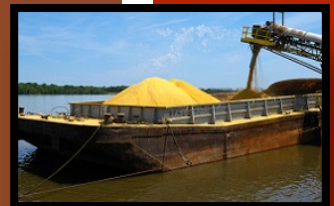


FREIGHT POLICY TRANSPORTATION INSTITUTE



U.S. Renewable Fuels (Ethanol)
Historical Policy and Future Prospects
May 2011

U.S. Renewable Fuels (Ethanol): Historical Policy and Future Prospects

FPTI Research Report Number 11

By

Eric Jessup, PhD
Associate Professor
Freight Policy Transportation Institute
School of Economic Sciences
Washington State University
Pullman, WA 99164-6210

May 2011

FPTI Research Reports: Background and Purpose

This is the eleventh of a series of reports prepared by the Freight Policy Transportation Institute (FPTI). The reports prepared as part of this Institute provide information to help advance knowledge and analytics in the area of transportation policy.

FPTI is funded by the United States Department of Transportation (USDOT). Dr. Ken Casavant of Washington State University is Director of the Institute. A Technical Advisory Committee (TAC) comprised of Federal, State and local representatives has been assembled in order to identify relevant and pressing issues for analysis, apply rigorous theoretical and analytical techniques and evaluate results and reports. The TAC includes Jerry Lenzi (WSDOT) as Chair, Ed Strocko (USDOT), Randall Resor (USDOT), Bruce Blanton (USDA), Timothy Lynch (American Trucking Association), Rand Rogers (MARAD), John Gray (AAR) and Daniel Mathis (FHWA – Washington State). The following are key goals and objectives for the Freight Policy Transportation Institute:

- Improve understanding of the importance of efficient and effective freight transportation to both the regional and national economy
- Address the need for improved intermodal freight transportation, as well as policies and actions that can be implemented to lower operating costs, increase safety and lower environmental impacts of freight transportation nationwide
- Improve freight transportation performance to specific industries and sectors of the economy

For additional information about the Freight Policy Transportation Institute or this report, please contact Ken Casavant at the following address:

Dr. Ken Casavant, Director
Freight Policy Transportation Institute
School of Economic Sciences
Washington State University
301C Hulbert Hall
Pullman, WA 99164-6210
(509) 335 1608
Or go to the following Web Address:
www.fpti.wsu.edu iii

DISCLAIMER

The contents of this report reflect the views of the various authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the United States Department of Transportation. This report does not constitute a standard, specification or regulation.

FPTI PREVIOUS REPORTS NOW AVAILABLE

1. Simmons, Sara and Ken Casavant. FPTI Research Report #1. "Historical Waterborne Commerce on the Columbia-Snake River System: Commodity Movements Up and Down River, 1991-2010." November 2010.
2. Simmons, Sara and Ken Casavant. FPTI Research Report #2. "Industry Preparations for the Columbia-Snake River Extended Lock Outage, July – December 2010." February 2011.
3. Khachatryan, Hayk, Jeff Poireman, and Ken Casavant. FPTI Research Report #3. "Determinants of Consumer Choice for Biofuels." March 2011.
4. Khachatryan, Hayk, Ken Casavant, Eric Jessup, Jie Chen, Shulin Chen, and Craig Frear. FPTI Research Report #4. "Biomass Inventory Technology and Economics Assessment." March 2011.
5. Khachatryan, Hayk and Ken Casavant. FPTI Research Report #5. "Spatial and Temporal Differences in Price-Elasticity of Demand for Biofuels." March 2011.
6. Casavant, Ken. FPTI Research Report #6. "The Critical Status of Agricultural Transportation in the Pacific Northwest." March 2011.
7. Casavant, Ken. FPTI Research Report #7. "Issues Affecting Barge Transportation in the Pacific Northwest." March 2011.
8. Casavant, Ken. FPTI Research Report #8. "Rail to Rail Competition and its Importance to Agriculture." April 2011.
9. Simmons, Sara and Ken Casavant. FPTI Research Report #9. "Industry Reactions to the Columbia-Snake River Extended Lock Outage, December 2010 – March 2011." June 2011.
10. Simmons, Sara and Ken Casavant. FPTI Research Report #10. "Return to the River: Columbia-Snake River Extended Lock Outage, April – June 2011." July 2011.

ACKNOWLEDGEMENTS

This study was partially funded by a grant from Transportation Northwest.

TABLE OF CONTENTS

1. Ethanol Background/Growth	1
2. Ethanol Policies/Mandates.....	3
3. Ethanol Subsidies.....	4
4. Current Situation	5
5. Corn Production/Utilization	6
6. Transportation/Logistics	8
Inland Waterways.....	12
Rail	12
7. Net Energy Balance Studies.....	13
8. Ethanol and Carbon Emissions	15
9. Policy Discussion	15
Energy Independence	15
Supports the Economy and Creates Domestic Jobs	17
Environmental	17
Consumers/Taxpayers	18
10. Policy Recommendations	21
References	25

TABLES

Table 1: Biofuels Expansion Phases, Identified by the Task Force on Biofuels	3
Table 2: Policy Recommendations from the Task Force on Biofuel Infrastructure.....	4
Table 3: Renewable Fuels Standard Mandate Schedule (billion gallons).	5
Table 4: Summary of Studies Estimating Net Energy Value of Ethanol	13
Table 5: Summary of Energy Calc. Between USDA 2004 and Pimentel/Patzek 2005	14
Table 6: BTU Equivalent for Gasoline and Ethanol.....	16

FIGURES

Figure 1	Historical U.S. Ethanol Production, 1980-2009.....	2
Figure 2	Total U.S. Ethanol Plants and Those Under Construction, Jan. 2011	2
Figure 3	U.S. Corn Production and Ethanol Plants	7
Figure 4	Cellulosic/Adv. Fuel Plant Locations in Development, Feb. 2010.....	7
Figure 5	U.S. Corn Yields and Acres Harvested, 1980-2010.....	9
Figure 6	Average U.S. Corn Production and Avg. Farm Prices, 1980-2010.....	9
Figure 7	U.S. Corn Utilization, 2009.....	10
Figure 8	Historical U.S. Corn Utilization, 1980-2010	10
Figure 9	U.S. Corn, Food, Seed and Industrial Use, 1980-2010	11
Figure 10	U.S. Transportation Sector Energy Consumption, by Fuel Type	16
Figure 11	Break-Even Threshold for Corn Ethanol Plants.....	20

Abstract

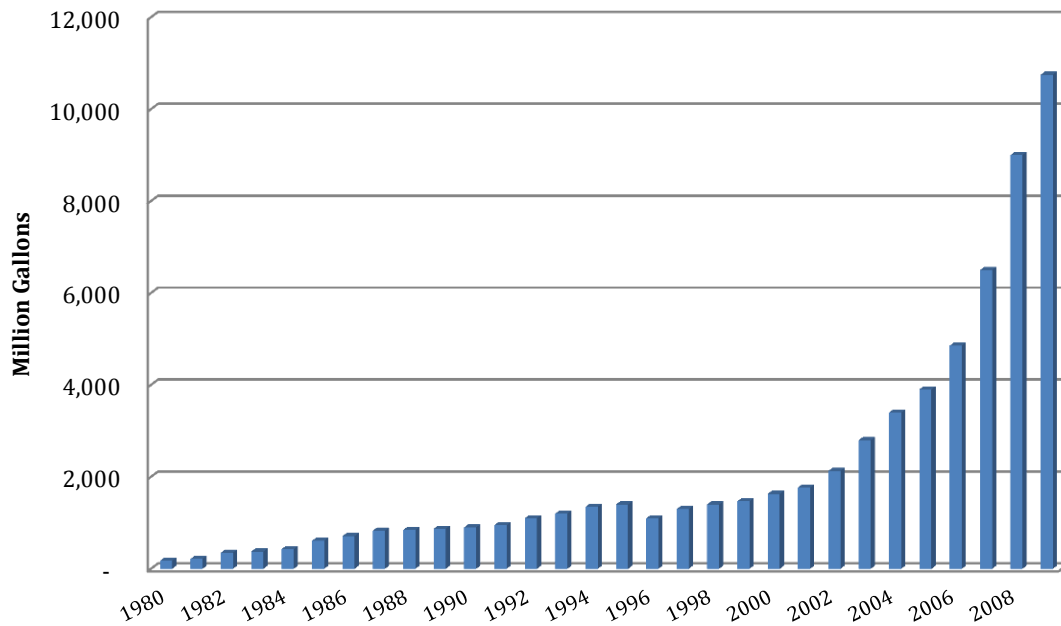
This paper reviews alternative fuel development in the U.S., specifically related to ethanol production given its prominence among renewable fuels. Responding to renewable energy mandates, production incentives and farm policy initiatives, ethanol production and utilization has experienced dramatic increases over the last ten years, going from less than 2 billion gallons per year in 2000 to almost 13 billion gallons per year in 2010. There has been significant public and private investment in processing technology and equipment over this time period, as ethanol plants are now heavily concentrated throughout the mid-west and beyond. The economic viability of these plants is influenced by many factors, including, but not limited to, government mandates, subsidies, import tariffs on ethanol and prices paid for inputs (mostly corn) relative to the prices received for the processed output (ethanol and DDGS). In spite of these various public supports and subsidies, many of these plants have struggled financially or even ceased production as higher corn prices and reduced demand for fuel have tightened or eliminated profit margins. In addition to the uncertain economic outlook, many other issues related to energy independence, environmental impact, transportation infrastructure and agricultural support influence how future policy evolves. This paper contributes to this dialogue by investigating the broader issues related to the various (often contradictory) policy goals and the trade-offs associated with each.

1. ETHANOL BACKGROUND/GROWTH

Ethanol production and use as an automobile fuel dates back to the early 1900's when the Ford Model T was capable of running on ethanol alcohol, gasoline, or some combination of the two. Ethanol production and use represented a significant share of automobile fuel in select markets through the 1920s and 1930's (DiPardo, 2007). Standard Oil utilized ethanol as a fuel additive throughout the 1920's to increase octane levels and minimize engine knocking. In 1938, one ethanol plant in Atchison, Kansas produced 18 million gallons of ethanol per year and supplied over 2,000 Midwest service stations (Hunt, 1981). Another large ethanol plant was constructed by the U.S. Army in Omaha, Nebraska in the early 1940's and used to supply ethanol to the army throughout the war years.

