Expanding the Role of Biofuels in America's Energy Portfolio: Analysis of the 25x'25 Vision

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I. Introduction

The use of biomass feedstocks for transportation fuels, bioproducts and power is increasingly being viewed as an opportunity to enhance energy security, provide environmental benefits and increase economic development, particularly in rural areas. Several studies have addressed various aspects of these issues (USDA-OCE, 2002a; Urbanchuk, 2001; Wang et al, 1999; House et al, 1993; Petrulis et al, 1993; USDA-OCE, 2002b; Evans, 1997; CEC, 2001; Shapouri et al, 2002; Whitten, 2000; Sheehan et al, 2002a and 2002b; Walsh et al, 2003; De La Torre Ugarte et al, 2003; English et al, 2000; USDOE-EIA, 2001a and 2001b; Delucchi, 1997; McLaughlin et al, 2002; Mann and Spath, 2001a and 2001b; and Sheehan et al, 1996). Previous economic modeling evaluating agriculture feedstocks for energy has been conducted in the context of carbon displacement potential (McCarl et al, 2000; McCarl et al, 2001; Adams et al, 1992; Adams et al, 1999) and has analyzed long-term and intermediate-run outcomes, that is, equilibrium situations that occur after twenty or more years. Adjustment costs incurred in the short run for implementing new technologies and/or policies are not considered by these models (Schneider, 2000). Additionally, such long-term modeling is incapable of assessing the near-term challenges of adoption. The POLYSYS model (De La Torre Ugarte and Ray, 2000; Ray et al, 1998a; De La Torre Ugarte et al, 1998; Ray et al, 1998b) has the unique ability to provide annual estimates of changes in land use resulting from the demand generated by bioenergy industries, and changes in economic conditions that affect adjustment costs. While maintaining a long-term analytical horizon, this study assesses the challenges faced by increasing competition for land from bioenergy and traditional agricultural uses.

Agriculture is uniquely positioned among the current renewable energy sources to be a source of energy feedstocks that can contribute to the production of both power (electricity) and transportation fuels (ethanol and biodiesel)), while still providing abundant quantities of food, feed and fiber. It is also well positioned to utilize the current infrastructure of distribution and energy utilization, in both electricity generation and transportation. Furthermore, agricultural feedstocks for energy include such diverse alternatives as traditional starch and sugar crops, crop residues, dedicated energy crops, animal waste, forest residues, mill wastes, and food residues. This diversity of feedstock resources enables different regions of the country to contribute, each with its own unique set of resources.

Increasing renewable energy to meet the energy needs of the country will command significant agricultural resources. In a recent study, De La Torre Ugarte *et al*. (2006) found that by the year 2015, agriculture could produce 5.3 quads of energy or 4.5 percent of projected energy demands through use of residues (stover and straw), crops such as corn and soybeans, and dedicated energy crops (using switchgrass as a model crop) as feedstocks in the production of electricity, ethanol, biodiesel, and selected bioproducts.

Previous economic impact modeling using IMPLAN for agricultural feedstocks for energy has evaluated the: 1) economic impacts of using alternative feedstocks for coal-fired plants in the southeastern United States (English, Menard, Walsh, and Jensen, 2004), 2) economic impacts of producing switchgrass and crop residues for use as a bioenergy feedstock (English, Menard, Wilson, and De La Torre Ugarte, 2004), and 3) potential regional economic impacts of converting corn stover to ethanol (English, Menard, and De La Torre Ugarte, 2000). Results from these studies included analysis of intraregional transfers of economic activity resulting from displacement of traditional energy sources such as coal, and the impacts to the regional and state economies for selected areas of the United States.

The goal of this study is to provide an economic analysis of agriculture's ability to contribute to the goal of supplying 25 percent of America's energy needs with renewable energy by the year 2025, while continuing to produce safe, abundant, and affordable food, feed, and fiber. The first objective of the study is to evaluate the ability of production agriculture to contribute to this goal, and the impacts on the economics of the agricultural sector associated with this effort. The second objective is to estimate the overall economic impact of production agriculture and other agro-forest sources on the nation's economy. These impacts involve not only the conversion of bioenergy feedstocks, but also the impacts of bioenergy feedstocks from food processing industries and forestry residues and mill wastes.

II. Methodology

The methodology to achieve the first objective starts with the definition of the energy targets for various sources of renewable energy, especially the target for energy produced with agricultural feedstocks. This information and data on conversion costs for agricultural and forest feedstock is introduced into an agricultural sector model to estimate the quantity and type of energy to be produced from agriculture, as well as the price, income and other economic impacts deriving from producing such a level of energy production. The process to estimate the overall economic impacts of producing renewable energy implies the linking of the agricultural sector model results with I/O model, like IMPLAN. This estimation seeks not only to quantify the impacts of producing the feedstock, but also the impacts of the conversion processes on the overall economy.

The key analytical instrument for the first objective is POLYSYS, a dynamic agricultural sector model. For the second objective the two main components are PII, the POLYSYS IMPLAN Integrator that takes information from POLYSYS, aggregates the information to a state level and modifies IMPLAN input files, and IMPLAN, an input-output model. These models are combined to provide a detailed picture of not only the agricultural sector and potential impacts of providing energy feedstocks, but also the impacts to the economy as these feedstocks are produced, transported, and converted to energy.

The POLYSYS System

POLYSYS is an agricultural policy simulation model of the U.S. agricultural sector that includes national demand, regional supply, livestock, and aggregate income modules (De La Torre Ugarte, et al, 1998). POLYSYS is anchored to published baseline projections for the agricultural sector and simulates deviations from the baseline. In this study, a 2006 10-year United States Department of Agriculture (USDA) baseline for all crop prices, yields, and supplies (except hay) is used. This baseline, which runs through the year 2015, was extended to 2025 using the assumptions.

The POLYSYS model includes the eight major crops (corn, grain sorghum, oats, barley, wheat, soybeans, cotton, and rice) as well as switchgrass and hay (alfalfa and other hay included). Corn and wheat residue costs and returns are added to the corresponding crop returns if profitable. POLYSYS is structured as a system of interdependent modules of crop supply, livestock supply, crop demand, livestock demand and agricultural income. The supply modules are solved first, then crop and livestock demand are solved simultaneously, followed by the agricultural income module. This project includes a bioenergy module, which fills exogenous demands from the feedstock sources.

The regional crop supply module consists of 305 independent linear programming regional models that correspond to USDA's Agricultural Statistical Districts (ASD). Each ASD is characterized by relatively homogeneous production. The purpose of the crop supply module is to allocate acreage at the regional level to the model crops given baseline information on regional acreage of the model crops, regional enterprise budgets of each crop, prices from the previous year and a set of allocation rules. For a full description of the land allocation rules, see the methodology section of *The Economic Impacts of Bioenergy Crop Production of U.S. Agriculture* (De La Torre Ugarte, et al, 2003).

The crop demand module estimates national-level demand quantities and prices using elasticities and changes in baseline prices. Crop utilization is estimated for domestic demand (food, feed, energy, and industrial uses), exports, and stock carryovers. Derivative products such as soybean oil and meal are also included. Demand quantities are estimated as a function of own and cross price elasticities and selected non-price variables such as livestock production. The crop prices are estimated using price flexibilities and stock carryovers are estimated as the residual element.

The livestock module is an integrated version of the Economic Research Service (ERS) econometric livestock model (Weimar and Stillman, 1996) that interacts with the crop supply and demand modules to estimate livestock production, feed use, and market prices. The livestock sector is linked to the supply and demand modules through the feed grain component. Livestock quantities affect feed grain demand and price, and feed grain prices and supply affect livestock production decisions.

The income module uses information from the crop supply, crop demand, and livestock modules to estimate cash receipts, production expenses, government outlays, net returns, and net realized farm income. In this analysis, all values are expressed in nominal terms through 2015. Beyond 2015, these variables are expressed in 2015 dollars.

POLYSYS was modified to allow the biomass feedstocks (switchgrass, corn stover, wheat straw, wood residue) to compete with corn grain feedstock in the production of ethanol. Because ethanol demand is such a large user of agricultural feedstocks, changes in feedstock mix will affect the market price of feedstocks and, therefore, total ethanol costs. An iterative process is used to find the annual feedstock mix where the cost of producing ethanol from corn grain is equal to the cost of producing ethanol from biomass.

Figure 1 shows the process of balancing the feedstock quantities so as to arrive at an equivalent price of ethanol from either corn grain or biomass. In the first iteration, ethanol demand is filled with corn grain. The crop module then responds with a high corn price resulting from the increased level of corn demand. At this point, the price of ethanol made from corn grain is used to figure a corresponding price for biomass that would produce ethanol at the equivalent price.

The extra cost of transporting biomass feedstocks from the farm gate to the production facilities is added to all biomass bioproduct conversion costs. The transportation cost is estimated at $8.85 per ton based on 2005 transportation cost estimates provided by Dager (2005) and assumes a one way maximum distance of 50 miles. The corresponding price of biomass is compared to the current iteration's price of biomass. If the corresponding price is higher than the

