TRANSITION TO A BIO ECONOMY

Integration of Agricultural and Energy Systems

Proceedings of a conference February 12-13, 2008
Atlanta, Georgia

Sponsored by
Farm Foundation
USDA Office of Energy Policy and New Uses
USDA Economic Research Service

Estimating and Comparing Alternative Ethanol Processes and Feedstock Choices

Brian J. Frosch, Roland J. Fumasi, James W. Richardson, Joe L. Outlaw, and Brian K. Herbst[1]

Introduction

Annual production of ethanol for fuel in the United States has risen from 175 million gallons in 1980 to nearly 6.5 billion gallons in 2007 (Renewable Fuels Association (RFA), 2008). While nearly all of the U.S. ethanol supply is currently derived from corn, concerns about environmental sustainability and potential impacts on the food supply chain have brought corn-based ethanol out of favor with some. The economic future of the grain-based ethanol industry has also been increasingly questioned in recent months, as declining ethanol prices have contributed to numerous cancellations of planned ethanol plants and expansions (Ngo, 2007). The demand for ethanol seems to have stagnated, even as crude oil price has continued to set record highs. Discretionary ethanol blending above that mandated by the Renewable Fuels Standard (RFS) relies on economics, as refineries will use more ethanol when it is economically advantageous to do so. These concerns have made it imperative that the ethanol industry take larger strides in developing and adopting low cost ethanol processing alternatives – regardless of source. Two options currently being explored are 1) The cellulosic process, where ethanol is produced using enzymatic breakdown of cellulosic materials and 2) the Brazilian "squeezing" method, where ethanol is produced from sugar that is squeezed from sugar producing crops such as sugarcane and sweet sorghum.

In contrast to grain-based ethanol, cellulosic ethanol can be made using any cellulosic-based feedstock, with focus on crops not competing with the food or feed industries. The Brazilians have had enormous success with the "squeezing" method, however, this method has yet to gain traction in the United States – due in large part to U.S. sugar policy. Even though cellulosic ethanol may be theoretically preferable to grain based ethanol, the ability to convert cellulose to ethanol on a commercial basis continues to elude the biofuels industry. Cellulosic production processes, such as MixAlco and other enzymatic processes, have been proven in the laboratory and are now in the process of being attempted on larger scales (Lau, 2004 and Farm Panel, 2007). For both the Brazilian and cellulosic processes, a number of different feedstocks are available for ethanol production. This study models feedstock production options for cellulosic and Brazilian processes at the farm level to determine the delivered cost to a biorefinery of a given capacity. The economic feasibility of ethanol production with these feedstocks is then modeled across the MixAlco cellulosic and Brazilian process alternatives to determine which type of ethanol production process and feedstock mix has the potential to produce ethanol at the lowest average total cost relative to grain.

Existing Studies

In the early 1990's Oak Ridge National Laboratory (ORNL) began to put forth research on the viability of switchgrass as a cellulosic biomass crop. The results of that research, which continues today, suggest that switchgrass may be one of the most advantageous crops for U.S. cellulosic feedstock production (ORNL, 2007). As a result of the ORNL findings, the majority of economic research has focused on switchgrass as the dominant cellulosic energy crop, where subsequent studies use an average conversion rate of 90 gallons of ethanol per dry ton.

In 2003, the USDA released its findings on the economic impacts of bioenergy crop production on U.S. agriculture (De La Torre Ugarte *et al.*, 2003). Their macro analysis, using the POLYSYS modeling framework, estimates shifts in acreage, production, and changes in prices for the major U.S. crops when a combination of switchgrass, poplar, and willow are introduced as dedicated energy crops on CRP land. The delivered prices for cellulosic feedstocks, which are exogenous to their model, range from $30 to $32.90 per dry ton (De La Torre Ugarte *et al.*, 2003).

In 2006, the University of Tennessee released an analysis of the feasibility of America's farms, forests, and ranches providing 25 percent of the U.S. total energy needs by 2025, while still providing a safe, abundant, affordable supply

---

[1] Frosch is a Research Associate; Fumasi is a Research Associate; Richardson is a Regents Professor and Senior TAES Faculty Fellow; Outlaw is a Professor and Extension Economist; and Herbst is a Research Associate, all respectively, in the Department of Agricultural Economics at Texas A&M University, College Station, Texas.

of food, feed, and fiber (English *et al.*, 2006). They found that the goal is achievable using a combination of forestry, food processing wastes, and dedicated energy crops such as switchgrass. Under their assumptions, the addition of dedicated, cellulosic energy crops to the U.S. crop mix benefits farmers as it raises crop prices and farm incomes.