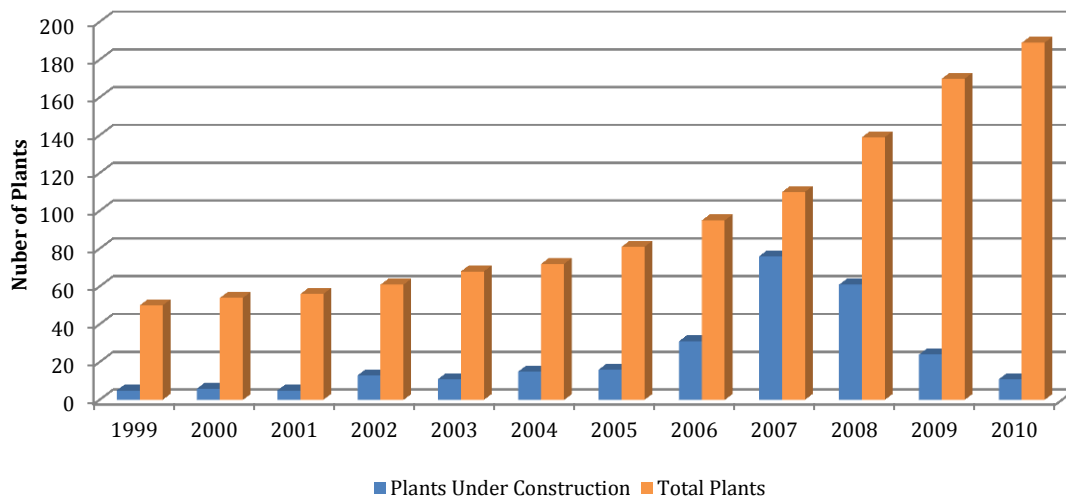
However, between the 1940's and mid-1970's very little commercial ethanol was produced or utilized for automobile fuel, primarily due to the availability of inexpensive gasoline. Prior to the mid-70's most gasoline sold was leaded but began being phased out around this time due to health concerns and was replaced with methyl tertiary butyl ether (MTBE) as the primary fuel oxygenator. But beginning in the late 1980's problems associated with MTBE contamination in groundwater and EPA emission standards for carbon dioxide led to several U.S. cities and states mandating the use of ethanol oxygenated fuels, especially during cold/winter use. The combination of the Clean Air Act amendment of 1990 and the Energy Policy Act of 1992 led to increasing demand for ethanol, utilized as an alternative to MTBE as an oxygenator and reducing U.S. dependence on foreign oil. But total production and use of ethanol remained relatively low between 1980 and the late 1990's, considerably less than 2 billion gallons per year as illustrated in Figure 1. It wasn't until the later 1990's and early 2000 that production and use began dramatically increasing, almost exponentially (Figure 1). This is primarily due to the introduction and availability of flexible fuel automobiles (flexible fuel vehicles may burn fuels up to 85% ethanol) by major car manufactures beginning in the late 1990's and the passage of the Energy Policy Act of 2005 requiring all automobile fuel sold in the U.S. to contain a minimum amount from renewable sources (predominately ethanol). Two additional policies significantly advanced the utilization and production of ethanol, including the Renewable Fuels Standard Program in 2006 and the Energy Independence and Security Act of 2007. The later act established blend rates of 10% (E10) ethanol in gasoline and insures total renewable fuels use to reach 15 billion gallons by 2015. Given that total annual ethanol production by the end of 2010 is almost 13 billion gallons, this target appears within reach. These blend rates for passenger and light fleet vehicles were recently re-evaluated by the EPA for vehicles made between 2001 and 2006. E15 blends have already been classified as safe for passenger and light fleet vehicles produced after 2006 but following the EPA's approval in January 2011, roughly 60% of passenger and light fleet vehicles will be able to use E15 blends and the total blend market for ethanol will effectively increase from 13.7 billion gallons to around 17.8 billion gallons per year.

Figure 1: Historic U.S. Ethanol Production, 1980-2009



Source: Renewable Fuels Association

Figure 2: Total U.S. Ethanol Plants and Those Under Construction as of January



Source: Renewable Fuels Association

2. ETHANOL POLICIES/MANDATES

In the summer of 2008, the National Commission on Energy Policy convened a Task Force on Biofuels Infrastructure and provided policy recommendations to advance infrastructure investment the commission identified as necessary to satisfy the federal renewable fuels standard mandate to 2022. This task force represented participants from a variety of energy, agricultural and transportation firms and task advisors from various governmental agencies, including the United States Department of Agriculture, Department of Energy, Environmental Protection Agency, Energy Information Administration and the Department of Transportation. This task force identified three phases of infrastructure expansion, summarized below:

Table 1: Biofuels Expansion Phases, Identified by the Task Force on Biofuels Infrastructure

Phase	Summary
Phase IA: 2008-2010	<i>U.S. corn ethanol production increases to 12 billion gallons per year and is distributed from processing centers in the Midwest to demand locations throughout the U.S. with rail shipments representing a large majority.</i>
Phase IB: 2010-2015	<i>U.S. corn ethanol production increases to 15 billion gallons per year following the RFS mandate. Existing blending and transportation infrastructure will be stressed to facilitate this volume of ethanol, requiring additional infrastructure investments. In order for demand to absorb this volume, E10 and higher blend fuels will be necessary at the national level in addition to modification of retail fueling infrastructure.</i>
Phase II beyond 2015	<i>U.S. corn ethanol expands beyond 15 billion gallons per year which will be influenced by a variety of factors, including, Flex-Fuel Vehicle production, mandate certainty, import volumes, market penetration of E85 and higher blends and the degree to which non-ethanol biofuels are developed.</i>

The Task Force on Biofuels Infrastructure also provided five primary policy recommendations, which are summarized in Table 2 below. These recommendations include extending the RFS mandate (Table 3) and increasing demand for ethanol fuel via increases in flex-fuel automobiles and infrastructure. The task force also recommends greater standardization across states, easier permitting and increased public subsidies on ethanol infrastructure.

Table 2: Policy Recommendations from the Task Force on Biofuels Infrastructure

Policy Recommendations		Description
I.	<i>RFS Mandate Certainty</i>	<i>Market confidence and investment is dependent upon the government's long-term commitment to the RFS mandate.</i>
II.	<i>Deployment of FFV and Fuel Distribution Infrastructure</i>	<i>In order to maintain adequate demand necessary to absorb the mandate schedule, more vehicles utilizing higher blend ratios and the distribution infrastructure necessary to deliver these volumes is recommended.</i>
III.	<i>Standardized Fuel Specifications</i>	<i>Having standardized blend specifications across all states will make it easier on refiners and lead to a more efficient distribution network</i>
IV.	<i>Greater Permitting Efficiency</i>	<i>Streamline and simplify the permitting process throughout the biofuels supply chain will reduce cost and reduce lead times for infrastructure investments to support biofuels use.</i>
V.	<i>Federal Support for Critical Infrastructure Investments</i>	<i>Refocusing public incentives and subsidies to include refueling infrastructure and related vehicle technologies in the form of loan guarantees and tax credits.</i>

3. ETHANOL SUBSIDIES

Ethanol production is subsidized in a variety of ways, both directly and indirectly. Initially, a combination of local, state and federal grant dollars, in addition to private investment, were utilized to build many of the ethanol processing facilities in operation today. Prior to 2009, a direct federal tax credit subsidy of 51 cents per gallon was provided to refiners for every gallon of ethanol blended with gasoline. Since January 2009 that tax credit subsidy, known as the Volumetric Ethanol Excise Tax Credit (VEETC) has been reduced to 45 cents per gallon for blenders and small producers receiving an additional 10 cents per gallon on the first 15 million gallons produced. Cellulosic ethanol producers receive a tax credit of \$1.01 per gallon of ethanol produced. In addition, there is a 2.5% ad valorem tariff and a 54 cent per gallon import tariff on any imported ethanol. Finally, the renewable fuels standard program in 2006 mandated that U.S. fuel producers follow scheduled ethanol blending amounts with gasoline (Table 3). The VEETC was scheduled to expire at the end of 2010, but has been extended for one more year.

The U.S. Congressional Budget Office released a study in 2010 estimating the total federal cost of the 2009 biofuel tax credits to be \$5.16 billion for the 10.8 billion gallons of corn ethanol produced in 2009. The same study estimates that the cost to taxpayers to reduce gasoline consumption by one gallon is \$1.78 per gallon for corn ethanol, \$3.00 per gallon for cellulosic ethanol and \$2.55 per gallon for biodiesel. Previous studies have estimated the total annual cost to taxpayers for ethanol

subsidies to be \$7 to \$9 billion per year. Total U.S. ethanol production for 2009 represented about 3.5% of U.S. transportation energy consumed as measured by BTUs with the remaining 96.5% provided by fossil fuels.

Table 3: Renewable Fuel Standard Mandate Schedule (billion gallons)

Year	Corn Ethanol	Cellulosic Ethanol	Other Adv. Biofuels	Total RFS All Fuel
1998	1.40			1.40
1999	1.47			1.47
2000	1.63			1.63
2001	1.77			1.77
2002	2.13			2.13
2003	2.80			2.80
2004	3.40			3.40
2005	3.90			3.90
2006	4.86			4.86
2007	6.89			6.89
2008	9.00			9.00
2009	10.75		.1	10.85
2010	12.00	.10	.2	12.30
2011	12.60	.25	.3	13.15
2012	13.20	.50	.5	14.20
2013	13.80	1.00	1.75	16.55
2014	14.40	1.75	2.0	18.15
2015	15.00	3.00	3.0	21.00
2016	15.00	4.25	3.5	22.75
2017	15.00	5.50	4.0	24.50
2018	15.00	7.00	4.5	26.50
2019	15.00	8.50	4.5	28.00
2020	15.00	10.50	4.5	30.00
2021	15.00	13.50	4.5	33.00
2022	15.00	16.00	5.0	36.00

Source: National Commission on Energy Policy's Task Force on BioFuels, 2008

4. CURRENT SITUATION

Even with substantial federal support, several bankruptcies in the ethanol processing industry occurred in 2008 and 2009, but financial conditions appear to be slightly improving in 2010-2011. The combination of record high corn prices, reduced fuel demand from a sluggish economy and the E10 "blend wall" constraint led to negative profit margins for much of the industry, but especially for small plants located a long distance from corn production where transportation costs exacerbated financial profitability. Investment in new plants also dropped dramatically after 2007, as is visible in Figure 2 above. These are primarily first generation ethanol plants which create ethanol from fermenting sugar, predominately from corn. The location of these first generation plants, relative to corn production is provided below in Figure 3. The heaviest concentration of these plants, driven by

the economics of collection cost for inputs, is centered in areas that are likewise the heaviest corn producing regions. There has been renewed investment in second generation ethanol plants where the lignin and cellulose are first separated and the cellulose then fermented into alcohol. These second generation plants offer greater feedstock flexibility and possibly improved energy processing efficiency. While no commercial cellulosic ethanol production currently exists, several Department of Energy demonstration projects are underway and these second generation cellulosic plants, displayed below in Figure 4, are therefore less concentrated around the corn producing regions as a variety of different feedstock may be utilized. While this improves operational efficiencies associated with processing feedstock that is abundant and available in the regional context, the processing technology is more complex. The two different approaches being pursued are biochemical or thermo-chemical conversions. However, following the renewable fuel mandate schedule, most of the growth in renewable fuel production is expected to come from cellulosic and other advanced biofuels, increasing from less than 1 billion gallons in 2011 to over 20 billion gallons in 2022. With a total of 36 billion gallons of renewable fuels scheduled/mandated to be produced in 2022, 15 billion will come from first generation corn ethanol while the remaining 21 billion gallons will be met from cellulosic and other advanced biofuels.