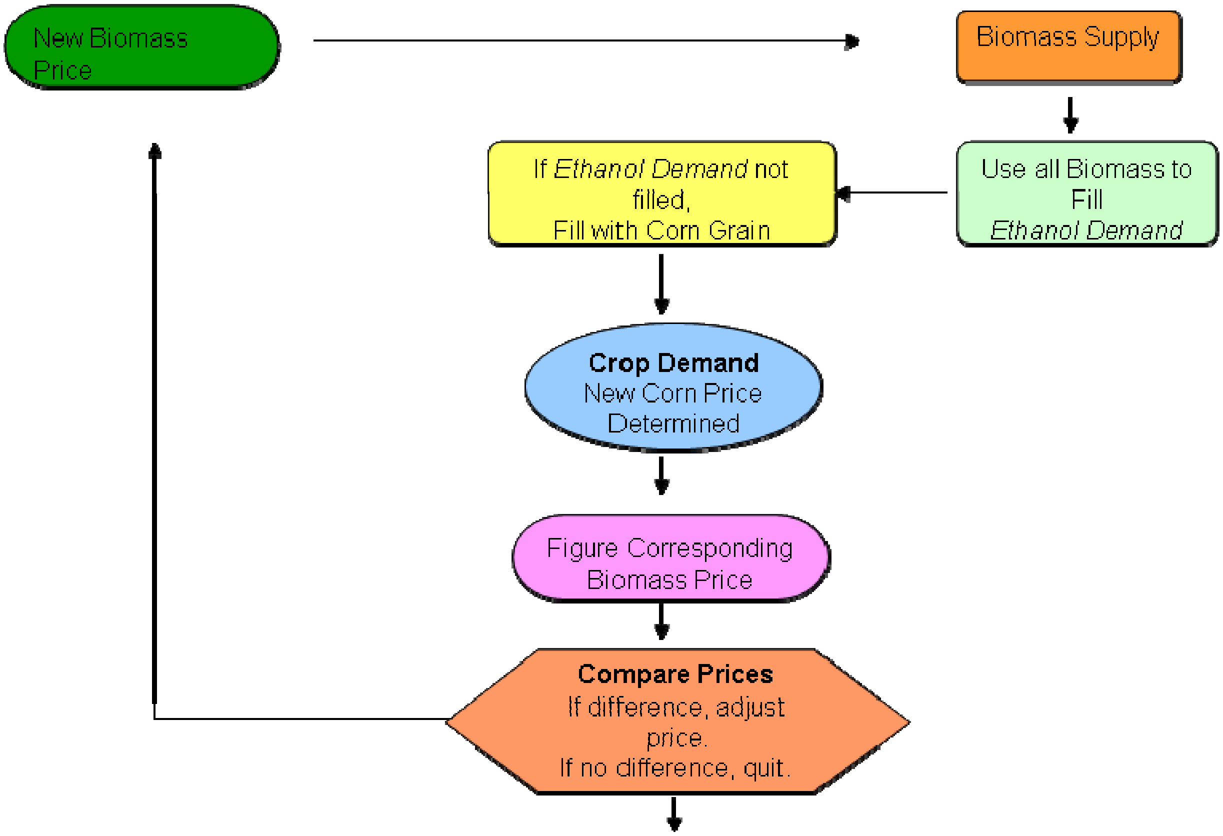


Figure 1. Schematic of the Methods Employed to Determine Feedstock Price Required to Meet Energy Demand.

iteration price, then it indicates that ethanol made from corn grain is more expensive than ethanol made from biomass. In this situation, the price of biomass is increased and the next iteration takes place. The higher biomass price will result in a positive supply response in the next iteration, thereby displacing some of the corn grain demand and lowering corn grain price. The iterations continue until the corresponding price of biomass is equal to the 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.

Distiller's dried grains (DDG's) 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. For every bushel of corn grain (56 pounds) used in ethanol production, 18.3 pounds of DDG's are produced. It is assumed that distillers dry grains substitutes for livestock corn grain demand. One ton of DDG's displaces 35.71 bushels of corn feed demand (Bullock, 2006). The amount of DDG's available for use is limited by current nutritional recommendations. The limits established for this study are 30 percent for beef production and ten percent for poultry, pork, and dairy.

POLYSYS and IMPLAN Integration

A variety of economic impacts would result with a movement away from non-renewable energy sources to renewable ones. There are numerous annual impacts that occur to the agricultural sector as a result of projected changes in crop acreage, crop prices, and government payments by POLYSYS, and the addition of an energy crop (switchgrass). The operation of the bioenergy conversion facilities also has an annual impact on the economy. New facilities will require employees, expenditures on inputs, and will increase the total industry output of the renewable energy sector. There will also be one-time construction impacts. Transportation of the energy feedstocks and the output from these firms will also occur. These impacts can not be estimated until firms are actually located. Knowledge of the available infrastructure and the methods (for example, truck, train, or barge) used to transport the commodities are needed before impacts to the economy as a result of energy transportation can be determined.

Economic impacts resulting from national policy changes can be evaluated using state IMPLAN models. Numerous publications have taken results from a national model and used those results in IMPLAN to show what impacts would occur to a state or a region's economy. However, in this study, there is a need to take the impacts from an interregional multi-state model that is national in scope and project the potential impacts changes in policy has on the nation's economy. The interface model, the POLYSIS/IMPLAN Integrator (PII) in Figure 2, developed at The University of Tennessee, takes POLYSYS acreage, price, changes in government programs, and cost output and makes two major types of changes to IMPLAN databases (English, Menard, Wilson, and De La Torre Ugarte, 2004). First, the program adds an energy crop sector to IMPLAN based on production and cost information supplied by the POLYSYS results for each of the 48 contiguous states. Next, agricultural impacts that occur as a result of projected changes in the agricultural sectors are placed in each state's IMPLAN model incorporating POLYSYS projected changes in crop production, prices, and income. A renewable energy sector is added to each state's model and the impacts from the renewable energy sector are estimated. The model can also estimate the investment impacts of developing the renewable energy sector.

Production, prices, and acreage from each of the 305 (ASD) are determined independently and aggregated to obtain information at the state level for barley, corn, cotton, hay, oats, rice, sorghum, soybeans, switchgrass, wheat, corn stover, and wheat straw. In addition, information on the cost of production of switchgrass by ASD is transferred from the POLYSYS solution, along with national energy production estimates for electricity generated from fuel sources, including animal waste, food waste, and wood; ethanol generated from corn, corn stover, wheat straw, switchgrass, and wood; and biodiesel from yellow grease and soybeans. To incorporate the POLYSYS data into IMPLAN for the agricultural (non-forest) impacts, the following procedure was followed: 1) the change in Total Industry Output (TIO) is calculated for corn, sorghum, oats, barley, wheat, soybeans, cotton, and rice including changes in proprietary income and government payments; 2) for states growing switchgrass and/or using corn stover and wheat straw, TIO, Employment, Total Value Added (employee compensation), and the Gross Absorption Coefficients (GACs) are calculated for a new agricultural fuel feedstock industry; 3) Total Revenue (TR) from POLYSYS is equated to TIO and is calculated by multiplying the price of the cellulose by the quantity produced; 4) the demands for inputs are represented by GACs and are developed by dividing cellulose input expenditures by TIO; and 5) labor costs and the number of employees are estimated (English, Menard, Wilson, De La Torre Ugarte, 2004).

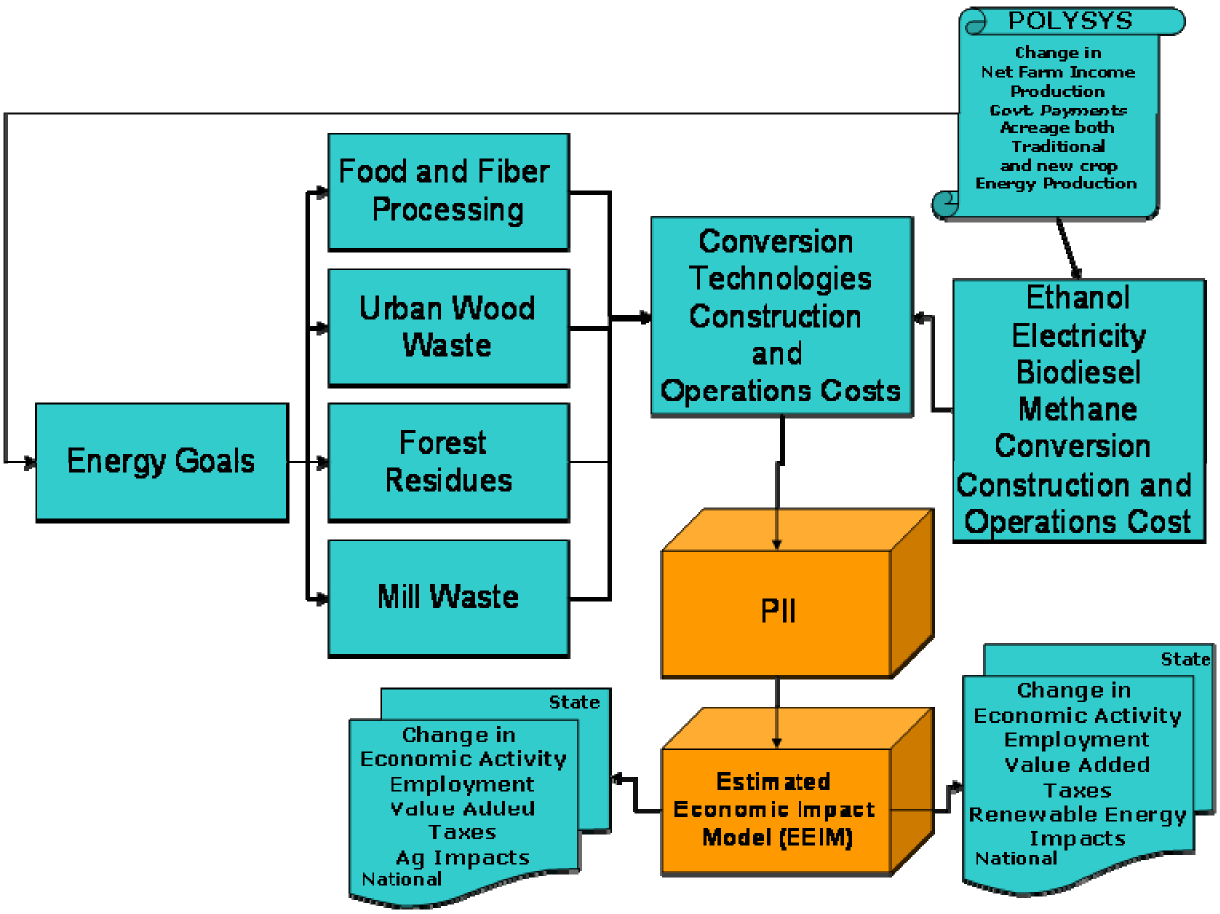


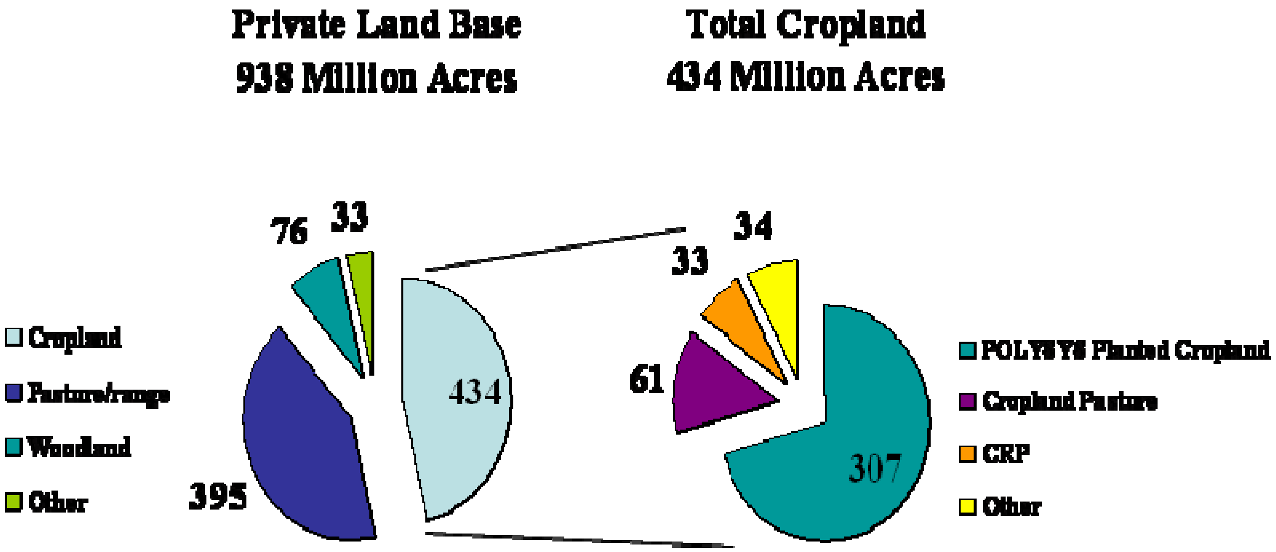
Figure 2. Schematic of PII, the Link between POLYSYS and IMPLAN