In 2007, Mapemba *et al.* estimated the cost to procure, harvest, store, and transport cellulosic feedstock to a biorefinery in the southern Great Plains. Their research focused on switchgrass hay being the delivered feedstock, and they analyzed alternative production scenarios on CRP lands. They recognized that transportation costs would comprise the majority of the delivered price. Their model also accounted for differences in potential harvesting periods between regions, and estimated average hauling distances. They estimate a delivered cost per dry ton of switchgrass to be between $26 and $58 depending on the biorefinery size and alternative CRP planting flexibilities (Mapemba *et al.*, 2007).

The work done by Mapemba *et al.* was later refined for a paper presented at the AAEA meetings in July 2007. The work included a two-stage contracting mechanism between farmers and biorefineries. Using a competitive bidding process, they estimated the contract prices needed to entice producers to begin growing dedicated energy crops, and the cost of harvesting and transporting the biomass to a biorefinery. Their results were some of the first to suggest that the previously estimated costs of delivered feedstock, which were all around $30/ dry ton, were actually too low. They estimated that actual costs would likely range between $50 and $65 per dry ton depending on available harvesting periods (Epplin *et al.*, 2007).

In November 2007, the Council for Agricultural Science and Technology (Fales, Hess, and Wilhelm, 2007) released a report verifying that under current infrastructure assumptions, the transportation and preprocessing costs of delivering cellulosic biomass range from 50% to 75% of the total delivered cost of feedstock. They further asserted that if these feedstock logistic costs continue to exceed 25% of total cellulosic ethanol production costs then very little margin would remain in the system for biomass producers and biorefineries (Fales, Hess, and Wilhelm, 2007).

While taking these findings into account, this study seeks to take a closer look at firm level production costs across different production processes in a specified region. If it is assumed that both cellulosic and Brazilian style ethanol production are superior to grain-based ethanol based on implications for the food supply-chain, and the two methods are at least as environmentally sustainable as grain-based ethanol, then the question is: Which of the three processes is economically preferable for the biofuels industry? The answer to that question depends not only on differences in technology and salable by-products, but also on the choice of feedstock input mix and scale.

Energy Crops

The specific type of technology employed will certainly impact the type of energy crop that the biorefinery must use as its primary input. The feedstock used must be both environmentally and economically sustainable within the geographic area chosen for the biorefinery. Crop density (acres planted per square mile) and energy yield are two vital components in feedstock choice. The crop chosen must have adequate energy yield per acre (gallons of ethanol that can be produced), which is a function of the crop yield. Sufficient crop density of the chosen feedstock is also required so that transportation costs can be minimized, as research done by Mapemba *et al.* (2007) has shown that approximately two-thirds of the cost of producing feedstock is the cost of harvesting and delivering the crop to the biorefinery. Discussions with university agronomists have revealed potential feedstocks, sugarcane and hybrid sorghum, that may be most suitable for ethanol production (Rooney, 2007). Different varieties of each crop have been developed to maximize either sugar yield per acre (for the Brazilian process) and/or maximize biomass yield per acre (for the cellulosic process). Both crops are recognized for their relatively low input usage, and are especially suited for climates such as those found in the southeastern United States. Grain-based ethanol production is primarily dominated by corn. While grain sorghum is also an alternative, currently it is not widely used.

Agronomically, it may seem logical to grow these energy crops in areas where per acre yield is maximized (based on soil type, water availability, etc.), economics, however, may yield a different conclusion. While per acre yields of dedicated energy crops may be highest in a particular geographic area, the price that a biorefinery would have to pay a farmer to forgo his next best alternative and grow the dedicated feedstock may be economically prohibitive. Because of competing alternatives, perhaps “marginal” growing areas may be better suited economically for energy feedstock production and biorefinery location. For this study, the coastal region of southeast Texas has been identified as a potential area suitable for the production of new varieties of energy crops. Cursory examination of the area suggests that both sugarcane and hybrid sorghum varieties should grow well. Growers in the area have the technical expertise to grow energy crops, and rainfall is abundant. The availability of suitable farmland, which is close to potential refinery building sites, and the fact that relatively few economically viable crop options are available to growers, suggest that this area may be a wise choice for biorefinery location (Farm Panel, 2007).

Data and Methods

Crop Mixes

Crop mixes for the Brazilian method were limited to those yielding high squeezable sugar content. Potential crops were identified by studying the Brazilian ethanol industry and through interviews with university agronomists and extension economists. Attention was given to those crops that the agronomists and economists believed to be most suitable for the growing conditions in southeast Texas. Texas A&M University plant breeders revealed new hybrids expected to maximize squeezable sugar per acre in the targeted geographic region. These potential feedstocks are sugarcane and a hybrid sweet sorghum variety (Rooney, 2007). Plant breeders also identified the most feasible harvest periods for each crop as well as parameters for yield estimates. Harvested biomass must be processed for sugar quickly and cannot be stored for any meaningful length of time. The fluid in the plant containing the sugar begins to escape after the plant is harvested. To operate in as many months possible each year, the biorefinery must have constant access to a sugar-based feedstock supply coming directly out of the field. The feasible crop mixes were identified such that the overlap of the harvest periods for each crop was minimized.