5. CORN PRODUCTION/UTILIZATION

The growth in renewable fuels mandates has likewise increased the demand for corn, raising corn prices and increasing the intensity of corn production over the past 15-20 years. Both corn yields and acreage allocated to corn production in the U.S. have increased since 1980 (Figure 5), with average yields increasing from 81 bushels per acre in 1983 to over 164 bushels per acre in 2009 and total corn production acreage increasing from 51 million acres to over 79 million acres in the same time period. With increases in both yields and acreage, total annual corn production has dramatically increased from just above 4 billion bushel in 1983 to over 12.5 billion bushels in 2009 (Figure 6) representing over 200% increase. Average corn prices have been more volatile over this time period, first dropping significantly from \$2.50/bu. in 1980 to \$1.50/bu. in 1986, and then increasing from \$1.82/bu. in 1999 to over \$5/bu. in 2009.

While corn is the primary feedstock for current ethanol production in the U.S., it is also utilized as an input for many other industrial products, animal feeds and exported. As of 2009, approximately 32% of total U.S. corn production was utilized for ethanol fuel production, second to feed and residual use (43%) but more than that which is exported (16%), other (6%) and high fructose syrup (3%) (Figure 7). The utilization for ethanol production has evolved and expanded since 1980, as is evident in Figure 1 above and Figures 8 and 9 below. Total corn utilization is presented in Figure 8 and the different components of food, seed and industrial uses of corn utilization is presented in Figure 9, with both evaluated between 1980 and 2010. In Figure 8, it is evident that most of the growth in

Figure 3: U.S. Corn Production and Ethanol Plants, Oct. 2010

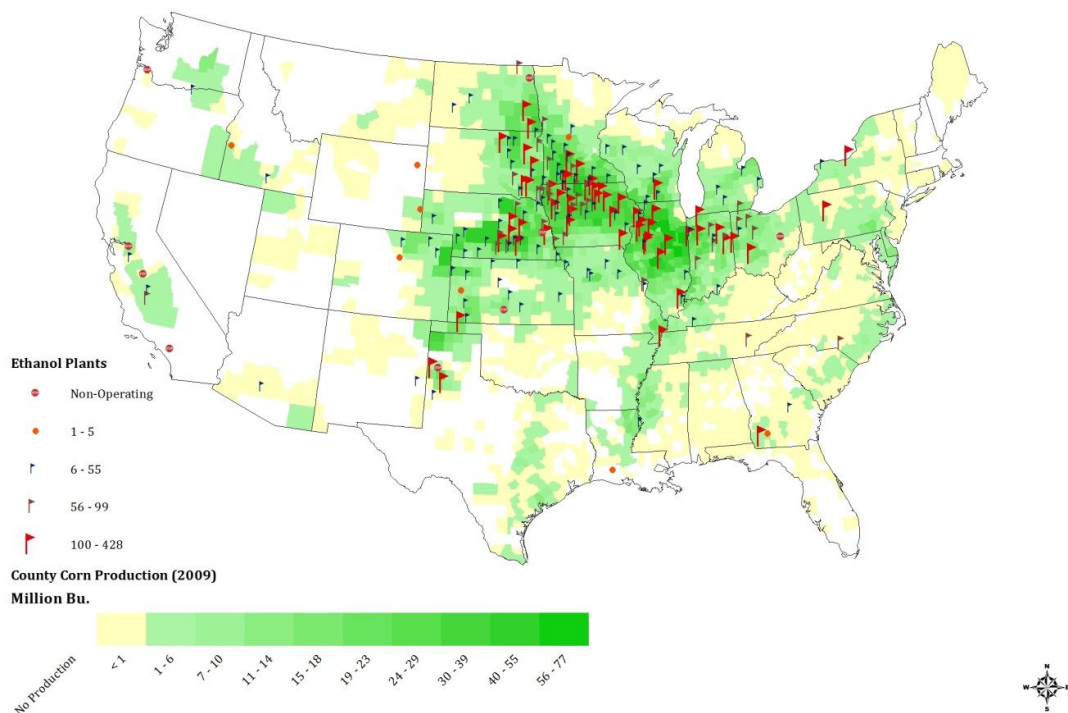
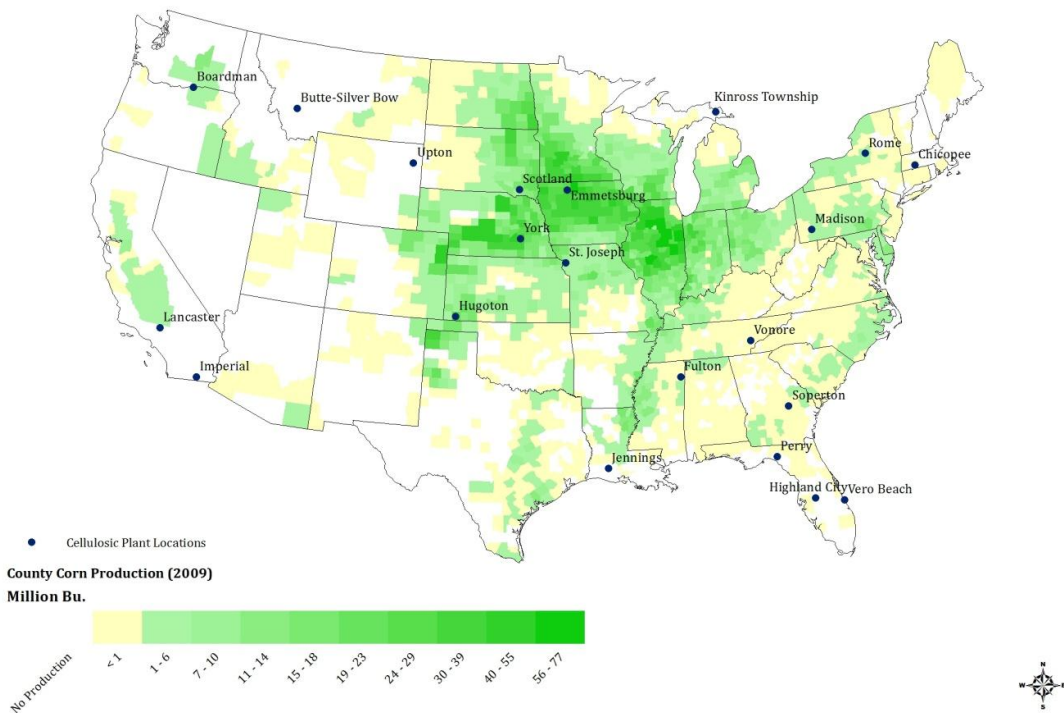


Figure 4: Cellulosic/Adv. Fuel Plant Locations in Development, Feb. 2010



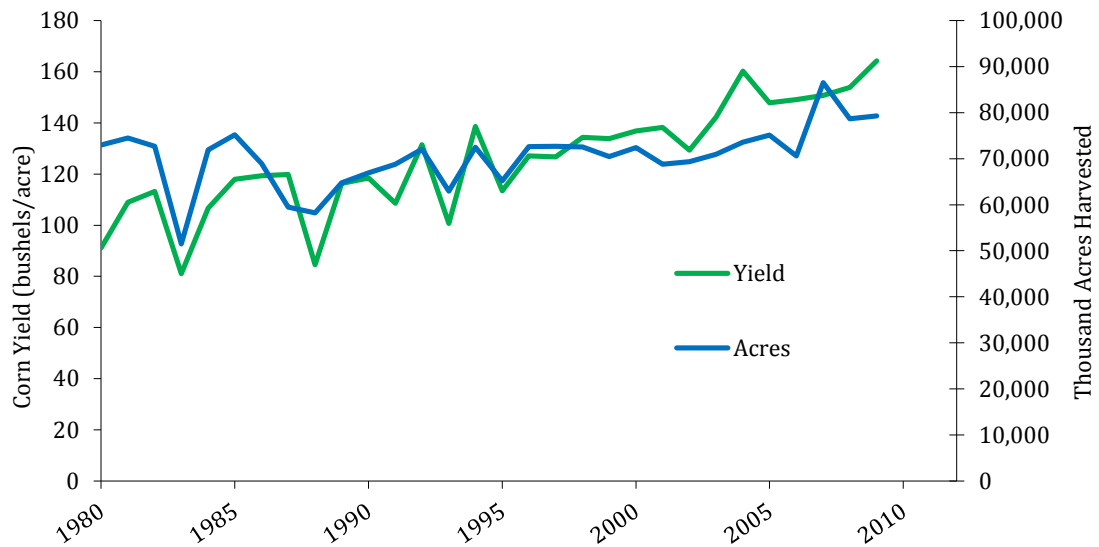
utilization of corn has been in the food, alcohol and industrial use category with the volume of exports, seed use, feed and residual use remaining relatively constant between 1980-2010. This is even more evident in Figure 9, where the components of the food, seed and industrial category are further distinguished. The volume of corn utilized for seed, cereals, beverages, starch, glucose and fructose have remained relatively constant, with small increases. The volume of corn utilized for ethanol fuel has experienced dramatic increases between 1980 and 2010 with the most pronounced increases occurring between 2000 and 2010. This likewise corresponds with the time period when corn prices have experienced the most dramatic increases as competition for corn has intensified (Figure 6).

The degree to which increasing biofuel production has resulted in higher food prices continues to be debated. In 2008, the World Bank estimated that rising food prices worldwide were primarily driven by rapid increases in biofuel production in the U.S. and Europe. This finding was supported by the Union of Concerned Scientists. However, the USDA has shown that increases in corn prices don't necessarily translate into the same magnitude of food price increases at the retail level due to a variety of factors. Roughly one-third of retail food spending is on food products that include corn as an ingredient with less than 10% of the corn price increases being passed on to consumers. As food manufacturers respond to higher input prices and begin substituting alternative products, the impact on higher retail food prices may also be dampened in the long-run. But for certain products (meat, eggs, dairy, high-fructose sweetener) that rely heavily on corn as an input, and for which the food manufacturing industry is considerably concentrated, price increases may be passed on to the consumer at the retail level to a higher degree. Corn ethanol production doesn't necessarily remove corn as an input to animal feed since the by-product DDGS is a high value animal feed source. Thus, while the magnitude of retail food price increases directly attributable to biofuel production is uncertain, it is clear that future increases in corn utilized for biofuel production will exert increased pressure on those food products that utilize corn as an input.