Based on information from POLYSYS, the non-agricultural energy goals, and the target goal, a renewable energy sector is created consisting of a weighted mix of conversion facilities. Quantities of electricity, ethanol, and biodiesel produced in each state from agricultural and non-agricultural renewable fuel types are estimated. These quantities are then used as weights to develop the estimated input expenditures required to meet the projected state level of production and inserted as GAC's into the model. Based on 2002-2004 energy prices, the total industry output is estimated and the sector impacted by that amount to determine induced and indirect effects. Finally, investment impacts are estimated using the number of facilities required to meet electric demand in each state assuming that the impacts occurred in the year that the facility was needed to meet renewable energy demand.

Production of energy will result in interstate commerce, which results in leakages in a state model, but increased economic activity in a national model. To capture these effects, the U.S. model is constructed in manner similar to each of the state models. The results are then compared to the sum of the state model impacts and the difference is assumed to occur as a result of interstate commerce.

Land base in POLYSYS

There are 938 million acres within the United States that are either owned or managed by agricultural producers. The 2002 Census of Agriculture has determined that 434 million acres can be classified as cropland, while 395 million acres is classified as pastureland or rangeland (Figure 3). Of these 434 million acres of total cropland, POLYSYS includes 307 million acres available for the eight major crops and for hay. Additionally, cropland pasture (61 million acres) can enter into production if the loss of regional pasture can be made up with additional hay production. Finally, in the AE scenario, conversion of 395 million acres of pastureland/range land is allowed if irrigation of hayland is not required for hay production. Assuming in regions where irrigated hay production exceeds dryland hay production, irrigation is needed, a total of 282 million acres of pasture/rangeland are available for conversion. The rate of conversion is restricted based on projected agricultural net returns. In addition, of the remaining 67 million acres of cropland including CRP, idle lands, etc., 15 million acres is available for production. The objective of the model is to fill projected energy demands from corn grain, soybeans, switchgrass, crop residue and wood residue supplies and estimate the effects upon production, prices, acreage, government payments and net returns of all model crops and livestock.



Source: USDA, National Agricultural Statistical Service, 2004.

Figure 3. Land Use by Major Use Category, 2002.

This study focuses on the use of cropland, and one of the uses of cropland is pasture. Cropland in pasture is defined as land that has been previously used for crop production that has shifted to pasture use. According to the latest Census of Agriculture, 61 million acres of cropland are currently being used for pasture. An increase in the intensity of the management of this cropland could free a significant portion of the acreage for crop production, especially for dedicated energy crops. In addition, there are 395 million acres of pastureland/rangeland (U.S. Department of Agriculture, National Agricultural Statistics Service, 2004). Not all of these lands will be available for conversion to cropland. Since the analysis assumes energy crop production will be undertaken using few inputs, in regions where irrigated hay production exceeds dryland hay production it is assumed that irrigation would be needed. Hence, in these areas an increased level of inputs would be required. Therefore, it is assumed the pasture/range lands would not be converted to energy crop production in these areas. These assumptions resulted in a total of 282 million acres of pasture/rangeland available for conversion (Figure 10). The rate of conversion is restricted reflecting changes in agricultural net returns. In addition, if pastureland is converted to energy crops, the increase in intensity is reflected through a requirement that if pasture is converted rather than hay, then additional hay production must occur to produce an equivalent of feed. This requirement results is the same amount of roughage being available for the beef industry and assumes that the pasture/range land is currently utilized for roughage.

Feedstock and Conversion Technologies in POLYSYS and IMPLAN

To evaluate the potential of switchgrass to provide feedstocks to the bioenergy market, potential geographic range, yields, and enterprise budgets of switchgrass are incorporated within POLYSYS. Switchgrass can grow in all regions of the United States. However, for the purpose of this analysis, the geographic ranges where production can occur are limited to areas where it can be produced with high productivity under rain-fed moisture conditions. Geographic regions and yields are based chiefly on those contained in the Oak Ridge Energy Crop County Level Database (Graham, et al, 1996). The production of switchgrass included in this analysis is assumed suitable on 368 million of the total 424 million acres included in POLYSYS. Switchgrass yields, by ASD, range from an annual rate of 2 to 6.75 dry tons per acre (dt/ac) depending on location. Switchgrass is not a crop option in western arid regions.

To assess 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 (dt/ac) as a function of corn and wheat grain yields, plus stover and straw production costs as a function of yields of removable residue (dt/ac). The removal of corn stover and wheat straw raises environmental quality issues such as erosion, carbon levels, tilth, moisture, and long-run productivity. The analysis accounts for quantities of stover and straw that must remain on the field to keep erosion at less than or equal to the tolerable soil loss level. The methodology for estimating quantities that must remain takes into account soil types, slope, crop rotations, type and timing of tillage and other management practices, and climate zones among other factors (Nelson, 2002). The estimated response curves incorporated into POLYSYS were obtained through the DOE Oak Ridge National Laboratory (ORNL) (Walsh et al, 2003).

The quantities of corn stover and wheat straw that can be removed are the amounts of stover or straw produced minus the highest of the estimated residue quantities needed to control for rain and wind erosion, along with soil carbon. Corn and wheat grain yields (bushel/acre) are converted to biomass quantities (dt/ac) using standard grain weights (lb/bu), moisture content, and residue to grain ratios (Heid, 1984; Larson, et al, 1979). Corn and wheat yield quantities are those used in POLYSYS. 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 and weighted by the number of acres using each tillage practice (Conservation Tillage Information Center, 2004).

The costs of collecting corn stover and wheat straw include baling and staging (loading on bale wagon and moving to field edge). Cost of nutrient replacement is included in the estimated collection costs. Costs are estimated as a function of the residue that can be removed (dt/ac).

Forest residues, mill wastes, fuel treatments and forestland thinnings are included in the model as wood residues for conversion to bioenergy. We assume 46 million dry tons (mil dt) of forest residues, 67 mil dt of mill residues, 60 mil dt of fuel treatments and 52 mil dt of forestlands thinnings are available for a total of 352 million dry tons. The price at which these feedstocks come into use is determined by regional harvesting costs plus transportation costs.

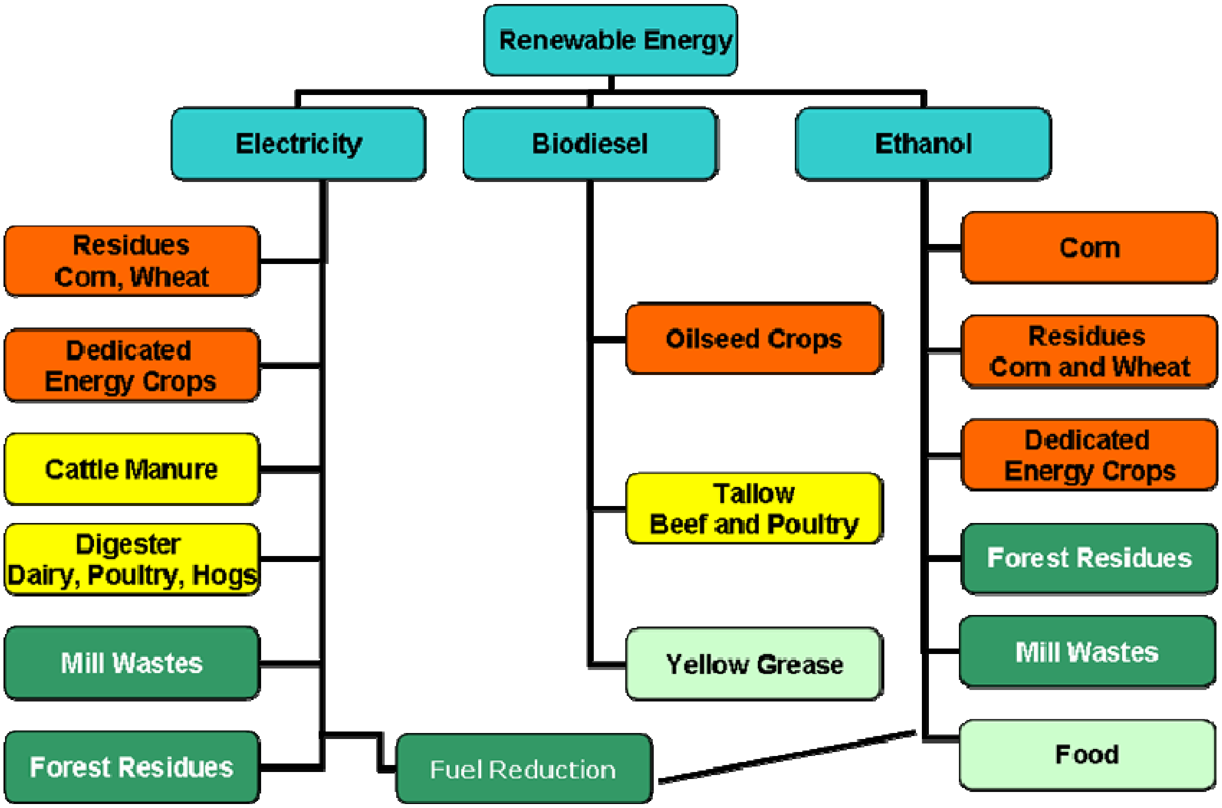


Figure 4. Feedstock and Energy Services in POLYSYS/IMPLAN.

