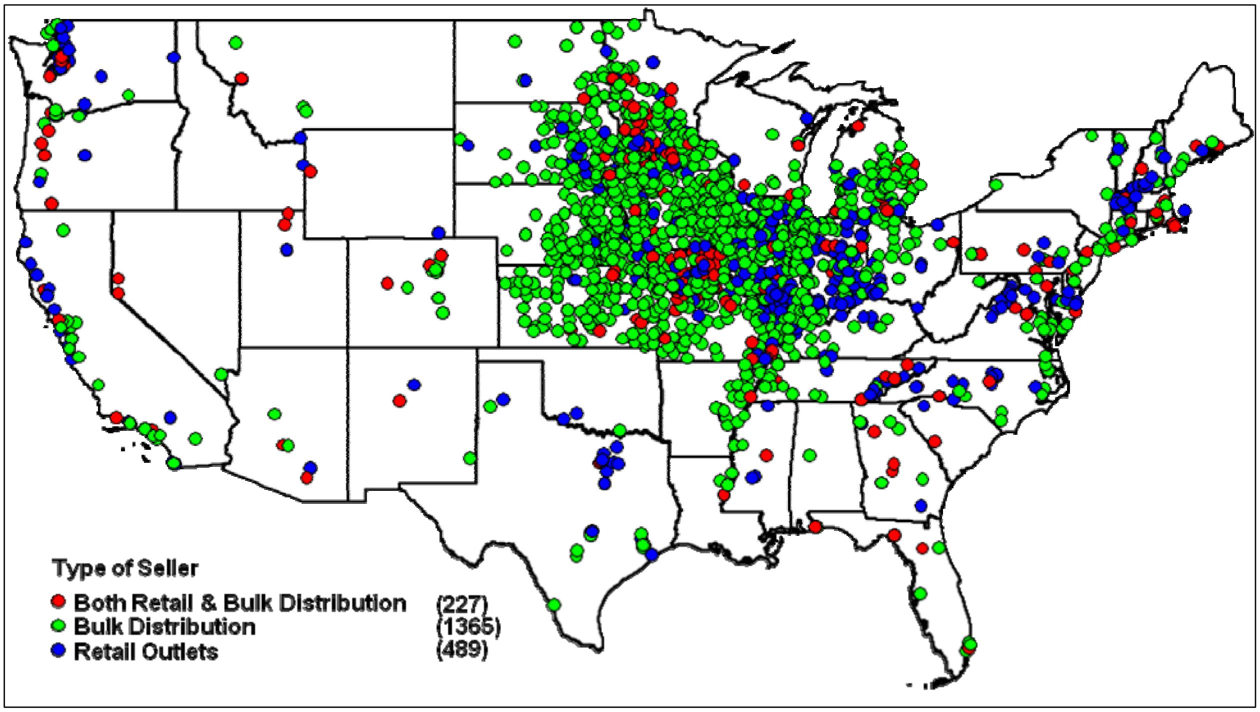
Figure 2 – U.S. Ethanol Biorefineries and Population Distribution



Source: U.S. Department of Agriculture[55] industry in Texas is centered in the state's panhandle, near the cities of Amarillo and Lubbock, where water availability is relatively scarce.

Similarly, biodiesel production and consumption are not collocated, though the problem is not as acute as it is for ethanol. Despite biodiesel synthesis from a wide variety of organic oils and greases, the ethanol ingredient has meant this biofuel is also largely concentrated in the American Midwest. Figure 3 illustrates that of the approximately 2,100 biodiesel distribution centers in the United States as of May 2006, 1,800 or about 86% are concentrated in the Midwest. The map suggests greater availability of biodiesel within Texas, particularly along the Interstate 35 corridor, which may partly be due to the Texas biofuel incentive discussed in Chapter 3.

Figure 3 – U.S. Biodiesel Distribution Locations



Source: Gulf Hydrocarbon[56]

Studies suggest the American biofuels market will grow, if the geographic separation between producers and consumers of ethanol and biodiesel can be resolved. One solution to this supply and demand problem incorporates increased international trade of biofuels. Brazil is the world's largest ethanol producer, synthesizing 17 billion liters or 4.5 billion gallons of the biofuel during the first six months of 2007. Like the United States, the origins of Brazil's modern ethanol industry stem from the 1970s energy crises. However, since its inception in 1975, Brazil's Proalcool program received greater financial backing from the country's government during the last quarter of the twentieth century. Public sector intervention on behalf of ethanol early on essentially gave Brazil's Proalcool industry a twenty-year head start when compared to the U.S.

corn ethanol sector, which floundered during the cheap oil period of the 1980s and 1990s. By the late 1990s, Brazil's ethanol industry had sufficiently grown to compete with petroleum on the open market without significant government subsidies. Ethanol is much more prevalent in Brazil than the United States, resulting in flex-fuel vehicles comprising a much larger market share in this South American country when compared to the United States. In 2006, only three years after the first dual-fuel models were introduced in Brazil, flex-fuel vehicles accounted for 78% of sales nationwide. Brazil already manufactures more ethanol than the United States, but plans to significantly increase production, reaching 40 billion liters or 10.6 billion gallons annually by 2012, to help meet burgeoning overseas demand.[57] Chapter 7 discusses the Brazilian sugarcane ethanol industry in greater depth and highlights how servicing coastal U.S. markets, like Houston, with Brazilian imports is potentially a less expensive alternative than delivering corn ethanol via rail or truck from the Midwest.

CHAPTER 5. CHARACTERISTICS OF DOMESTIC VERSUS INTERNATIONAL BIOFUELS

Biofuels, notably ethanol and biodiesel, constitute the alternative fuels most capable of facilitating a reduction in petroleum consumption within the U.S. transportation sector during the next five to ten years. Citing the energy intensity of biofuel production and the potential deleterious impacts to land and water resources, biofuel critics maintain that the characteristics of the fuel synthesis process should disqualify these biomass-derived energy sources as a partial solution to America's oil addiction. However, subsequent analysis reflects the origin of a particular biofuel largely determines its characteristics, both positive and negative. Currently, ethanol dominates the alternative fuel market and the world's most prolific ethanol producers are Brazil followed by the United States. Although both countries' production quantities are similar, the two nations derive their fuels from different sources. Brazilian and American ethanol are synthesized from sugarcane and corn, respectively. The remainder of this chapter assesses why the Brazilian sugarcane ethanol model represents a more efficient and sustainable approach to biofuel production.

Ethanol is the biofuel currently most ready for commercialization.[58] A three parameter comparison focusing on the energy budget, carbon emissions reduction, and land use of each ethanol type strongly suggests Brazil's fuel is technologically a better alternative compared to the American derivative.

Energy Return on Investment

Energy return on investment, lifecycle greenhouse gas emissions, land use, and production costs constitute four primary ways for assessing whether sugarcane or corn-derived ethanol possess greater utility. In recent years, ethanol advocates and critics have greatly politicized the energy return on investment (r_E). Numerous published papers, primarily focusing on corn ethanol, have cited the requisite energy to produce a given quantity of the biofuel ranges from a significant net gain to a minor net loss. An objective approach to describing these energy budgets first requires definition of the relevant terminology.

The energy return on investment is the ratio of thermal energy per liter of ethanol, E_{out}, shown to be a constant 23.6 mega-Joules or 5,640.4 kilocalories per liter, to the amount of nonrenewable energy required for fuel synthesis, $E_{in,nonrenewable}$. Mathematically, $r_E = E_{out} / E_{in,nonrenewable}$. The energy return on investment ratio is an ideal non-unit specific mechanism for comparing Brazilian sugarcane and U.S. corn ethanol energies, which tend to be in kcal and MJ, respectively. Nonrenewable energy includes energy allocations from all fossil fuels, plus any nuclear power input required to develop the ethanol product. Energy requirements include fuel used to power agriculture machinery used to tend corn and sugarcane crops, energy needed to synthesize fertilizer and pesticides applied to the crops, fuel necessary for harvesting the crops and transporting them to biorefineries, as well as electricity needed to power the ethanol plants. Inadequate clarification of nonrenewable fuel sources is one primary reason why different studies report variable returns on investment for ethanol. For example, some authors exclude nuclear energy from the calculation believing this fuel is an alternative or renewable source of fuel.[59]

Energy return on investment is a key indicator of how well a biofuel transfers its nonrenewable inputs into renewable energy. The larger the value of r_E, the more efficient the energy conversion. A value of 1 represents a threshold value for the energy return ratio. $r_E < 1$ implies more energy is required to synthesize a fuel than the fuel releases. Such "energy intensive" or "energy negative" biofuels yield no commercial benefit since direct use of fossil fuels has lower associated energy requirements. An $r_E > 1$, signals the energy conversion process has managed to maximize the biofuel's nonrenewable investment with its renewable energy value. Only alternative fuels harboring energy returns on investment greater than 1 are industrially viable given the energy output exceeds the input.[60]

United States corn ethanol production grew explosively during the first five years of the twenty-first century. Between 2000 and 2004, corn ethanol synthesis more than doubled from 6.2 to 13 billion liters or 1.6 to 3.4 billion gallons. Corn ethanol has represented the logical domestic counter to more expensive gasoline because a limited infrastructure already exists for this alternative fuel. Current domestic production of corn ethanol originated as a potential solution to the 1970s energy crises. By the late 1980s, technology for manufacturing corn ethanol was assumed mature and fuel studies published in 1990 or later describe contemporary, industrial-scale production. In 2006, Hammerschlag inventoried six key studies published post 1990, which reported corn ethanol's energy return on investment or a related variant. The six investigations subdivided the nonrenewable energy input into two categories 1) fuel and electricity, and 2) upstream energy. Fuel and electricity comprises fossil fuels utilized by the farmer, transporter, or manufacturing plant. Upstream energy refers to inputs used by commodity suppliers, such as fertilizer manufacturers, collaborating with the farmer or plant operator. All six studies identified energy-intensive nitrogen fertilizer as the largest contributor to upstream energy. Table 2 provides the total fuel and electricity plus the total upstream energy for the six studies. These values are added together to obtain the gross energy input. Each investigation also reported a "coproduct energy input." Most ethanol plants manufacture coproducts along with ethanol that effectively utilize a portion of the waste generated during fuel synthesis, such as corn stover. Energy earmarked for coproduct production is deducted from gross energy input to yield the net energy input for ethanol, $E_{in,nonrenew}$. The energy return on investment is tabulated by dividing the heating value of ethanol, E_{out}, by the net energy input. Five of the six investigations reported r_E values between 1.29 and 1.65, suggesting a positive return on energy investment for corn ethanol. However, the Pimentel & Patzek analysis yielded $r_E = 0.84$. This endeavor's conclusion of corn ethanol's inefficiency stemmed from several conservative assumptions other studies failed to consider, most notably an electricity-intensive manufacturing process. The five other investigations attributed a greater portion of the biorefinery power requirements coming from natural gas or petroleum versus more inefficient coal.[61] As of 2006, coal provided 49.0 percent of domestic electricity production, more than twice as much as the second largest contributor, natural gas, at 20.0 percent.[62] Prescribing a greater proportion of ethanol plant power to coal may not be as conservative as realistic. Overall, an energy return on investment assessment of corn ethanol production shows the biofuel to be energy neutral to marginally positive.

Table 2 – Results of Corn Ethanol Studies

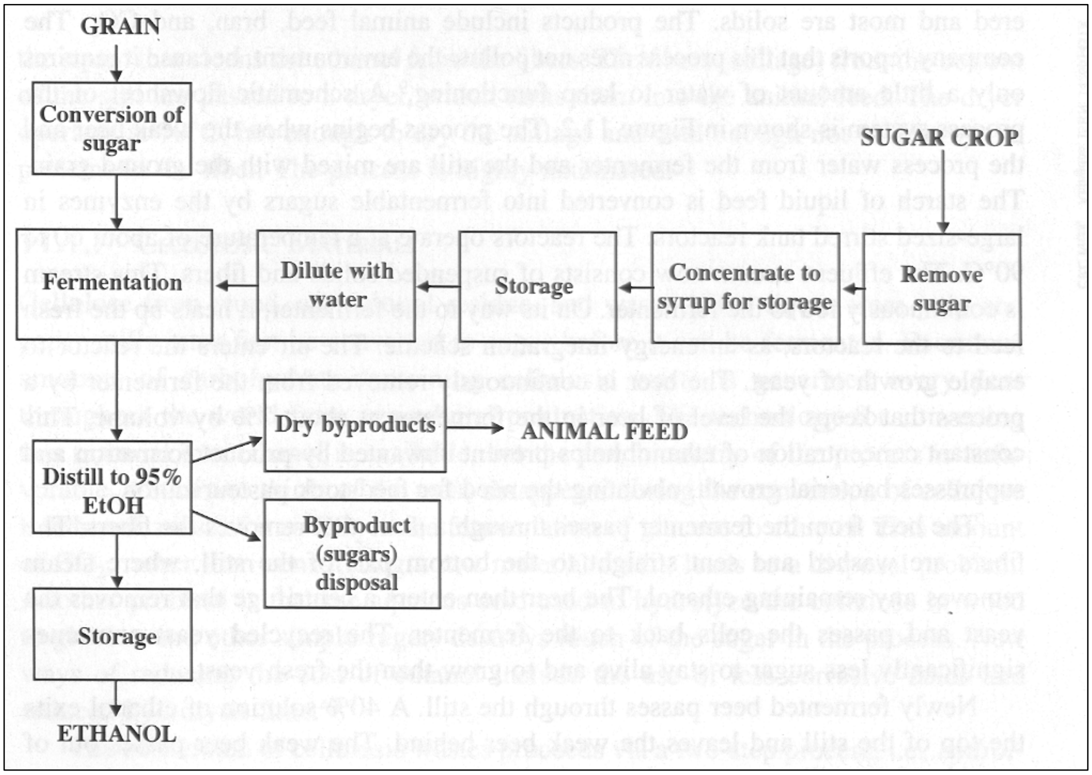
Milling technology:	**Marland & Turhollow 1991**	**Lorenz & Morris 1995**	**Graboski 2002**	**Shapouri et al. 2002**	**Pimentel & Patzek 2005**	**Kim & Dale 2005**
	all values in MJ per liter ethanol unless otherwise noted					
Agriculture	**Fuel and electricity**					
fuel	2.0	0.7	2.2	2.7	2.0	0.8
electricity	0.2	2.0	0.5	0.6	0.5	0.1
Feedstock transport		0.4	0.5	0.6	1.5	0.5
Industrial process						
fuel	10.5	10.9	11.8	10.0	11.7	12.5
electricity	3.5	3.2	2.9	3.6	5.3	2.2
Ethanol distribution			0.4	0.4		0.6
Total fuel and electricity*	16.1	17.1	18.4	17.9	21.0	16.8
	Upstream energy					
Agriculture						
fertilizer	4.2	3.6	2.6	2.3	4.7	2.0
biocides	0.3	0.3	0.2	0.4	1.3	0.4
other		0.9	0.3	0.1	3.1	0.1
Other nonagriculture					0.1	
Total upstream energy*	4.5	4.9	3.2	2.8	9.2	2.5
Gross energy input**	20.6	22.0	21.6	20.7	30.2	19.3
Coproduct energy input	-2.3	-7.7	-4.5	-3.7	-2.0	-4.8
Net energy input ($E_{in,nonrenew}$)* **	18.3	14.3	17.1	17.0	28.2	14.5
Ethanol heating value (E_{out})	23.6	23.6	23.6	23.6	23.6	23.6
Energy return on investment, $r_E = E_{out} / E_{in,nonrenew}$	**1.29**	**1.65**	**1.38**	**1.39**	**0.84**	**1.63**

Notes:
* Sums may not match due to rounding error
**Gross energy input = Fuel and electricity + Upstream energy
***Net energy input = Gross energy + Coproduct energy "credit"

Adapted from: Environmental Science and Technology[63]

Figure 4 shows inherent differences in the ethanol manufacturing process for corn versus sugarcane that lead the sugarcane derivative to have a higher return on investment, r_E. Processing Brazilian sugarcane yields glucose, a sugar-containing solution or syrup that can be directly fermented by yeast to yield ethanol. In contrast, starch feedstocks like corn must undergo a preceding step involving starch-to-sugar conversion. The starch macromolecules are first decomposed to simpler, smaller glucose units through a chemical process called hydrolysis. During hydrolysis, starch feedstocks are ground and mixed with water to produce a mash consisting of 15 to 20% starch. This mixture is then heated to boiling and treated with two enzymes. The first enzyme, amylase, hydrolyzes the starch to short-chain molecules while the second catalyst, pullulanase or glucoamylase, converts the short chains to glucose, $C_6H_{12}O_6$, through a sequence known as saccharification. The "grain conversion to sugar" step significantly increases the energy requirements of ethanol derived from corn and other grains. Following these additional steps required to refine corn, Figure 4 illustrates the remaining glucose to ethanol conversion for corn and sugarcane is identical.[64]

Figure 4 – Ethanol Synthesis from Sugar and Grain Sources



Source: Handbook of Alternative Fuel Technology[65]

Complementing the simplified chemical sequence necessary to convert sugarcane to ethanol, the Brazilian Proalcool industry holds one additional energy advantage over American corn ethanol production. The commercial processing of sugarcane generates bagasse, a fibrous pulp byproduct of the plant. Since the early 1990s, bagasse has largely replaced fossil fuel oil in the production of industrial heat and electricity in Brazil's sugar mills and distilleries. A comprehensive 2004 study undertaken by the Secretary of the Environment of Sao Paulo state, Brazil, indicated bagasse usage saved as much as 6.1 kilograms fuel oil per metric ton of sugarcane. De Carvalho Macedo, Leal, and da Silva report the more direct sugarcane to ethanol synthesis coupled with sugarcane distilleries powered by bagasse rather than fossil fuel derived electricity result in sugarcane ethanol exhibiting an energy return on investment between 8.3 and 10.2 (see Table 3). The lower r_E value of 8.3 assumes values of energy and material consumption common throughout the Brazilian sugarcane sector in 2004. $r_E = 10.2$ was achieved incorporating a "best values" approach. Best values constitute utilizing sustainable agriculture practices and modern distillery technology to minimize both material and energy consumption. A best values approach is more expensive than prevailing industrial practices. The best values methodology approximates the level of improvement the Brazilian ethanol industry can hope to attain during the next decade. In terms of energy lifecycle, Brazilian sugarcane ethanol is superior to the corn variety by nearly an order of magnitude.[66]

Table 3 – Results of Sugarcane Ethanol Studies

Activity	**Energy consumption**			
	Scenario 1* (kcal/TC)		Scenario 2** (kcal/TC)	
	Input	Output	Input	Output
Agriculture	48208		45861	
Factory	11800		9510	
Ethanol produced		459100		490100
Surplus bagasse		40300		75600
Total	60008	499400	55371	565700
r_E = Output / Input	**8.3**		**10.2**	

Notes:

* Scenario 1: Average values of energy, material consumption

** Scenario 2: "Best values" currently practiced in the sugarcane sector

kcal / TC = kilocalories / metric ton of sugarcane

Adapted from: Secretariat of the Environment, State of Sao Paulo, Brazil[67]

Lifecycle Greenhouse Gas Emissions

Differences in ethanol generation from corn versus sugarcane that lead to a marked variation in energy return on investment, r_E, similarly affect the associated greenhouse gas (GHG) emissions. Ethanol's carbon footprint only encompasses GHGs released through fossil fuels utilized in crop cultivation or fuel manufacture. Carbon released through ethanol combustion in engines is negated since scientific consensus exists that this newly freed carbon dioxide was previously sequestered in plants during photosynthesis. Hammerschlag argues that fossil fuels' carbon dioxide intensity, or CO_2 emissions per unit energy, fluctuates within a limited range. Worded differently, the greater the quantity of whatever fossil fuel required to synthesize a type of ethanol, the larger the ethanol's associated GHG emissions.[68]

Dividing the output energy by the nonrenewable fossil fuel input, a fuel's energy return on investment is inversely proportional to its carbon footprint. Extending this logic, Brazilian sugarcane ethanol, harboring r_E values nearly ten times larger than corn ethanol, will have associated greenhouse gas emissions roughly one-tenth as large as corn ethanol. Once again, the simpler, more exothermic conversion of sugarcane to ethanol combined with the innovative use of bagasse as renewable energy for alcohol distilleries implies sugarcane ethanol has a smaller carbon footprint and is more environmentally sustainable than corn ethanol.