Agronomists and ethanol industry representatives were consulted to determine the most feasible types of cellulosic ethanol crops for the growing region (Rooney, 2007 and Farm Panel, 2007). Feedstocks most attractive for this process are those that yield a high amount of cellulosic material per acre, including sugarcane and high biomass hybrids of sorghum. Since cellulosic ethanol production has yet to occur on a commercial basis, the potential yields and harvesting periods of these hybrid crops were based on experimental plots in the targeted geographic region. Loss of sugar during storage of cellulosic crops is of little consequence; however, the biorefinery should use a crop mix that minimizes storage costs while providing needed feedstock on a year-round basis. Alternative harvesting/storage techniques were identified such that biomass could be delivered to the biorefinery in months where harvesting is not possible due to climatic conditions.

Figures 1 and 2 provide a description of the annual feedstock mix choices included in the study for each process. For grain-based ethanol production, both corn and grain sorghum were selected as potential feedstocks. It was assumed the plant would purchase corn or grain sorghum on the market and then have the grain trucked or railed in on a year-round basis. Cellulosic feedstock options were identified as hybrid sorghum greenchop (HSGC), hybrid sorghum hay (HS hay), hybrid sorghum high biomass (HSHB) and sugarcane. Feedstock options for the Brazilian method were identified as sugarcane and hybrid sweet sorghum (HSS) with corn or grain sorghum serving as a backup for ethanol production after the harvest periods for sorghum and sugarcane have ended. For the cellulosic and Brazilian processes, it is assumed all feedstocks, except those for the grain backup, will be grown in the surrounding area. Final delivered feedstock costs to the biorefinery rely on a combination of factors. These include the contract prices paid to growers to attract the required amount of acres, and harvest and transportation costs.

Minimum Contract Prices to Induce Growing

Price, yield, and cost data for existing non-energy crop alternatives were provided by a panel of producers in the identified potential growing region (Farm Panel, 2007). Estimates of energy crop yields and costs of production were reached using a combination of information from the panel farmers, representatives from the cellulosic ethanol industry, and Agricultural Extension agronomists (Rooney, 2007 and Farm Panel, 2007). December 2007 FAPRI baseline estimates for U.S. crop prices and inflation rates were localized and used to estimate alternative crop budgets through 2017 (FAPRI, 2007). Budgets for program crops included estimated loan deficiency payments. Historical yield, price, and inflation rate data were used to create Monte Carlo simulations of estimated net returns per acre for 2008-2017. Using stochastic dominance analysis as the ranking procedure between crop choices, estimated minimum grower contract prices were produced endogenously for each energy crop.

Estimation of Actual Prices Paid to Growers

Minimum contract prices per unit of feedstock were based on the expected values of crop yields. However, since it is assumed that the biorefinery – grower contract have some portion of payments that is fixed on a per acre basis, the actual price paid per unit of feedstock depends on yield risk. To make contract price per unit a stochastic variable, random yield shocks were introduced into the model once the initial contract specifications were made. This method accounted for the time lag between original contract negotiations and actual harvest. The random shocks to yield were draws from a multivariate GRKS distribution, while extreme weather shocks to yield were simulated using a Bernoulli random variable (Richardson, Schumann, and Feldman, 2007). The probability of an extreme weather shock occurring was based on historical data provided by the grower panel. The actual yield loss due to extreme weather depended on the particular crop, and was estimated by the Extension agronomists.

Estimation of Harvest and Transportation Costs

Based on interviews with ethanol industry representatives, it is assumed that the biorefinery would be responsible for the harvesting and transportation of costs for biomass produced for both the Brazilian method and the cellulosic method (Rooney, 2007 and Farm Panel, 2007). Grain prices to the biorefinery were considered FOB, then localized with a trans-