Beef cattle, dairy cow, hog and broiler manure is used as feedstocks for the production of electricity. Each manure type is modeled as a function of total yearly inventories of the particular livestock sector.

Yellow grease from beef, food and poultry waste is used as a feedstock for biodiesel production. Beef waste is modeled as a function of beef cash receipts. Food waste is a function of population while poultry waste is modeled as a function of poultry cash receipts.

The renewable energy conversion technologies used in the analysis and as modeling inputs for IMPLAN are discussed in this section of the report. Studies existing in the literature which provide sufficient cost data for each technology were used in allocating expenditures to the appropriate IMPLAN sectors. Cost information for a representative conversion facility for each technology was used to assign expenditures on inputs and services to IMPLAN sectors. A summary of the conversion technologies, facility size, total industry output, employees, and cost information sources is presented in the Appendix A.

III. Renewable Energy Scenario

To meet the 25x'25 vision, 25 percent of the projected 117.7 quads, or 29.42 quads (henceforth referred to as the "All Energy" or AE scenario), are needed from renewable energy sources. At present, an estimated 1.87 quads are produced from biomass (agricultural/forestry) resources in the production of electricity and/or heat. Using information from the RAND study, it is estimated that, by 2025, 12.10 quads will be annually produced from geothermal, solar photovoltaic, hydro, and wind generation. The sum of those two is 13.97 quads. Therefore, to meet the 25x'25 goal of 29.42 quads, an additional 15.45 quads would need to come from agricultural and forestry lands. Meeting this goal will require development of feedstock production and conversion capabilities that not only use corn and soybeans, but also those that use cellulosic materials to generate electricity and produce ethanol.

Therefore sevaral other significant assumptions are made. The first assumption is with respect to the timing of commercial introduction of the "cellulosic to ethanol" conversion technology, which is crucial for expanding U.S. agriculture's ability to produce energy. This study assumes that in the year 2012, this technology would be in place. The second assumption is with respect to yields of the major crops and crops dedicated for bioenergy, using switchgrass as a model crop[1]. A third assumption is the use of increased no-till and reduced-till practices, thus allowing removal of additional cellulosic materials (corn stover and wheat straw).

Yields of traditional crops are assumed to increase beyond the baseline yields assumed under the USDAExt scenario. The rationality of this assumption is that as energy use becomes an important demand for agricultural sector, the prices for traditional uses would increase and generate additional incentives for the introduction of new technology and improved production practices, resulting in additional yield gains. This implies that the efforts for yield improvement should not only be dedicated to the cellulosic sources, but should also include traditional crops as they are also potential energy feedstocks – corn, soybeans, and crop residues. To simulate yield improvements over time, this scenario (AE) increases the rate of growth in yields by 50 percent compared with the yield growth rate in the USDAExt scenario (Table 1).

Most of the seed improvement in switchgrass has been limited to seed selection, but there are significant gains that can be achieved from the use of modern seed improvement research and technology. To reflect this potential, switchgrass base yields are increased each year, starting in the first year of switchgrass production (2012). However, rates of yield increase vary regionally. To account for increased harvesting costs as yields rise, total costs are increased at the rate of 5 percent per ton increase in yield (Table 2).

Residues from the production of corn (corn stover) and the production of wheat (wheat straw) are likely to be important sources of cellulosic material. These residues are already part of the production system, and an increase in the use of reduced and no-till practices could increase availability without affecting the amount of residues that need to be left in the ground for erosion control and soil sustainability. Burning wheat stubble is a common practice in certain regions of the country. This practice improves yield by reducing disease potential. Tillage use is changed from baseline to increase reduced and no-till for corn and wheat following the path listed in Table 3.

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[1] For this analysis, it is assumed that switchgrass is the modeled crop and reflects the appropriate cost to yield and land to yield relationships that might occur with other cellulosic crops.

Table 1. Crop Yields under USDAExt and AE Scenario.

Crop (unit)	Projected % Annual Growth in Yields USDAExt	Projected % Annual Growth in Yields AE Scenario*	National Average Projected Yields Under the AE Scenario 2015	National Average Projected Yields Under the AE Scenario 2025
	Percent Change		Units	
Corn (bushels)	1.13%	1.69%	163.90	193.76
Sorghum (bushels)	0.76%	1.13%	69.00	77.24
Oats (bushels)	0.61%	0.91%	69.00	75.58
Barley (bushels)	0.88%	1.31%	69.80	79.53
Wheat (bushels)	0.88%	1.32%	46.30	52.78
Soybeans (bushels)	0.93%	1.39%	44.30	50.85
Cotton (pounds)	0.43%	0.64%	805.0	858.0
Rice (pounds)	0.79%	1.19%	7477	8417

* The growth in yields over time under the USDAExt scenario is multiplied by 1.5 to obtain a 50 percent increase in the rate of growth of yields over time for the AE Scenario.

Table 2. Changes in Switchgrass Yield Assumed Through the Year 2025.

REGION	Base Yield	Annual Breeding Gains	Projected Yields 10 Years	Projected Yields 20 Years
		Tons/Acre		
North East	4.87	1.5%	5.6	6.3
Appalachia	5.84	5.0%	8.8	11.7
Corn Belt	5.98	3.0%	7.8	9.6
Lakes States	4.8	1.5%	5.5	6.2
Southeast	5.49	5.0%	8.2	11.0
Southern Plains	4.3	5.0%	6.5	8.6
North Plains	3.47	1.5%	4.0	4.5

Source: Role of Biomass in America's Future (RBAEF), ALMANAC Simulation.

Table 3. Change in Percentage Tillage Mix for Corn and Wheat.

Year	Conventional Tillage	Reduced Tillage	No Tillage
		Maximum Percent Allowed	
2005-2010	60	20	20
2011-2015	55	20	25
2016-2020	40	20	40
2021-2025	25	20	55

IV. Results

The results are divided into three major sections. The first section discusses renewable energy projections met in the analysis. The impacts in the agricultural sector are discussed next, and finally, the economic impacts to each state and the nation are discussed.

Renewable Energy Production Projections

The goal expressed of 29.43 quads of renewable energy by the year 2025 (Table 4). Agricultural (non-wind) resources can provide over 17.3 quads of energy (including the 1.8 quads currently produced from wood, black liquor, and other wood waste, plus the .07 quads currently used in the generation of electricity) through the production of 86.9 billion gallons of ethanol (7.35 quads), 1.1 billion gallons of biodiesel (0.15 quads) and 962 billion kWh of electricity (7.95 quads). In addition, our analysis contains 12.1 quads from solar, geothermal, hydro, and wind.

Table 4. Projected Bioenergy Production for the Years 2007, 2010, 2015, 2020, and 2025 Under AE Scenario.

Energy Scenario and Renewable Fuel Type	Units	Projected for the Year of: 2007	2010	2015	2020	2025
AE:						
Ethanol	Bil. Gallons	5.83	8.09	30.41	57.97	86.86
Biodiesel	Bil. Gallons	0.16	0.22	0.45	0.72	1.10
Electricity	Bil. kWh	87.00	89.00	379	698	962
Total Energy	Quads	**1.23**	**1.45**	**5.77**	**10.77**	**15.45**

Agricultural Sector Impacts

The results from the analysis indicate that reaching the energy goal is a plausible target if, in addition to current level of cropland, additional land from pasture and/or forestland is available to farmers for traditional uses and energy production. To meet the energy demands placed on renewable energy by the year 2025, additional land resources are required. In this analysis, of the 338 million acres of pasture/rangeland available for alternative production, 172 million acres are converted with 100 million acres converted to hay and 72 million acres to switchgrass. In addition, because of a shift in land use, another 33.8 million acres is planted to dedicated energy crops, such as switchgrass. It is imperative that the conversion of cellulosic feedstock – crop residues, switchgrass, wood residues – is essential for the attaining the AE goal from agriculture.

The regional analysis of the feedstock production distribution indicates that while the Southeast and the Northern Plains will experience significant gains in energy dedicated crops, the Midwest area will also be an important producer of cellulosic feedstock in the form of corn residues. The gains in net revenues indicate that income gains accrue in all areas of the country. Finally, the use of cropland for the production of energy feedstock will contribute to generate significant savings in the cost of commodity programs.

Feedstock Utilization

Bioenergy production is derived from several feedstocks. Corn for grain, in the initial years of the scenario, provides the foundation of the bioenergy industry. Even after the introduction of the cellulosic-to-ethanol conversion technology, corn is projected to continue to play a key role in the overall supply of feedstock. However, additional energy production is produced from corn stover. Moreover, it is certain that corn stover and wheat straw are not the only cellulosic feedstocks required. Reaching the AE goal requires a significant use of cellulosic feedstock. Attaining the goal is also dependent on the successful introduction of bioenergy dedicated crops such as switchgrass and conversion of wood to ethanol. As production reaches the year 2025, the contribution of bioenergy dedicated crops is over 50 percent of the total feedstock required by the bioenergy industry (Figure 5). Other sources of cellulosic feedstock contributing to overall supply are wheat straw and wood and forest residues. While the contribution of soybeans represents a seven-fold increase from 2007, it is a relatively minor contributor to the availability of feedstock.