Although corn ethanol falls significantly short of its sugarcane counterpart in terms of energy budget and residual carbon footprint, this starch biofuel's advantages over traditional gasoline should be noted. Assessing corn ethanol's utility, using the six investigations conducted between 1991 and 2005, Hammerschlag highlighted industrial inefficiencies associated with refining gasoline from crude oil cause petroleum to have an energy return on investment less than one. Prevailing literature agrees a r_E equal to 0.76 sufficiently approximates gasoline. Even Pimentel & Patzek's conservative investigation, yielding a corn ethanol r_E equal to 0.84, exceeds the petroleum parameter.

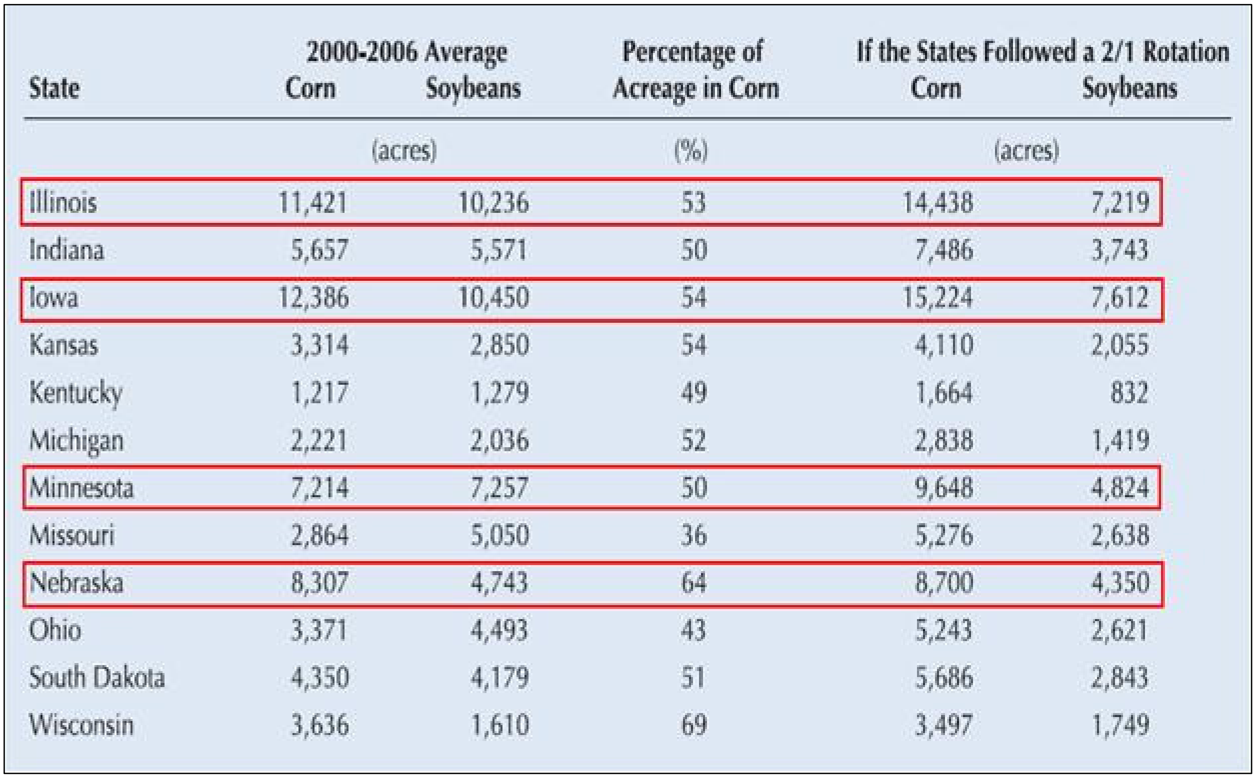
Land Use

Land utilization is perhaps the variable that most starkly portrays corn as an inferior substitute for sugarcane in terms of ethanol generation. This metric is subdivided into acreage and water requirements. Chapter 8 examines the Brazilian sugarcane ethanol supply chain highlighting how the state of Sao Paulo is uniquely situated to support the majority of Brazil's ethanol industry. In 2006, Brazil produced 17 billion liters of ethanol utilizing only 5.7 percent of its land available for sugarcane cultivation. Expansion into arable savannah in south-central regions of the country will make annual ethanol production quotas around 40 billion liters readily attainable in the next three to five years. Despite its subtropical climate, irrigation is and will continue to be critical to Brazil's ethanol sector accounting for a quarter to three-quarters of the sugarcane's water demands.

The acreage and water requirements of corn used for ethanol synthesis differ from sugarcane. Overall, sugarcane is a denser, more compact crop than corn. One hectare yields approximately 85,000 kilograms of sugarcane, which can produce 7,080 liters or 1,870 gallons of ethanol. However, the same area only supports 10,000 kilograms of corn, which translates to approximately 3,570 liters or just 943 gallons of ethanol. For corn ethanol to compete with sugarcane ethanol liter-for-liter, corn must be planted over an area nearly twice as large as sugarcane.[69] Unlike Brazil's sugarcane regions, the U.S. Corn Belt cannot support such a drastic increase in corn acreage earmarked for ethanol. Table 4 illustrates, as of 2006, the four states primarily comprising the Corn Belt--Iowa, Illinois, Minnesota, and Nebraska--already devoted at least fifty percent of their available acreage to corn. The Center for Agricultural and Rural

Development at Iowa State University predicts future increases in corn acreage will likely come from altering the corn-soy bean crop rotation ratio. Currently, most farmers alternate planting corn and soybeans year-to-year given wholesale prices of the two crops have traditionally been commensurate. Moving to a three-year crop rotation cycle, in light of the cost of corn exceeding $6.00 per bushel, will certainly decrease the supply and therefore increase the price of soybeans.[70] The significance of both corn and soybeans to the American food chain has been the focus of much recent criticism of corn ethanol. Significant expansion of corn agriculture to meet burgeoning domestic ethanol demand will likely elevate food prices, at least in the short term. The Brazilian sugarcane agronomy's ability to develop fallow land boasts fewer negative repercussions.

Table 4 – Corn versus Soybean Acreage



State	2000-2006 Average Corn	2000-2006 Average Soybeans	Percentage of Acreage in Corn	If the States Followed a 2/1 Rotation Corn	If the States Followed a 2/1 Rotation Soybeans
	(acres)		(%)	(acres)	
Illinois	11,421	10,236	53	14,438	7,219
Indiana	5,657	5,571	50	7,486	3,743
Iowa	12,386	10,450	54	15,224	7,612
Kansas	3,314	2,850	54	4,110	2,055
Kentucky	1,217	1,279	49	1,664	832
Michigan	2,221	2,036	52	2,838	1,419
Minnesota	7,214	7,257	50	9,648	4,824
Missouri	2,864	5,050	36	5,276	2,638
Nebraska	8,307	4,743	64	8,700	4,350
Ohio	3,371	4,493	43	5,243	2,621
South Dakota	4,350	4,179	51	5,686	2,843
Wisconsin	3,636	1,610	69	3,497	1,749

Adapted from: Iowa Agricultural Review[71]

While corn is a much less water intensive crop than sugarcane, the U.S. Upper Midwest is decidedly dryer than Southeast Brazil. The North Dakota State University Agriculture and University Extension cites most American varieties of corn require 18 to 22 inches or 460 to 560 mm of water during a given growing season to optimize crop yield.[72] The National Oceanic and Atmospheric Administration indicates on average Iowa, at the heart of the Corn Belt, should expect 34 inches or 860 mm of precipitation annually. However, rainfall variation year-to-year can be significant with the state receiving as little as 12 inches or 310 mm of precipitation during drought conditions.[73] The Upper Great Plains can generally support current levels of corn production. However, hydrologists contend if the ethanol industry were to significantly enlarge the amount of land dedicated to corn, the increased water demands due both to crop cultivation and ethanol plant manufacture may jeopardize the longevity of the region's groundwater table. For example, in the western reaches of the Corn Belt, such as Nebraska, intensive agriculture is drawing down the Ogallala Aquifer at levels exceeding the replacement rate by several orders of magnitude. The same worries extend southward into the Texas Panhandle, which is the Lone Star State's primary ethanol producing region. If the Ogallala, the world's largest freshwater aquifer, were depleted, then agriculture throughout the American Great Plains would suffer.[74]

In terms of energy life cycle, climate change impact, and land-use intensity, Brazilian sugarcane ethanol has a competitive advantage over the U.S. corn variety. However, a holistic market characterization of both biofuels must look beyond agriculture production dissimilarities and assess the logistical requirements of transporting and distributing each alternative fuel. Chapter 6 will describe the infrastructure limitations of biofuel transport within the United States. The prevailing modal inefficiency of the ethanol industry both limits growth of the biofuel sector and leaves open the possibility of a collaborative partnership between corn and sugarcane ethanol, which is discussed further in the Chapter 7 case studies.

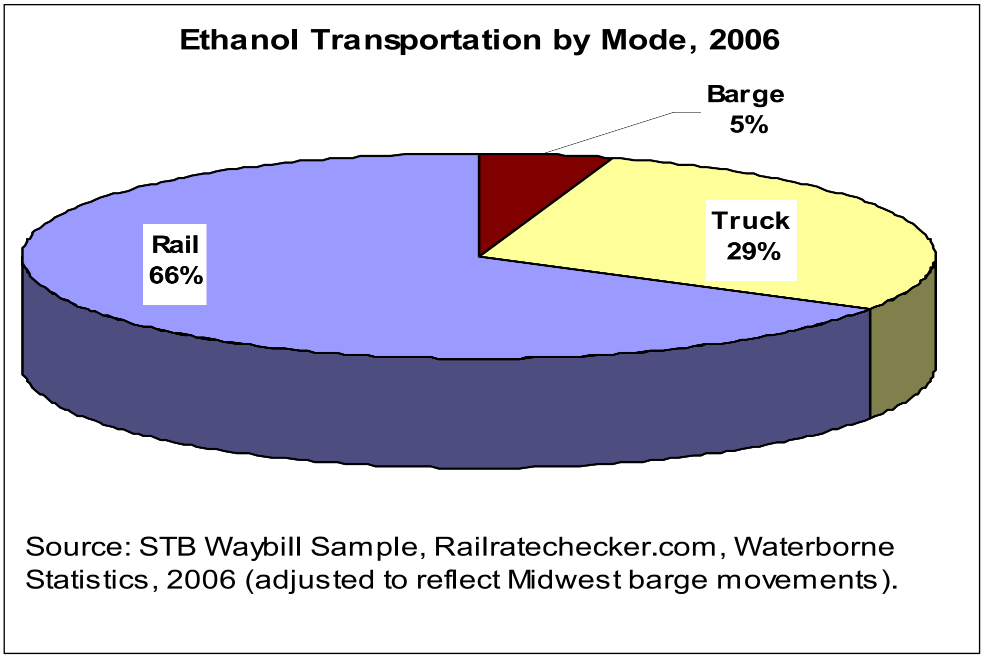
CHAPTER 6. BIOFUEL TRANSPORT REQUIREMENTS

Chapter 5 explained the energy and resource requirements for biofuel synthesis at biorefineries. Once fuels like ethanol and biodiesel are produced, these liquids must still be transported to distribution centers. Transportation is typically the third-largest expense to an ethanol producer, behind feedstock and production energy costs. Chapter 4 illustrated the geographical separation between the majority of biorefineries in the Midwest and 80% of the U.S. population living along the East, Gulf, and Pacific Coasts. Alternative fuels must be cost effective and relatively abundant in order to provide a viable alternative to gasoline. A reliable biofuel transportation infrastructure is critical for supply to meet demand. The following discussion of transportation requirements will emphasize ethanol, although biodiesel (which utilizes ethanol) is governed by similar parameters.

Within the United States, three transportation modes--truck, railroad, and barge--predominantly handle ethanol shipments. To avoid costly long-haul distances, most ethanol biorefineries are located within fifty miles of corn growing farms. This close proximity between field and factory popularizes trucks as the mode of choice for transporting corn to ethanol plants. Between 2000 and 2004, trucks accounted for 67%, rail comprised 30%, and barges only 2% of corn modal share. However, trucks carried 98% of corn delivered to ethanol biorefineries for processing. Generally speaking, transport cost advantages shift from trucks to rail to barges as both the bulk quantity of the good and the haul distance increases. Short-haul distances less than fifty miles particularly favor trucks as evidenced by their dominance of the corn field-to-ethanol plant market. Although more expensive per mile, trucks provide greater flexibility to move ethanol according to market forces. In certain instances, the increased responsiveness afforded by trucks reduces storage needs at ethanol plants, which may partially offset the higher trucking fuel costs.[75]

Figure 5 illustrates longer-haul distances and larger fuel quantities make freight railroad the mode of choice for transporting newly manufactured ethanol from biorefineries to distribution centers, where blending with gasoline generally occurs. In 2006, rail shipped more than 3.1 billion gallons or 66% of refined ethanol, trucks were responsible for an estimated 1.4 billion gallons or 29%, and barges accounted for the remaining 238 million gallons or 5% of ethanol shipments. For comparison purposes, ethanol is generally delivered in 630,000-gallon tanker barges, which are equivalent to 80 7,875-gallon railcars or 300 2,100-gallon tanker trailers.[76]

Figure 5 – Percent of U.S. Ethanol Production Moved by Mode, 2006



Source: STB Waybill Sample, Railratechecker.com, Waterborne Statistics, 2006 (adjusted to reflect Midwest barge movements).

Adapted from: Biomass Research and Development Board[77]

Ethanol is shipped in standard rail tank cars approved for flammable liquids, namely DOT 111A or AAR T108 rail cars. As of January 1, 2007, 41,000 rail tank cars approved for ethanol transport were in use. Leasing companies or shippers, not rail carriers, own the vast majority of rail tank cars. In terms of trucks, standard gasoline tanker trucks or DOT MC306 Bulk Fuel Haulers ship ethanol from ethanol plants to blending terminals. The current fleet size of the independently operated tank trucks is approximately 10,000. Tanker truck fleets owned by petroleum companies are not included in this total. Barges account for an estimated 5% of ethanol shipments. The primary terminals served by barge include: Chicago, Illinois; New Orleans, Louisiana; Houston, Texas; and Albany, New York. Ethanol is generally transported in 10,000 to 15,000 barrel tank barges equivalent to 420,000 to 630,000 gallons. However, the number of ethanol plants near a river facility is relatively small. As the ethanol industry matures, the barge modal share may increase.[78]

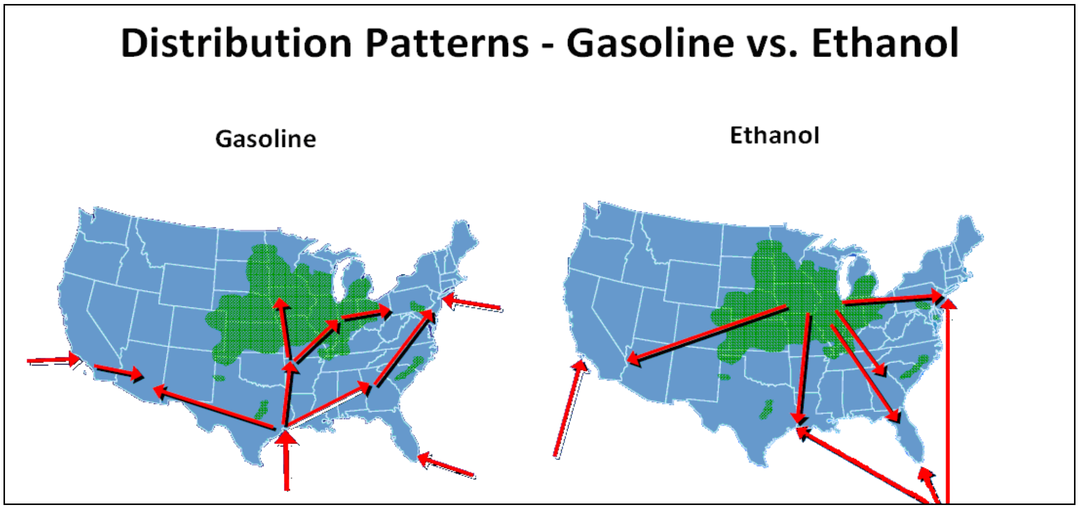
Truck and rail modes used to ship ethanol are currently operating at or near capacity. Total rail freight is forecast to increase from 1,879 million tons in 2002 to 3,525 million tons by 2035, a growth of almost 88%.[79] The Federal Highway Administration (FHWA) anticipates truck freight nearly doubling between 2002 and 2020, with driver shortages forecast to climb to 219,000 by 2015.[80] Limited excess transportation capacity heightens the sensitivity of infrastructure to disruptions in transportation demand and distribution patterns. Escalating domestic ethanol production required to meet the revised 2007 renewable fuel standards prescribing 15 billion gallons of corn ethanol in 2015, have the potential to impact rail network performance, highway congestion, and barge traffic. As ethanol synthesis ramps up, the following particular concerns should be anticipated –

- Uncertainty regarding the demand from and location of distribution markets that blend ethanol.
- Modal shifts among truck, rail, barge, and potentially pipeline in terms of transporting corn, ethanol, and ethanol by-products, such as distillers' grains.
- Heightened transportation demand for agricultural inputs, especially additional fertilizer for increased corn acreage.[81]

Transportation shifts are expected to continue over the next several years as commodity prices adjust to sustained, heightened ethanol production. Between 2005 and 2008, the price per bushel of corn rose from below $4.00 to above $7.00, largely due to elevated demand from the corn ethanol industry. However, during the same time period, inadequate corn ethanol transport created localized surpluses of the biofuel in the Midwest eventually dropping the fuel's price below $2.00 per gallon during the summer of 2007. Increased ethanol production could lead major corn-producing states to actually become corn-deficient, mandating the sourcing of corn from other states and raising the transportation distances for the feedstock thereby placing further pressure on the transport sector. Corn prices are expected to vary among Midwest locations to balance the demand among domestic feedlots, ethanol plants, and corn exports. As an example, corn demand at ethanol plants may strengthen commodity prices in close proximity to the ethanol-producing areas compared to corn prices in regions where the grain is primarily exported. In contrast, the Brazilian sugarcane ethanol market creates smaller regional distortions in the price of raw sugar because the simplified glucose-to-alcohol sequence allows sugarcane plants to switch back and forth between processed sugar and ethanol production depending on which commodity commands the higher price at the given time. The result is the prices of refined sugar and sugarcane ethanol are less likely to decouple compared to the costs of corn and its biofuel derivative.

