Sixty Billion Gallons by 2030: Economic and Agricultural Impacts of Ethanol and Biodiesel Expansion

by

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Challenges and Policy Implications of Developing an Economically Competitive Bioenergy Production System with Cellulosic Feedstock

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Use of bioenergy feedstocks to produce transportation fuels could not only help reduce reliance on foreign oil, but could also provide significant environmental benefits and invigorate rural economies. Agriculture is well positioned as a feedstock source because the fuels can be utilized with current engine technologies and are compatible with the current distribution infrastructure. The anticipated commercialization of cellulosic to ethanol technology will enable fuels to be derived from a diverse portfolio of feedstocks from numerous regions of the country.

The Energy Policy Act of 2005 establishes a renewable fuel requirement for the nation, mandating 7.5 billion gallons of renewable fuels by 2012. Ethanol and biodiesel are both defined as eligible renewable fuels. A more sweeping renewable fuels standard was proposed as part of The Biofuels Security Act of 2007 (sponsored by Senator Tom Harkin and co-sponsored by Senators Lugar, Biden, Dorgan, and Obama). This proposal would require 10 billion gallons of renewable fuels by 2010, 30 billion by 2020 and 60 billion by 2030. Furthermore, the Governors' Ethanol Coalition has recommended that replacing at least 25 percent of petroleum used as transportation fuels by the year 2025 (Governor's Ethanol Coalition, 2006).

The objective of this study is to project the U.S. agricultural sector and economic impacts of increasing ethanol and biodiesel production beyond the levels specified in the recently enacted renewable fuel standard. The levels of ethanol production analyzed are 10, 30, and 60 billion gallons of ethanol annually by 2010, 2020 and 2030, respectively. Furthermore, sensitivity to the timing of commercialization of cellulosic feedstock to ethanol technology and impacts of associated corn to ethanol industry adjustments associated are projected. Impacts of producing 1 billion gallons of biodiesel production by 2012 and 1.6 billion gallons by 2030 are also projected.

Prior Research

Several studies have addressed various aspects bioenergy production and contribution toward renewable energy (USDA-OCE, 2002; Urbanchuk, 2001; Shapouri, Duffield, and Wang, 2002; Sheehan 2002; Walsh et al, 2003; McLaughlin et al, 2002). Previous economic modeling evaluating agriculture feedstocks for energy has been conducted in the context of carbon displacement potential (McCarl and Schneider, 2000) and have analyzed long-term and intermediate-run outcomes. Adjustment costs incurred in the short-run for implementing new technologies and/or policies are not considered by these models (Schneider, 2000). The potential regional economic impacts of converting corn stover to ethanol have been projected using IMPLAN (English, Menard, and de la Torre Ugarte, 2000).

Methodology

Key methodological steps to conducting the analysis are definition of biofuels goals, selection of representative conversion technologies and collection of associated cost information, definition of key assumptions, updating and expansion of POLYSYS (a dynamic agricultural sector model), development of a program to integrate POLYSYS results into IMPLAN (PII), modification of IMPLAN (economic input output model) to accommodate biomass feedstock production and biofuels conversion industries, and scenarios development. The biofuels targets are 10 billion gallons annually of ethanol by

2010, 30 billion by 2020, and 60 billion by 2030, and 1 billion gallons of biodiesel production by 2012 and 1.6 billion gallons by 2030.

The conversion technologies include ethanol from shelled corn, ethanol from cellulosic residues (stover, switchgrass, and wheat straw), ethanol from food residues, ethanol from wood residues (forest residues, mill wastes, fuel treatment and forestland thinnings, harvesting of standing stock is not included), biodiesel from soybeans, and biodiesel from yellow grease/tallow. Representative facility output, feedstock use, and associated costs are developed based on prior studies (McAloon, Taylor, Yee, Ibsen, and Wooley, 2000; e-mail correspondence from V. Eidman, 2006; Aden, Ruth, Ibsen, Jechura, Neeves, Sheehan, Wallance, Montague, Slayton, and Lukas, 2002; BBI International, 2002; English, Jensen, and Menard, 2002; Fortenberry, 2005). Conversion coefficients of cellulose to ethanol are increased linearly for stover, straw and dedicated energy crops from 2015 to 2030. Conversion coefficients of feedstocks to corn grain ethanol and biodiesel are assumed to increase through 2019 and thereafter remain steady.