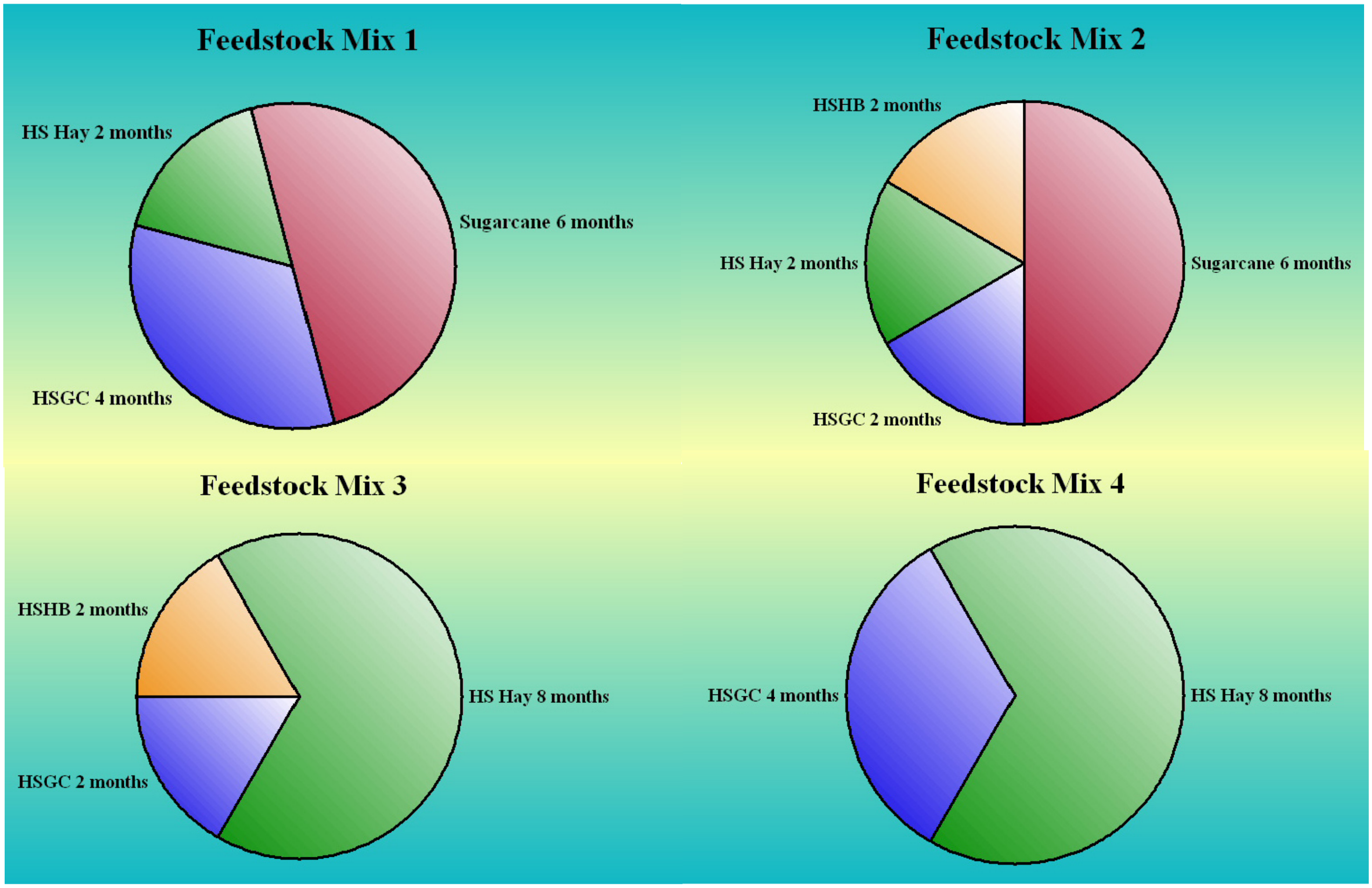

Figure 1. Feedstock Options Analyzed for the MixAlco Cellulosic Ethanol Production Process

portation wedge. Harvest costs per unit of feedstock were based on the 2004 Texas Custom Rates Statistics publication (USDA/NASS, 2004) and then adjusted using FAPRI baseline inflation estimates through 2017.

Transportation costs per unit of feedstock were modeled as a function of the average distance hauled and the variable transportation cost per mile. The average distance hauled for each feedstock did not depend on stochastic yields, because the actual acreage contracted is a function of the expected yield at the time the contract is negotiated. Contracted acres needed was modeled as a function of the dry matter tons of each feedstock needed (given choice of crop mix and scale of biorefinery), the expected dry matter yields per acre, and the expected biodensity of each crop per square mile. Work done by McCarl *et al*. was critical in estimating the expected biodensities (2000). Once total planted acres needed were estimated, average hauling distances were calculated using work done by French, which accounts for a square road system (1960). Variable transportation costs per mile were based on the 2004 Texas Custom Rates Statistics publication (USDA/NASS, 2004) and were adjusted using FAPRI baseline inflation estimates through 2017.

Total Delivered Cost of Feedstock

Table 1 provides a summary of the average delivered price of each feedstock to the plant by process. Delivered costs of grain feedstocks were estimated using the FAPRI baseline for U.S. price projections and using a basis to localize to the study region. Historical prices were used to add variability to point estimates using Monte Carlo draws from a multivariate empirical distribution to estimate percent deviations from point forecasts, as outlined by Richardson, Klose, and Gray (2000). Probabilistic forecasts of delivered costs for biomass feedstocks were made by simultaneously simulating actual prices paid to growers and harvest/transportations costs. Forecasts were made for each potential crop mix under each of the biorefinery scale choices.