In terms of transporting petroleum, pipelines are considered to be the safest and most cost-efficient transport mode. Until recently, characteristics of the existing corn ethanol industry have prevented pipelines from gaining a greater foothold in this sector. Figure 6 illustrates the ethanol industry, centered in the Midwest, is approximately one thousand miles north of the large, aggregated oil refinery complexes along the Texas and Louisiana coastal regions. The contents of pipelines flow in one direction. The current network of crude oil and petroleum product dedicated pipelines, which took decades to build, emanates northward from the Texas and Louisiana refining centers. The most optimistic ethanol growth forecast embodied in the updated 2007 RFS entails the E10 blend, 90 percent gasoline and 10 percent ethanol, saturating the national automobile fuel market by 2013 or 2014. Given U.S. gasoline consumption of approximately 140 billion gallons in 2008, this "E10 wall" is approximately 14 billion gallons. Typical cross-country pipelines range between 12 and 16 inches in diameter and can transport between 100,000 and 150,000 barrels per day or 1.5 and 2.3 billion gallons per year, respectively. Individual Midwest biorefineries only have production capacities between 2,000 and 4,000 barrels per day. The existing Midwest corn ethanol industry is not sufficiently concentrated to warrant the capital investment of an ethanol dedicated pipeline costing between $1.5 and $1.8 million per mile.[82]

Figure 6 – Corn Ethanol Industry and Existing U.S. Petroleum Pipeline Networks



Source: Biomass Research and Development Board[83]

Prohibitive construction costs are not the only drawbacks to an ethanol dedicated pipeline network originating in the Midwest. Uncertainty remains over the structural integrity of pipelines carrying denatured E95 ethanol (i.e. 95 percent ethanol, 5 percent gasoline). Research over the past two decades has revealed Internal Stress Corrosion Cracking (SCC) can compromise the structural steel comprising the pipeline casing. Oxygen and chloride levels in ethanol drive the initiation of SCC. Twenty-four SCC failures were observed in ethanol tanks and in production facility piping. The steel grades in these two types of structures are similar to steels in existing petroleum pipelines. Controlling the oxygen and chloride levels in pipelines will mitigate SCC threats. Brazil has taken this approach in designing its network of ethanol dedicated pipelines connecting biorefineries in upland Sao Paulo State with coastal ports. Chemical inhibitors added to the pipeline's contents help reduce the risk of SCC within E95 carrying pipelines. However, structural modifications still must be made to the pipeline walls because non-metallic pipeline components such as seals and gaskets can swell and potentially rupture in the presence of ethanol.[84] These specialty connections risk inflating the cost of an ethanol dedicated pipeline significantly above a similar petroleum structure.

A potential ethanol transport solution including pipelines emerges from collaborative research conducted by the U.S. Departments of Transportation, Energy, and Agriculture along with private industry partners like Kinder Morgan and Colonial Pipeline Company. Diluting or cutting ethanol with gasoline significantly reduces the SCC threat. Specifically, the proposed national E10 fuel standard should not instigate Stress Corrosion Cracking within pipelines. A joint study conducted by Colonial Pipeline and Duke University indicates the existing petroleum pipeline network fanning north and east from the Texas and Louisiana refineries to the Atlantic Seaboard requires minimal retrofits to handle E10 blends.[85] Houston refineries are readily accessible to international oil imports via the Houston ship channel. This geography compels investigating the feasibility of ethanol reaching Houston by waterway, blending with petroleum, and traveling via pipeline as E10 to supply Texas and other Southeastern markets. Ethanol barge and pipeline transport could become an attractive multimodal alternative to the currently bottlenecked rail option. Chapter 7 will detail the steps and associated costs of three potential ethanol supply chains terminating in Texas: transport of domestic corn ethanol via railroad, movement of domestic ethanol via barge and pipeline, and transport of sugarcane ethanol from Brazil.

CHAPTER 7. DOMESTIC AND INTERNATIONAL BIOFUEL SUPPLY CHAINS

Chapters 5 and 6 described the characteristics of ethanol synthesized both domestically and overseas, as well as biofuel transportation limitations within the United States. One trend that emerges is Brazilian sugarcane ethanol production boasts technological advantages compared to Midwest corn ethanol synthesis. Given the United States' burgeoning biofuel demand, as articulated in the expanded 2007 renewable fuel standards, future American need will require ethanol from multiple sources. The corn ethanol industry, which manufactured an estimated 6 billion gallons in 2007, will need to increase production 250% to attain the corn ethanol quota of 15 billion gallons by 2015. Also in 2015, the 2007 RFS dictates 5.5 billion gallons coming from biofuels not derived from corn, which increases to a staggering 21 billion gallons just seven years later in 2022.[86] These ambitious targets suggest increasing U.S. biofuel imports will not supplant the corn ethanol industry, but actually make RFS attainment more feasible. Corn ethanol alone cannot satisfy the renewable fuel standard legislation.

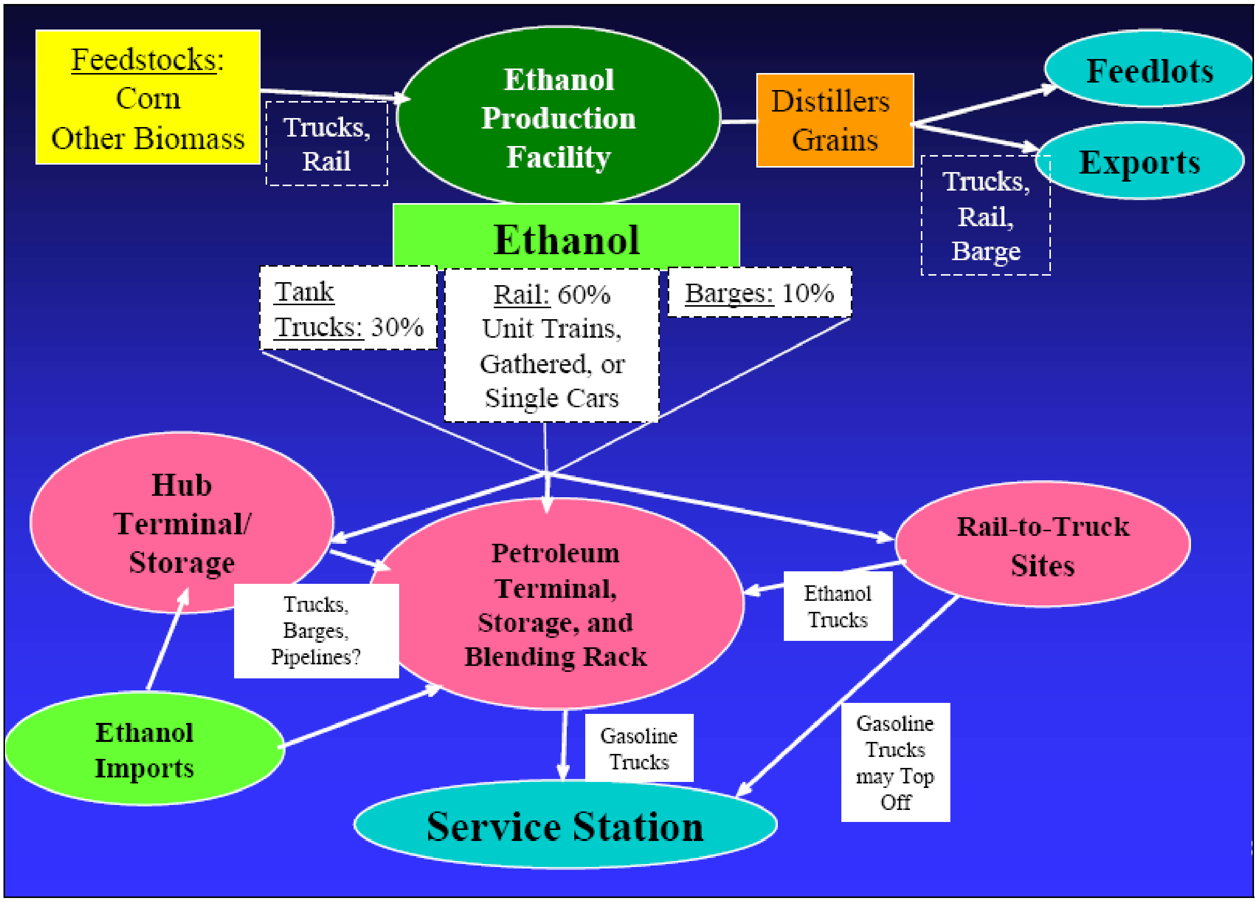
A growing body of knowledge suggests an appropriate strategy to grow the biofuels industry from a regional Midwest enterprise to a true national market is to target different geographical regions of the United States with different ethanol sources. Corn ethanol would gradually expand service to interior portions of the country, including the Midwest, Great Plains, and possibly Intermountain West. Imported sugarcane ethanol could better reach deepwater marine ports on the Atlantic, Gulf, and even Pacific Oceans via tanker thereby exposing 80% of the American populace living in coastal regions to biofuels.[87] Investigation of both domestic and international biofuel supply chains is necessary to gain a better understanding of the cost and infrastructure requirements associated with moving a quantity of fuel from its production source to distribution locations. Texas enjoys a unique geographic orientation as both a Great Plains and Gulf Coast state. Two case studies describing shipment of corn ethanol from Iowa and transport of sugarcane ethanol from Sao Paulo, Brazil to Texas markets will attempt to determine whether the Lone Star State is more economically served by domestic or overseas biofuel sources.

This report emphasizes transporting biofuels to Texas because the Southwest region is not a prime candidate for the cultivation of existing bioenergy crops common to the United States, namely corn for ethanol. Aside from literature questioning the energy gain from and greenhouse gas emissions associated with corn ethanol synthesis, the intensive resource requirements to sustain a corn ethanol industry largely disqualifies all but the eastern portions of the southwest region, namely Louisiana and Arkansas. Chapter 6 indicated most American varieties of corn require 18 to 22 inches of precipitation per year.[88] This amount of moisture often exceeds the year-to-year rainfall variation experienced by Texas agricultural towns like Amarillo and Lubbock, which boast average precipitations of 19.0[89] and 18.0 inches,[90] respectively. Unfortunately, Texas' primary corn ethanol producing regions are located in the state's semiarid Panhandle. Pumping groundwater from wells is a common practice in regions where rainfall fails to meet agricultural demands during a given season. The drawdown of the Ogallala Aquifer in the Texas Panhandle already presents a worrisome trend at current levels of corn ethanol production.[91]

Figure 7 illustrates the domestic ethanol supply chain commencing with the agricultural production of corn and ending with distribution of E15, E85, or some other ethanol-gasoline mixture to service stations. This schematic also largely describes the international supply chain required to transport sugarcane ethanol from South-central Brazil to the Texas market. However, Figure 8 underscores four distinguishing characteristics of South American sugarcane ethanol logistics. Sugarcane ethanol production facilities or refineries do not generate distillers' grains as a byproduct. Instead bagasse, the woody cane material, remains after the sugar ferments. Chapter 6 indicated burning bagasse powers a growing percentage of Brazilian ethanol distilleries. The Sao Paulo environmental ministry anticipates all Sao Paulo sugar-ethanol refineries with annual production capacities at least 115 million liters to be fully bagasse powered within the next decade. Figure 7 shows corn ethanol leaves American ethanol refineries via one of three modes. As described in Chapter 6, tanker trucks, rail cars, and barges roughly account for 29 percent, 66 percent, and 5 percent of ethanol transport, respectively.[92] The U.S. Department of Agriculture's schematic released one year prior maintains a larger barge transport capacity, where trucks, rail cars, and barges constitute 30 percent, 60 percent, and 10 percent, respectively.[93] Figure 8 illustrates Brazil's different intermodal mix. Tanker trucks, rail cars, and *pipelines* carry 30 percent, 60 percent, and 10 percent of ethanol, respectively, from sugarcane refineries predominantly located in upland Sao Paulo State to coastal storage terminals for international export. Ethanol currently exports predominantly from two Brazilian ports: Sao Sebastiao in Sao Paulo State and Ilha D'Agua, Rio de Janeiro's primary marine terminal. Approximately 240 kilometers or 150 miles separate the upland Paulinia refining district from the port city of Sao Sebastiao whereas ethanol refined in Sao Paulo must travel 520 kilometers or 320 miles to reach Rio de Janeiro. Tanker vessels carry the ethanol from either Sao Sebastiao or Rio north to the United States.[94]

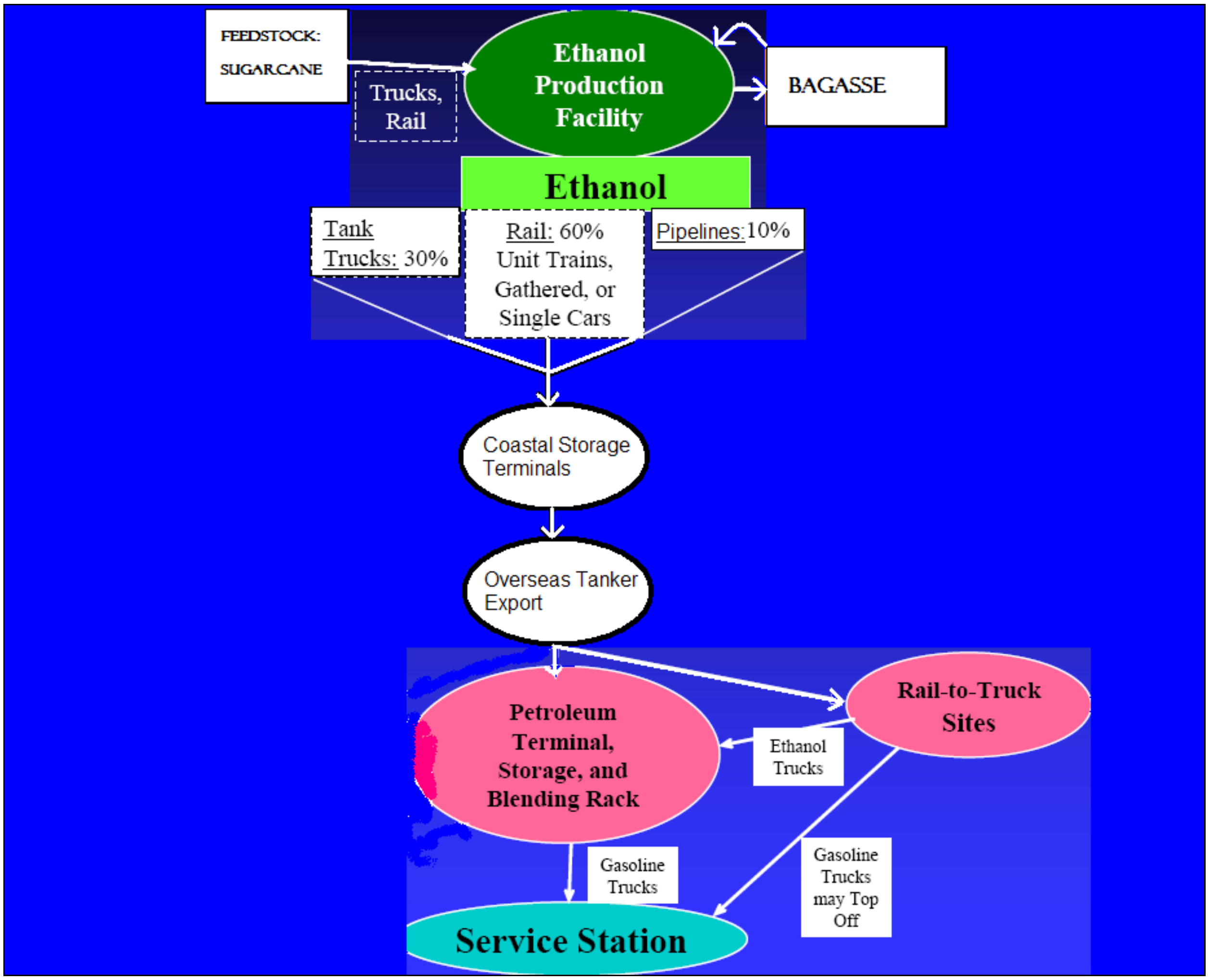
After arriving at a domestic port like Houston, the sugarcane ethanol must be offloaded from the tanker ship and transferred to storage terminals or railroad tanker cars. Beyond this final port step, transport of the Brazilian biofuel relies heavily on rail and trucks analogous to the corn variety. Ethanol is either blended with petroleum within the storage tanks or is "splash blended" with gasoline within tanker trucks during "last-mile" distribution to filling stations.[95] The following two case studies tracking ethanol imports to Texas from the American Midwest and Brazil provide more detailed estimates of requisite equipment, time, and, where possible, costs. Knowledge of where and how costs are derived will enable a comparison of whether American or Brazilian ethanol is the more economical biofuel for the Texas market.

Figure 7 – United States Domestic Ethanol Supply Chain



Source: USDA Ethanol Transportation Backgrounder[96]

Figure 8 – Brazil International Ethanol Supply Chain

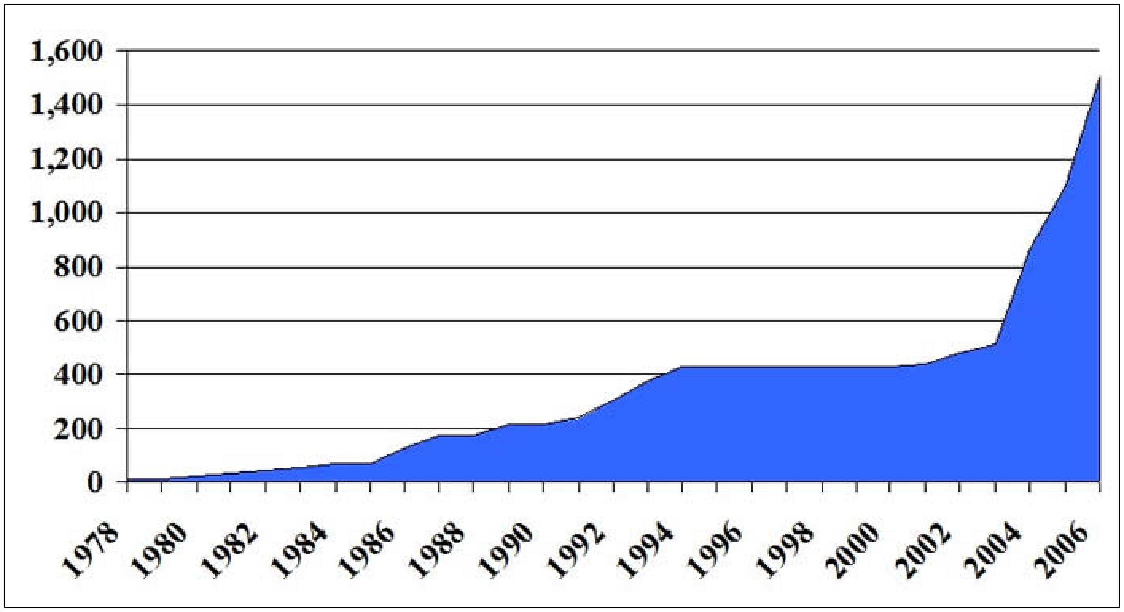


Adapted from: USDA Ethanol Transportation Backgrounder[97]