Several key study assumptions are required in addition to setting biofuels targets and selecting conversion technologies. Cellulosic to ethanol is assumed to be commercially available in 2012. Switchgrass serves as a proxy for dedicated energy crops, with yields increasing over time that range from 1.5 percent to 5 percent, depending on region. No till adoption increases from 20 to 55 percent. The available land base includes 307 million acres of cropland in major crops plus hay and 56.2 million acres of cropland in pasture. Maximum percents of Distiller's Dry Grains (DDG's) in rations are assumed at 30 percent for beef, 10 percent for dairy, hogs, and broilers.

The targeted biofuels production levels plus data on conversion costs for agricultural and forest feedstocks are introduced into POLYSYS to estimate the quantity and type of energy to be produced from agriculture, as well as the price, net farm income, and other agricultural sector impacts. The POLYSYS model (De La Torre Ugarte and Ray, 2000) has the unique ability to provide annual estimates of changes in land use resulting from the demand generated by bioenergy industries, including changes in economic conditions that affect adjustment costs.

In regions where dedicated energy crops are determined to be profitable, pasture is made available to dedicated energy and other crops. Loss of forage production is replaced with new hay production. The livestock module in POLYSYS is an integrated version of the Economic Research Service's econometric livestock model. To project the potential of dedicated energy crops to provide feedstocks, enterprise budgets and yields for switchgrass are incorporated into POLYSYS. Production is assumed suitable on 368 million acres.

To evaluate the potential of crop residues to provide feedstocks to the bioproduct markets, POLYSYS includes corn stover and wheat straw response curves that estimate stover and straw quantities as a function of corn and wheat grain yields, and stover and straw production costs as a function of yields of removable residue. Estimated response curves are obtained through the Oak Ridge National Laboratory (Walsh et al, 2003). Residues needed to keep erosion at less than or equal to the tolerable soil loss level are incorporated. Total quantities of corn stover and wheat straw that can be collected in each county are estimated for each tillage and dominant crop rotation scenario. The costs of collecting corn stover and wheat straw include baling, staging, and nutrient replacement.

The cost of transporting biomass feedstocks from the farm gate to the production facilities is added to conversion costs. An iterative process is used until the corresponding price of biomass is equal to current iteration biomass price. Once this is achieved and equivalent ethanol costs of production exist, the model has determined the optimal market level of feedstock quantities. The price at which these wood residues feedstocks come into use is determined by regional harvesting costs plus transportation costs.

Distiller's dry grains from ethanol production and soybean meal from biodiesel production are integrated within the model to evaluate how their quantities and prices affect the final market equilibrium. The market price of distiller's dry grains is estimated as a function of corn price.

For biodiesel, beef and poultry wastes are modeled as a function of beef and poultry cash receipts, respectively. Yellow grease from food waste is a function of population. Soybean meal byproduct from crushing enters into the POLYSYS soybean product module where prices are endogenously determined.

An interface program, the POLYSYS/IMPLAN Integrator (PII), developed at The University of Tennessee, takes POLYSYS projections of acreage, price, change in government programs, and cost output and makes changes to IMPLAN databases (English, Menard, Wilson, and De La Torre Ugarte, 2004). PII adds an energy crop sector to IMPLAN based on information supplied by POLYSYS. A renewable energy sector is added to each state's IMPLAN model, and the operating impacts from the renewable energy sector are estimated. IMPLAN employs a regional social accounting system to generate a set of balanced economic/social accounts and multipliers (MIG, 1999). The model estimates total industry output, employment, and value-added for over 500 industries.

Results under three scenarios are compared with a baseline scenario called USDAExt, which is an extension of the 2006 USDA baseline. The first scenario projects the impacts of attaining the targets assuming the cellulose-to-ethanol technology would be commercially available by 2012 (ETH60). In this scenario, use of corn grain is kept at near production capacity of plants, even with introduction of cellulosic technology. The second scenario allows the corn grain to ethanol industry to adjust as cellulose-to-ethanol becomes commercially available in 2012 (ETH60CA). In the third scenario (ETH60CACD), the cellulose-to-ethanol technology would be delayed until 2015 and the corn grain based ethanol industry is allowed to adjust in response to cellulosic introduction. Results from these three scenarios are compared with the extended baseline to illustrate how various paths of ethanol industry expansion may influence the agricultural sector. Furthermore, results from the scenarios are compared with each other to project the impacts of cellulosic delay and the impacts of protection of the corn grain to ethanol industry.