6. TRANSPORTATION/LOGISTICS

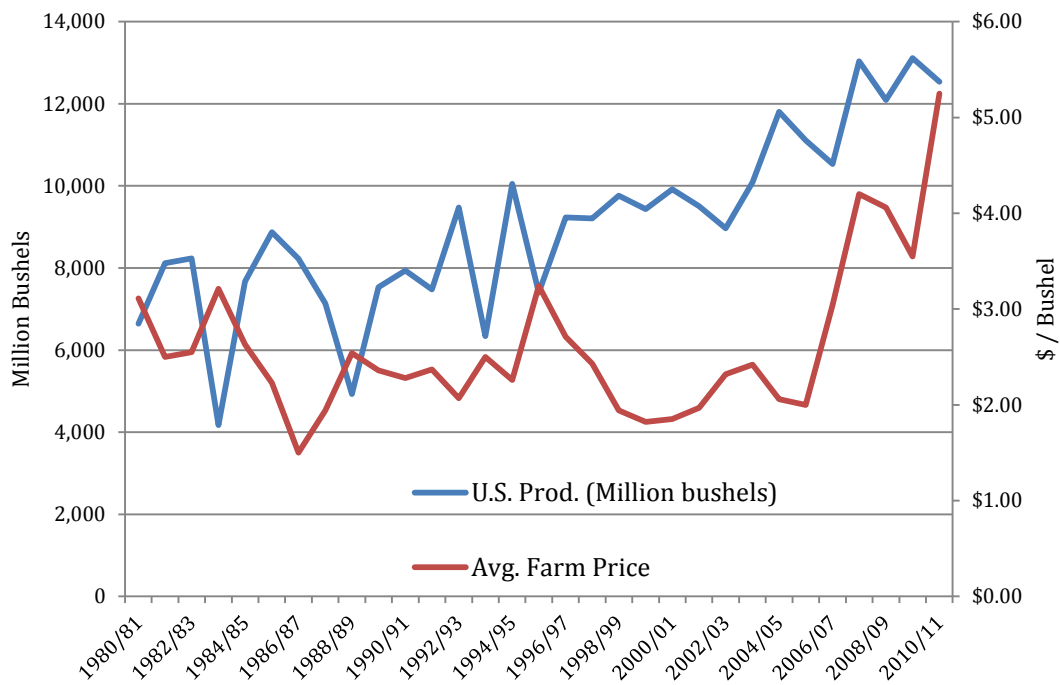
The development of policies to support the production and utilization of alternative fuels for the U.S., in addition to the market viability of these fuels, is largely influenced by transportation challenges and cost realities. The transportation and logistical efficiencies associated with feedstock collection and biofuel distribution significantly influence the economic viability of individual processing plant profitability and overall industry performance. The bulky and dense product attributes of alternative feedstock and processed fuel implies that efficiencies may be gained when the collection, processing

Figure 5: U.S. Corn Yields and Acres Harvested



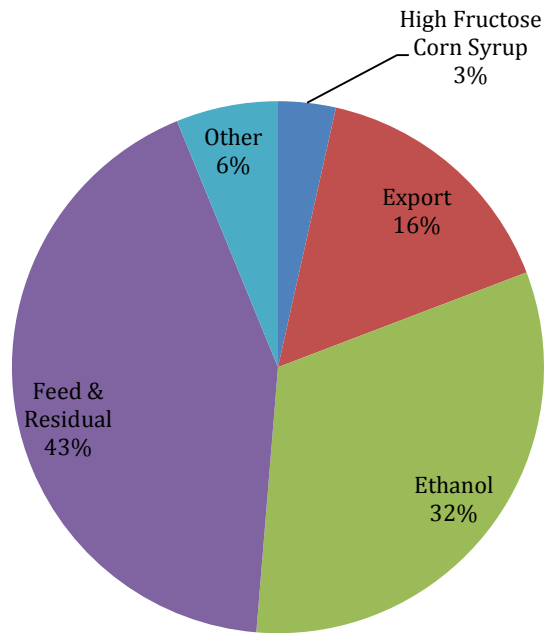
Source: www.afdc.energy.gov/afdc/data/

Figure 6: Average U.S. Corn Production and Avg. Farm Prices, 1980-2010



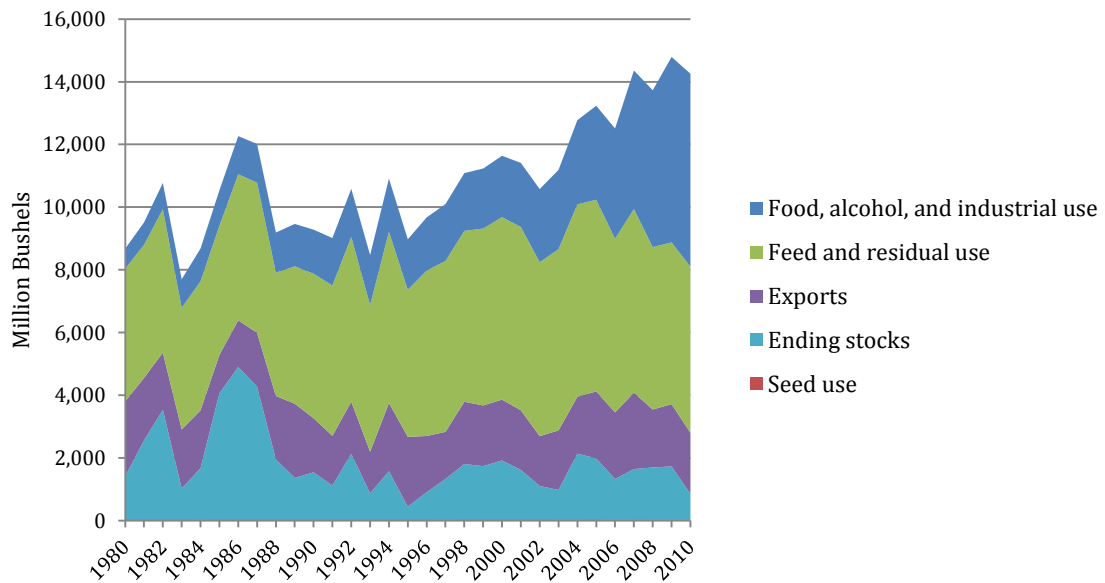
Source: USDA, Economic Research Service

Figure 7: U.S. Corn Utilization, 2009



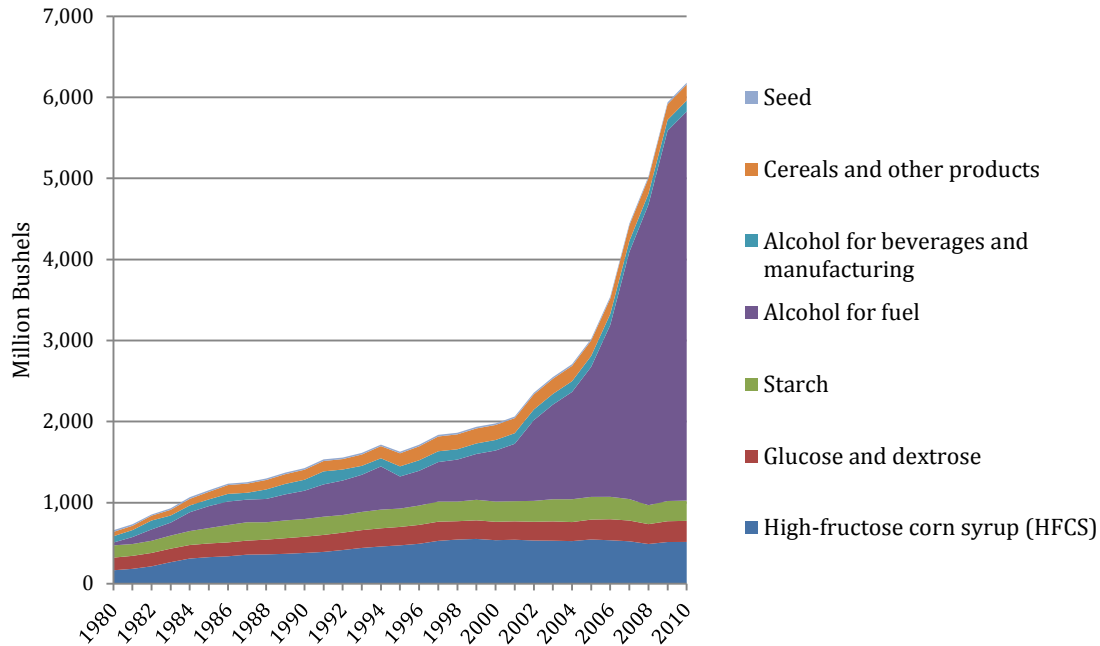
Source: USDA, Economic Research Service

Figure 8: U.S. Corn Utilization, 1980-2010



Source: USDA, Economic Research Service

Figure 9: U.S. Corn, Food, Seed and Industrial Use, 1980-2010



Source: USDA, Economic Research Service

and distribution activities can be completed within relatively short geographical distances. Assuming everything else is equal, as the geographical distance connecting these activities grow, so do inefficiencies and transportation costs throughout the supply chain and the ability to deliver biofuel that may compete (cost wise) with traditional fossil fuels or biofuel that is produced, processed and distributed within relatively close proximity. This also holds for environmental/carbon emissions related to the life cycle of bio fuel production/processing/distribution. In reality, everything else isn't equal and certain regions may have natural attributes that lead to better feedstock production, both cellulosic and non-cellulosic ethanol, but demand for alternative uses of the feedstock (or the land that produces it) may limit the availability and lead to higher feedstock prices. Likewise, demand characteristics for fuel in some regions may lead to market prices that allow shipment of processed fuel over long distances utilizing a variety of transportation modes (truck, rail, barge). Or finally, transportation efficiencies may be the driver and lead to identification of both feedstock source locations and biofuel markets previously not considered. In all conditions, the geographical proximity between likely feedstock production, biofuel processing, distribution and final demand consumption plays a significant role. This is especially true for the Midwest U.S. when the regional market for ethanol production becomes saturated and distant markets in the southeast, west coast and east coast markets are sought. The movement of ethanol via pipeline is currently not possible in existing infrastructure and shipment by truck to distant markets cost prohibitive. Thus, the freight and transportation challenge impacting these markets is primarily concentrated to water and rail.