Iowa, United States – Corn Ethanol Cultivation and Production

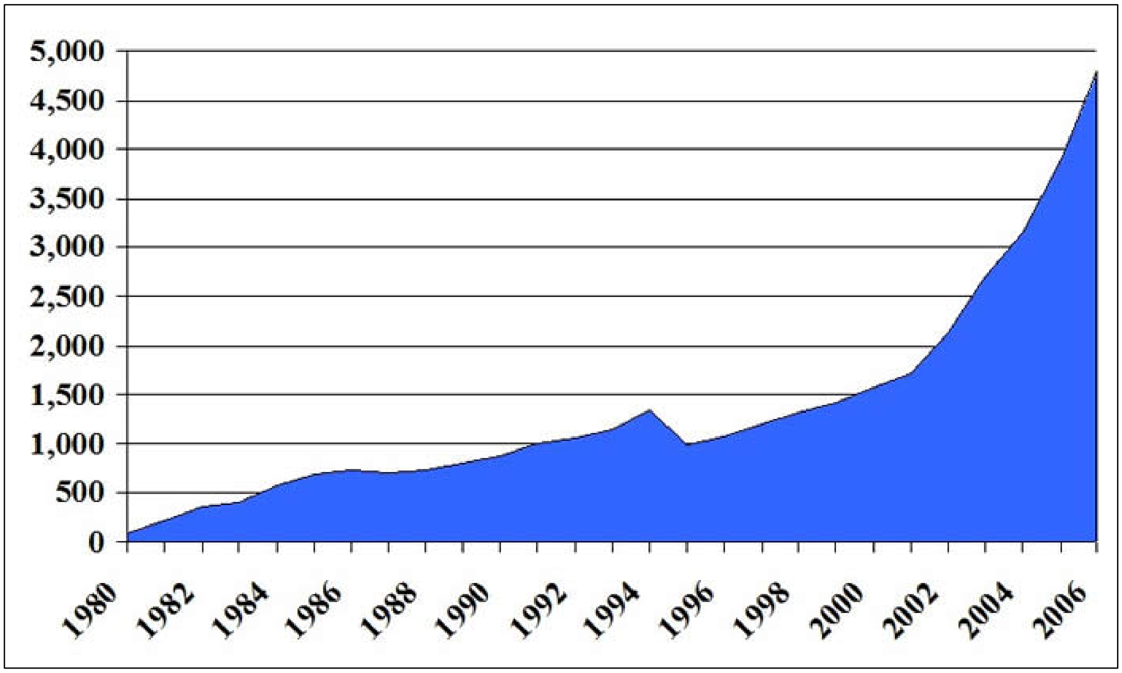
Ethanol production in the Midwestern state of Iowa is the largest in the nation. Figure 9 demonstrates Iowa's annual ethanol production capacity had climbed to roughly 1.5 billion gallons per year by 2007. 2007 serves as the reference year for this case study because domestic corn ethanol production peaked during this year. Biofuel production quantities within the Midwestern states declined during 2008 because of two primary factors: ethanol's competition with the food chain for corn as a feedstock and the deepening worldwide recession, which lowered overall transportation demand during the latter half of the year. Iowa's ethanol volume is roughly 30% of total U.S. ethanol output, which reached an estimated 4.75 billion gallons in 2007 as shown by Figure 10.[98] Iowa ethanol manufacture provides an accurate case study for the entire corn ethanol market because Iowa accounts for such a large proportion of total U.S. corn ethanol output. In 2007, Iowa boasted twice the ethanol capacity of Nebraska, the second-largest state supplier of the biofuel.[99]

Figure 9 – Iowa Ethanol Production 1978 to 2007 (in Millions of Gallons)



Source: Iowa Corn Promotion Board[100]

Figure 10 – U.S. Ethanol Production 1980 to 2007 (in Millions of Gallons)

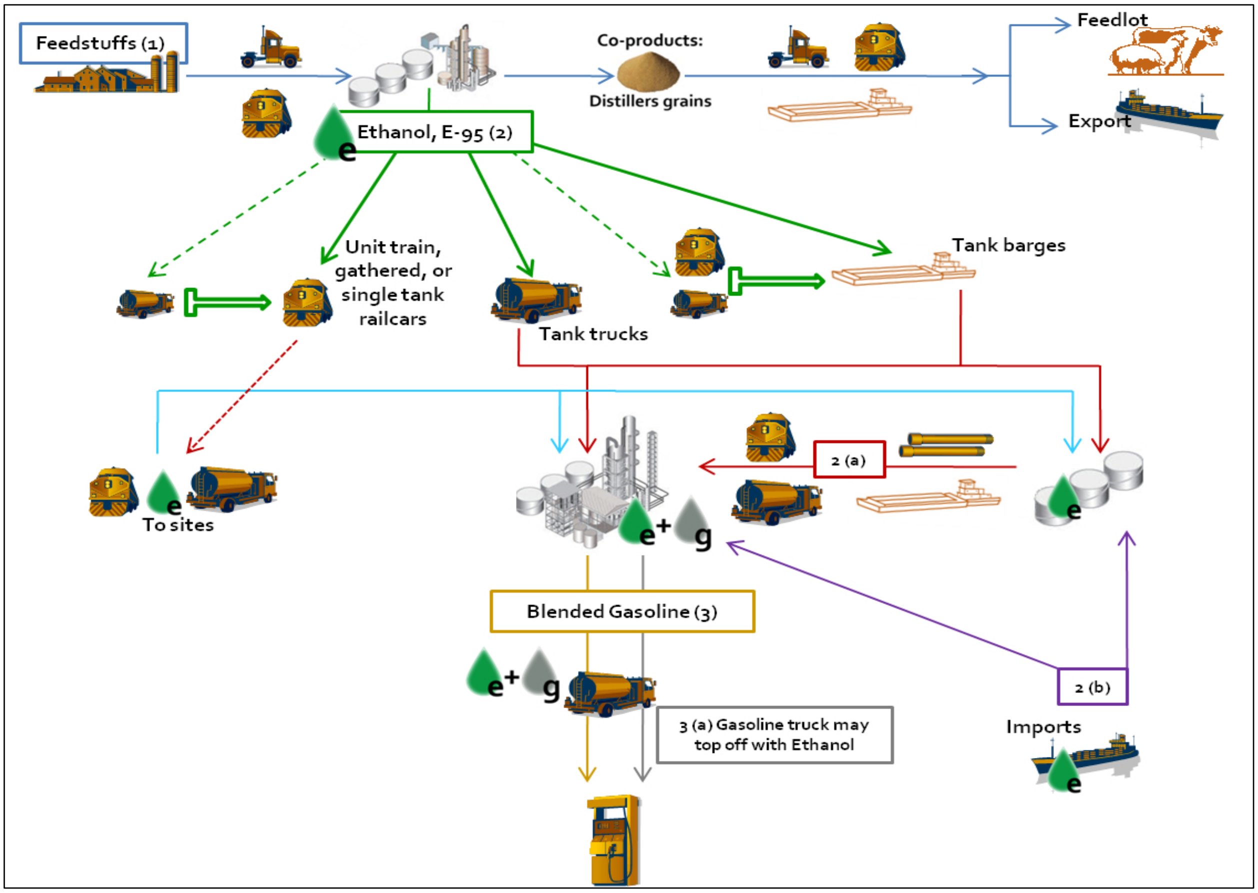


Source: Iowa Corn Promotion Board[101]

Ethanol production from biomass requires sugar fermentation. Two different types of biorefineries process the corn grain to remove the sugar. The type of sugar extraction method practiced depends on the kind of corn ethanol plant. Wet mills soak the corn, whereas dry mills crush the grain. Additional chemical treatments are applied to isolate the sugar, which is then fermented, and the resulting mix is distilled and purified to obtain anhydrous ethanol. Major byproducts from the ethanol production process include dried distillers' grains and solubles (DDGS), which can be used as animal feed. On a smaller scale, corn gluten meal, gluten feed, corn oil, CO_2, and sweeteners are also byproducts of the ethanol production process common throughout the Midwest. Corn-to-ethanol extraction and distillation procedures are chemically intensive. As of 2007, the combined costs of nitrogen-rich fertilizers, like urea, irrigation, harvesting, trucking corn bushels to biorefineries, and ethanol plant synthesis suggested producers would pay approximately $650 to convert one acre of corn into ethanol. One gallon of ethanol would cost $1.70 to produce.[102] These costs do not include the expansive ethanol supply chain required to transport the biofuel from ethanol mills to distribution centers.

Ethanol transactions are either direct sales to customers or movement of the fuel to a strategic distribution location. Direct consumer purchasing generally occurs at the biorefinery. Therefore, the well-to-wheels price analysis for this category is approximately equivalent to the production costs, about $1.70 per gallon of ethanol. Transportation of corn ethanol to distribution centers, where the biofuel is generally blended with gasoline as E10 or E85, applies to the vast majority of ethanol synthesized. Movement of the product can be arranged by the customer, supplier, or a third party, referred to as the marketer in the petroleum industry. Marketers keep ethanol supply disruptions to a minimum by collectively moving large volumes of the biofuel produced at several smaller ethanol plants. Figure 11 presents a more detailed view of the transportation alternatives available to ethanol producers, who wish to bring their fuel to market. The following two sections will elaborate on two pathways linking biorefineries with ethanol distribution stations. Rail delivery operations command attention since railroads represent the primary transportation mode of ethanol to market. The second alternative investigates whether barges coupled with ethanol-combination pipelines carrying E10 and other ethanol-gasoline blends would provide a cost competitive multimodal system for Iowa ethanol to more effectively penetrate the Texas market.

Figure 11 – Domestic Ethanol Distribution System Alternatives



Source: Biomass Research and Development Board[103]

Domestic Ethanol Infrastructure – Rail Dominant Option

The least expensive method for moving ethanol from origin to destination via rail is utilizing unit trains, consisting of 85 to 100 ethanol tanker cars. Unit trains boast several advantages, including a higher asset utilization rate and lower inventory carrying costs. Compared to single-car shipments of ethanol, which have an average 12 turns per year, the mean annual utilization rate for unit trains is 30 turns, indicating unit trains are used nearly three times as much as their single-car counterparts.[104]

Rail tariffs for unit trains are typically lower than single- and multiple-car ethanol shipments. This scoping study relied on the fee schedule provided by the Burlington Northern Santa Fe Railway (BNSF) to transport ethanol volumes from the Midwest to Texas and other southwest destinations. BNSF routes the majority of its intermodal traffic along its Southern Transcontinental (Transcon) route. This rail line extending east from California through Texas and eventually terminating at Chicago, Illinois has 2,254 miles of double-tracked lines.[105]

BNSF's ethanol service features several important attributes. The railway company only provides rail services for the ethanol industry. BNSF trucks do not ship ethanol. The Burlington Northern Santa Fe does not provide the rail tanker cars. Ethanol tank cars are independently owned or leased by the biofuel producers. Large, commercial ethanol producers that the BNSF routinely contracts with include Archer Daniels Midland Company (ADM) and Cargill. Given separate tanker car ownership, the ethanol suppliers are responsible for packing or filling the tankers. As an industry standard, 30,000-gallon tanker cars, approximately 60 feet in length, are normally used to each transport 29,400 gallons of ethanol. The 600-gallon volume differential is a factor of safety against damage to a car's steel frame caused by excessive vapor pressures. Once the cars are fully loaded, the Burlington Northern Santa Fe transports the tankers but does not perform in-transit safety or stability checks. One factor why BNSF does not provide specialty handling for ethanol is the lack of government incentives. Traditionally, government ethanol subsidies only benefit the ethanol producer or blender, not the biofuel transporter. The rail carrier as well as its competitors, such as Union Pacific (UP), charge flat shipping rates per rail tank car to move ethanol from its source to destination. All rates are public. These shipping rates fall into three service categories. Single car service has a variable cost. Table 5 illustrates the cost of transporting and coupling / decoupling a single ethanol car from either southeast or southwest Iowa to a destination in New Mexico or Texas ranges between $4,400 and $5,200. For a full unit train consisting of at least 95 cars, also known as an Ethanol Express, Table 6 indicates that a discount of approximately $900 per tanker car is levied so single cars from southwest Iowa to Fort Worth, Texas, previously costing $4,425, now only cost $3,525. Often times, ethanol producers have more than one tanker to ship but cannot amass enough cars to meet the requirements of an entire unit train. In these situations, the BNSF offers an additional option entitled gathered train service. Gathered trains allow up to two or three ethanol shippers or plants to split a 95-car unit train. Since the Burlington Northern Santa Fe must complete more coupling for a gathered train than a unit train but significantly less connecting than required for individual tanker cars, the $700 discount per car is commensurate.[106] Tables 5 through 7 indicate that transport distance and costs are directly proportional no matter the flat discount. Shipments to Illinois and Minnesota are generally about $700 per car less while tankers to Watson, California are each charged roughly $900 more than cars bound for Fort Worth.

Table 5 – Burlington Northern Santa Fe Single Car Ethanol Rates

Single car rates effective - February 4, 2009 (includes coupling charges)					
FROM		NM	TX		
			Ft Worth, TX	Gulf (0370)	El Paso, TX
IA	Southwest IA (0080)	$4,750	$4,425	$4,825	$5,075
	Southeast IA (0090)	$4,850	$4,525	$4,925	$5,175

Adapted from: BNSF Railway[107]

Table 6 – Burlington Northern Santa Fe Ethanol Unit Train Rates

<table>
<tr><th colspan="6">Unit Trains</th></tr>
<tr><th colspan="6">New unit train rates effective February 4, 2009</th></tr>
<tr><th colspan="6">(see unit train guidelines - rates are for 95 car ethanol trains)</th></tr>
<tr><th colspan="6">originating at 1 plant - origins must be approved by BNSF operations</th></tr>
<tr><th colspan="2" rowspan="2">FROM</th><th colspan="4">TO</th></tr>
<tr><th>IL</th><th>TX (Gulf)</th><th>Ft Worth, TX</th><th>Watson, CA</th></tr>
<tr><td rowspan="2">IA</td><td>Southwest IA (0080)</td><td>$2,960</td><td>$3,925</td><td>$3,525</td><td>$4,400</td></tr>
<tr><td>Southeast IA (0090)</td><td>$2,860</td><td>$4,025</td><td>$3,625</td><td>$4,500</td></tr>
</table>

Adapted from: BNSF Railway[108]

Table 7 – Burlington Northern Santa Fe Ethanol Gathered Train Rates

<table>
<tr><th colspan="6">Gathered Trains</th></tr>
<tr><th colspan="6">New Gathered train rates effective - February 4, 2009</th></tr>
<tr><th colspan="6">(see unit train guidelines - rates are for 95 car ethanol trains)</th></tr>
<tr><th colspan="6">originating at 2 or 3 plants - origins must be approved by BNSF operations</th></tr>
<tr><th colspan="2" rowspan="2">FROM</th><th colspan="4">TO</th></tr>
<tr><th>MN</th><th>IA</th><th>TX (Gulf)</th><th>NM</th></tr>
<tr><td rowspan="2">IL</td><td>Chicago, IL</td><td>$3,500</td><td>$3,050</td><td>$4,100</td><td>$3,900</td></tr>
<tr><td>Southern IL (0070)</td><td>$3,500</td><td>$3,050</td><td>$4,100</td><td>$3,900</td></tr>
</table>

Adapted from: BNSF Railway[109]

Despite the preferential cost given unit and gathered trains, the majority of ethanol has continued to be shipped under single car rates through spring 2009. Two important reasons largely account for the continued popularity of individual car service. Electing gathered or unit train service severely limits the destinations to which producers can ship ethanol. Fort Worth is the only destination in the Southwest region that has facilities large enough to accommodate 95-car trains comprised entirely of ethanol tankers. Along with Fort Worth in Texas, Houston, San Antonio, and El Paso are directly served by BNSF's single-car ethanol service. The company does not rail ethanol directly to Dallas or Austin. Additionally, the domestic ethanol industry has not yet grown sufficiently to a point where the majority of producers can synthesize the biofuel on a large enough scale to warrant unit or even gathered train service. Chapter 5 revealed the typical ethanol biorefinery can produce between 2,000 and 4,000 barrels per day or 30.0 million and 61.3 million gallons per year, respectively. Three ethanol plants each producing in the middle of this range (i.e. 45.7 million gallons per year) would collectively produce 2.63 million gallons per week. A 95-car ethanol gathered train has a capacity of 2.79 million gallons, which exceeds the collective weekly output of the three hypothetical plants by more than 158 thousand gallons of ethanol. Although efforts to consolidate are underway, the corn ethanol landscape remains defined by independently owned, smaller scale biorefineries.

In the scope of overall rail transportation, ethanol deliveries currently only account for less than one percent of all rail shipments. Over the last six years, the volume of ethanol rail transport has grown significantly. In 2001, out of 8 million total rail car deliveries, ethanol comprised 11,000 tankers or approximately 0.14%. In 2006, the number had grown to approximately 35,000 tankers out of 10.5 million rail cars total, or roughly 0.33%.[110]

During 2007, the Burlington Northern Santa Fe moved approximately 223 million gallons of ethanol through its three-tiered biofuel service platform.[111] Ethanol origin locations are dictated by where ethanol plants exist, primarily the Midwest. Common destination points coincide with areas featuring ethanol blending mandates. On the destination end, a lack of blending station infrastructure is currently curtailing expansion of the ethanol market. Rail destinations tend to be bottlenecks in the ethanol supply chain. As a general rule, BNSF trains do not deliver ethanol to oil refineries. Traditionally, most petroleum refineries were not built with rail access since oil and gas traditionally have been delivered via pipeline. Instead, BNSF rails ethanol to outgoing terminals and the biofuel is splash blended with gasoline already in tanker trucks. Ethanol unit trains comprised of 95 cars must be able to unload within 24 hours for Burlington Northern Santa Fe to agree to transport inventory to a given terminal destination. As of spring 2009, larger depot terminals that were expected to come on-line in the next year have been delayed because of the recession and corresponding downturn in the domestic ethanol market. The BNSF and Shell developed the first large depot to unload ethanol unit trains in the Los Angeles Basin in response to California's burgeoning ethanol demand. The BNSF is also currently building a similar facility in Fort Worth. The CSX and Norfolk Southern, competing rail carriers, service several shipping centers in the eastern United States, including Albany, New York; Providence, Rhode Island; and Baltimore, Maryland.[112]

Considering cost comparisons will be made between railroading and barging domestic corn ethanol from Iowa and shipping sugarcane ethanol from Sao Paulo, Brazil, a common destination point would facilitate evaluation. Houston is the largest and most logical Texas port to receive Brazilian imports. Therefore, a price of $5,095 per 29,400 gallons of ethanol will approximate the transportation costs between Iowa and Texas. Considering the majority of ethanol shipments are single car deliveries, $5,095 estimates a single tanker originating somewhere in Iowa and terminating along the Texas Gulf Coast. This amount translates to one gallon of corn ethanol costing $1.87, where $1.70 is due to production costs and $0.17 is due to railroad transport pricing.