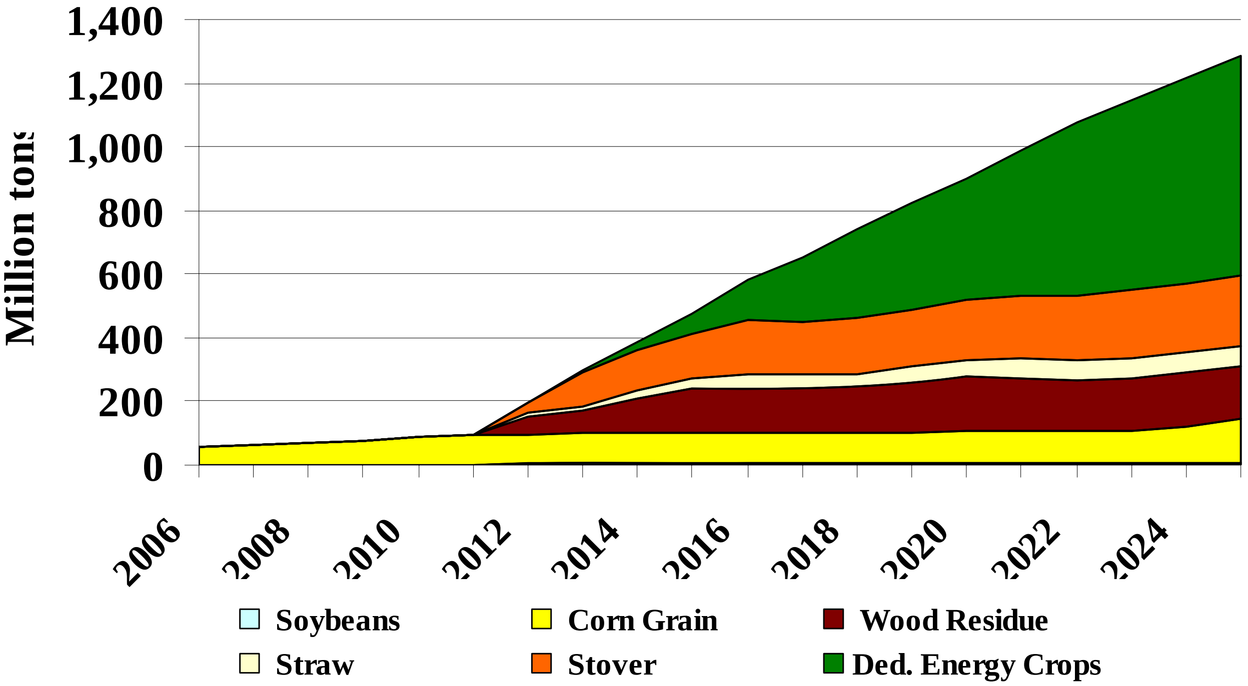

Figure 5. Projected Use of Feedstock for Energy.

4.2.2. Changes in Land Use

To support the level of feedstock reported above, significant changes in land use were projected to be necessary. Use of agricultural cropland changes when compared to the baseline as agriculture attempts to meet the AE goal (Figure 6). Dedicated energy crops, such as switchgrass, will likely become major crops in U.S. agriculture, with 105.8 million acres planted. Significant shifts from current uses (2007) are projected. For instance, about 20 million acres of soybeans would slowly shift into dedicated energy crops, along with 8 million acres of wheat. In the case of corn, during the last five years of the analysis period, a shift of about 3 million acres

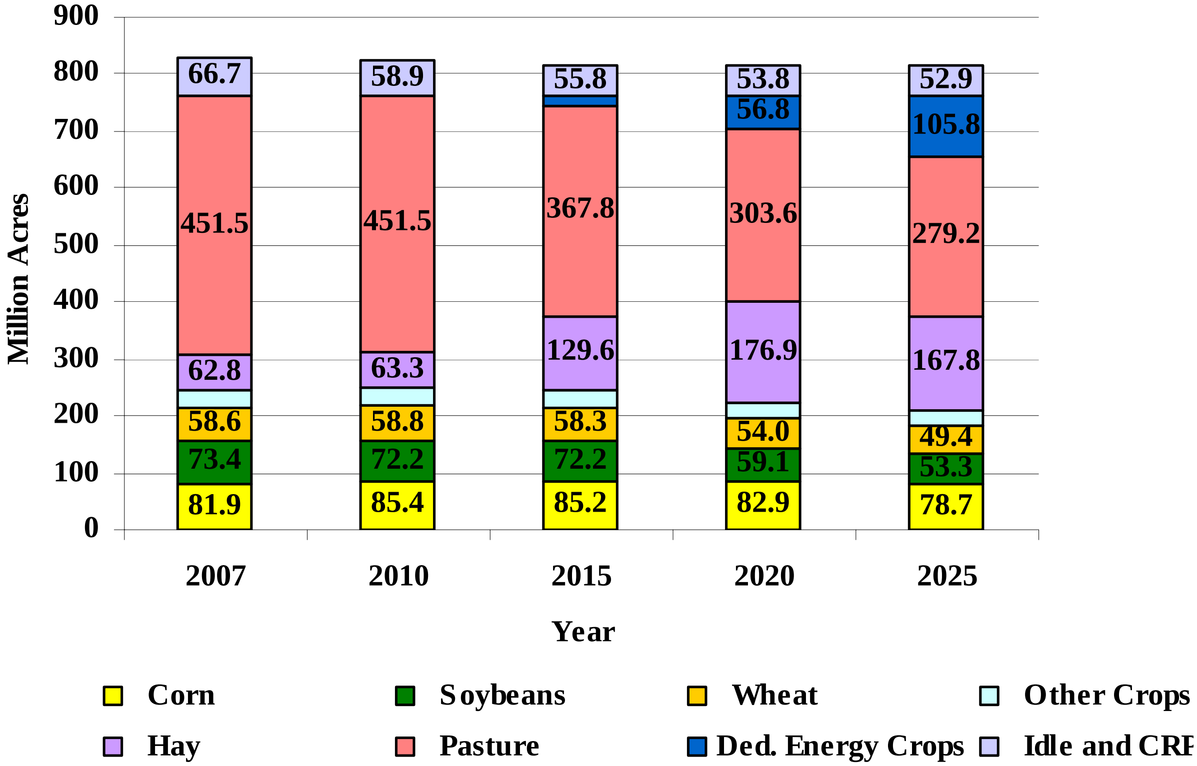

Figure 6. Projected changes in land use.

would occur, as acreage becomes constrained and more energy per acre is required to achieve the target reflected in both scenarios.

Perhaps the most significant projected change is the shift of pastureland/rangeland and cropland in pasture, hereafter referred to as pastureland, towards the production of energy under the assumption that the feed value of the converted pastureland is replaced through hay production. An assumption of the study is that all pasture was already in use by the livestock industry. Therefore, it was necessary to replace the feed value of this pasture. Since information is not available regarding the intensity of pasture/range land use, the assumption that all pasture is currently in use by the livestock industry may over estimate the need for hay.

A share of the shift of 172 million pasture acres (100 million acres) was used to produce more intensive grasses for animal feed, and the remaining pasture in cropland and the grassland (not cropland) are projected to experience an increase in their management intensity, as it is well recognized that pasture and grassland are significantly under utilized. Consequently, this increase in management intensity is likely to occur at a very low additional cost, and while causing changes in the livestock industry, would not likely jeopardize the welfare of the livestock industry.

Price Impacts

With a dramatic shift in land use toward energy crops, a corresponding change in average crop prices is anticipated. Therefore, as most major crops have some acreage shifted to energy dedicated crops, an overall increase in commodity prices is projected (Table 5). Notably, when compared with USDAExt prices, the crops that experience larger increases in price have the largest acreage decreases, as is the case of soybeans and wheat. However, the price increases corresponding to the AE scenario are within price ranges experienced in the last decade.

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Table 5. Impact on the Average Crop Price by Scenario for Selected Simulated Years.

	Projected for the Year:				
Crop and Scenario	2007	2010	2015	2020	2025
			$/bushel		
Corn:					
AE	2.13	2.76	2.62	2.67	3.17
USDAExt	2.20	2.60	2.60	2.51	2.46
Wheat:					
AE	3.06	3.13	3.32	3.83	3.94
USDAExt	3.10	3.25	3.55	3.50	3.46
Soybeans:					
AE	5.46	6.04	6.26	7.54	7.73
USDAExt	5.40	5.95	6.10	5.85	5.69
Cotton			$/pound		
AE	0.51	0.51	0.62	0.63	0.63
USDAExt	0.51	0.51	0.57	0.57	0.58
Switchgrass:			$/dry ton		
AE	0.0	0.0	46.85	60.90	81.85
USDAExt	0	0	0	0	0

Regional Impacts: Feedstock and Net Revenues

The national changes discussed thus far summarized shifts occurring at the regional level. Among those regional impacts is the location where the new cellulosic feedstock is being grown. Figure 7 indicate the distribution of the cellulosic feedstock production. The results indicate that the cellulosic feedstock (crop residues, wood residues, and wood thinning) are initially is concentrated in the corn growing areas of the Midwest. Then, the production of feedstock expands towards the Southern Plains and the Southeast. Importantly, the sources of feedstock expand to nearly all 48 contiguous states The Midwest and Northern Plains would be the major sources of crop residues (corn and wheat), while the Southeast and Western states would be a major source of wood residues and forest thinning. It is important to reiterate that no forest is specifically harvested for energy purposes in these scenarios. However, the addition of forest resources could have substantial impacts on bioenergy markets and should be the subject of future research.

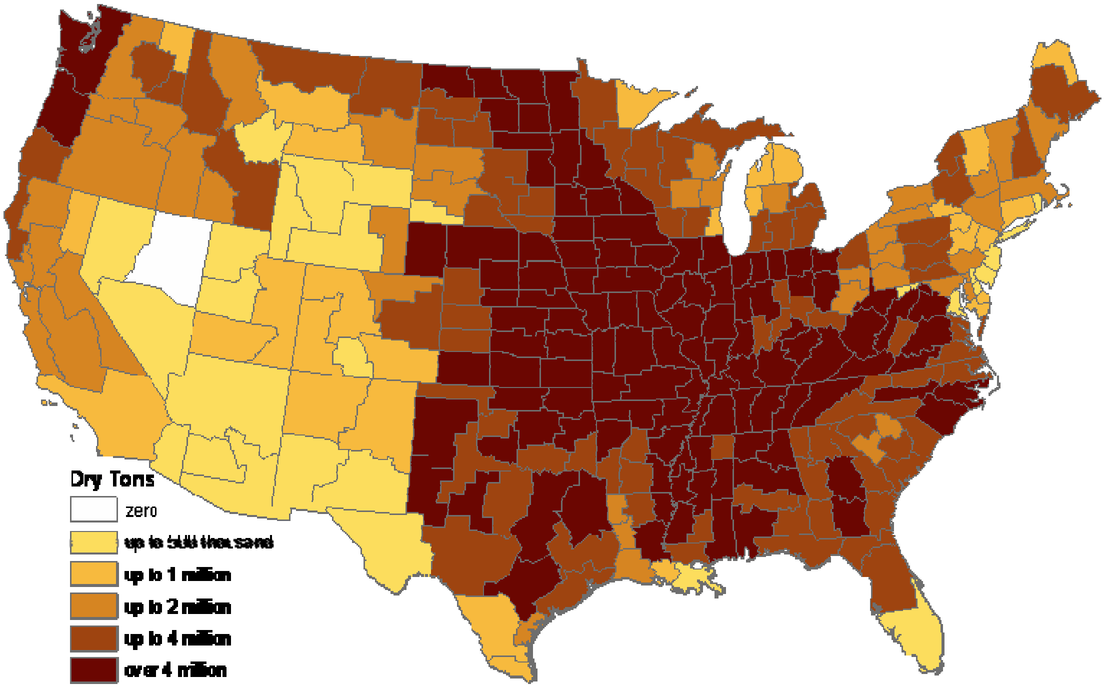

Figure 7. Distribution of All Cellulosic Feedstock (Crop Residues, Dedicated Energy Crops, Forest Residues, Mill Wastes, and Wood from Fuel Reduction), AE Scenario

By 2025, many of the Agricultural Statistical Districts in the Southern United States are producing in excess of a million tons of cellulosic material from dedicated energy crops. The regions in which dedicated energy crops will first expand are in the Southeast and Southern plains. After a few years, dedicated energy crops expand towards the north, but the Southeast and Southern Plains remain the areas with a higher density. This is the result of the model energy crop being a warm climate grass, which has better yields performance in the South, and faces less competition from traditional Midwest corn and soybean production.