Inland Waterway:

The Mississippi river system offers a very cost effective avenue for moving large volumes of dense products, north and south. As has been evident, the balancing of north/south bound grain movements can improve system efficiencies as backhaul barge movements of grain northbound to ethanol processing facilities can balance what has traditionally been predominately southbound grain movements. This should effectively lower the cost of feedstock supply for ethanol processors and contribute to the scale efficiencies associated with ethanol production/processing/distribution. The distribution of processed ethanol and DDGS to markets south of the grain belt could also significantly impact the bottom line of the ethanol industry, assuming access to adequate barge equipment is available. In addition, the reported lock delays along the Missouri, Illinois, Ohio and Mississippi rivers may not improve in the immediate future. The prevailing maintenance and infrastructure needs of this river system and the financial limits of the Inland Waterway Trust and Federal funds will effectively impede system efficiency and limit movements on this transportation system. The investment needs system-wide are substantial and current funding prospects tenuous.

Rail:

Rail has played a significant role in the movement of both grain and processed ethanol over the past few years. Given that rail approaches the cost effectiveness of barge transport and the prevailing river system issues/constraints described above for inland waterway service, rail will continue to play a significant role. The issues impacting rail efficiency are primarily associated with equipment cost and availability. Given the unique vapor pressure and moisture characteristics of ethanol, specialized tank cars are required, increasing capital costs for primarily ethanol processors. The large railroad companies, similar to their grain car ownership patterns, have shifted the investment cost to ethanol shippers. This is one of the reasons the Taskforce on Biofuels Infrastructure has requested increased subsidies and federal funding on loans for infrastructure and equipment to move ethanol. This also may reveal the railroad's perspective on the long-run capital return on investment for this type of equipment, preferring to shift the risk to the processors/shippers. In addition to rail cars, the business model of the class I railroads have become more demanding for shippers as they operate 100 unit trains and increasingly provide service to only those terminals that can load/unload and accommodate these large trains. The infrastructure cost of building these loading/unloading terminals is the responsibility of the shipper, in addition to providing the capability of loading/unloading within tight time constraints. While this has resulted in improved network efficiency across the rail network nationwide, the operating and investment costs of ethanol processors and shippers are increased.

7. NET ENERGY BALANCE STUDIES

Since the mid-1990's, there have been several studies focused on estimating the net energy value of corn ethanol. The time progression and results from many of these studies are presented below in Table 4, and reveal significant differences associated with net energy balance estimates. All energy, regardless of the source, requires energy to transform/process/transport it into a useable form. Gasoline made from crude oil must be pumped, processed, transported and distributed to fuel stations in order to be utilized in automobiles, and each of these activities require energy. These same activities are also required for renewable fuels, such as corn ethanol, but unlike oil, there is additional energy required in the production of the original feedstock and the inputs supporting this feedstock prior to the processing stage. Hence the net energy balance, or the energy produced relative to the energy input required of various feedstock has received considerable attention from researchers/policymakers. If this balance is negative, it raises questions regarding the long-term viability of the national energy program. These life-cycle studies have also been utilized to estimate other important impacts of alternative renewable fuels, including emissions and land use changes.

Table 4: Summary of Studies Estimating Net Energy Value of Ethanol

<i>Year</i>	<i>Author</i>	<i>Organization</i>	<i>Net Energy Value*</i>
1995	Shapouri, H, et. Al.	USDA	1.21
1995	Lorenz and Morris	Institute of Self-Reliance	1.40
1999	Wang, M, et. Al.	Argonne National Labs	1.29
2001	Pimentel, D.	Cornell University	-1.44
2002	Shapouri, H., et. Al.	USDA	1.28
2002	Kim and Dale	Michigan State Univ.	1.31 to 1.46
2003	Pimentel, D.	Cornell University	-1.29
2003	Wang, Shapouri et. Al	USDA	1.34
2004	Shapouri, H.	USDA	1.67
2005	Pimentel and Patzek	Cornell and UC Berkeley	-1.29
2008	Shapouri, H. et al.	USDA	1.9 to 2.3
2010	Murphy, David	State University of New York	0.36 to 1.18
*This net energy value is calculated by taking the net energy (measured in BTUs/gal) gain (or loss), plus or minus the baseline low-heat value of ethanol (76,330 BTUs), and then divided by the baseline of 76,330 BTUs. Thus, a net energy value of 1.21 indicates that corn ethanol produces 21% more energy than required to produce, process and distribute it.			

The majority of these life-cycle analyses attempting to estimate the net energy balance of corn ethanol have been conducted by the U.S. Department of Agriculture (Shapouri, H. et. al.) and rely upon the Greenhouse gasses, Regulated Emissions, and Energy Use in Transportation (GREET) Model developed at the Argonne National Laboratory (<http://greet.es.anl.gov/>). The reasons for these discrepancies are primarily related to the complexity of the system being modeled and difficulty associated with accurately representing this dynamic system with a model that attempts to simulate

these dynamics. Certain assumptions are required, regardless of how robust the model or current the data, and this often leads to an additional source of variation in study results and recommendations.

The USDA studies have consistently shown the net energy balance to be positive and increasingly positive with each subsequent study. The studies conducted by Pimentel and later Pimentel and Patzek show the net energy balance to be negative, but less negative with each subsequent study. In 2005, MathPro Inc. provided a side-by-side comparison of the itemized energy calculation between USDA's 2004 study results and the 2005 Pimentel and Patzek study results. As indicated in Table 5 below, Pimentel/Patzek report higher energy use in the production, transport and processing of corn while calculating a much lower energy credit for the co-product DDGS. The studies relied upon different data sources for much of the input and processing calculations, but also included different categories. The Pimentel/Patzek calculation included energy estimates for farm machinery in the production of corn and an estimate of energy used in the processing of water and equipment for ethanol processing which was not part of the USDA estimate. The later 2008 USDA results are updates to the earlier study after updating both corn production and ethanol processing data from two surveys. The producer survey (Agricultural Resource Management Survey (ARMS)) conducted by the National Agricultural Statistics Service resulted in significant reduction in the energy required for corn production, primarily due to improvements in production efficiency. In addition, results from an ethanol production survey to sixteen ethanol plants in 2008/2009 was used to determine the extent and amount of thermal and electric energy used at ethanol processing plants, resulting in a significant decrease in energy use for ethanol processing. The upper end of the 2008 USDA estimate includes using biomass (corn-stover) to generate electricity at the processing plants. The most recent study by David Murphy applies a meta-error analysis to five previous studies and illustrates the spatial variability associated with the net energy balance with processing plants located in optimal corn producing areas achieving the highest net energy balance.

Table 5: Summary of Energy Calculations Between USDA 2004 and Pimentel/Patzek 2005

Categories of Energy Use	BTU/Gal Ethanol (Low Heat Value)	
	USDA	Pimentel and Patzek
a) Production of Corn	18,713	37,890
b) Transport of Corn	2,120	4,837
c) Ethanol Processing	45,802	56,441
d) Ethanol Distribution	1,487	
e) Energy Credit for DDGS	26,251	6,685
f) Total Energy Input (a+b+c+d-e)	45,802	92,482
g) Energy Content of Ethanol	76,330	76,330

8. ETHANOL AND CARBON EMISSIONS

The net energy balance issue is only one aspect of a larger environmental question that many of these life cycle studies have attempted to address. Another focus has been on the relative carbon value of alternative biofuels and the impact that each would have in reducing total carbon emissions from traditional fossil fuel use. The early life cycle studies, while producing differing results, collectively supported corn ethanol use as a fuel that would reduce greenhouse gas emissions when compared to gasoline. Delucchi found that corn-based ethanol use may lead to an increase in greenhouse gas emissions while the National Renewable Energy Laboratory (NREL) found significant greenhouse gas reductions from corn ethanol use, as compared to gasoline (Delucchi, 1991, 1993 and NREL 1991, 1992). The NREL studies estimated as much as 90-96% reductions in CO₂ using E95. Other studies through the 1990's also showed significant emission improvements using ethanol over gasoline (Wang and Santini, 1993, EcoTraffic, 1992). Wang, 1999 found that the life cycle production and use of corn ethanol would reduce greenhouse gases by 1% for E10 blends, 14-19% for E85 blends and 19-25% for E95 blends, as compared to gasoline. However, more recent studies show total greenhouse gas emissions from land use changes to be less favorable for corn ethanol. Fargione, et. al. and Searchinger estimate that the growth in corn ethanol use leads to significantly more greenhouse gas emissions due to land use changes that converts high carbon sequestering areas such as rainforests into crop land (Fargione, 2008, Searchinger, 2008). Searchinger estimated that corn-based ethanol production and use would lead to double the greenhouse gas emissions over the next 30 years.

9. POLICY DISCUSSION

Energy Independence

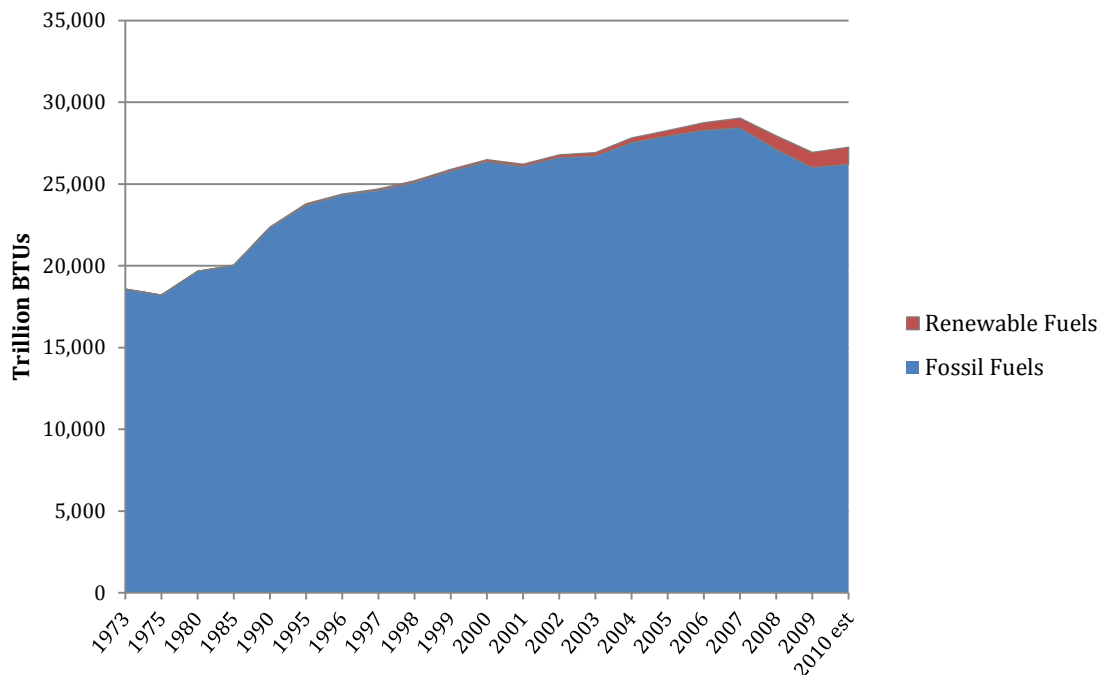
The investments, both public and private, in renewable fuels in the U.S. have to date primarily produced a corn ethanol industry that produces around 13 billion gallons of ethanol from first generation processing plants. According to the U.S. Department of Energy, the total percent of transportation energy consumed from renewable biofuels (ethanol) has increased from less than 0.5 percent prior to 1999 to 3.47 percent in 2009, measured in BTUs (Figure 10). Since ethanol has less energy per unit as compared to gasoline (Table 6), comparisons are more relevant in BTUs. Following the RFS mandate of 15 billion gallons of corn ethanol production after 2015, the percent of transportation energy provided by ethanol will be approximately 4.5%, at current (2010) transportation consumption levels. The remaining transportation sector energy comes from fossil fuel sources. The future growth of cellulosic ethanol is expected to satisfy the remaining RFS