Domestic Ethanol Infrastructure – Barge Alternative

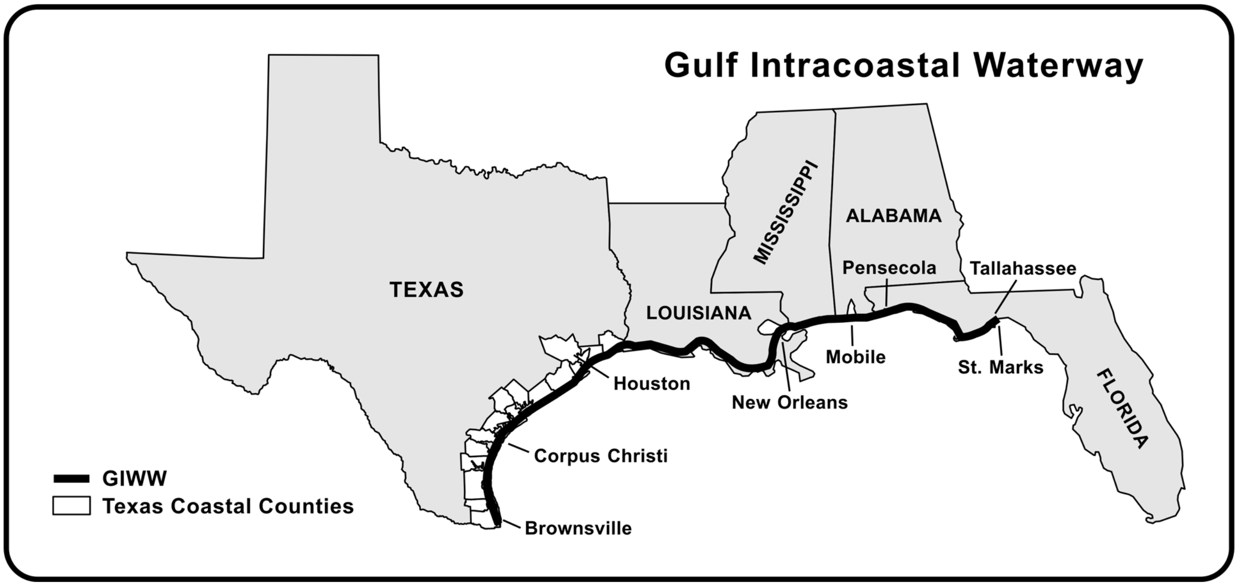
Of the three main ethanol transport modes (i.e. truck, rail tanker, and barge), Chapter 6 indicated barges have the largest biofuel capacity. A typical 630,000-gallon tanker barge equates to 80 7,875-gallon railcars or 300 2,100-gallon tanker trailers.[113] Economies of scale would dictate the per-gallon ethanol moving costs associated with barges are commensurately smaller than rail and truck. Geography is the greatest obstacle to barges gaining a share of the ethanol transport market greater than 5 percent. The nation's waterways that are used for freight movement do not typically provide direct access to centers of ethanol production. Figure 12 illustrates the Mississippi River is the logical candidate for ethanol barge transport southward from the Corn Belt to the Gulf Coast. Although the 2,160-mile navigable river borders corn ethanol producing states like Iowa, the majority of biorefineries are located within the state's interior, removed from river terminals by tens or hundreds of miles.[114] Ethanol producers wishing to barge their product would most likely contract with commercial trucking firms to bring the ethanol from the refinery to the point of river embarkation.

Figure 12 – Mississippi River System Connects the Midwest with the Gulf Coast

Source: WorldAtlas.com[115]

Unlike freight railroad tariffs, which are publicly available, truck and barge transport costs are largely proprietary. Anecdotal studies suggest trucking firms charge approximately $0.15 more than single tanker railcar rates. Therefore, truck transport of ethanol from inland biorefineries, no more than one hundred miles to terminals located along the Missouri and Mississippi Rivers, would add approximately $0.32 per gallon to the cost of transporting ethanol to market. Conversely, barge transport is approximately $0.05 less than single tanker railcar rates. For instance, a barge company responsible for the shipment of ethanol 150 miles on the Hudson River between Albany and New York City, New York charges approximately $0.09 per gallon of ethanol. The cost of barging Iowa ethanol to Houston, Texas would likely be more expensive since the requisite transport distances are significantly longer. Following the 1,000 mile southward track along the Mississippi River to New Orleans, the barge would turn west and traverse approximately 400 miles of the Gulf Intracoastal Waterway (GIW), which connects to the Houston Ship Channel, as shown in Figure 13. The United States Department of Agriculture ballparks the entire cost of barging along the Mississippi River and GIW at $0.14 per gallon of ethanol.[116] Utilizing the barge option, the cost to produce and transport Iowa corn ethanol to refinery centers in the Houston metropolitan area would be approximately $2.16 per gallon, where per gallon costs of $1.70 account for agriculture and refinery activities, $0.32 for truck transport, and $0.14 for barge shipment.

Figure 13 – Domestic Ethanol Barge Shipment to Houston follows GIWW



Source: United States Geological Survey[117]

Table 8 suggests the single ethanol tanker railcar option is financially preferable to the barge alternative by approximately $0.29 per gallon. Houston, Texas is once again the supply chain terminus. This common destination city will facilitate a sensitivity analysis in Chapter 9 comparing the three ethanol supply chains: railroad shipment of domestic ethanol, barge shipment of domestic ethanol, and import of the Brazilian sugarcane variety. This next chapter will assess which logistics alternative most economically supplies the seven Texas urban regions: Houston, Dallas-Ft. Worth, San Antonio, Corpus Christi, Austin, Amarillo-Lubbock, and El Paso with ethanol. Future pipeline shipment feasibility will help establish a given supply chain alternative’s market access.

Table 8 – Domestic Ethanol Railroad vs. Barge Supply Chain Costs

Stage	Railroad ($ per Gallon)	Barge ($ per Gallon)
Production – Iowa, U.S.[1]	$1.70	$1.70
Refinery-to-Port Transportation (via truck)	N/A	0.32
Single Tanker Railcar to Texas (Gulf Coast)	0.17	N/A
Barge Transport (via Mississippi R. and GIW)	N/A	0.14
Total Cost to Houston, TX Market	**$1.87**	**$2.16**

[1] Average per-gallon costs for 2007

Sao Paulo State, Brazil – Sugarcane Cultivation

Figures 14 and 15 show the State of Sao Paulo, which occupies an area of approximately 927,286 square kilometers in Southeast Brazil. Sao Paulo factors heavily into Brazil's agriculture and economic interests. Some 10.2 billion liters or 60 percent of Brazil's ethanol are produced in Sao Paulo state, primarily in the state's western regions of Campinas, Riberao Preto, and Bauru.[118]

Figure 14 – Map of Brazil

Source: Destination360 [119]

Figure 15 – Map of Sao Paulo State, Brazil

Source: Brazil Travel[120]

Sao Paulo's commercial sugarcane growing regions are located on the eastern periphery of the Planalto Central, Brazil's expansive central plateau, and average approximately 1,000 meters or 3,280 feet in elevation.[121] This altitude explains why, despite its low latitude, Sao Paulo enjoys a relatively temperate climate featuring a temperature range normally between 12 and 27 ^{o}C or 54 and 82 ^{o}F.[122]

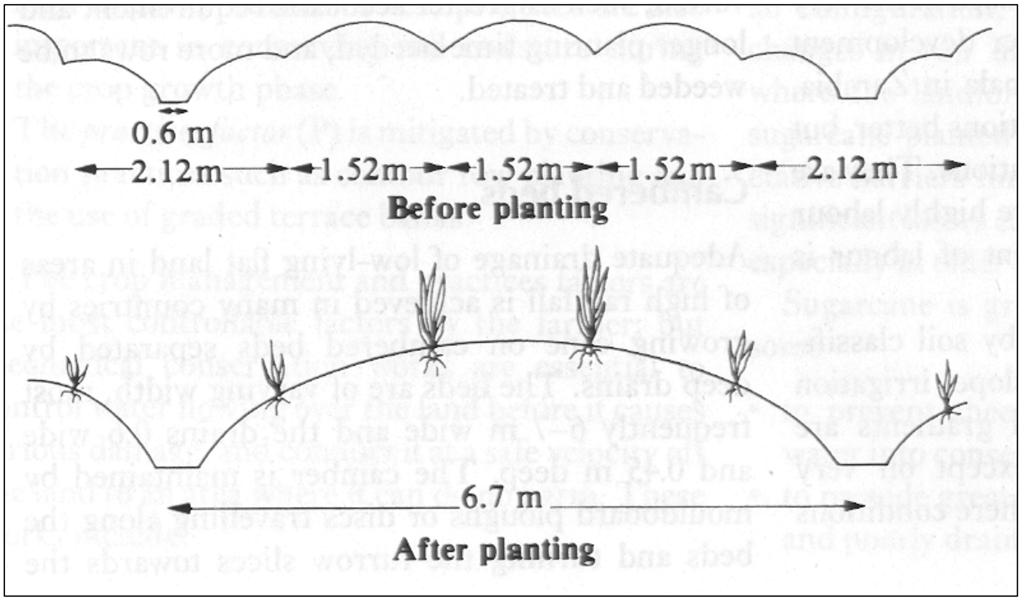
Along with its marked geographical concentration in Sao Paulo state, the Brazilian sugarcane industry has increasingly become dominated by large agribusiness since the inception of Brazil's

Proalcool ethanol program in 1975. Traditionally, minifundio and latifundio production have characterized the sugar sector. Minifundio refers to any rural establishment less than 50 hectares while latifundios are properties greater than 50 hectares. The Brazilian agriculture census of 1970 reported 82.5 percent of all sugarcane workers farmed minifundio-sized plots of land.[123] However, once the government began to subsidize ethanol production in the late 1970s, minifundio consolidation commenced with latifundio owners acquiring more than 75 percent of all sugarcane production capacity by 2000. While latifundio operations are increasingly mechanized, labor intensive sugarcane activities such as harvesting still rely on migrant workers from Northeast Brazil.[124] As Brazil's Proalcool industry matured latifundios forged popular partnerships with usineiros, individuals or companies who controlled the industrial apparatuses, namely the ethanol mills. Highly centralized farming and plant production resulted in the sugarcane ethanol agribusiness that employed more than 1 million workers and produced 17 billion liters of ethanol in 2006.[125]

One sugarcane crop yields five to six cuts or harvests over the same number of years. Considering the lifespan of sugarcane is five to six times that of an annual crop, such as corn, both latifundio and minifundio sugarcane farmers must take precautions not to degrade the soil, which would otherwise curtail the longevity of their investment. Soil conservation is highly dependent on field layout. Individual sugarcane farmers have the most control over crop management and practices factors. Generally, the soil erosion hazard is greatest during the bare or fallow period. Best practices should restrict bare fields to dates when high intensity rainfall events are unlikely. The driest period in Southeast Brazil occurs during the winter season from June to September.[126] Come harvest time workers in Sao Paulo traditionally burned the sugarcane to facilitate its removal with machetes. However, since 2000, field burning practices have declined in Sao Paulo due to increased air pollution regulations and greater mechanization of harvest operations.[127]

After soil readiness, the amount of water received dictates the success of any sugarcane crop. Sugarcane is one of the most moisture intensive of commercial crops with most varieties in the Sao Paulo state region requiring upwards of 1800 mm or 71 inches of water over the course of a growth cycle. Sugarcane's moisture demands, more than its sensitivity to cold temperatures, restrict United States cane production to Florida, the Louisiana Delta, and Hawaii. Much of Brazil lies within temperate-wet or tropical-wet biomes explaining why the nation already is the world's largest sugarcane producer and can offer significantly more land to sugarcane cultivation. However, even the State of Sao Paulo, which enjoys approximately 1350 mm or 53 inches of rain annually, primarily during the summer months of December through March, cannot support entirely rain fed cane crops. Irrigation in sugarcane fields typically accounts for 25-75 percent of the sugarcane's water demand. In Sao Paulo, surface water irrigation concerns generally warrant planting rows of cane 1.5 meters or 4.9 feet apart on cambered beds 6 to 7 meters or 20 to 23 feet wide (Figure 16). Designing sugarcane fields in a cambered or raised fashion minimizes interaction effects between irrigation and groundwater that could lead to oversaturation of the cane's root system. Over irrigating a sugarcane field will raise the groundwater table to within the root zone potentially exposing the plant to root rot. Irrigation and drainage are clearly interrelated. Surveys conducted by the International Commission on Irrigation and Drainage (ICID) indicate furrow irrigation is the preferred sugarcane water dispersal mechanism both globally and in Sao Paulo state. This irrigation system relies solely on gravity instead of external, expensive power sources. Furrow irrigation is also versatile, adaptable to different field contours and boundaries.[128]

Figure 16 – Typical Dimensions of Sugarcane Cambered Bed



Source: Sugarcane Agriculture[129]

Sugarcane Ethanol Synthesis

Widespread implementation of the land preparation and irrigation practices previously described result in a 7 to 8-month growth cycle, yielding approximately 85,000 kilograms sugarcane per hectare in Sao Paulo state, Brazil. Both the monetary expense and emissions associated with transporting harvested sugarcane to ethanol plants affect the alternative fuel's lifecycle costs and energy footprint, respectively. Therefore, viable crop fields tend to be within 20 kilometers or 12 miles of one of Brazil's 335 sugar-ethanol plants.[130] Once at a mill, the first step in ethanol production requires separation of the sugarcane crop into molasses syrup and bagasse, sugarcane stalk biomass. Burning the bagasse stalks powers the sugar-ethanol plants and releases into the atmosphere carbon dioxide equivalent in amount to the CO_2 consumed by the sugarcane via photosynthesis during its growth cycle. Therefore, powering the sugar-ethanol mills using bagasse is carbon neutral. The ethanol plants dilute the molasses syrup byproduct with water. Yeasts of the *saccharomyces* genus primarily facilitate industrial fermentation. Lastly, distillation processes separate the ethanol, generally having concentrations of 95 percent, from the water solvent. The chemical equation summarizing the synthesis of sugarcane ethanol is given below.

$$C_6H_{12}O_6 \xrightarrow{\text{Yeast}} 2C_2H_5OH + 2CO_2$$

Figure 4 in Chapter 5 provides a flowchart illustrating steps in the industrial process, which is identical to corn following the starch-to-glucose preparatory sequence necessary for ethanol derived from grain.[131] Steady refinements to sugar-ethanol production practices have lead to significant increases in the efficiency of Brazil's Proalcool Program over the past decade. In 2007, 48 kilograms of sugarcane synthesized 4 liters or one gallon of ethanol. At a more industrial scale, one sugarcane hectare accounted for 7,080 liters or 1,870 gallons of the biofuel.[132] Total sugarcane ethanol lifecycle energy estimates are more variable with the Latin Business Chronicle reporting in May 2007 that production of one liter of Brazilian sugarcane ethanol requires 6.4 mega-Joules (MJ) or 1,518 kilocalories (kcal) of energy. Regardless of the absolute total energy requirement, transportation of the biomass material from its source to the conversion site must be minimized.[133] Adhering to Brazil industry standards, the cost of growing sugarcane, transporting the harvested cane to Sao Paulo ethanol mills, and producing sugarcane ethanol ascribes a cost of approximately $0.302 USD per liter of finished biofuel.[134] Transportation costs are now considered.

Brazil's Ethanol Export Infrastructure

An important factor facilitating the evolution of Brazil's Proalcool program over the last thirty years concerns the centralization of operations. Compared to the United States, Brazil is less politically opposed to nationalized industry. Despite the market disadvantages characterizing state-run businesses, strong backing from Brasilia enabled the sugarcane industry to afford the large expenditures required to develop an ethanol infrastructure. In contrast, prevailing American free-market principles during the last quarter of the twentieth century precluded development of a commensurate corn ethanol distribution network.

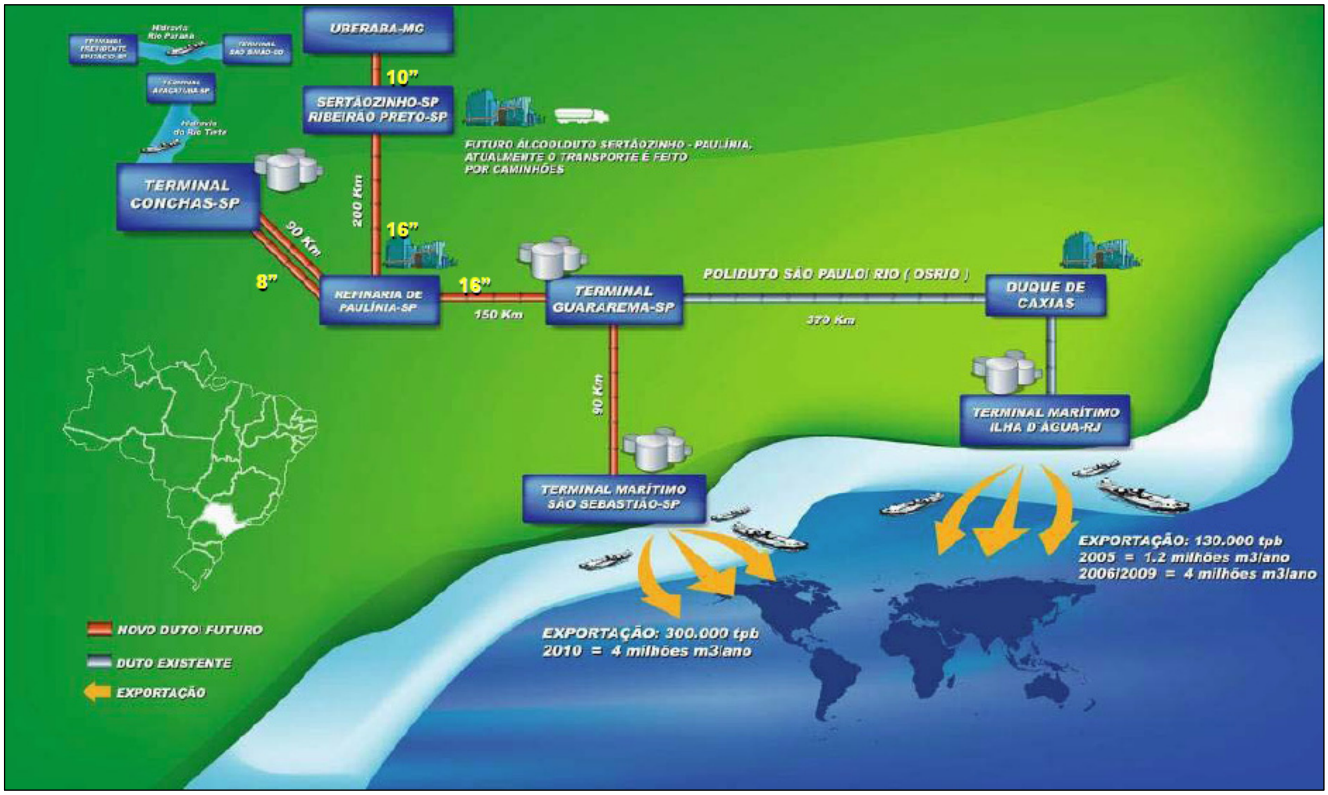
Petrobras, Brazil's state-run oil company, oversees the country's ethanol operations and is well positioned logistically for international commerce. Traditionally, Petrobras has specialized in crude oil production, petroleum product development, and natural gas generation. Since 2005, when the company initiated ethanol shipments of approximately 6.6 million gallons per month to Venezuela, Petrobras has been intent on participating in the renewable fuels export market. Petrobras is now considered the world's largest ethanol marketer, transforming Brazil's Proalcool from a program domestic in scope and security minded in focus to an international revenue source. As of 2007, the company utilized twenty tank farm terminals, twenty-four marine terminals, 10,000 kilometers or roughly 6,200 miles of pipeline, and a tanker fleet numbering fifty-one with a collective tanker capacity of 10 million cubic meters or 353 million cubic feet.[135]

One of the biggest advantages Brazil's Proalcool program has provided the country's ethanol industry is significant investment in dedicated ethanol pipelines linking sugarcane producing regions in western Sao Paulo State to the south-central coastal ports of Sao Sebastiao and Rio de Janeiro. Compared to other modal alternatives (i.e. tanker trucks, railroads, and barges), commercial size pipelines, generally at least one foot in diameter, transport the largest quantities of liquid. However, initial capital investment for a pipeline dwarfs commensurate costs of the three other transport modes. Industry accepted construction prices for new pipelines are approximately $1.38 million USD per mile or $860,000 USD per kilometer. Factoring construction costs into the per unit transport price of pipelines can significantly inflate the cost of this modal alternative.[136]

The United States boasts extensive networks of petroleum and natural gas designated pipelines. However, efforts to transport ethanol through oil pipelines have been hampered by the biofuel's tendency to collect water and impurities residing on the inside tunnel surface. A more serious problem affecting such combination or batched pipelines is stress corrosion cracking of the pipeline's steel interior. Composition differences between pure ethanol and petroleum cause this longitudinal cracking which can compromise the structural integrity of the pipelines allowing leaks to develop. Unless special cleaning procedures are undertaken, as currently advocated by TEPPCO Pipelines, dual use petroleum-ethanol pipelines generally are not commercially feasible. To date, the prohibitive cost of pipeline construction has prevented development of a long distance, ethanol dedicated pipeline within the United States.[137] Without significant federal government investment, development of a domestic ethanol pipeline network appears unlikely in the near future. As of September 2008, Transpetro Brazil, Petrobras's supply chain subsidiary that manages the company's ethanol transport, has not detected any stress corrosion cracking in its ethanol dedicated pipelines. The company has budgeted \$3 to \$4 million USD for quality assurance and control to monitor pipeline performance during 2008 and 2009.[138] The capital investment disparity between the two countries emphasizes why Brazil's ethanol supply chain infrastructure is significantly more robust than the United States.