Results

Under the ETH60 Scenario, the targeted production of ethanol can be achieved for the years 2010, 2020, and 2030. The targeted goals of 1 billion gallons of biodiesel by the year 2012 and 1.6 billion gallons by 2030 can also be achieved. The amounts of ethanol that would be derived from the various feedstocks under the three scenarios are shown in Table 1. Under the ETH60 Scenario, through 2012, corn grain continues to be the base of ethanol production. In subsequent years, with the commercial introduction of cellulosic technology, the increase of corn grain for ethanol slows down and remains flat after 2020 at around 14 billion gallons. Initially cellulosic to ethanol conversion relies on wood residues, but as dedicated energy crops come into commercial production, they ~~are projected to~~ become the dominant feedstocks. By 2030, even holding corn grain to ethanol plants at near capacity, less than one in four gallons of ethanol are projected to be derived from corn grain.

Under the ETH60CA Scenario, use of corn reaches a peak in 2012, but with cellulosic introduction declines to less than 8 billion gallons by 2030. This suggests excess production capacity in corn grain to ethanol will appear in 2013, and corn grain ethanol plants will likely convert to cellulose or exit the industry. By 2030, as the corn grain ethanol industry adjusts, less than one in six gallons of ethanol are projected to be derived from corn grain.

For the ETH60CACD Scenario, in which commercial introduction of cellulosic technology is delayed, use of corn for ethanol will not peak at just under 18 billion gallons until 2015. After the peak year, there will be a significant reduction in the use of grain corn resulting in excess capacity. With a cellulosic delay, the impacts on the corn grain ethanol industry by 2030 are dampened slightly, about 120 million gallons or about 1.4 percent, as compared with cellulosic introduction in 2012. Also, by 2030, the contribution of corn residues is more significant than under the other two scenarios. Ethanol from corn stover is about 36 percent higher than the ETH60 Scenario and 12 percent higher than the ETH60CA Scenario.

In the years beyond 2012, most of the growth in biodiesel production is projected to come from yellow grease and tallow, rather than soybeans. By 2030, 1 billion gallons comes from soybeans, while .6 billion gallons is derived from yellow grease and tallow. An alternative target of 2 billion gallons of biodiesel was considered, but to reach this target using soybeans as a feedstock required a price above $8 per bushel.

With a major change in ethanol feedstocks and overall growth in feedstock use, land use patterns would change. For example, under the ETH60 Scenario, dedicated energy crops reach about 34.4 million acres by the year 2030 from very low levels in 2007. Pasture declines from 56.5 million acres to 24.3 million by 2030. Corn acreage increases from 81 million acres and then declines with the introduction of cellulosic technology to around 83 million acres in 2030. About 32.2 million acres of cropland in pasture would come back into hay, dedicated energy crops, and other crop production. Acreage planted to soybeans goes from 73.3 million acres in 2007 to 62.7 million acres in 2030, a reduction of 10.6 million acres coming primarily from the Southeast.

The projected changes in prices of major crops away from baseline levels are shown in Table 2. For the ETH60 Scenario, the price estimates indicate that corn, wheat, and soybeans experience a significant price impact. The price impact for corn peaks during the highest period of corn demand for grain ethanol. By the year 2030, corn prices are more than 60 cents above the baseline. For the ETH60CA and ETH60CACD

Scenarios, the increases in corn prices by 2030 are slightly dampened compared with the ETH60 Scenario, 10 cents per bushel and 2 cents per bushel lower, respectively. With the introduction of cellulosic technology, positive pressure on corn prices is reduced and land is released for production of soybeans. Because the corn grain ethanol industry adjusts under the ETH60CA or ETH60CACD Scenarios, soybean price increases above baseline are lower than under the ETH60 Scenario.

As can be seen in Table 2, the various sectors within the livestock industry react differently to higher feed prices. These differences depend on the relative importance of corn in rations, importance of feed expenses in costs of production, and by the ability to transfer cost of the additional feed expenses through the market channel. Notably, cattle sector impacts are quite different compared with hog and poultry sector impacts. Reduction in cattle inventories leads to higher prices that offset the sector's increased production costs and reduces the total expenditures in feed. Furthermore, dried distillers grains (DDG's) can be more heavily incorporated into cattle rations compared with hog or poultry rations. For hogs and poultry, the inventory adjustments and increase in prices are not large enough to compensate for increases in feed costs. Without corn grain industry adjustment (ETH60), the net returns to the hog and poultry sectors are more negatively affected than when the industry is allowed to adjust (ETH60CA). In the nearer term, the delay of cellulosic introduction also puts negative pressure on hog and poultry sector returns relative to 2012 introduction.