mandate of 21 billion gallons between now and the year 2022 (total of 36 billion gallons). Should the RFS mandate of 36 billion gallons of ethanol be met in 2022, approximately 10% of the U.S. transportation energy needs will be met from renewable sources (given current consumption levels). However, the economic viability of cellulosic ethanol remains uncertain as the remaining pilot projects have yet to meet the RFS quantity mandate for cellulosic ethanol production for 2010 (Maron). Given that approximately 90% of the energy needs are still being met by fossil fuels, arguing that ethanol production will lead to energy independence may be a stretch.

Table 6: BTU Equivalent for Gasoline and Ethanol

Fuel	BTU/Gallon
Gasoline	116,090
Ethanol (E100)	76,330
Ethanol (E85)	82,000

Figure 10: U.S. Transportation Sector Energy Consumption, by Fuel Type



Source: U.S. Department of Energy, http://www.eia.doe.gov/mer/pdf/pages/sec2_11.pdf

Reducing energy consumption levels would certainly improve energy independence, but current RFS policies provide no incentive for energy conservation. Mandates that increase the demand for corn ethanol do so by increasing the market through the number of flex fuel vehicles and blend proportions, as well as subsidizing the cost through blender's credit which helps keep fuel costs low and consumption levels high.

Supports the Economy and Creates Domestic Jobs

There is little doubt that the U.S. ethanol industry contributes to the economy, both directly and indirectly. However, the magnitude and distribution of the economic benefits for this industry is unclear, especially when considering the total subsidies and source of these subsidies (taxes). One recent input-output study by John. M. Urbanchuk for the renewable fuels association estimated the total economic contribution of the ethanol industry to the U.S. GDP in 2010 to be \$53.6 billion. The total U.S. GDP at the end of 2010 was approximately \$14.6 trillion, making the ethanol industry roughly 1/3 of 1% of the U.S. economy. In terms of employment, 8,320 jobs are directly related to ethanol production (about 43 jobs per ethanol plant), representing \$494 million in income. The majority of the total 400,677 jobs related to the ethanol industry were in agriculture, representing 276,757 jobs for a total of \$28.68 billion in income.

Domestic U.S. grain producers benefit from higher grain prices in the short-run with improved income and earnings that then are invested to some extent in the regional economy. However, history has shown the problems associated with farm policy that leads to rapid expansion of agriculture and the long-run problems associated with over-valued asset prices such as land. The recent surge in land prices through the Midwest (\$10,000/acre for grain land, see Neuman, March, 2011) is partially the result of ethanol mandates, subsidies and import tariffs. Other farmers who utilize corn as an input do not benefit from higher input costs. Consumers paying higher food costs also don't benefit. Other than corn farmers, the primary recipients of ethanol mandates and tax credits have been the fuel blenders, primarily energy and oil companies, receiving roughly \$6 billion per year from the tax credits alone. The ethanol processing industry, even with the substantial government support, hasn't proved to be a profitable industry. Many of the initial ethanol processing firms have either filed bankruptcy or have sold their plants/facilities to energy/oil and agricultural companies who additionally benefit by paying cents on the dollar for plant facilities. This of course improves their ability to cash flow plant operations. Recent ethanol plant purchases by oil refiners include ADM, Sunoco, Marathon Oil Corp. and Valero Energy Corp.

Environmental

Many questions remain whether continued corn ethanol production will lead to improvements in the environment, particularly the global environment. The earlier studies suggested approximately a 20% improvement in total carbon emissions from producing/processing/distributing and burning corn ethanol. However, Searchinger and others estimate drastic land use changes, changes that are currently evident in Brazil, Indonesia and Argentina and reported in recent popular press articles (Grunwald, Time Magazine). These changes are effectively replacing powerful carbon sequestering land use (rainforest) with land use that has marginal carbon sequestering capabilities (corn production).

Domestically, we can expect more intense corn production and increased pressure to grow corn in marginal areas that may not be ideally suited for corn production. In large portions of the Midwest, corn is grown as part of a three crop, two-year rotation including corn, winter wheat and soybeans. This has helped reduce the need for large levels of nitrogen to be applied, following a nitrogen fixing plant such as soybeans with a nitrogen hungry plant like corn. With current corn futures around \$7.25 per bushel, we may see less three crop rotation, more corn-following-corn year after year and increased nitrogen application. As less wheat and soybeans are grown and supplied to the market, the market prices for these products increase as well, putting upward pressure on food items that utilize these products as inputs.

Consumers/Taxpayers

It is difficult to identify the tangible benefit to U.S. consumers and taxpayers from current renewable fuels subsidies, mandates and import restrictions, especially those not living in the corn-belt. Given that ethanol sold in the U.S. is blended with traditional gasoline and in terms of BTUs represents a very small fraction of energy being consumed, the price of automobile fuel continues to be predominately driven by the economics of oil supply and energy demand around the world. While some argue that without investments in ethanol, automobile fuel would be much higher in the U.S. However, one recent study by Bruce Babcock at Iowa State University estimated that removing the blender's tax credit and the import tariffs would reduce ethanol prices in the U.S. by 12 cents per gallon in 2011 and as much as 34 cents per gallon by 2014. This result is primarily driven by the tremendous growth in ethanol production in Brazil (45% by 2014) and the trade liberalization would result in increased imports of ethanol from Brazil. The U.S. markets along the gulf and east coasts would most likely be penetrated by imported ethanol from Brazil. According to the Petroleum Administration for Defense District's estimation of energy consumption by U.S. region, these two regions represent over 55% of the petroleum fuel consumed in the U.S.

The economics of corn ethanol production (and government program cost) rest largely on three factors:

1. Technical operating efficiency and cost of converting corn to fuel energy. The more cost effective this can be done, the better equipped this industry can compete in the market. Generally speaking, larger scale plants have more efficient and lower operating costs.
2. Corn price relative to the price of DDGS (low corn prices and higher DDGS prices lead to better profit margins).
3. Oil price and price of natural gas (higher oil prices, the more attractive corn-ethanol may appear as a product substitute).

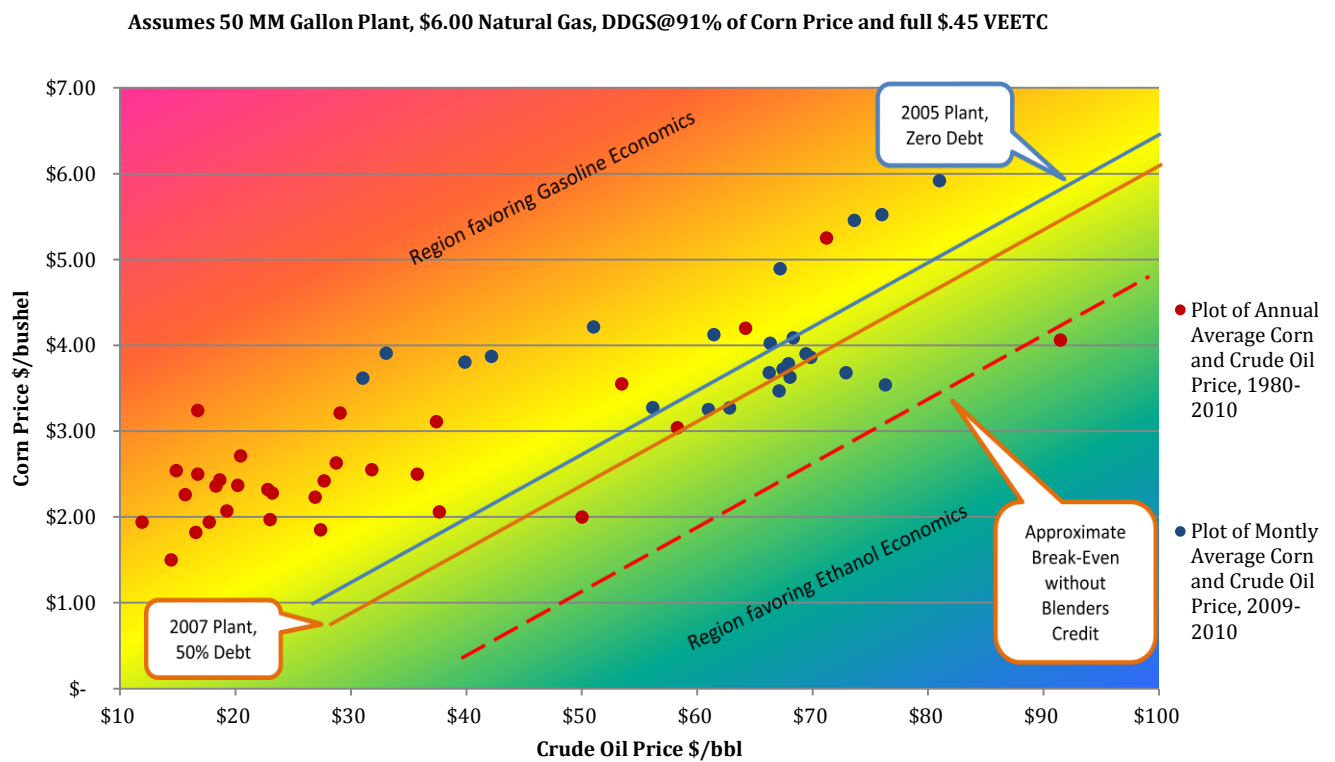
The relationship between these three factors is illustrated by recent work from Doug Tiffany at the University of Minnesota in Figure 11 below. The estimated break-even threshold for a 50 mm gallon ethanol plant is presented between various corn and oil prices under three separate scenarios; 1) a plant with zero debt, 2) one with 50% debt and then 3) removing the blender's credit. On the same graph, the actual historical corn and oil prices are plotted showing both the annual average prices for each year between 1980-2010 and the monthly average for the months 2009-2010. The breakeven threshold presented represents a point in time (2007 and 2005) and the market conditions prevailing at that point in time. As market conditions change, the breakeven threshold also will change. Any comparisons with historical prices should include knowledge of how close the assumptions used in creating the breakeven threshold compare with those through time (\$6 natural gas and DDGS price 91% of corn price). The historical prices for both natural gas and DDGS has fluctuated widely, but these assumptions are generally reasonable estimates over the past 3 to 5 years (see appendix). The information in Figure 11 is presented to illustrate the economic viability and tradeoff between corn and oil prices, under what might be considered average or normal conditions for the price of DDGS and natural gas.