Figure 8 indicates either tanker trucks, railroads, or pipelines are utilized to transport the hydrous ethanol 150 or 320 miles to either the Sao Paulo port of Sao Sebastiao or Rio de Janeiro, respectively. In Brazil, like the United States, cost savings vary by transport mode depending on haul distance. Preference shifts from trucks, to railroad, to pipeline as the haul distance increases. Transpetro Brazil manages the supply chain segments connecting sugarcane ethanol production facilities and coastal deepwater ports. Figure 17 illustrates Transpetro Brazil's export infrastructure linking the Paulinia refinery district to Sao Sebastiao and Rio de Janeiro. While not shown in Figure 17, highways and railroad tracks roughly parallel the pipeline routes connecting Paulinia, Guararema, Sao Sebastiao, and Rio de Janeiro. Transpetro constructed an intermediate storage terminal complex at Guararema in Sao Paulo state to increase transport efficiency. From Guararema the biofuel is routed to either of the two ports.[139] If a shipping disruption creates an ethanol backlog in either Rio or Sao Sebastiao, the ethanol supply to that particular port can be reduced and the quantity directed to the other export terminal commensurately increased at the Guararema complex. These proactive measures would lessen the magnitude of export slowdowns precipitated by various disturbances, such as a longshoreman strike at one of the harbors.

Figure 17 – Brazil Sugarcane Ethanol Export Corridor



Source: Brazil-Texas Chamber of Commerce[140]

Table 9 illustrates during calendar year 2008, Brazil exported approximately 5.12 billion liters of ethanol with 90 percent or 4.59 billion liters passing through the south central ports of Sao Sebastiao and Rio de Janeiro.[141] By month, Table 10 shows South Central Brazil ethanol export volumes ranged from a low of 171.2 million liters in January 2008 to a high of 621.5 million liters in August 2008, which corresponded with the winter sugarcane harvest.[142] The average price of ethanol leaving the South Central Brazilian ports during 2008 was $468.26 USD per cubic meter or $0.468 per liter of ethanol. This price includes all agricultural, refining, and transport costs required prior to export.[143] Recalling that farming and production practices levied a price of 0.302 per liter of ethanol, the cost differential of $0.166 per liter summarizes the average transportation costs required to transfer the sugarcane ethanol from refinery to port. The $0.166 per liter cost assumes truck, rail, and pipeline transport percentages of 30, 60, and 10 percent, respectively.

Table 9 - Brazil Annual Ethanol Export Quantities and Price

CALENDAR YEAR	VOLUME (million liters)			US$ FOB (million dollars)			AVERAGE PRICE (US$/m³)		
	Brazil	South Centre	North Northeast	Brazil	South Centre	North Northeast	Brazil	South Centre	North Northeast
2000	227.3	183.6	43.7	34.8	24.2	10.6	153.07	131.72	242.75
2001	345.7	300.0	45.7	92.1	78.9	13.2	266.57	263.13	289.13
2002	789.2	576.1	213.0	169.2	121.9	47.3	214.35	211.58	221.84
2003	757.4	457.3	300.1	158.0	91.1	66.9	208.57	199.11	222.98
2004	2,408.3	1,865.8	542.5	497.7	376.5	121.2	206.68	201.80	223.44
2005	2,600.6	2,090.8	509.8	765.5	602.0	163.5	294.36	287.92	320.79
2006	3,416.6	2,966.3	450.3	1,604.7	1,415.1	189.6	469.69	477.07	421.09
2007	3,530.1	3,055.4	474.7	1,477.6	1,266.9	210.7	418.58	414.65	443.87
2008	5,118.7	4,590.3	528.4	2,390.1	2,149.5	240.6	466.94	468.26	455.41

Adapted from: Brazil Sugarcane Industry Association (UNICA)[144]

Table 10 - Brazil Monthly Ethanol Export Quantities and Price for 2008

MONTH	VOLUME (million liters)			US$ FOB (million dollars)			AVERAGE PRICE (US$/m³)		
	Brazil	South Centre	North Northeast	Brazil	South Centre	North Northeast	Brazil	South Centre	North Northeast
Jan 2008	220.7	171.2	49.5	89.0	69.7	19.3	403.37	407.08	390.52
Feb 2008	364.7	268.1	96.6	158.2	118.3	39.9	433.92	441.28	413.47
Mar 2008	278.2	206.9	71.3	125.0	94.3	30.7	449.19	455.63	430.52
Apr 2008	289.7	241.9	47.7	137.4	116.7	20.7	474.32	482.22	434.30
May 2008	391.7	304.2	87.4	182.6	143.9	38.8	466.23	472.83	443.25
June 2008	423.0	393.2	29.8	198.2	185.1	13.1	468.44	470.72	438.43
July 2008	600.6	593.0	7.6	280.8	277.4	3.4	467.53	467.82	444.96
Aug 2008	621.5	621.5	0	303.0	303.0	0	487.48	487.48	0.00
Sept 2008	592.5	592.5	0	287.5	287.5	0	485.28	485.28	0.00
Oct 2008	481.1	467.7	13	226.3	218.9	7.4	470.35	468.02	552.12
Nov 2008	506.6	435.5	71	238.7	200.9	37.7	471.20	461.38	531.44
Dec 2008	348.5	294.5	54.1	163.5	133.8	29.6	468.98	454.48	547.97

Adapted from: Brazil Sugarcane Industry Association (UNICA)[145]

Petrobras and Transpetro's ethanol export infrastructure underscores Brazil, unlike the United States, is profiting from an international ethanol trade. Knowing which countries receive ethanol from Brazil is requisite in ascertaining overseas tanker shipping prices. Table 11 lists the top ten foreign destinations for Brazilian ethanol between 2006 and 2008. This tabulated information emphasizes a bona fide ethanol trade already exists between Brazil and the United States. Annual imports of 1.75 billion, 850 million, and 1.52 billion liters during 2006, 2007, and 2008, respectively, made the United States the largest foreign recipient of Brazilian sugarcane ethanol.[146] However, the halving of imports between 2006 and 2007 is evidence of the protectionist $0.54 per gallon foreign ethanol offset tariff constricting trade following its implementation in December 2006. Direct Brazil-to-United States biofuel volumes constitute a conservative estimate of the amount of sugarcane ethanol reaching American shores on an annual basis during the last three years. Jamaica, El Salvador, Trinidad and Tobago, the U.S. Virgin Islands, and Costa Rica comprise five of the remaining top-ten foreign destinations for Brazilian ethanol. These four countries and one U.S. territory are members of the Caribbean Basin Initiative (CBI). CBI status allows these governments to ship ethanol duty-free to the United States mainland. Petrobras Transpetro and other Brazilian suppliers can take advantage of a loophole that does not require ethanol exports to originate in CBI member states but only undergo dehydration, the final production step required to make ethanol usable as motor fuel, in Central America.[147] In 2008, Brazilian biofuel exports to these five CBI members totaled 1.31 billion liters, potentially doubling overall American imports that year to approximately 2.83 billion liters.[148]

Table 11 - Top Ten Recipient Countries of Brazil Ethanol Exports, 2006 - 2008

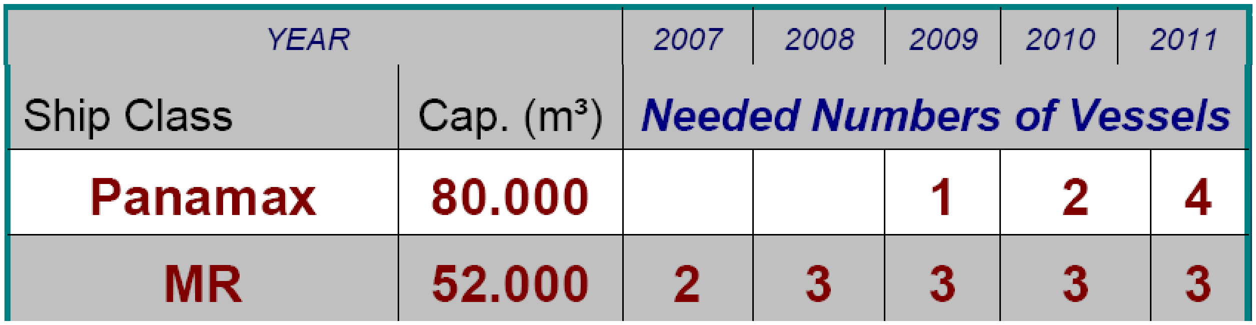
COUNTRY	VOLUME (million liters)		
	2006	2007	2008
United States	1,749.2	849.7	1,519.4
Netherlands	344.5	800.9	1,331.4
Jamaica	133.0	312.1	436.1
El Salvador	182.7	226.8	355.9
Japan	227.7	367.2	263.2
Trinidad and Tobago	72.3	160.5	224.3
Virgin Islands (U.S)		52.7	187.9
Korea, Republic of (South Korea)	93.4	67.4	186.6
Costa Rica	92.2	172.2	109.4
Nigeria	43.1	124.2	97.8

Adapted from: Brazil Sugarcane Industry Association (UNICA)[149]

The fact Brazil sugarcane ethanol exports reach U.S. markets enables a discussion of the equipment and costs required to transport the biofuel overseas. It should be noted even if all Brazil exports to CBI nations continued onto American ports, the Brazil – U.S. ethanol trade could still undergo significant growth. Approximately 2.83 billion liters equals less than seven percent of the Expanded Renewable Fuel Standard (RFS) for 2009 of 11.1 billion gallons (see Table 1).[150] Growth in the volume of South American biofuel imports would decrease the tanker transport costs required to reach the United States mainland through economies of scale.

Sao Sebastiao and Rio de Janeiro's marine terminal, Ilha D'Agua, can handle tankers as large as 300,000 deadweight tonnage (dwt) and 130,000 dwt, respectively.[151] In 2007, Transpetro developed a five-year international ethanol export strategic plan focusing on these two deepwater harbors. Table 12 summarizes Transpetro's forecast. The company anticipates using two types of tanker ships for ethanol transport: Panamax freighters, which have a capacity of 80,000 cubic meters or 80 million liters, and smaller MR product tankers, which hold approximately 52 million liters. Figures 18 and 19 illustrate both ship types. Transpetro has decided dedicated-ethanol ships will comprise its overseas biofuel fleet to avoid any potential problems with stress-crack corrosion that could compromise the integrity of ethanol-petroleum combination tanks. Assuming roundtrip deliveries would require approximately four weeks time on average, both of Transpetro's MR tankers completed approximately thirteen deliveries in 2007 exporting 1.35 billion liters of ethanol. This amount represents just under 40 percent of all 2007 exports, with smaller temporary vessels used by Transpetro and other private carriers comprising the remaining 60 percent of deliveries. Table 12 illustrates Transpetro's total ethanol export capacity increases annually, reaching four dedicated Panamax and three MR product tankers in 2011 that collectively offer a single delivery volume of 476 million liters and annual export potential of 6.19 billion liters assuming a four-week turnaround time.[152]

Table 12 – Petrobras Transpetro's Five-Year Export Capacity Expansion



YEAR		2007	2008	2009	2010	2011
Ship Class	Cap. (m³)	*Needed Numbers of Vessels*				
Panamax	**80.000**			**1**	**2**	**4**
MR	**52.000**	**2**	**3**	**3**	**3**	**3**

Adapted from: Brazil-Texas Chamber of Commerce[153]

Figure 18 – Panamax Tanker

Source: Mining-Technology.com[154]

Figure 19 – MR Product Tanker

Source: StenaBulk[155]

Embarking from the ports of Sao Sebastiao or Rio de Janeiro, Transpetro and other container lines such as Maersk Sealand, Hapag-Lloyd, and Hamburg Sud operate tankers bound for the United States. As of July 2008, the three major U.S. ethanol import markets were New York Harbor, the Gulf Coast (namely Houston), and the West Coast (namely Los Angeles / Long Beach). Typical transit times vary between 15 and 24 days depending on the number of intermediate stops in the Caribbean Basin, including Port-of-Spain, Trinidad and Tobago and Kingston, Jamaica, and the remaining distance to the final U.S. terminus.[156] Both New York and Houston are decidedly shorter itineraries compared to Los Angeles. To reach West Coast ports, the ethanol carriers must utilize the Panama Canal, a definite bottleneck for ship commerce linking North and South America. International tanker transport fees from Brazil to the United States vary according to the American destination. As of July 2008, spot prices for overseas tanker export charges from the State of Sao Paulo, Brazil to the United States were \$0.18 (\$0.048), \$0.195 (\$0.052), and \$0.23 (\$0.061) per gallon (liter) for the Gulf Coast, New York Harbor, and West Coast, respectively.[157]

Figure 20 – Sao Paulo to Texas Shipping Routes

Adapted from: Ocean Schedules[158]

Figure 20 illustrates the sea lanes utilized for ethanol transport between the State of Sao Paulo and the State of Texas. Stops at Kingston, Jamaica are of strategic significance considering Jamaica's status as a CBI nation.[159] Upon arrival in Texas, Petrobras Transpetro takes advantage of the multimodal facilities offered by the Port of Houston. The second busiest United States port, in terms of total tonnage, the Port of Houston is a 25-mile-long complex of diversified public and private facilities located just a few hours' sailing time from the Gulf of Mexico. The Port of Houston Authority collaborates with more than 150 private industrial companies along the Houston Ship Channel. In terms of direct rail and truck access, the Turning Basin Terminal is a competitive alternative to handle Brazilian ethanol imports. This multipurpose complex is located eight miles from downtown Houston at the navigational head of the Houston Ship Channel, approximately 50 miles from the Gulf of Mexico. The banks along this section of the channel are lined for 2.5 miles downstream, with an alternating arrangement of open wharves and docks backed by transit sheds and warehouses. The Turning Basin is particularly suited for direct discharge and direct loading operations, including handling of fuel ethanol. Each year, some 2,800 containerized ship and barge calls are recorded at the Turning Basin Terminal's 37 docks making the facilities sufficient for supporting Brazil's growing ethanol trade.[160]

Direct discharge and loading are possible at this terminal, using either rail cars or trucks. Berths are assigned on a first-come, first-served basis, rather than preferential berthing, and the average turnaround time for a ship at the terminal is two to three days. Every wharf at the Turning Basin, except Wharves 1 through 4, is served by rail. Two railroads serve Houston and provide service to all points in the United States. The Burlington Northern Santa Fe (BNSF) and Union Pacific railroads are members of the Port Terminal Railroad Association, which provides switching service to all Turning Basin docks. Once the sugarcane ethanol is loaded onto BNSF trains, the same rate and fee schedules would apply to this Brazilian biofuel as the corn ethanol described earlier. In terms of vehicular ethanol transport, more than 100 truck lines serve the Turning Basin, which is located just five miles from Interstates 10 and 610, the two major freeways that run east-west and north-south through the greater Houston metropolitan region, respectively.[161]

Table 13 – Cost Breakdown of Brazilian Sugarcane Ethanol (Houston, Texas)

Stage	Cost (per Liter) [1]	Cost (per Gallon) [2]
Production - Sao Paulo, Brazil	$0.302	$1.143
Refinery-to-Port Transportation (Brazil)	0.166	0.628
Tanker Export - Brazil to Texas (Gulf Coast)	0.048	0.180
Ethanol Offset Tariff	0.143	0.540
Total Cost to Houston, TX Market	**$0.658**	**$2.492**

[1] Average per-liter costs for 2008

[2] Conversion, 1 gallon = 3.785 liters

Table 13 recaps the production and transport costs required to synthesize and transfer Brazilian sugarcane ethanol to Houston, Texas. This supply chain study assumes suppliers pass on 100 percent of costs to the consumer. Therefore, $2.49 per gallon was the going rate of Brazilian sugarcane ethanol in Houston averaged over all 2008 imports. Table 13 illustrates this cost sum includes the $0.54 per gallon offset tariff. Once inserted into the United States transportation system, both domestic corn ethanol and foreign sugarcane ethanol are subject to the same modal constraints and financial expenditures. The following chapter describes Texas's seven potential ethanol markets. A sensitivity analysis compares which ethanol fuel type (American corn or Brazilian sugarcane) is more economical in each region given the existing magnitude of the offset tariff and the tariff halved in value.

CHAPTER 8. SUPPLYING THE TEXAS ETHANOL MARKETS

Texas is second in the nation both in terms of population and land area. As of January 2009, approximately 24,327,000 people resided in the 268,601 square miles of the Lone Star State. Until the last fifteen to twenty years, Texas's massive size characterized the state as predominantly rural in terms of population density. However, since the 1980s, a diversifying and robust economy has attracted many newcomers to this Sunbelt state, primarily Texas's metropolitan areas. By the first decade of the twenty-first century, more than fifty percent of the state's population resided in the nine cities of Amarillo, Austin, Corpus Christi, Dallas, El Paso, Fort Worth, Houston, Lubbock, and San Antonio.[162] Furthermore, the petroleum industry has established approximately 80 percent of the gas volume consumed by Texans is expended by customers in these nine cities.[163] The Energy Information Administration reports Texas drivers consumed approximately 7.12 million gallons per day or 2.60 billion gallons per year. Texas does not yet have an ethanol fuel blend mandate. However, it is common to find E10 marketed throughout the state. Statewide adoption of a 10 percent ethanol, 90 percent gasoline fuel blend is a logical assumption for predicting a floor for ethanol demand in the Lone Star State over the next five to ten years.[164] Adoption of E10 as the fuel standard would imply an annual demand of approximately 260 million gallons of ethanol in Texas. This estimated demand is roughly 5.5 percent of the entire 2007 U.S. ethanol production of 4.75 billion gallons. 80 percent of Texas's gasoline and thereby 80 percent of the state's future ethanol demand would originate in the nine urban areas described above. Discussion of the transportation energy infrastructure supplying each city will provide insight as to what ethanol source would be able to satisfy the given metropolitan region's demand at the lowest price.

Houston

Boasting a population of more than 2.2 million people in 2007, Houston is Texas's largest city and the fourth most populous city in the country after New York, Los Angeles, and Chicago. Chapter 7 addressed the equipment and costs required to transport ethanol via three modal alternatives to the Bayou City. Results for railroading and barging domestic ethanol from Iowa as well as shipping foreign ethanol from Brazil are recapitulated in Table 14.

Table 14 – Cost Comparison for Ethanol arriving in Houston

Stage Cost (USD per gallon)	Iowa (Rail)	Iowa (Barge)	Brazil w/ Tariff	Brazil w/out Tariff
Production	$1.700	$1.700	$1.143	$1.143
Refinery-to-Port Transportation (barge and tanker)	N/A	0.320	0.628	0.628
Single Tanker Railcar (U.S. rail)	0.166	N/A	N/A	N/A
Barge Transport	N/A	0.140	N/A	N/A
Tanker Export (Brazil)	N/A	N/A	0.180	0.180
Ethanol Offset Tariff (Brazil)	N/A	N/A	0.540	N/A
Total Cost to Houston, TX Market	**$1.866**	**$2.160**	**$2.492**	**$1.952**

As the “energy capital of the world” Houston has a well developed infrastructure capable of handling both foreign and domestic energy commodities. Figure 21 depicts refineries in Baytown and Texas City adjacent to the Houston Ship Channel. Storage tanks on the premises are readily accessible to blend gasoline with ethanol arriving via barge or tanker at the nearby Turning Basin Terminals. Chapter 7 described how BNSF also services the ship channel corridor. Musket and Magellan, two petroleum transport firms, jointly operate another large rail facility near Pasadena. The plethora of ethanol rail and shipping options makes Houston one of the easiest markets to service in Texas.