It is important to mention than under the three scenarios considered, the variable costs at the farm gate for dedicated energy crops remain between $21.60 and $30.00.

Dedicated energy crops farmgate costs would be $22.80 by 2020 and $27.60 by 2030 under the ETH60 Scenario. Under the ETH60CA and ETH60CACD Scenarios, the farmgate costs of dedicated energy crops would be $26 per ton by 2020 and $30 per ton by 2030.

Under the ETH60 Scenario, there is a projected cumulative increase in net farm income over the 2007-2030 of $210 billion. With these increases in net farm income, decreases in loan deficiency and countercyclical payments are projected. The cumulative reduction in loan deficiency payments is projected to be nearly $1 billion and the cumulative reduction in countercyclical payments is an additional $7.8 billion. Hence the projected cumulative reduction in government payments is $8.7 billion compared with baseline.

The geographic distribution of the cellulosic feedstock production in 2030 for the ETH60 Scenario is presented in Figure 1. As can been seen in Figure 1, by 2030, a wide geographic area of the United States contributes cellulosic feedstock. Dedicated energy crops production is concentrated in the Southeast, Southern and Northern Plains, while corn stover is concentrated in the Midwest. Wheat straw is concentrated in the Northern Plains and Mountain states. The largest availability of wood and forest residues would be located west of the Rocky Mountains, in the Southeast, and in New England.

Under the ETH60 Scenario, by 2030, a total of $110 billion (2006$), annually is directly generated in the economy via purchasing inputs, adding value to those inputs, and supplying biofuels to the nation. Of these direct impacts, $25 billion are from the agricultural sector and $85 billion are from the renewable energy sector. About 236,000 jobs are added directly to the agricultural sector, while just under 58,000 jobs are added directly to the biofuels sector. The total impact to the nation's economy, including indirect and induced impacts, is estimated at $368 billion per year creating an estimated 2.4 million jobs.

Conclusions

The analyses performed indicate that U.S. agriculture is in a position to play a significant role as a source of energy. For the entire period through 2030, the cumulative displacement could be as high as 10.48 billion barrels of oil, causing a potential reduction in imports of $629 billion dollars. In addition to the ethanol, by 2030, 1.6 billion gallons of biodiesel per year could be produced. Overall, for the period 2007 to 2030, the estimated accumulated gains in net farm income are over $210 billion; and the accumulated potential savings in government payments are estimated to be $150 billion. Due to the geographic decentralization of the production of feedstock, economic gains are projected to accrue to the majority of regions of the country. Significant expansion beyond 60 billion gallons per year would likely require expansion of the region suitable for the production of bioenergy crops, ability to convert other pastureland (beyond cropland in pasture) into energy crops; allowing CRP acreage to be used in feedstock production, increasing short-rotation wood crops in the Northeast and Northwest regions, increased yields above those assumed in the analysis, and/or increasing the efficiency of cellulosic conversion. Further research should examine the agricultural, environmental, and economic impacts of one or more these factors changing.

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Table 1. Ethanol Production from Feedstocks Under the ETH60, ETHCA, and ETHCAD Scenarios

	Billions of Ethanol Gallons				
	2010	2015	2020	2025	2030
Corn Grain:					
ETH60CACD	10.00	15.93	10.78	9.23	8.90
ETH60CA	10.00	9.60	9.15	8.84	8.78
ETH60	10.00	12.96	14.09	14.09	14.09
Wood Residues:					
ETH60CACD	0.00	1.62	3.77	4.40	5.51
ETH60CA	0.00	4.23	3.75	4.51	5.15
ETH60	0.00	3.63	2.33	4.31	4.54
Wheat Straw:					
ETH60CACD	0.00	0.00	0.46	0.97	1.77
ETH60CA	0.00	0.55	0.41	1.15	1.70
ETH60	0.00	0.26	0.01	0.97	1.14
Corn Stover:					
ETH60CACD	0.00	0.00	0.01	5.69	12.10
ETH60CA	0.00	1.82	0.01	8.37	10.76
ETH60	0.00	0.00	0.00	5.91	8.88
Dedicated Energy Crop:					
ETH60CACD	0.00	0.00	14.40	24.81	32.10
ETH60CA	0.00	3.56	16.66	22.36	34.01
ETH60	0.00	3.40	13.69	19.93	31.71
Total Production:					
ETH60CACD	10.00	17.56	29.41	45.08	60.37
ETH60CA	10.00	19.77	29.97	45.22	60.39
ETH60	10.00	20.25	30.11	45.20	60.35