Estimation of Actual Ethanol Output

Total acreage of biomass contracted (as estimated above) depends on the size of the biorefinery in terms of planned scale of ethanol output. For grain-based production, where grain is purchased from the market rather than through contracted growers, actual ethanol output is assumed to reach full capacity.

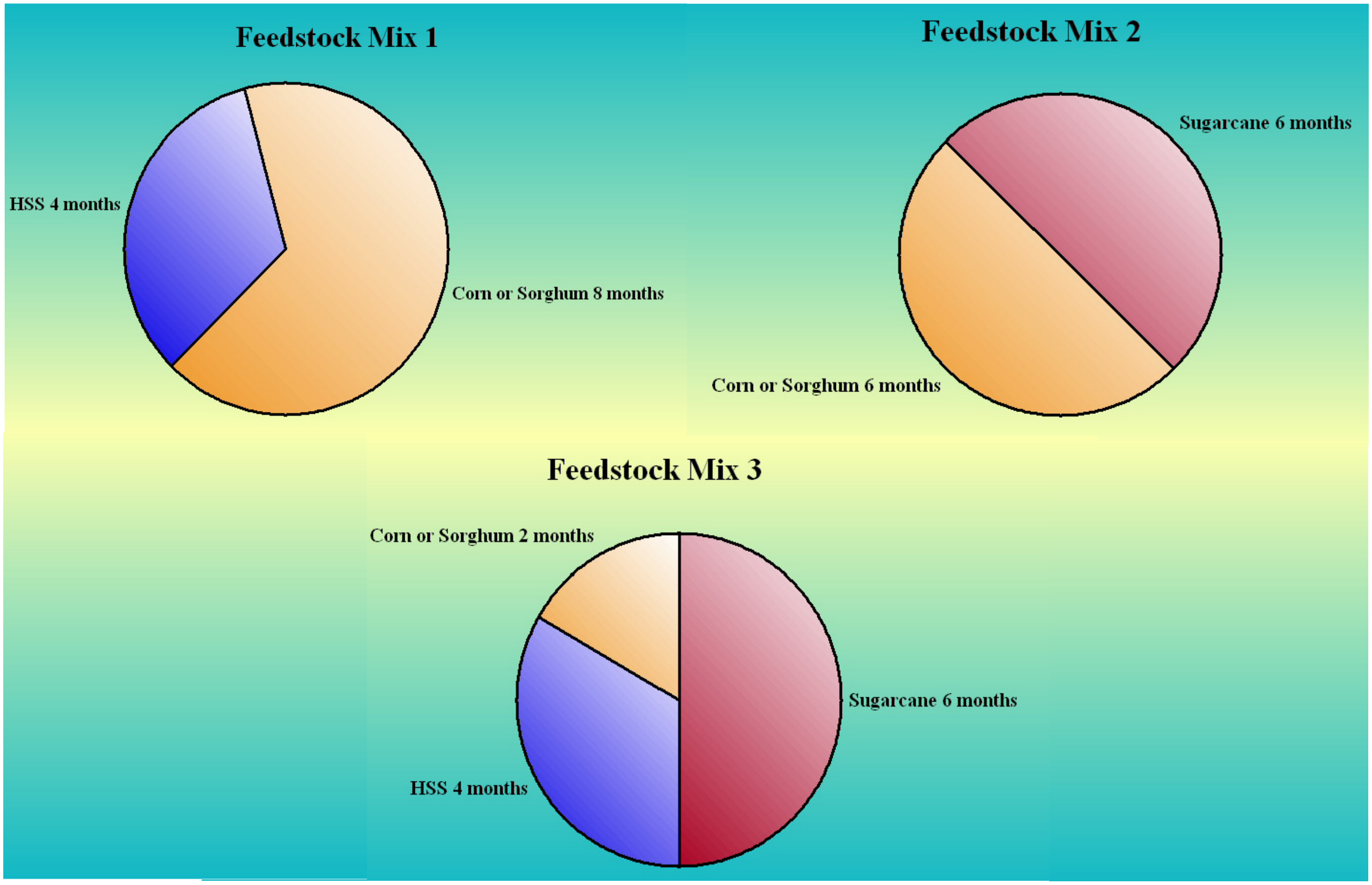

Figure 2. Feedstock Options for the Brazilian Ethanol Production Process

Since biomass-based ethanol, either Brazilian method or cellulosic, is based on contracting acreage of dedicated energy crops, actual ethanol production is subject to yield risk as well as conversion risk and shutdown risk. The yield risk was incorporated into the model when estimating the actual price paid to growers. Any excess biomass (due to higher than expected crop yields) is assumed to be used for energy generation within the biorefinery, providing an additional revenue stream.