Figure 21 – Houston Metropolitan Area

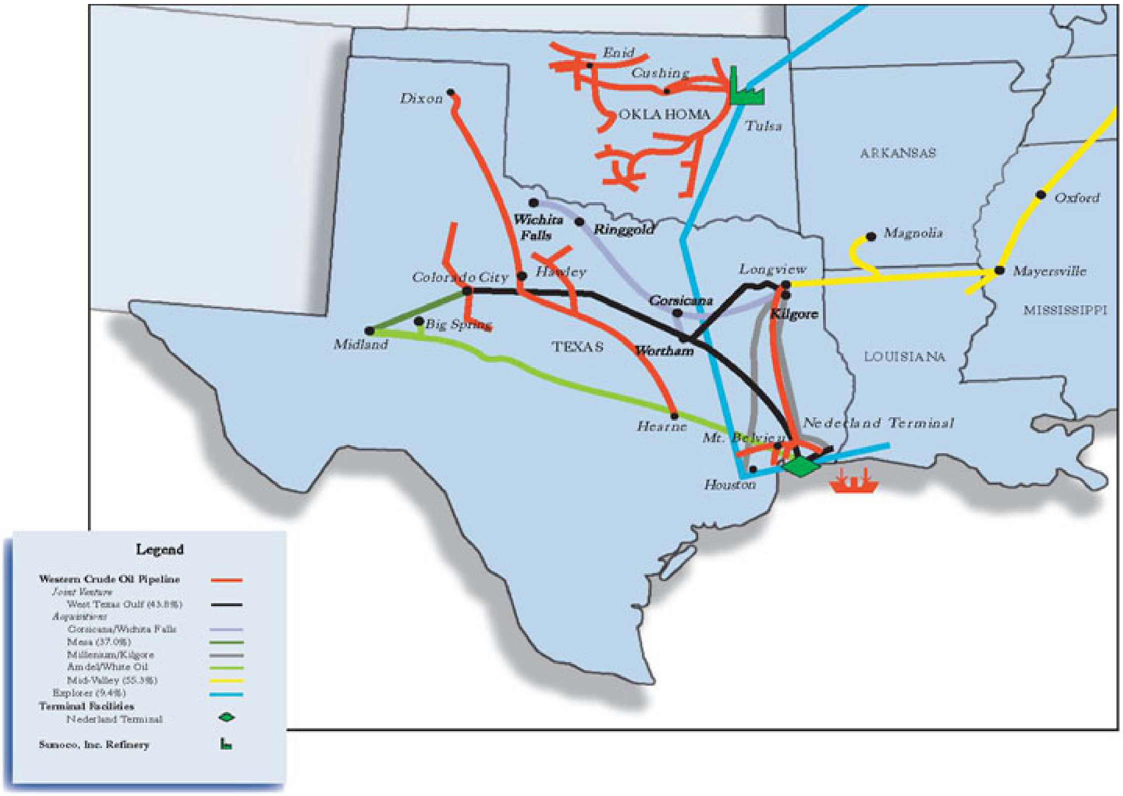
Source: Greater Houston Partnership[165]

Despite Houston’s coastal orientation, Table 14 suggests railroading ethanol is more cost competitive than either barging or ocean shipping the biofuel. However, the cost data fails to convey the availability issues associated with ethanol trains. Houston ethanol train service would pass through the Dallas-Fort Worth Metroplex (DFW) on its way south from Iowa. Assuming a statewide E10 mandate, DFW may generate enough demand to consume the majority of ethanol arriving from the Corn Belt. Any ethanol shortfall in Houston would be handled by biofuel volumes arriving via barge or tanker. It is interesting to note that repealing the federal ethanol offset tariff of $0.54 per gallon would lower the price of Brazilian sugarcane ethanol below $2.00 per gallon, approximately $0.21 per gallon less expensive than barged ethanol from the Midwest. This variation in the attractiveness of Brazil's biofuel as a function of the magnitude of the excise tariff levied will repeat for the other metropolitan areas investigated.

Dallas - Fort Worth Metroplex

After Houston, the Dallas – Fort Worth metropolitan area (DFW) is the second most populous region in Texas. More than 4.0 million people reside in Dallas and Tarrant Counties, which encompass the cities of Dallas and Fort Worth, respectively. The Burlington Northern-Santa Fe Railway is headquartered in Forth Worth. Not surprisingly, rail is the dominant freight transportation mode servicing DFW. DFW single tanker railcar rates are one penny less per gallon compared to Houston. No refineries exist in the Metroplex necessitating gasoline brought in via pipeline from either Houston or Corpus Christi. Four pipelines service Dallas. Explorer, Exxon, and Magellan originate in Houston whereas the Koch pipeline begins in Corpus Christi. Figure 22 highlights the Explorer pipeline in blue, which extends north of Dallas to Tulsa, Oklahoma. Explorer is part of Sunoco's Western Pipeline System. The Exxon and Magellan pipelines follow similar paths between Houston and Dallas.

Figure 22 – Crude Oil Pipelines Servicing the Southwest Region



Source: Sunoco Logistics[166]

Petroleum pipeline transportation costs are approximately $0.02 per gallon, which compares quite favorably to the tanker railcar cost of $0.15 per gallon. Currently, rail supplies 100 percent of DFW's ethanol needs. Gasoline is pipelined into the Metroplex and deposited in storage tanks adjacent to ethanol dedicated storage tanks near train terminals, such as BNSF's unit train receiving facility in Fort Worth or Musket Corporation's new rail depot in Dallas. Collectively, these storage tanks hold four to five days supply of fuel. Metered blending of ten percent ethanol with 90 percent gasoline to make E10 occurs within tanker trucks in transit to distribution stations. Dallas and Fort Worth's remoteness from the coast make a change in rail's domination of the ethanol supply unlikely in the near future. If the Departments of Transportation, Energy, and Agriculture approved transport of E10 and other low ethanol to gasoline blends, conveyance of E10 through Explorer, Exxon, Magellan, or Koch pipelines is conceivable. The $0.02 per gallon charge that applies to gasoline alone represents a suitable estimate of the additional cost required to bring E10 inland from Houston. Additional cost savings of $0.10 per gallon are likely since E10 arriving via pipeline into DFW would not need to be stored in separate ethanol and gasoline tanks. The gasoline and ethanol transporters would save between $0.5 and $1.0 million in avoided construction costs for each storage tank deemed unnecessary. The ten percent ethanol blends could be readily distributed to service stations via tanker trucks negating the four- to five-day storage tank intermediate step.[167] However, Table 15 illustrates while this blended pipeline component of the E10 supply chain may reduce the ethanol transit time to DFW, rail would still command a significant cost advantage of at least $0.22 per gallon compared to the barge alternative if protectionism of corn ethanol remains policy. Alternatively, the fourth scenario underscores railed ethanol at $1.85 per gallon is barely less expensive than Brazilian sugarcane ethanol imported into Houston and then pipelined to DFW. These circumstances remain unlikely given the slim chance the ethanol offset tariff would be *completely* repealed.

Table 15 – Cost Comparison for Ethanol arriving in Dallas-Fort Worth

Stage Cost (USD per gallon)	Iowa (Rail)	Iowa (Barge)	Brazil w/ Tariff	Brazil w/out Tariff
Production	$1.700	$1.700	$1.143	$1.143
Refinery-to-Port Transportation (barge and tanker)	N/A	0.320	0.628	0.628
Single Tanker Railcar (U.S. rail)	0.152	N/A	N/A	N/A
Barge Transport	N/A	0.140	N/A	N/A
Tanker Export (Brazil)	N/A	N/A	0.180	0.180
Ethanol Offset Tariff (Brazil)	N/A	N/A	0.540	N/A
E10 Pipeline Transport from Houston	N/A	0.020	0.020	0.020
Combined Storage Tank (cost savings)	N/A	-0.100	-0.100	-0.100
Total Cost to Dallas - Fort Worth, TX Market	**$1.852**	**$2.080**	**$2.412**	**$1.872**

Corpus Christi

Texas's second largest port is also the most attractive to the ethanol barge and tanker import supply chains. Corpus Christi is the largest port along the mid-Texas coast, approximately two hundred miles southwest of Houston. Like the Bayou City, the Port of Corpus Christi Authority oversees both public and private terminals. The public marine terminals are those owned by the Port of Corpus Christi Authority and include the Corpus Christi Public Elevator, the Public Bulk Terminal Docks 1 and 2, the Public Oil Docks, and the Public General Cargo Docks. Also included are private marine terminals such as those associated with chemical plants and refineries located in the Corpus Christi Port District. The main imports passing through the Port of Corpus Christi include: iron and steel products, machinery, military cargo, temperature controlled break bulk cargo, bagged grains and products, bulk grain, alumina, bauxite and ore, liquid fertilizer, and petroleum.[168] Although significantly fewer oil imports pass through Corpus Christi compared to Houston, the metropolitan region still boasts a robust petroleum refining industry. Particularly of note, the Koch pipeline servicing Dallas, via San Antonio and Austin, begins in Corpus Christi.[169]

Table 16 – Cost Comparison for Ethanol arriving in Corpus Christi

Stage Cost (USD per gallon)	Iowa (Rail)	Iowa (Barge)	Brazil w/ Tariff	Brazil w/out Tariff
Production	N/A	$1.700	$1.143	$1.143
Refinery-to-Port Transportation (barge and tanker)	N/A	0.320	0.628	0.628
Single Tanker Railcar (U.S. rail)	N/A	N/A	N/A	N/A
Barge Transport	N/A	0.140	N/A	N/A
Tanker Export (Brazil)	N/A	N/A	0.180	0.180
Ethanol Offset Tariff (Brazil)	N/A	N/A	0.540	N/A
Total Cost to Corpus Christi, TX Market	**N/A**	**$2.160**	**$2.492**	**$1.952**

Corpus Christi does not have rail access comparable to Houston. For example, the Burlington Northern-Santa Fe does not provide ethanol service to this Texas port. The two alternatives for supplying Corpus Christi and the rest of South Texas with ethanol are to barge the biofuel further southwest along the Gulf Intracoastal Waterway or supply the Brazilian sugarcane variety using Panamax and MR Product tankers. Table 16 indicates the approximate costs for ethanol in Corpus Christi are comparable to Houston excluding the rail option. The continuance of the domestic ethanol offset tariff will determine whether barging domestic corn ethanol or importing the sugarcane variety is more lucrative for suppliers.

Austin and San Antonio

The Interstate 35 corridor is one of the fastest growing regions in the State of Texas. This interstate highway connects San Antonio and Austin, the seventh and sixteenth largest cities in the country, respectively, with the Dallas-Fort Worth Metroplex to the north. Central Texas is one of several regions in the Sunbelt that has experienced double digit population increases over the last twenty years. Drivers in this region of the Lone Star State have commensurately demanded an ever larger volume of gasoline to fuel the growing transportation needs of the local economies. However, the energy infrastructure of both San Antonio and Austin is decidedly less developed than Houston, Corpus Christi, or Dallas-Fort Worth. San Antonio and Austin lack significant refining capacity. The Three Rivers refinery is San Antonio's only local refinery while no refining capacity exists near Austin's city limits. Austin claims only one, local storage terminal. Figure 23 illustrates the Koch Pipeline Company provides both cities gasoline via its Texas pipeline. The Koch pipeline travels along the eastern side of the San Antonio metropolitan area near the Interstate 610 beltway before paralleling I-35 northward to Austin.[170]

Figure 23 – Koch Texas Pipeline System

Adapted from: GreenwichMeanTime.com[171]

Like the state overall, neither San Antonio nor Austin have E10 mandates. Given the historic low demand for ethanol in Central Texas, BNSF never established single ethanol railcar service, let alone ethanol unit or gathered train options for the Interstate 35 corridor. Like Corpus Christi, the lack of established ethanol train service increases the difficulty of railroading domestic ethanol to either San Antonio or Austin.[172] Table 17 underscores the approximate costs of transporting ethanol along Interstate 35 are only slightly higher than the Corpus Christi rates given the nominal charge of $0.02 per gallon associated with moving E10 via combination pipeline. Once again, per gallon rates between $2.00 and $2.20 appear competitive in the current biofuels market. The domestic biofuel offset tariff obviously hurts the cost competitiveness of Brazilian sugarcane ethanol compared to barging corn ethanol south from the Midwest.

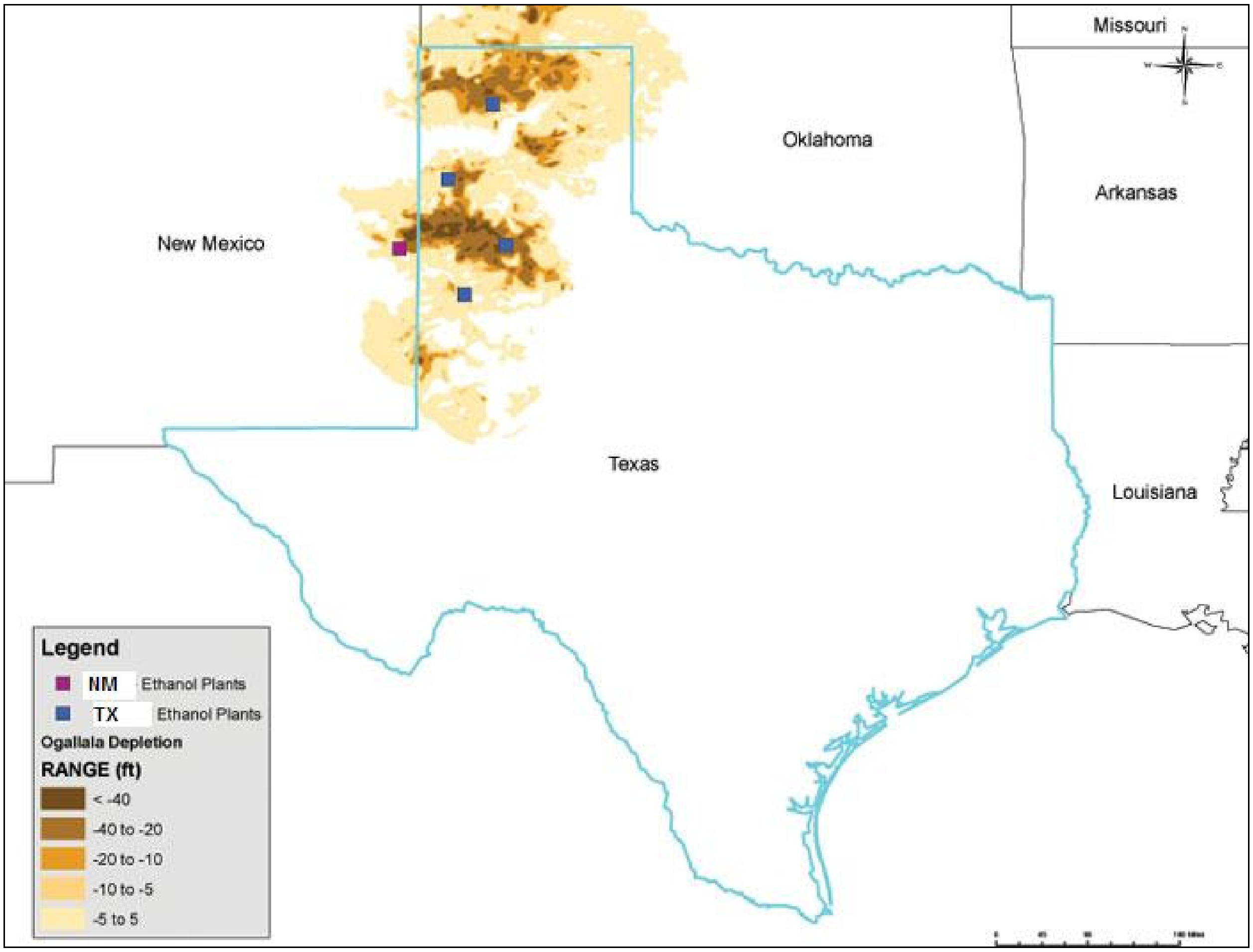
Table 17 – Cost Comparison for Ethanol arriving in Austin and San Antonio

Stage Cost (USD per gallon)	Iowa (Rail)	Iowa (Barge)	Brazil w/ Tariff	Brazil w/out Tariff
Production	N/A	$1.700	$1.143	$1.143
Refinery-to-Port Transportation (barge and tanker)	N/A	0.320	0.628	0.628
Single Tanker Railcar (U.S. rail)	N/A	N/A	N/A	N/A
Barge Transport	N/A	0.140	N/A	N/A
Tanker Export (Brazil)	N/A	N/A	0.180	0.180
Ethanol Offset Tariff (Brazil)	N/A	N/A	0.540	N/A
E10 Pipeline Transport from Corpus Christi	N/A	0.020	0.020	0.020
Total Cost to Austin and San Antonio, TX Markets	**N/A**	**$2.180**	**$2.512**	**$1.972**

Amarillo and Lubbock

Amarillo and Lubbock are the two largest population centers in the Texas Panhandle. In addition to being one of the drier areas of the state, Chapter 5 described how the Panhandle is the largest corn ethanol producing region in Texas. As of March 2009, the State Energy Conservation Office (SECO) reports all four operational Texas ethanol plants are located in the Panhandle, as illustrated by Figure 24. One of these four refineries is the Hereford Ethanol Plant operated by Panda Ethanol. Completed in 2008, the Hereford Plant has a capacity of 115 million gallons per year, reputedly the largest biomass fueled ethanol refinery in the nation. Collectively, the four Panhandle refineries are capable of producing 355 million gallons of ethanol annually.[173] Recalling the EIA's finding that Texas drivers consume approximately 2.60 billion gallons of gasoline per year and given only two percent of the Texas population resided in the Panhandle as of 2000, Panhandle drivers would proportionally consume 52 million gallons of gasoline per year.[174] Adhering to the E10 mandate assumption, 5.2 million gallons represents the threshold, annual base demand for ethanol in the Texas Panhandle. Since the capacity of the four current biorefineries is more than 68 times the local E10 ethanol demand, the Texas Panhandle is a net export region for ethanol. Such close proximity to refineries implies Panhandle residents would have access to ethanol at prices roughly equal to the cost of production, $1.70 per gallon.