A 16.5 percent increase occurs in realized net returns occurs to the agricultural sector when meeting the AE energy goal. The gains are distributed across the 48 contiguous states of the nation. The gains first occur as a result of the expanded demand for corn, so they are initially concentrated in the Midwest, but as the use of cellulosic feedstock expands, the gains of net returns also expand to all areas of the country (Figures 8). By 2025, the areas with higher gains are located east of the Rockies, where agricultural lands are concentrated and areas to grow energy dedicated crops were identified. However, if pastureland begins to be converted into energy production, it is possible that Western states could also experience a significant grow in agriculture

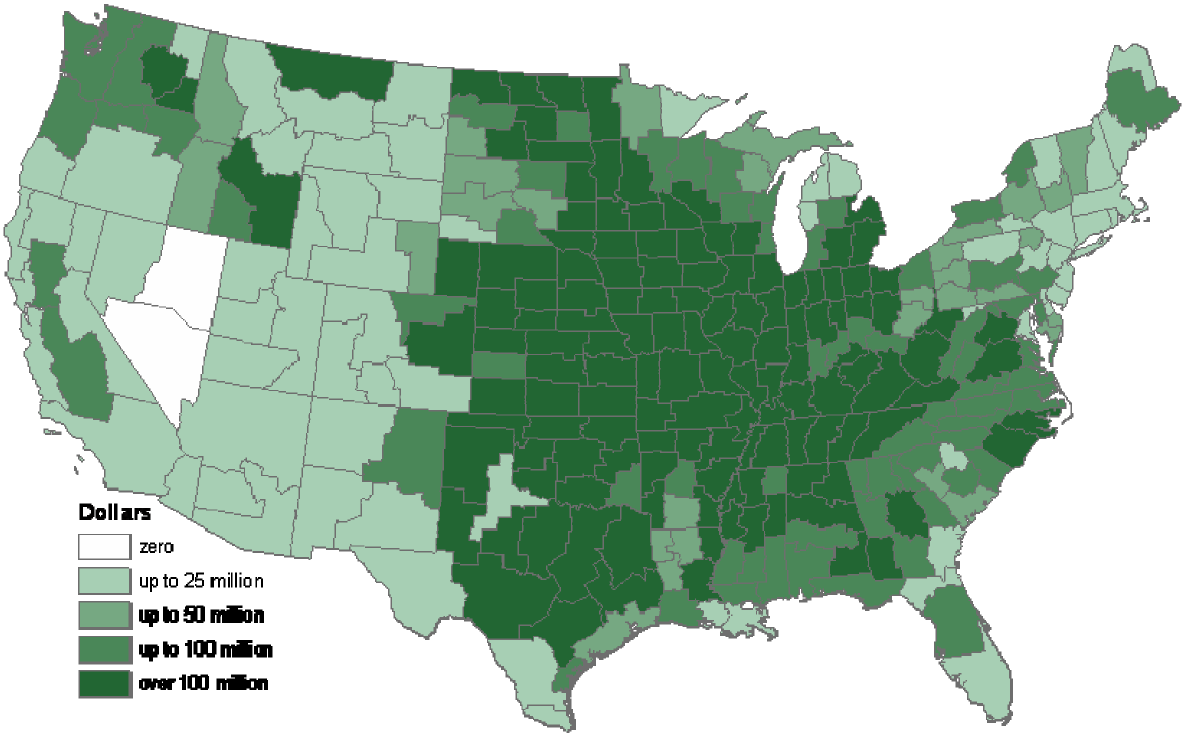

Figure 8. Distribution of Net Returns, AE Scenario

Cost of Ethanol and Biodiesel

Increasing the renewable energy level to those reflected in AE results in an increase in the cost of transportation fuels as the price of the feedstocks increase (Table 6). The cost of ethanol and biodiesel increases as the demand for feedstocks for these fuels increases, thereby increasing the price of the feedstock. The cost of ethanol is not significantly affected as the availability of cellulosic feedstock does not change dramatically and the change in yields was applied to traditional agricultural crops and not to dedicated energy crops. However, in the case of biodiesel, without increased rates of growth in yields, a relatively higher soybean price resulted, which in turn increased the projected cost of biodiesel by 20 cents.

Table 6. Estimated Cost of Biofuels for Selected Years, AE and EPT Scenarios.

	Projected for the Year:				
	2007	*2010*	*2015*	*2020*	*2025*
Ethanol:	*(Dollars per gallon).*				
AE	*1.34*	*1.57*	*1.38*	*1.44*	*1.60*
Biodiesel[a]*:*					
AE	*1.80*	*2.57*	*2.50*	*2.74*	*2.74*

[a] *The biodiesel costs reflect use of both soybean and yellow grease. Yellow grease collection costs are not includ*

Government Payments and Net Farm Income

The impact of the increased demand for agricultural resources, as a result of expanding the role of agriculture as a source of bioenergy, can be observed in the changes in net farm income. As prices of the major crops increase, a reduction in the level of government payments, such as loan deficiency payments and counter cyclical payments, both based on average market prices, would be anticipated. However, the projected payments under the USDAExt are already substantially lower than historical farm program spending, so the savings in these government payments are relatively.

In the AE Scenario, producers could expect over the entire 20 year period a realized net income of over $900 billion. An increase in realized net farm income of $180 billion, compared with the USDAext baseline scenario, is projected to occur over the period of analysis with larger gains in realized net farm income occurring in the latter years under the AE energy goal.

The changes projected for realized net farm income resulting from expanding the role of agriculture as an energy source are displayed in Figure 9. By the year 2025, gains of $37 billion in net farm income are estimated if the AE scenario's energy goals and assumptions are in place. The gains in net returns in this scenario occur once cellulosic ethanol becomes available and a dedicated energy crop is being utilized. Figure 20 also indicates the potential savings in government payments.

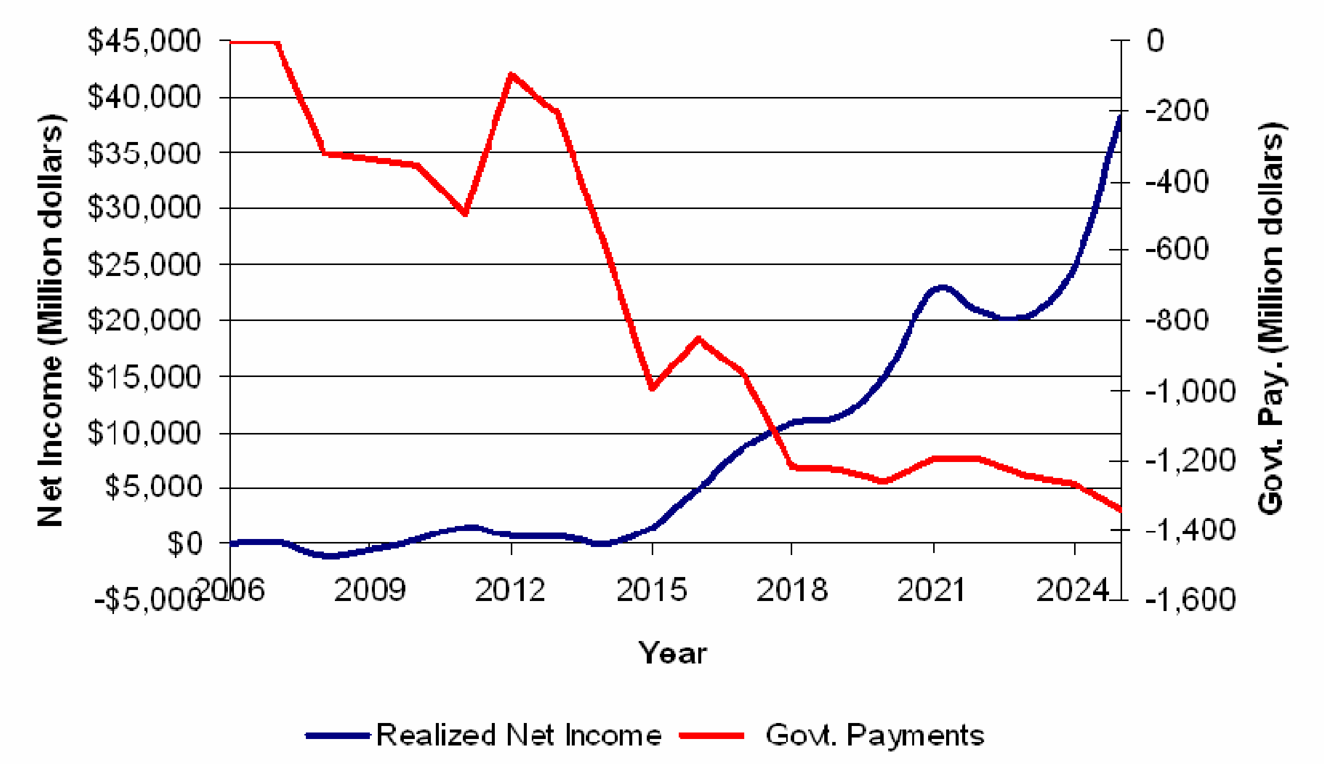

Figure 9. Changes in Net Farm Income (NFI) and Government Payments Under AE Scenario

4.2.9. Impacts on the Livestock Sector

The results of the analysis indicate that the livestock sector would face higher feed expenses. However, of the primary feed sources for livestock - hay, soybean meal and corn - only corn is expected to experience a significant increase in price. Hay price is determined at the regional level and is not determined in the POLYSYS model, but in order for cropland in pasture to come into crop production a portion of pasture must be converted to hay production to make up for the regional loss in pasture forage productivity.