Selected input assumptions are outlined in Table 2. The fixed costs associated with each type of production process under each scale choice were estimated using cost information from Lau (2004), and Brazilian ethanol industry repre-

Table 1. Average Delivered Feedstock Costs across Each Feedstock Mix for Grain, Cellulosic, and Brazilian Ethanol Production Processes

		Feedstock Mix			
		1	2	3	4
Grain					
Corn	$/bu	3.34			
Sorghum	$/bu	3.18			
Cellulosic					
HSGC	$/ton dry matter	87	85	85	87
HS Hay	$/ton dry matter	116	116	121	121
HSHB	$/ton dry matter	--	75	75	--
Sugarcane	$/ton dry matter	88	88	--	--
Brazilian					
HSGC	$/ton dry matter	89	--	89	
Sugarcane	$/ton dry matter	--	89	89	

Table 2. Operational Input Assumptions across Grain, Cellulosic, and Brazilian Ethanol Production Processes for a 25 Million Gallon Facility

	Units	Value
Grain Ethanol		
Proposed Capital Cost	$/gallon of ethanol	2.25
Ethanol Processing Costs	$/gallon of ethanol	0.61
Grain Ethanol Yield:		
Corn	gallons/bushel	2.75
Sorghum	gallons/bushel	2.75
DDGS Yield	gallons/bushel	18.00
Local Basis:		
Corn	$/bushel	0.05
Sorghum	$/bushel	0.15
Denaturant Added	fraction	0.05
Cellulosic Ethanol		
Proposed Capital Cost	$/gallon of ethanol	0.63
Percent Dry Matter:		
Sweet Sorghum	fraction	0.30
Sweet Sorghum Hay	fraction	0.85
Sweet Sorghum HB	fraction	0.40
Sugarcane	fraction	0.33
Ethanol Processing Costs	$/gallon of ethanol	1.25
Cellulosic Ethanol Yield:		
Yield for Contracting Acres	gallons/ton of dry matter	90.00
Yield Parameters for Production:		
Min	gallons/ton of dry matter	70.00
Med	gallons/ton of dry matter	90.00
Max	gallons/ton of dry matter	110.00
Denaturant Added	fraction	0.05
Brazilian Ethanol		
Proposed Capital Cost	$/gallon of ethanol	6.07
Percent Dry Matter:		
Sweet Sorghum	fraction	0.30
Sugarcane	fraction	0.33
Brazilian Ethanol Yield:		
Sweet Sorghum	gallons/ton of dry matter	49.00
Sugarcane	gallons/ton of dry matter	61.68
Cane Processing Costs	$/gallon of ethanol	0.19
Ethanol Processing Costs	$/gallon of ethanol	0.38
Grain Ethanol Backup		
Grain Ethanol Yield:		
Corn	gallons/bushel	2.75
Sorghum	gallons/bushel	2.75
DDGs Yield	pounds/bushel	18.00
Ethanol Processing Costs	$/gallon of ethanol	0.61
Denaturant Added	fraction	0.05

Table 3. Average Total Cost of Producing Ethanol across Each Feedstock Mix for Grain, Cellulosic, and Brazilian Production Processes for a 25 Million Gallon Facility

	Year 1
Grain	1.99
Corn	2.02
Sorghum	1.96
Cellulosic	2.56
Feedstock Mix 1	2.46
Feedstock Mix 2	2.44
Feedstock Mix 3	2.65
Feedstock Mix 4	2.67
Brazilian	2.41
Feedstock Mix 1	2.37
Feedstock Mix 2	2.32
Feedstock Mix 3	2.54

sentatives (Campos, 2006; Chaves, 2006; Fernandes, 2003). All fixed cost estimates from previous works were inflated to arrive at estimates for 2007, using FAPRI's inflation rate estimate for fixed costs. Stochastic estimates of fixed cost per gallon of ethanol produced were then estimated for each forecast period using the stochastic estimates of ethanol output.

For consistency, a 25 million gallon capacity level was selected for each process in this study. The per unit variable costs of production were based on research done by Bryan and Bryan International (2004) for the grain-based ethanol process, research conducted by Lau (2004) for the cellulosic process, and industry representatives for the Brazilian process (Campos, 2006; Chaves, 2006; Fernandes, 2003). All variable costs were inflated to the current time period, and then for each year 2008-2017 using FAPRI baseline inflation estimates (FAPRI, 2007). Total variable costs were dependent on the stochastic estimates of ethanol production.