Table 2. Agricultural Sector Impacts Compared with Baseline by Scenario

Changes in Crop Prices from Baseline

	Corn ($/bushel)			Wheat ($/bushel)			Soybeans ($/bushel)			Cotton ($/pound)		
Year	ETH60 CACD	ETH60 CA	ETH60	ETH60 CACD	ETH60 CA	ETH60	ETH60 CACD	ETH60 CA	ETH60	ETH60 CACD	ETH60 CA	ETH60
2010	0.86	0.86	0.89	0.11	0.11	0.11	0.75	0.75	0.82	0	0	0
2015	2.05	0.38	0.69	0.46	0.19	0.32	1.42	0.65	1.49	0.02	0.04	0.04
2020	0.19	-0.06	0.36	0	0	0.07	0.75	0.81	0.97	0.03	0.03	0.03
2025	-0.15	-0.14	-0.04	-0.07	-0.06	0.01	0.54	0.55	0.98	0.03	0.02	0.03
2030	0.59	0.52	0.62	0.36	0.36	0.53	0.89	0.91	1.23	0.02	0.02	0.02

Changes in Livestock Net Returns Compared with Baseline (Million dollars)

	Cattle			Hogs			Poultry		
Year	ETH60 CACD	ETH60 CA	ETH60	ETH60 CACD	ETH60 CA	ETH60	ETH60 CACD	ETH60 CA	ETH60
2010	585	585	585	-522	-522	-522	-1079	-1079	-1079
2015	3181	995	1401	-1532	165	-246	-3850	-414	-1232
2020	1161	348	853	369	275	-17	166	-81	-669
2025	571	75	520	439	413	170	452	164	-440
2030	713	390	827	-146	-135	-272	-414	-612	-1204

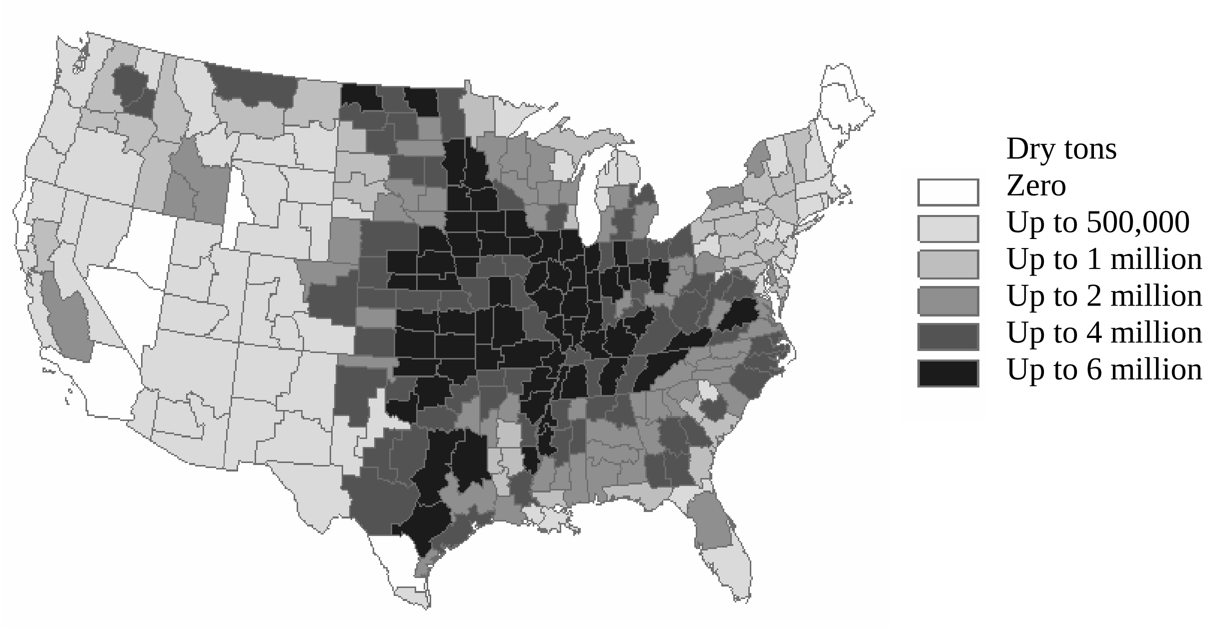

Figure 1. Cellulosic Feedstock Production in 2030 Under the ETH60 Scenario