The results of the AE are presented in Table 7. By 2025 national hay acreage is expected to rise from 62 million acres to more than 167 million acres, an increase of 100 million acres. This represents an intensification of the management of the pasture land. While there could be a one time cost of shifting cropland in pasture to hay, it is not expected to be of any long term significance. As cropland in pasture is replaced with hay acreage, hay price is not expected to rise.

The various components of the livestock industry react differently to the higher feed prices driven by the inclusion of corn in the feed ration, by the importance of the feed expenses in the overall cost of production, and by the ability to transfer the cost of the additional feed expenses to the consumer.

The cattle sector reacts to the cost increase by adjusting cattle inventories. The reduction in inventories leads to higher prices that offset the sector's increased production costs. The hog and poultry industries experience decreases in net returns. In both industries, corn is a major component of feed ration, and consequently the cost of feed increases result in noticeable drop in net returns. The model results indicate that the production adjustment and increase in prices are not large enough to compensate for that increase in feed expenditures. However, it is very important to emphasize that the model is not fully capable to capture the high degree of vertical coordination in the poultry and hog industry.[2] Vertical coordination and associated production contracts make predicting market adjustments difficult. The model also reflects consumption of DDG's by the hog and poultry sectors of up to 10 percent. Given emerging technologies and genetic improvements, it could be possible that a greater portion of DDG's may become part of the feed ration for these species.

Other factors need to be mentioned which have not been accounted for in the quantitative analysis. First, as the production of forage increases as a result of the added management, there would be a long-term change in the feed ration of cattle, in which corn and soybean meal would be partially replaced by increased pasture and forages. This would in turn contribute to reduce the price pressure for the feed in the poultry and hog industries. Second, the process of converting cellulosic material to ethanol through fermentation opens up the opportunity to produce byproducts with a high content of protein and energy suitable to replace corn and soybean meal in the livestock industry (Dale, 2006). This integration of the energy feedstock conversion and livestock production would result in gains for the livestock industry not quantified in this report. Finally, no changes in feeding efficiency are considered during the period of analysis.

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[2] Vertical coordination in the poultry and hog industries involves processors coordinating successive stages of production and marketing. Coordination mechanisms include contract production and ownership of production.

Table 7. Change in Livestock Sector Net Returns, AE Scenario.

	Projected for the Year:				
	2008	2010	2015	2020	2025
Costs and Returns by Livestock Type	Million Dollars				
AE Scenario					
Cattle:	-1.0%	0.4%	-0.8%	2.9%	3.9%
Hogs:	3.6%	-4.4%	7.1%	-10.9%	-11.0%
Chickens:	2.1%	-2.7%	2.7%	-6.8%	-6.6%

Sensitivity of the results

Yields for traditional crops, which increase at rates greater than baseline, are projected to dampen price increases as a result of acreage conversion to energy crops. The price impacts without the higher yields are significantly higher, and even well above average market prices experienced in a number of years, especially for corn, wheat, and soybeans. This is an indication that an expansion of a biofuels industry has to be accompanied not only by investments in bioenergy related elements of the supply chain, but also investments in traditional crops. This will increase the likelihood of success of the bioenergy industry growth.

The results would also be very sensitive to the time in which the cellulose-to-ethanol path becomes commercially available. For example a delay in the commercial introduction of the cellulose-to-ethanol path would imply an increase in 100% of the price of corn, considering that the ethanol target is not changed.

Impacts on the Nation's Economy

The impacts on the economy are also spread throughout the United States. An estimated $533.8 billion dollars is generated annually in the conversion of renewables to energy under the AE scenario.

In total, $252 billion is directly generated in the economy purchasing inputs, adding value to those inputs and supplying the energy under the AE scenario. These expenditures create additional impacts. The total impact to the nation's economy is estimated at slightly more than $700 billion creating an estimated five million jobs (Table 8). Since the 29 quads of energy created by the renewable energy sector would not impact current production levels, any reduction in economic activity resulting from current energy industry displacement is minimal and no adjustments were made to the current renewable energy sector

If increased reliance on renewable energy feedstocks do occur, then a shift toward energy conservation could occur, resulting in a structural shift in the economy. This potential shift is not incorporated in this analysis. The impacts projected in this study are divided into two areas: 1) those caused by changes in the agricultural sector, and 2) those caused by the development of a renewable energy industrial sector.

As a result of changes in the agricultural sector under the AE scenario, Illinois, Iowa, Missouri, and Nebraska receive benefits in excess of $10 billion . Assuming the renewable energy sector is developed in close proximity to the feedstocks, the states that receive the greatest benefit include the same states Illinois, Iowa, Missouri, and Nebraska. However, states receiving over ten billion dollars in increased economic activity include in addition to these four states, Texas, Kansas, Minnesota, and Indiana. Interstate commerce associated with conversion that cannot be assigned to any individual state is nearly equal to impacts that are allocated. Including both allocated and unallocated economic activity, 3.4 million jobs are estimated to be created from the development of a renewable energy sector beyond what exists today. The regional distribution of the economic impacts and employment generation are shown in Figures 10 and 11.

Table 8. Estimated Annual National Impacts Under the AE Scenario, 2025.

Scenario, Year and Impacted Sector	Change in Industry Output		Impact in Employment	
	Direct Impact	Total Impact	Direct Impact	Total Impact
	Million Dollars		Number of Jobs	
AE Scenario				
2025:				
Agricultural Production Sector	$113,664.2	$170,512.2	1,171,760.4	1,749,625.0
Renewable Energy Sector	$138,776.0	$280,854.1	93,390.3	1,460,017.7
Interstate Commerce	$0.0	$252,990.5	0.0	1,955,891.1
Total	$252,440.2	$704,356.8	1,265,150.7	5,165,533.8

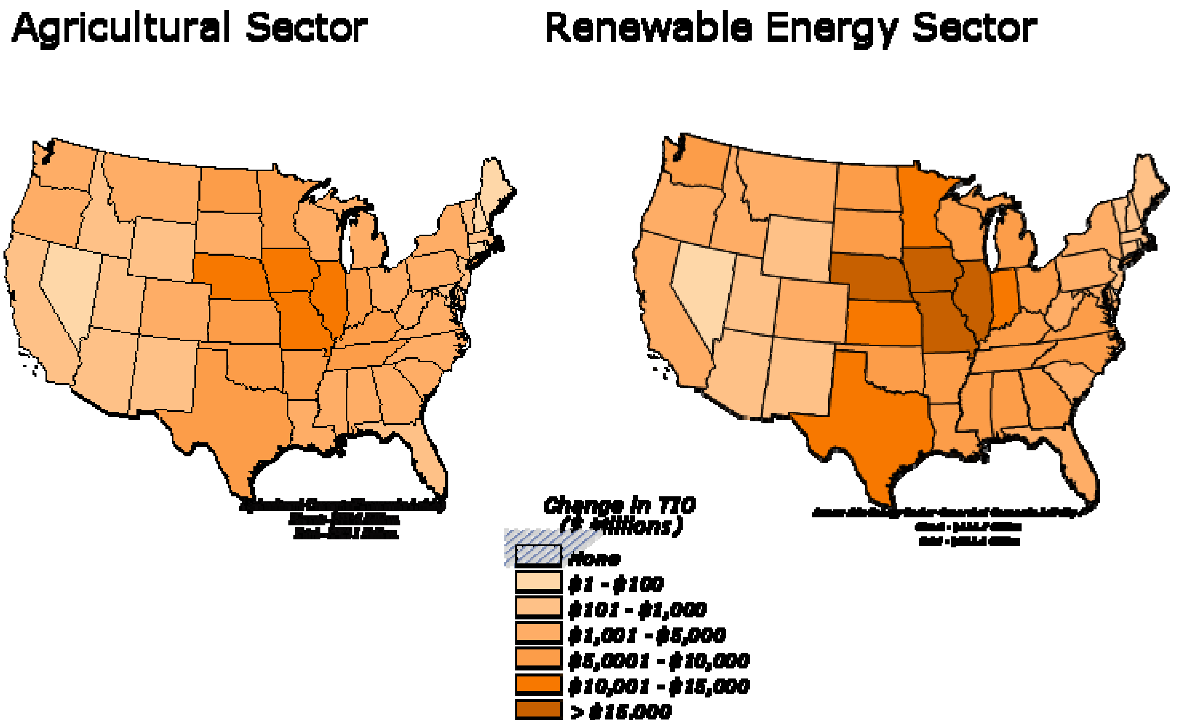

Figure 10. Estimated Impacts to the National Economy as a Result of Scenario AE.

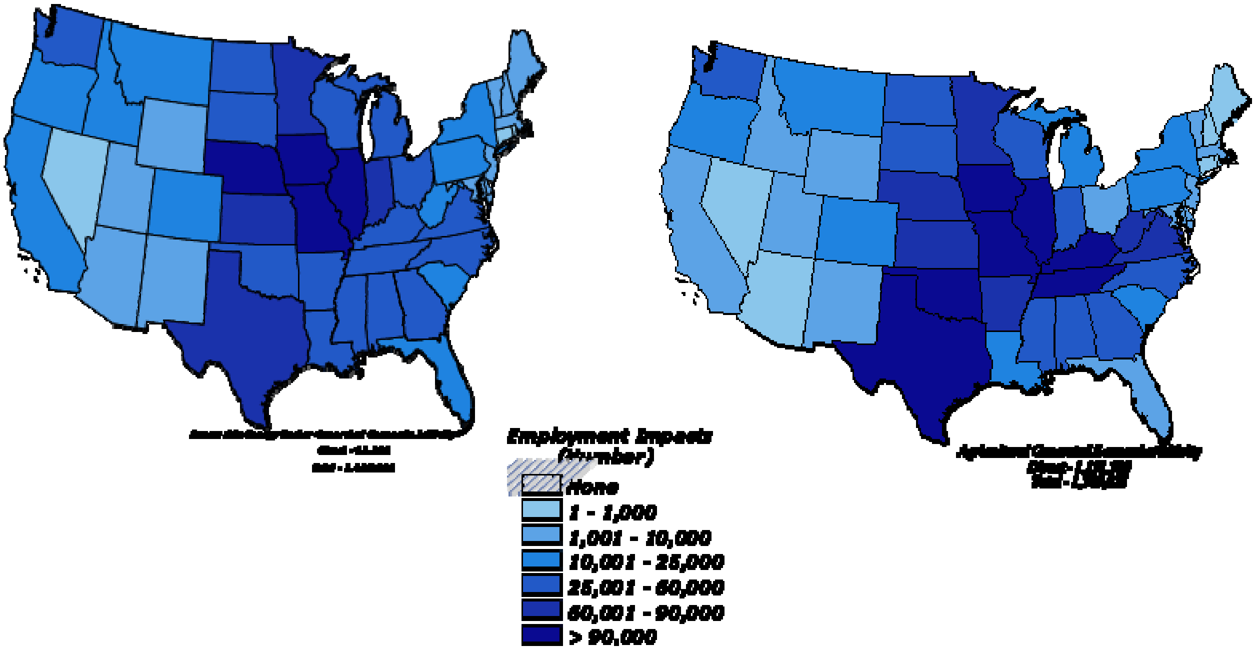

Figure 11. Estimated Impacts in Employment Generation as a Result of AE Scenario.