Estimating Total Average Cost per Gallon of Ethanol

Following Richardson *et al.* (2006), a Monte Carlo simulation model was developed to analyze the future performance across each alternative production scenario. Stochastic accounting relationships, which are based on the fixed and variable input parameters and prices outlined above, are maintained throughout a 10 year planning horizon to analyze financial performance under risk. The model is programmed in Microsoft© Excel, using standard accounting relationships, and made stochastic using Simetar©, an add-in for Excel (Richardson, Schumann, and Feldman, 2007). Each production scenario is simulated at the 25 mmgy capacity level for 500 iterations. Stochastic estimates of total average cost per gallon of ethanol were produced for each combination of production process, crop mix, and choice of scale. Estimated total costs were divided by the stochastic estimates of ethanol production in each iteration of the Monte Carlo simulation for each year forecasted. Estimated distributions of total average cost per gallon under each scenario were then compared to find the optimal production process and feedstock mix at different production levels.

Results

Results of the analysis focus on the total cost of production for one year at the 25 million gallon capacity level. These results identify the grain process as returning the lowest average total cost of production, followed by the Brazilian and cellulosic processes. Table 3 summarizes the average total cost of production for each process and feedstock mix. For grain ethanol, sorghum proved to be the feedstock of choice, as its average total cost of production is slightly lower than that of corn. For cellulosic production, the second production scenario of HSGC for two months, HS hay for two months, HSHB for two months, and sugarcane for six months returned the lowest total cost of production. For the Brazilian process, the scenario of sugarcane for six months with a grain backup for six months, returned the lowest total cost of production. Table 4 demonstrates the sensitivity of the cost of producing grain ethanol at high grain prices, or values more consistent with recent trends. Cellulosic costs of production do not change since grain is not included in the feedstock mix. When comparing across each production process at higher grain prices, the first and second feedstock mixes for the cellulosic process become competitive at grain prices of $4.50 per bushel. Because of the grain backup included in the Brazilian process feedstock mixes, the grain process remains economically preferable to this process as grain prices increase.

Table 4. Sensitivity of Average Total Cost of Producing Ethanol at High Grain Prices for a 25 Million Gallon Facility

		Grain Price, FOB				
	$/bu	4.00	4.25	4.50	4.75	5.00
Grain	average	2.28	2.37	2.46	2.55	2.63
Corn	$/gallon	2.27	2.35	2.44	2.53	2.61
Sorghum	$/gallon	2.30	2.39	2.48	2.56	2.65
Cellulosic	average	2.56	2.56	2.56	2.56	2.56
Feedstock Mix 1	$/gallon	2.46	2.46	2.46	2.46	2.46
Feedstock Mix 2	$/gallon	2.44	2.44	2.44	2.44	2.44
Feedstock Mix 3	$/gallon	2.65	2.65	2.65	2.65	2.65
Feedstock Mix 4	$/gallon	2.67	2.67	2.67	2.67	2.67
Brazilian	average	2.56	2.60	2.64	2.68	2.72
Feedstock Mix 1	$/gallon	2.58	2.64	2.70	2.76	2.82
Feedstock Mix 2	$/gallon	2.48	2.53	2.57	2.62	2.66
Feedstock Mix 3	$/gallon	2.61	2.63	2.64	2.66	2.68

Conclusions

As pressures continue to mount concerning the net environmental impacts of grain-based ethanol and its potential impacts on the food supply chain, alternative feedstocks and processes may begin to play a larger role. Based on current corn and grain sorghum price estimates, grain-based ethanol production should continue to have a place in the future of the biofuels industry. As grain prices increase above these baseline estimates, cellulosic and Brazilian methods become more economically competitive. When looking at the current market environment for attracting acres for energy crops and the technologies available, the cellulosic process and the Brazilian processes appear to be less economically feasible than grain-based ethanol production in the United States. As new crop varieties and new conversion technologies continue to develop, it is possible that cellulosic ethanol production will become more economically favorable by the time it becomes technologically feasible on a commercial basis. While the sugar "squeezing" method is dominant in Brazil, the higher cost of attracting acres and growing feedstocks in the United States makes the Brazilian method more costly than that of grain-based production. As plant geneticists continue to develop sugarcane varieties that can potentially increase sugar yields by 50%, perhaps the feedstock costs can be offset and the Brazilian method can have a place in the U.S. ethanol industry (Informa Economics, 2007). Under current price projections and assumptions made in this study, alternatives to grain-based ethanol in the U.S. may be looming, but they have yet to become economically viable.

References

Bryan and Bryan International (BBI International). *Ethanol Plant Development Handbook, 4th ed.* Cotopaxi, CO: Bryan and Bryan International, 2004.

Campos, R. Personal Communication. Export Manager – Alcohol, Dedini, Piracicaba. Sao Paulo, Brazil, March 7, 2006.

Chaves, I. Personal Communication. CEO, Chaves Consultoria. Riberao Preto, Sao Paulo, Brazil, August 3, 2006.

De La Torre Ugarte, D., M. Walsh, H. Shapouri, and S. Slinsky. 2003. "The Economic Impacts of Bioenergy Crop Production on U.S. Agriculture." U.S. Department of Agriculture, Office of the Chief Economist, Office of Energy Policy and New Uses. Agricultural Economic Report No. 816. Available at http://www.usda.gov/agency/oce/reports/energy/AER816Bi.pdf.