Figure 24 – Texas Ethanol Plants located in Water-Scarce Panhandle



Adapted from: Environmental Defense Fund[175]

El Paso

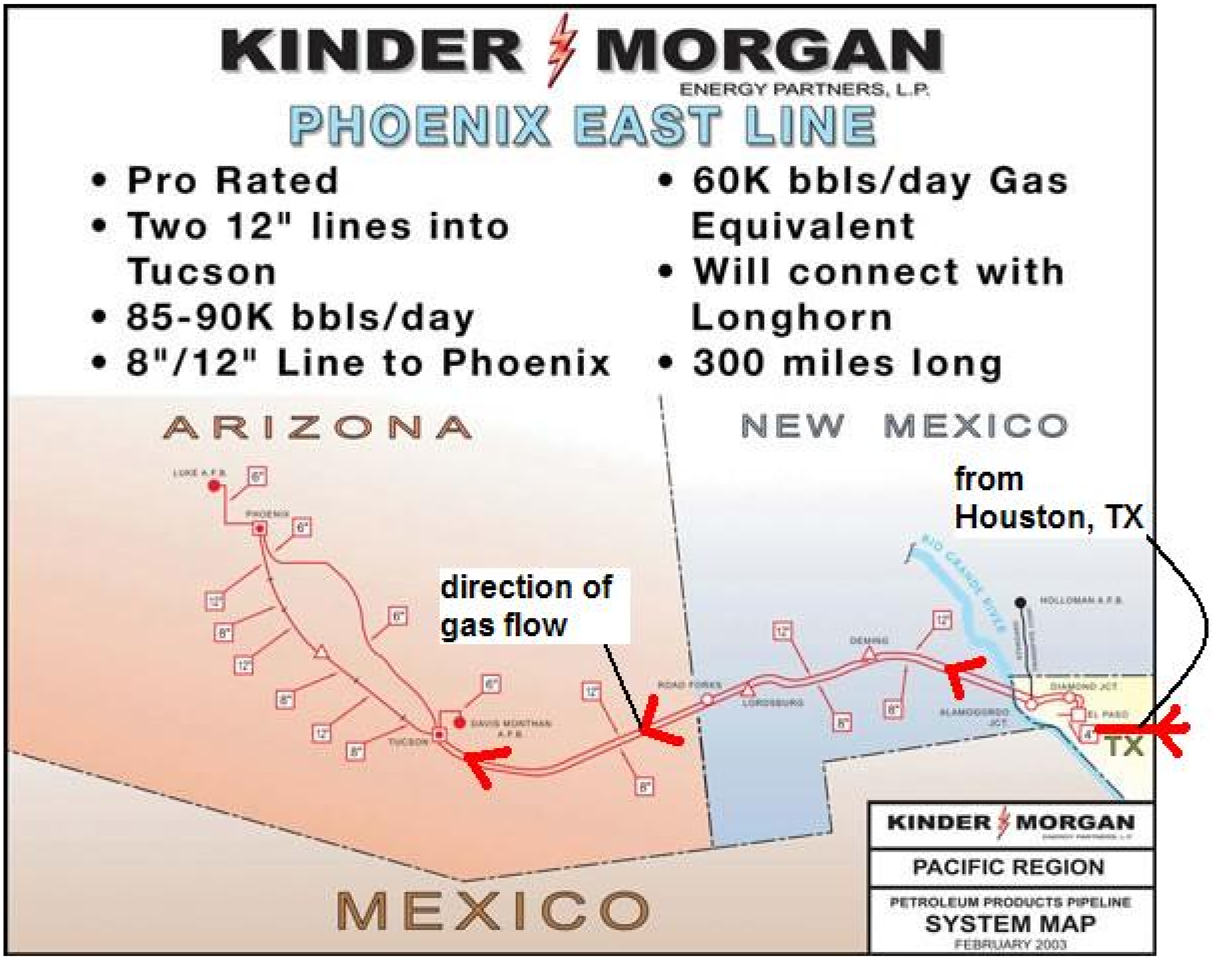
Prospects are Texas's westernmost city of El Paso would provide a competitive market for ethanol transported by both railcar from the Midwest and pipeline from the Gulf Coast. El Paso County, with an estimated 2007 population of 735,000 people, was the first region in Texas to utilize ethanol as a fuel blend. In the early 1990s, El Paso adopted widespread use of E10 to combat seasonal air pollution inversion problems. El Paso's geography resembles that of Los Angeles, a valley nestled within mountains.[176] The El Paso metropolitan region comprises three percent of the Texas population with a commensurate ethanol demand of 7.86 million gallons per year, assuming 100 percent adoption of E10.

Figure 25 – El Paso Serviced by BNSF Southwest Division

Adapted from: BNSF[177]

Figure 25 illustrates El Paso is serviced by the Burlington Northern-Santa Fe's Southwest Division while Table 5 indicates a single, 29,400 gallon rail tanker from Iowa to El Paso would cost approximately $5,125 or $0.174 per gallon. Figure 26 shows El Paso is also an intermediate destination along Kinder Morgan's Longhorn-Phoenix East petroleum pipeline system linking Houston with the Phoenix and Tucson, Arizona markets. Conversion of this 60,000 barrel per day gasoline system to E10 combination flow would likely add a $0.02 per gallon of ethanol transported.[178] However, like Dallas-Fort Worth a cost savings approximately $0.10 per gallon could be realized compared to the BNSF rail option since the already blended E10 fuel would not need to be stored in separate ethanol and gasoline storage tanks. Table 18 compares total costs of ethanol in El Paso for the railroad and pipeline transit options.

Figure 26 – Pipeline System connecting El Paso to Houston and Phoenix



KINDER MORGAN
ENERGY PARTNERS, L.P.
PHOENIX EAST LINE

- Pro Rated
- Two 12" lines into Tucson
- 85-90K bbls/day
- 8"/12" Line to Phoenix
- 60K bbls/day Gas Equivalent
- Will connect with Longhorn
- 300 miles long

Adapted from: Arizona Motor Fuel Supply and Distribution[179]

Table 18 – Cost Comparison for Ethanol arriving in El Paso

Stage Cost (USD per gallon)	Iowa (Rail)	Iowa (Barge)	Brazil w/ Tariff	Brazil w/out Tariff
Production	$1.700	$1.700	$1.143	$1.143
Refinery-to-Port Transportation (barge and tanker)	N/A	0.320	0.628	0.628
Single Tanker Railcar (U.S. rail)	0.174	N/A	N/A	N/A
Barge Transport	N/A	0.140	N/A	N/A
Tanker Export (Brazil)	N/A	N/A	0.180	0.180
Ethanol Offset Tariff (Brazil)	N/A	N/A	0.540	N/A
E10 Pipeline Transport from Houston	N/A	0.020	0.020	0.020
Combined Storage Tank (cost savings)	N/A	-0.100	-0.100	-0.100
Total Cost to El Paso, TX Market	**$1.874**	**$2.080**	**$2.412**	**$1.872**

As alluded to at the beginning of this section, water carrier coupled with pipeline conveyance of ethanol to El Paso is cost competitive with the single ethanol tanker railcar option. This conclusion may seem counterintuitive given El Paso's remoteness from any large body of water. Moreover, Table 18 demonstrates how pivotal removal of the existing $0.54 per gallon ethanol offset tariff is to development of a bona fide biofuels trade with Latin America. Repeal of this excise fee transforms Brazilian ethanol's cost disadvantage of more than $0.50 per gallon compared to rail to the sugarcane alternative being the most economically priced.

The Last Mile Problem

The preceding six-market sensitivity analyses underscore the potential competitiveness of both domestic and international supply chains providing ethanol to different regions of Texas. Figures 27 and 28 summarize which ethanol fuel source is more competitive within each region of Texas depending on whether or not the domestic ethanol offset tariff is preserved or repealed, respectively. The Houston, Dallas-Fort Worth, and Panhandle markets do not vary with the tariff. However, South, Central, and West Texas switch from domestic to international biofuel sources depending on the regulatory actions of the United States Congress.

Figure 27 – Most Economical Ethanol Supply Chain by Region (Offset Tariff Preserved)

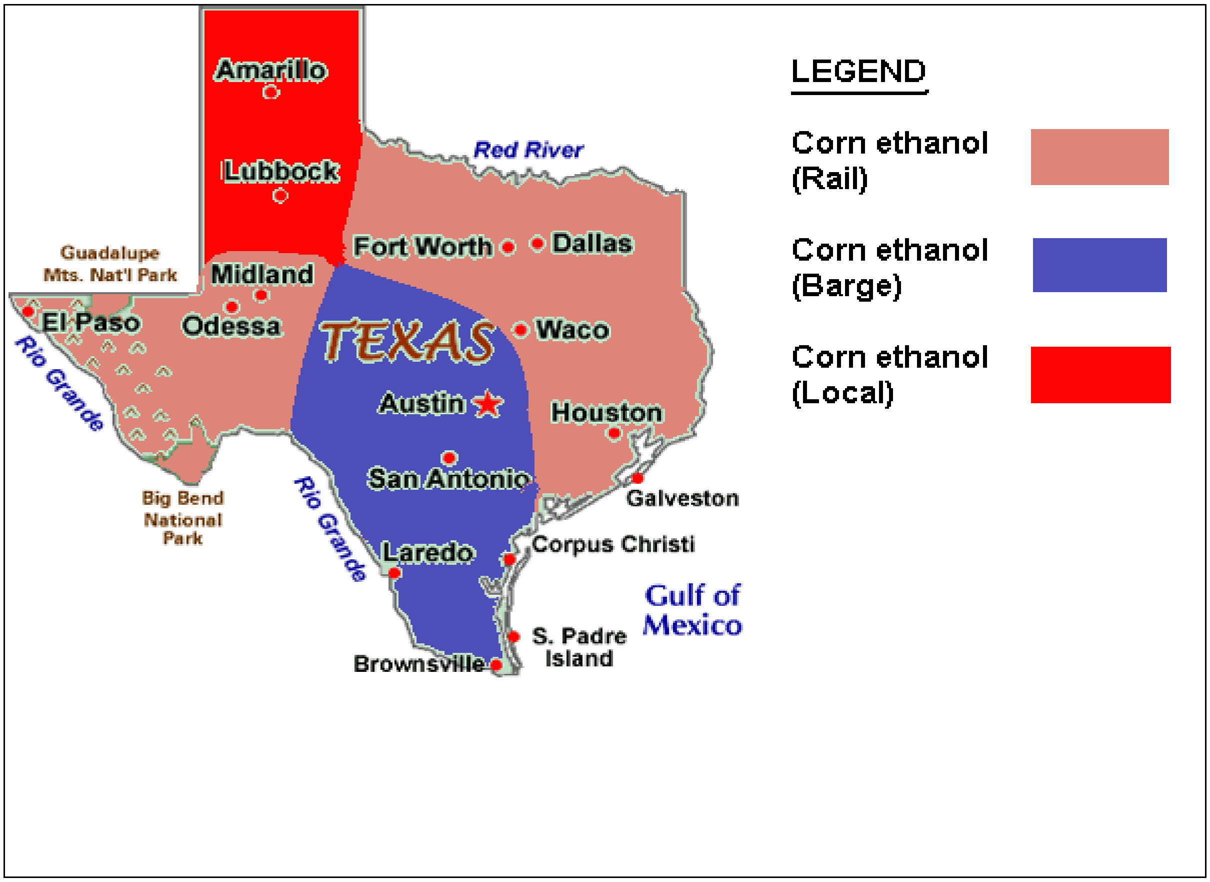
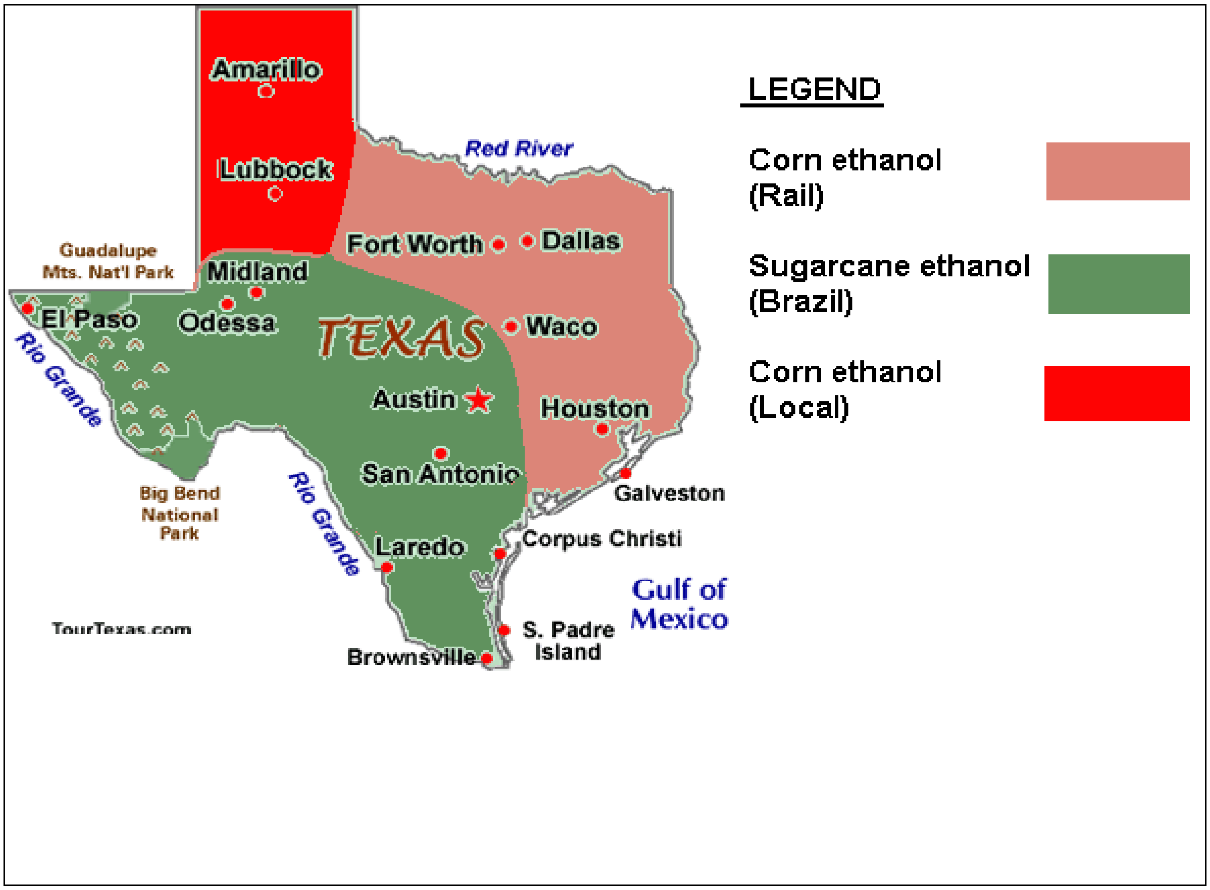


Figure 28 – Most Economical Ethanol Supply Chain by Region (Offset Tariff Repealed)



Biofuels represent an area of significant growth for both the national and Texas economies. Prior chapters have discussed different types of alternative energy sources located both domestically and abroad, as well as the transportation requirements to route these fuels to market destinations. Simply railroading or shipping ethanol to a metropolitan area like Houston, Texas does not complete the supply chain. At this juncture, the developing renewable energy industry faces the "last mile problem" or how to ensure these fuels are both convenient and relatively inexpensive to the consumer to warrant a market shift from traditional petroleum. At first glance, routing alternative fuels several miles from a city's central repository to local fueling stations in the community may seem a trivial issue compared to the costs of energy production and large scale transport over hundreds or thousands of miles between Iowa and Texas or Brazil and Texas, respectively. However, unlike biofuel production and corridor transport, which tend to be arterial and centralized, decentralization characterizes the service station network within urban areas such as Dallas-Fort Worth or Albuquerque, New Mexico.

Fortunately, E10, the focus of this supply chain study, does not require significant retrofits to fuel dispensary units traditionally providing gasoline. Therefore, once the biofuel corridor transport problems discussed in Chapters 6 and 7 are resolved, last-mile infrastructure issues will not impede national availability of this low biofuel blend. The same cannot be said for renewable fuel alternatives like E85 and B100, which were the focus of a related 2008 alternative energy scoping study for the Southwest Region University Transportation Center.

Biofuels hold promise as a partial solution to the United States' existing overreliance on petroleum. However, Chapters 6, 7, and 8 have illustrated the numerous production and transport deficiencies that must be overcome to develop a national biofuels market. Furthermore, Chapters 6 and 8 highlight the energy lifecycle, climactic impact, land use, and financial reasons why Midwest corn ethanol may not be a suitable model for the Southwest and other regions of the U.S. to follow. The deepwater marine ports of Houston and New Orleans have the potential to provide the Southwest region access to Brazilian sugarcane ethanol, a more sustainable, higher quality renewable energy source. Less expensive biofuel imports would also provide greater financial incentive to make costly retrofits to retail and distribution infrastructure throughout the five-state region. Exposure and affordability represent critical metrics that must be satisfied in order to grow a bioenergy market within Texas and the rest of the Southwest.

CHAPTER 9. RECOMMENDATIONS FOR FUTURE RESEARCH

This 2008-09 ethanol supply chain study illustrates how more efficient sugarcane ethanol imported from Brazil could successfully compete with domestic corn ethanol in certain Texas markets. Despite the lower agriculture and refining costs associated with sugarcane ethanol synthesis, Petrobras Transpetro must still expend a sizable intermodal transport cost of $0.808 per gallon ($0.628 per gallon for rail, truck, or pipeline transfer from refinery to marine terminal and $0.180 per gallon for tanker passage) to move the biofuel from Brazilian refineries to the Ports of Houston or Corpus Christi, Texas. A logical follow-up investigation would assess the feasibility of commercial sugarcane ethanol synthesis closer to the United States.

Chapter 5 emphasized that sugarcane's high moisture and warm temperature demands relegate U.S. crop production to South Florida, the Louisiana Delta, and the Hawaiian archipelago. However, abundant sources of sugarcane lie south of the U.S. border. After Brazil, Mexico is the most prolific producer of sugarcane in the Western Hemisphere, harvesting 45.1 million tons of cane in 2008.[180] On January 1, 2008, the U.S. tariff imposed on all Mexican sugar imports expired under terms of the North American Free Trade Agreement (NAFTA).[181] Dropping this trade barrier has the potential to create a loop hole. Increased quantities of Brazilian sugar or even sugarcane ethanol could reach the U.S. market and not be subject to the $0.54 per gallon offset tariff if Mexico is used as an intermediate stop in the supply chain, much like the Caribbean Basin Initiative countries. Although a year has passed since repeal of the tariff, the ensuing worldwide economic downturn and commensurate decline in transportation fuel demand may have delayed entrepreneurs from exploiting these circumstances. The same can be said for Cuba, the twelfth largest producer of sugarcane in the world, lying just ninety miles south of Key West, Florida. In 2008 Cuba harvested 22.9 million tons of sugarcane.[182] The island nation has been the United States's perennial adversary since Fidel Castro's 1959 communist revolution. However, recent developments including Castro's demise and the election of President Barack Obama signal a potential thaw in diplomatic relations across the Florida Straits. The United States may forge biofuel alliances across the Gulf of Mexico to bolster its energy security, if fossil fuel prices once again spike during the economic recovery forecast in late 2009 or 2010.

Finally, how the current severe economic recession will impact the United States biofuel industry is a conundrum energy analysts will ponder for years. As recently as the summer of 2008, five new corn ethanol plants were slated to come on-line in Central and West Texas.[183] Between July and December 2008, the price of oil dropped precipitously from just under $150 to barely $40 per barrel. In response, gasoline prices nationwide are less than half their summer 2008 highs. In contrast, the price of corn feedstock has declined but not as significantly as oil. As of March 9, 2009 corn was trading at $3.66 per bushel, approximately 50 percent below its June 2008 high above $7.20.[184] Refiners are limiting their ethanol purchases to a level required to meet federal blending mandates, far below the industry's built capacity. Analysts forecast national gasoline consumption in 2009 and 2010 to be 6 percent or more below the United States's peak 2007 level. If this steep downturn materializes, the current 2007 Renewable Fuel Standard will mandate future ethanol production levels exceeding ten percent of gasoline consumption.[185] If Americans' reduction in driving is more short lived, likely Congress would leave the 2007 RFS in place. However, if current economic forecasts of a deep, protracted recession materialize and American driving habits diminish for the long term, the federal government may lower its biofuels mandates. Any downward revision of mandated biofuel volumes would retard all aspects of the United States's ethanol industry: production, transport, and distribution for years to come.

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