V. Conclusions

This study projected the potential impacts on agriculture and the economy from meeting a 25 percent renewable energy goal. Based on existing conversion technologies, an assessment of the impacts on the economics of the agricultural sector associated with bioenergy production effort was conducted. Also, the overall economic impacts of producing and converting agriculture and other agro-forestry feedstocks to bioenergy were projected.

A key finding from this study is that the nation, with investment in improving traditional crop yields, has the capability of producing enough biomass feedstock to produce 15.45 quads of bioenergy by the year 2025. The resulting mix of bioenergy includes a projected 86.9 billion gallons of ethanol, over a billion gallons of biodiesel, and 962 billion kWh of electricity from biomass.

To obtain the amount of renewable energy in the goal, two conditions need to be met. First is the commercial introduction of the technology for cellulosic-to-ethanol conversion. Second is the development of an energy dedicated crop economy with 105.8 million planted acres. This acreage is projected to come in production by intensifying the management of pasture in cropland, in order to release 172 million acres of pasture/rangeland to energy feedstock production. The impetus for shifts in acreage from traditional crops to energy dedicated crops would be energy crop prices that are competitive with those of traditional crops. Acreage shifts are projected at 20 million acres from soybean production, 9 million acres from wheat production, and the remaining from corn and minor crops production.

To achieve the renewable energy goal at reasonable crop and feedstock prices, investment in research to improve yields of energy feedstock, along with yields of traditional crops, is crucial. Improved yields would enable the production of the 15.45 quads of energy at prices that would imply a cost of ethanol of $1.60 per gallon and of $2.74 per gallon of biodiesel.

There is a projected gain in net farm income from expanded bioenergy production. Realized net farm income increases $180 billion in total over the next 20 years and by $37 billion/year in the year 2025 compared with baseline estimates. Furthermore, there is an accumulated government savings of more $15 billion in commodity program payments.

At the regional level, the Midwest would have the comparative advantage to produce cellulosic ethanol from corn and wheat residues, while the Southeast and the South would have the comparative advantage in dedicated crops production. In addition, cellulosic material from wood and forest residues would come primarily from the West, Southeast, and Northeast. The increase in the demand for agricultural resources would also imply gains in net returns for the 48 contiguous states. The gains would primarily be concentrated in the areas in which agricultural production occurs, but the use of wood and forest residues expands the gains beyond the agricultural areas.

The additional economic activity from meeting a bioenergy goal, such as that represented in the AE Scenario, exceeds $700 billion dollars and generates in excess of an estimated 5.1 million jobs annually once the renewable energy sector has been established in 2025. This does not include economic impacts from increased investment on the nation’s economy.

Finally, consumption of 86.9 billion gallons of ethanol has the potential to decrease gasoline consumption by 59 billion gallons in 2025. This reduction in gasoline consumption could significantly decrease the nation’s reliance on foreign oil.

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Appendix A. Summary of Conversion Technologies and Cost Information Sources.

Conversion Technology	Facility Size—Output	Facility Size—Feedstock Use	Cost Information Source
Ethanol from Shelled Corn (Dry Mill)	48 MM Gal/ year	17,105,455 bushels	McAloon, A., F. Taylor, W. Yee, K. Ibsen, and R. Wooley. 2000. "Determining the Cost of Producing Ethanol from Corn Starch and Lignocellulosic Feedstocks". National Renewable Energy Laboratory (NREL/TP-580-28893). Joint study sponsored by USDA and DOE; e-mail correspondence from Dr. Vernon R. Eidman
Ethanol from Cellulosic Residues (Stover, Switchgrass, Rice Straw, and Wheat Straw)	69.3 MM Gal/year	Stover 772,333 Switchgrass 984,375 dry tons Rice Straw 670,573 dry tons Wheat Straw 1,061,538 dry tons	Aden, A., M. Ruth, K. Ibsen, J. Jechura, K. Neeves, J. Sheehan, B. Wallance, L. Montague, A. Slayton, and J. Lukas. 2002. "Lignocellulosic Biomass to Ethanol Design and Economics Utilizing Co-Current Dilute Acid Prehydrolysis and Enzymatic Hydrolysis for Corn Stover". National Renewable Energy Laboratory & Harris Group (NREL/TP-510-32438).
Ethanol from Food Residues	69.3 MM Gal/year	984,375 dry tons	Aden, A., M. Ruth, K. Ibsen, J. Jechura, K. Neeves, J. Sheehan, B. Wallance, L. Montague, A. Slayton, and J. Lukas. 2002. "Lignocellulosic Biomass to Ethanol Design and Economics Utilizing Co-Current Dilute Acid Prehydrolysis and Enzymatic Hydrolysis for Corn Stover". National Renewable Energy Laboratory & Harris Group (NREL/TP-510-32438).
Ethanol from Wood Residues	32.4 MM Gal/year	500,036 dry tons	BBI International. 2002. "State of Maine Ethanol Pre-Feasibility Study". Prepared for Finance Authority of Maine.
Biodiesel from Soybeans	13.0 MM Gal/year	9,000,000 bushels	English, B., K. Jensen, and J. Menard in cooperation with Frazier, Barnes & Associates, Llc. 2002. "Economic Feasibility of Producing Biodiesel in Tennessee".
Biodiesel from Yellow Grease	10.00 MM Gal/year	80,000,000 pounds	Fortenberry, T. 2005. "Biodiesel Feasibility Study: An Evaluation of Biodiesel Feasibility in Wisconsin". University of Wisconsin-Madison, Department of Agricultural & Applied Economics. Staff Paper No. 481.
Horizontal Axis Wind Turbine Power Plant	131,400,000 kWh/year	NA	Electric Power Research Institute & BBF Consult. 2004. "Renewable Energy Technical Assessment Guide – TAG-RE: 2004". Technical Report - 1008366
Solar Thermal Technology (Parabolic Trough)	700,800,000 kWh/year	NA	Electric Power Research Institute & BBF Consult. 2004. "Renewable Energy Technical Assessment Guide – TAG-RE: 2004". Technical Report – 1008366
Utility Scale Solar Photovoltaic Power Plant (One-Axis Tracking)	438,000,000 kWh/year	NA	Electric Power Research Institute & BBF Consult. 2004. "Renewable Energy Technical Assessment Guide – TAG-RE: 2004". Technical Report – 1008366
Wood Fired Power Plant	219,000,000 kWh/year	110,500 dry tons	Electric Power Research Institute & BBF Consult. 2004. "Renewable Energy Technical Assessment Guide – TAG-RE: 2004". Technical Report – 1008366

Appendix A. Continued.

Conversion Technology	Facility Size—Output	Facility Size—Feedstock Use	Cost Information Source
Co-fire (15%) of Cellulosic Residues (Corn, Wheat, Rice, Switchgrass, Forest, Poplar, Mill, and Urban) with Coal	137,313,000 kWh/year	Corn Residues 74,452 dry tons Wheat Residues 78,284 dry tons Forest Residues 69,307 dry tons Switchgrass 72,841 dry tons Poplar 69,307 dry tons Mill Residues 69,307 dry tons	English, B., J. Menard, M. Walsh, and K. Jensen. 2004. "Economic Impacts of Using Alternative Feedstocks in Coal-Fired Plants in the Southeastern United States".
Co-fire (10%) of Cattle Feedlot Biomass with Coal (Feedlot Size 45,000 head)	137,313,000 kWh/year	NA	Sweeten J., K. Annamalai, K. Heflin, and M. Freeman. 2002. "Cattle Feedlot Manure Quality for Combustion in Coal/Manure Blends". Presented at the 2002 ASAE Annual International Meeting, Chicago. Paper No. 024092; English, B., J. Menard, M. Walsh, and K. Jensen. 2004. "Economic Impacts of Using Alternative Feedstocks in Coal-Fired Plants in the Southeastern United States".
Landfill Gas	34,457,555 kWh/year	NA	Environmental Protection Agency, Landfill Methane Outreach Program. 2005. Documents, Tools, and Resources. Energy Project Landfill Gas Utilization Software (E-Plus).
Warm Climate Methane Digester for Swine (4,000 Sow Farrow to Wean Pig with Pit Recharge)	438,000 kWh/year	NA	Moser, M., R. Mattocks, S. Gettier, and K. Roos. 1998. "Benefits, Costs and Operating Experience at Seven New Agricultural Anaerobic Digesters". Presented at Bioenergy '98, Expanding Bioenergy Partnerships, Madison, Wisconsin, October 4-8.
Cool Climate Methane Digester for Swine (5,000 Sow Farrow to Finish Operation)	525,600 kWh/year	NA	McNeil Technologies, Inc. 2000. "Assessment of Biogas-to-Energy Generation Opportunities at Commercial Swine Operations in Colorado". Prepared for State of Colorado and Department of Energy.
Methane Digester for Dairy (1,000 head)	1,080,000 kWh/year	NA	Nelson, C. and J. Lamb. 2002. "Final Report: Haubenschild Farms Anaerobic Digester Updated". The Minnesota Project 2002.
Methane Digester for Poultry	438,000	NA	Moser, M., R. Mattocks, S. Gettier, and K. Roos. 1998. "Benefits, Costs and Operating Experience at Seven

(40,000 head)	kWh/year		New Agricultural Anaerobic Digesters". Presented at Bioenergy '98, Expanding Bioenergy Partnerships, Madison, Wisconsin, October 4-8.