It is corn and oil prices above these break-even lines that imply industry losses (the region favoring gasoline economics), and the region below these lines that imply industry profits (the region favoring ethanol economics). In general, while there have been periods that favored ethanol production economics, most actual corn/oil price plots are well above the region favoring ethanol economics, especially if the blender's credit is removed. This may also explain why there were a large number of bankruptcies in the corn ethanol industry during 2008/2009, and with current corn prices above \$7/bushel one reason why plants are struggling today. The first two solid lines in Figure 11 illustrated the break-even threshold with the full 45 cent blender's credit. Removing that subsidy would result in the red dotted, line moving further from economic viability. High oil prices alone can't guarantee corn ethanol viability with current oil prices above \$110 per barrel and corn prices above \$7/bushel. However, larger scale ethanol plants offer greater opportunity for weathering high corn prices and low oil prices given the economies of scale and lower processing costs. The break-

even thresholds presented in Figure 11 represent 50 mm gallon plants. Larger processing plants would exhibit breakeven thresholds above and to the left of those displayed in Fig. 11, thus offering better operating margins at actual historical and recent corn/oil price levels.

Given the existing government debt and program cost, increasing pressure on food prices (both domestically and abroad), in addition to higher fuel prices without significant gains in energy independence, U.S. consumers should question the continuation of these policies.

Figure 11: Break-Even Threshold for Corn Ethanol Plants



Source: The 2005 and 2007 break-even lines above are taken from analysis conducted by Doug Tiffany, University of Minnesota¹. These thresholds are calculated based upon assumptions stated above that were reflective of market conditions during those time periods. The price and quantity plots have been added separately. It is noted that the actual breakeven threshold is not static, but dynamic and moves up and down depending on the changing market conditions.

¹ http://www.agmrc.org/renewable_energy/ethanol/the_plight_of_ethanol_plants.cfm

10. POLICY RECOMMENDATIONS

Improving future alternative fuel policy must begin with a broad assessment of current policy goals and progress towards these goals. As discussed above, the U.S. has invested vast amounts of public and private capital into corn ethanol production, primarily using the mantra of:

1. Reduced dependence on foreign oil
2. Creates jobs and supports the local economy
3. Cleaner for the environment
4. Supports farm income

Government and public investments have come in the form of grants/subsidies for initial construction of plants/equipment, renewable fuels standard mandates that guarantee a market for corn ethanol fuel, a blender's credit of 45 cents per gallon (annual cost of around \$7-9 billion), a 2.5% ad valorem tariff, and a 54 cent per gallon import tariff on any imported ethanol. In addition to these supports, the Taskforce on Biofuels Infrastructure is requesting additional public monies to fund infrastructure development (retail fuel stations, investment cost of rail/truck tanker equipment, pipeline, etc.) while increasing the market for corn ethanol.

The results of these investments have only marginally reduced U.S. dependence on foreign oil and directly employed only about 8,230 people at the 184 ethanol plants in operation today. While corn ethanol fuel emissions are better for the environment, the global environmental changes may not be an improvement given land-use changes worldwide. And while corn growers' income have been supported, dairy, poultry, pork and beef producers' incomes have not increased as a result of corn and feed cost increases. In addition, the effect upon U.S. consumer welfare may not be positive given government program cost, higher food cost and higher fuel cost (Babcock's study showing removing import tariffs would lower domestic fuel cost). Most concerning, however, is the development and evolution of an industry whose future will require substantial public subsidy to exist. In light of the severe state and federal budget deficits facing the U.S., continuation of policies that have relatively high marginal cost and relatively low marginal improvement (and concentrated to a very small number of recipients) does not seem preferable. What may seem reasonable, are the following policy recommendations.

I. Promote economic viability in the open market

The renewable fuels and energy landscape of the future must offer better economic viability without long-term public subsidy. There is little doubt that the renewable fuels and energy policies of the past have led to inefficient and wasteful public investment, overexpansion in ethanol plant facilities,

and construction of facilities that offer little hope of profitable operation in the market place. Even with periodic high oil prices, corresponding high corn prices (due to increasing pressure from Renewable Fuel Standard volume mandate increases), the blender's credit and import restrictions (evident from Fig. 11 above), ethanol plants will still likely operate in the red. Of the 184 ethanol plants in operation, 43% of these plants are 50 million gallon plants or smaller, 35% are between 51 and 100 million gallon plants, 20% between 101 and 200 million gallons, and less than 1% above 200 million gallons. Most of the small plants were the first plants built and were designed to be small to take advantage of the small producer subsidy. The operating cost disadvantage of these plants, compared to much larger size plants, places them under increased financial pressure when the corn prices are high and oil prices are low. Unfortunately, the existing policies don't promote industry changes and consolidation that would improve their long-term economic sustainability in the marketplace. What would initiate these industry adjustments include:

- a. Eliminate VEETC credit
- b. Eliminate volume mandate
- c. No infrastructure subsidies

This would essentially result in structural changes that offer greater hope of long-term economic viability and instead of an industry comprised of many small and medium size producers, consolidation to fewer large scale producers would offer several operational and economic efficiencies. These same changes have occurred in the grain processing/storage industry over the past 30 years. Instead of over 180 small inefficient corn ethanol plants, perhaps 50 or less plants in excess of 250 million gallon operating capacity with greater processing efficiency and costs would give a greater chance for economic viability. In addition to lower processing costs, there would be significant gains from the transportation/logistics of inbound grain and outbound fuel with improved bargaining power (for both price and service) with class I railroads, similar to the evolution in the grain elevator industry, resulting in significant cost savings per unit moved (processed). Likewise, the ability to protect and hedge against adverse price movements in both corn and oil markets is enhanced given the larger operating volume, in addition to the ability to buy/sell in the rail freight market to protect against transportation price increases. Collectively, these changes may result in the ability to process, distribute and market corn ethanol in geographic areas competitively with foreign oil or even imported ethanol. The geographic extent of the corn ethanol market would be dictated by the corn and oil price market fluctuations, resulting in a regional corn ethanol industry throughout the Midwest that changes as market conditions change, which would allow the industry to evolve into something sustainable without long-term public subsidization. Removing the volume mandate and allowing the market to dictate volumes produced could result in less upward pressure on corn prices.

II. Develop biofuels policy together with future vehicle development

Some consideration of incoming automobile attributes should also guide policies for future biofuel processing plants and transportation infrastructure. It is very unlikely that vehicles on the road today will be identical to those of the future given the dynamic changes occurring in the automotive industry and the investment by automakers in electrical hybrid vehicles. If the majority of vehicles are powered from some combination of electricity and fuel, then the demand for all liquid fuels, and biofuels, may be drastically altered. From a transportation cost and carbon impact framework, greater utilization of the electrical grid to provide power to passenger vehicles may prove more environmentally and economically viable in the future. The movement toward electric vehicles would reduce many network inefficiencies associated with moving heavy, bulky products long distances and instead create electricity from local sources and distribute via the available electrical grid. This would apply for both feedstock collection and biofuel distribution and may allow different regions to adopt modular plant technologies and sizes that are most effective and sustainable to each region while providing power to the electrical grid.

III. Must evolve in recognition of existing transportation infrastructure and financing limitations

Fifty years ago, the U.S. had one of the most efficient transportation systems in the world, following a long period of massive investments in rail, water and highway transportation systems. Those investments have stimulated economic growth and subsequent increases in utilization of transportation infrastructure that today is aging and in need of substantial maintenance and rehabilitation. While investments in rail infrastructure and operating technology has continued, the available funding for public infrastructure investments and maintenance on highways, bridges and waterways has fallen exceedingly short. The federal highway administration estimated in 2008 that over 45% of federal highways and major roads are in poor condition, and over 12% of U.S. bridges (approximately 71,000 bridges) are “structurally deficient.” The I-35 bridge collapse near Minneapolis, MN in 2007 tragically illustrates what may become more common as the end of the design life for highways and bridges approaches. The average age of the 575,000 highway bridges in the U.S. is 43 years with over 185,000 bridges in excess of fifty years old. And while the federal transportation situation seems dire, many states face even greater budget shortfalls and higher investment needs on local/state highway systems.

The U.S. Department of Transportation estimates that maintaining (no new construction) the existing federal highway system would require over \$100 billion per year. The highway trust fund,

historically used to fund highway maintenance/rehabilitation, provides about \$35 billion per year and has been declining over the past few years due to changes in vehicle types and consumer behavior (hybrid vehicles, higher miles per gallon, less tax revenue per mile driven). Given the current total U.S. budget deficit, any increases in transportation funding appear unlikely at best and reductions in total transportation spending inevitable. The current federal budget proposal offered by Representative Paul Ryan from Wisconsin seeks to reduce federal transportation spending by 31% between 2012 and 2021. While the outcome of budget deliberations on future transportation bills is unclear, how the U.S. funds transportation systems in the future must likewise change. Given these budget and political realities, future alternative energy and biofuels development must be compatible with existing transportation infrastructure.

IV. If there are government grants/subsidies, let it fund technological development

If federal funds are available to help foster emerging science and technology in the alternative fuels arena, it is perhaps best spent in the early laboratory research, development and testing stage, as opposed to federal subsidies for building plants and support to fund operations through import restrictions and blending credits. Public/private partnerships in the research and development of alternative fuels could produce better long term value with less program cost. There is already significant investment from the private sector in alternative biofuels from algae, microalgae and blue-green algae, in addition to advance cellulosic ethanol fuel and clean diesel combustion technologies. Many of these have the potential to be compatible with existing engines and transportation systems (pipelines, storage tanks and fueling stations).