English, B., D. De La Torre Ugarte, K. Jensen, C. Hellwinckel, J. Menard, B. Wilson, R. Roberts, and M. Walsh. 2006. "25% Renewable Energy for the United States By 2025: Agricultural and Economic Impacts." Department of Agricultural Economics, The University of Tennessee, Knoxville, Tennessee. Available at http://www.agpolicy.org/ppap/REPORT%2025x25.pdf.

Epplin, F., C. Clark, R. Roberts, and S. Hwang. 2007. "Challenges to the Development of a Dedicated Energy Crop." *American Journal of Agricultural Economics* 89(December):1296-1302.

Fales, S., R. Hess, and W. Wilhelm. 2007. "Convergence of Agriculture and Energy: II. Producing Cellulosic Biomass for Biofuels." Council for Agricultural Science and Technology (CAST) Commentary, QTA2007-2. Available at http://www.cast-science.org/websiteUploads/publicationPDFs/CAST%20Commentary%202007-2%207o12145.pdf.

Farm Panel. Panel Discussion with Southeast Texas Farmers and Representatives of Verenium, September 2007.

Fernandes, A. 2003. "Calculations of the Sugarcane Agro-Industry." Brazilian Society of Sugar and Ethanol Technicians (STAB). Piracicaba, SP, Brazil. Second Edition, 2003.

Food and Agricultural Policy Research Institute (FAPRI). "FAPRI Agricultural Outlook 2007." University of Missouri-Columbia and Iowa State University, 2007. Available at http://www.fapri.iastate.edu/publications/outlook.aspx.

French, B. 1960. "Some Considerations in Estimating Assembly Cost Functions for Agricultural Processing Operations". *Journal of Farm Economics* 3(August):767-778.

Informa Economics. 2007. "The Food & Fiber Letter." Vol. 27, No. 44, November 19.

Lau, M. "Location of an Agribusiness Enterprise with Respect to Economic Viability: A Risk Analysis." Ph.D. dissertation, Texas A&M University, December 2004. Available at http://txspace.tamu.edu/bitstream/handle/1969.1/3263/etd-tamu-2004C-AGEC-Lau.pdf?sequence=1.

Mapemba, L., F. Epplin, C. Taliaferro, and R. Huhnke. 2007. "Biorefinery Feedstock production on Conservation Reserve Program Land". *Review of Agricultural Economics* 29(July):227-246.

McCarl, B., D. Adams, R. Alig, and J. Chmelik. 2000. "Competitiveness of Biomass-Fueled Electrical Power Plants". *Annals of Operations Research* 94(March):37-55.

Ngo, P. 2007. *Renewable Fuel News*. "Ethanol Plant Projects Begin to go Under as Investors Back Out." Vol. XIX, Issue 42, October 16. Available at http://www.worldfuels.com/TRIAL/MARKETING/RenewableFuels_News/rf_VolXIX_Issue42__20071016_Print.php.

Oak Ridge National Laboratory (ORNL). Comprehensive Publications and Presentations Registry, Keyword: Switchgrass. Available at http://lib1.isd.ornl.gov:8182/TSEARCH/BASIS/tidd/fqma/tpsext/SF.

Renewable Fuels Association (RFA). 2008. Industry Statistics. Available at http://www.ethanolrfa.org/industry/statistics.

Richardson, J., B. Herbst, J. Outlaw, D. Anderson, S. Klose, and C. Gill. 2006. "Risk Assessment in Economic Feasibility Analysis: The Case of Ethanol Production in Texas." Agricultural and Food Policy Center, Texas A&M University, College Station, Texas. Available at http://www.afpc.tamu.edu/pubs/2/447/RR%2006-3.pdf.

Richardson, J., S. Klose, and A. Gray. 2000. "An Applied Procedure for Estimating and Simulating Multivariate Empirical (MVE) Probability Distributions in Farm-Level Risk Assesment and Policy Analysis". *Journal of Agricultural and Applied Economics*, 32(August):299-315.

Richardson, J., K. Schumann, and P. Feldman. 2007. "Simetar©: Simulation & Econometrics to Analyze Risk." Simetar, Inc., 2006. Available at http://www.afpc.tamu.edu/courses/622/files/technical/Simetar%202008%20Manual.pdf.

Rooney, L. Personal Communication. Professor of Plant Breeding and Genetics, Department of Soil and Crop Sciences, College of Agriculture and Life Sciences,, Texas A&M University, 2007.

U.S. Department of Agriculture, National Agricultural Statistics Service (NASS). "2004 Texas Custom Rates Statistics." Available at http://www.nass.usda.gov/Statistics_by_State/Texas/Publications/Custom_Rates_Statistics/index.asp.