REFERENCES:

- Babcock, B., Barr, K., and Miguel Carriquiry. *"Costs and Benefits to Taxpayers, Consumers and Producers from U.S. Ethanol Policies."* Center for Agricultural and Rural Development, Iowa State University, Staff Report, 10-SR 106, July 2010.
- Bryse, Robert. "Ethanol Bankruptcies Continue, 14 Studies Have Exposed the High Cost of Ethanol and Biofuels." Article in the Energy Tribune, Feb. 2009.
<http://www.energytribune.com/articles.cfm/1281/Ethanol-Bankruptcies-Continue-14-Studies-Have-Exposed-the-High-Cost-of-Ethanol-and-Biofuels>
- Delucchi, M.A., , *Emissions of Greenhouse Gases from the Use of Transportation Fuels and Electricity, Volume 1: Main Text*, ANL/ESD/TM-22, Center for Transportation Research, Argonne National Laboratory, Argonne, Ill., Nov. 1991.
- Delucchi, M.A., , *Emissions of Greenhouse Gases from the Use of Transportation Fuels and Electricity, Volume 2: Appendixes A-S*, ANL/ESD/TM-22, Center for Transportation Research, Argonne National Laboratory, Argonne, Ill., Nov. 1993.
- Delucchi, M.A., "A Revised Model of Emissions of Greenhouse Gases from the Use of Transportation Fuels and Electricity." Institute of Transportation Studies, University of California, Davis, Calif., Nov. 1997
- Grunwald, Michael. "The Clean Energy Scam." Article in Time Magazine, March, 27, 2008.
<http://www.time.com/time/magazine/article/0,9171,1725975-2,00.html>
- Fargione, J., Hill, J., Tilman, D., Polasky, S. and Peter Hawthorne. "Land Clearing and the Biofuel Carbon Debt." Science, Vol. 319, no. 5867, pp. 1235-1238, Feb. 2008.
- Ho, S.P., *Global Warming Impact of Ethanol Versus Gasoline*, Washington, DC, October, 1989.
- Keeney, D.R., and T.H. DeLuca, *Biomass as an Energy Source for the Midwestern U.S.*, American Journal of Alternative Agriculture, Vol. 7 (1992), pp.137-143.
- Leibtag, Ephraim. "Corn Prices Near Record High, But What About Food Costs?", Amber Waves, February 2008.
<http://www.ers.usda.gov/AmberWaves/February08/Features/CornPrices.htm>
- Lorenze, David, David Morris, *How Much Energy Does it Take to Make a Gallon of Ethanol?*, Institute for Local Self-Reliance, August, 1995.
- Marland, G., and A.F. Turnhollow, *CO2 Emissions From the Production and Combustion of Fuel Ethanol From Corn*, U.S. Department of Energy, February, 1991.
- Maron, D. F., "Much-Touted Cellulosic Ethanol is Late in Making Mandated Appearance." Article in the New York Times, Jan. 2011.
<http://www.nytimes.com/cwire/2011/01/11/11climatewire-much-touted-cellulosic-ethanol-is-late-in-ma-13070.html>
- Mitchell, Donald. "A Note on Rising Food Prices." The World Bank Development Prospects Group. July, 2008
<http://oldweb.econ.tu.ac.th/archan/RANGSUN/EC%20460/EC%20460%20Readings/Global%20Issues/Food%20Crisis/Food%20Price/A%20Note%20on%20Rising%20Food%20Price.pdf>

- Morris, David, Irshad Ahmed, *How Much Energy Does it Take to Make a Gallon of Ethanol?*, Institute for Local Self-Reliance, December, 1992.
- Murphy, D., Charles A.S. Hall, and Bobby Powers. *"New perspectives on Energy Return on Investment of Corn Ethanol."* Environment, Development and Sustainability. July 2010
- National Renewable Energy Laboratory et al. *"A Comparative Analysis of the Environmental Outputs of Future Biomass-Ethanol Production Cycles and Crude Oil/Reformulated Gasoline Production Cycles."* U.S. Department of Energy, Office of Transportation Technologies and Office of Planning and Assessment, Golden, Colo., Dec. 1991.
- National Renewable Energy Laboratory et al., *Fuel Cycle Evaluations of Biomass-Ethanol and Reformulated Gasoline."* U.S. Department of Energy, Office of Transportation Technologies and Office of Planning and Assessment, Golden, Colo., Oct. 1992.
- Neuman, William. "In Price of Farmland, Echoes of Another Boom." Article in the New York Times, March, 4, 2011.
http://www.nytimes.com/2011/03/04/business/04farms.html?_r=1&ref=us
- Pimentel, D.; T.W. Patzek. *"Ethanol Production Using Corn, Switchgrass, and Wood; Biodiesel Production Using Soybean and Sunflower."* Natural Resources Research **14** (1): 65-75. 2005.
[doi:10.1007/s11053-005-4679-8](https://doi.org/10.1007/s11053-005-4679-8) http://journeytoforever.org/biofuel_library/Pimentel-Tadzek.pdf
- Pimental, David, *Ethanol Fuels: Energy Security, Economics, and the Environment*, Journal of Agricultural and Environmental Ethics, Vol. 4 (1991), pp.1-13.
- Rosenthal, Elisabeth. *"Rush to Use Crops as Fuel Raises Food Prices and Hunger Fears."* Article in the New York Times, April, 6, 2011.
http://www.nytimes.com/2011/04/07/science/earth/07cassava.html?_r=3&hp
- Searchinger, T. Heimlich, R., Houghton, R., Dong, F., Elobeid, A., Fabiosa, S., Tokgoz, S. Hayes, D., and Tun-Hsiang Yu. "Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land-Use Change." *Science*, Vol. 319, no. 5867, pp. 1238-1240, Feb. 2008.
- Searchinger T., "Letter to Science responding to Wang's criticism." Feb. 2008.
http://www.bioenergywiki.net/images/3/31/Searchinger_Response.pdf
- Shappouri, H., J. A. Duffield, and M. Wang. *"The Energy Balance of Corn Ethanol: An Update."* U.S. Department of Agriculture
- Shappouri H., J. A. Duffield, A. McAloon, and M. Wang. *"The 2001 Net Energy Balance of Corn Ethanol."* U.S. Department of Agriculture, Report No: AER-814
- Shapouri, Hosein, James A. Duffield, Michael S. Graboski, *Estimating the Net Energy Balance of Corn Ethanol*, U.S. Department of Agriculture, Economic Research Service, Office of Energy, Agricultural Economic Report No. 721, July, 1995.
- Tyner, W., Taheripour, F., Zhuang, Q., Birur, D., and Uris Baldos. "Land Use Changes and Consequent CO2 Emmissions due to US Corn Ethanol Production: A Comprehensive Analysis." Department of Agricultural Economics, Purdue University, Final Report, July, 2010
<http://www.transportation.anl.gov/pdfs/MC/625.PDF>

U.S. National Alcohol Fuels Commission, *Ethanol: Farm and Fuel Issues*, August, 1980.

U.S. National Alcohol Fuels Commission, *Energy Balances in the Production and End-Use of Alcohols Derived From Biomass, A Fuels-Specific Comparative Analysis of Alternate Ethanol Production Cycles*, U.S. Department of Energy, October, 1980.

Wang, M., , *GREET 1.5 – Transportation Fuel-Cycle Model, Volume 1: Methodology, Development, Use, and Results*, ANL/ESD-39, Volume 1, Center for Transportation Research, Argonne National Laboratory, Argonne, Ill., Aug. 1999.

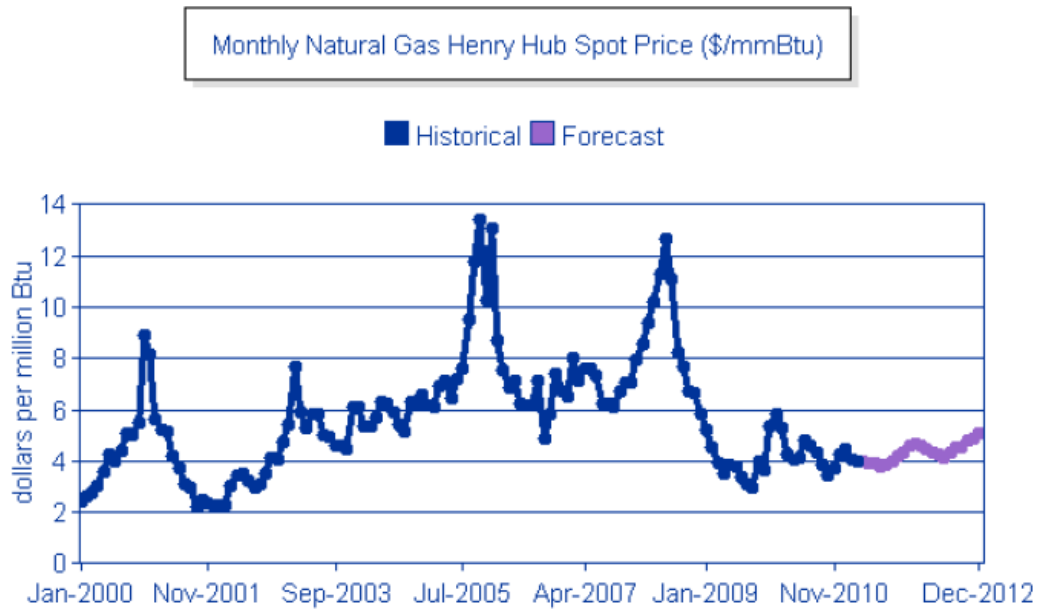
Wang, M, M. Wu, and H. Hong, "Life-Cycle Energy and Greenhouse Gas Emission Impacts of Different Corn Ethanol Plant Types," *Environmental Research Letter*, 2: 024001 (13 pages). 2007,

Wang, M., "Letter to Science criticizing Searchinger's article. Feb, 2008,
[http://www.bioenergywiki.net/images/0/0a/Michael_Wang-Letter to Science ANLDOE 03 14 08.pdf](http://www.bioenergywiki.net/images/0/0a/Michael_Wang-Letter_to_Science_ANLDOE_03_14_08.pdf)

Wayman, Morris, Sarad R. Parekh, *Biotechnology Of Biomass Conversion, Fuel and Chemicals From Renewable Resources*, Prentice Hall, New Jersey, 1990.

APPENDIX:

Natural Gas Prices, from EIA Natural Gas Weekly



DDGS Prices, USDA Livestock and Grain Market News

