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

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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 (House *et al.*, 1993; Petrulis *et al.*, 1993; Sheehan *et al.*, 1996; Delucchi, 1997; Evans, 1997; US Department of Agriculture, 1999; Wang *et al.*, 1999; English *et al.*, 2000; Whitten, 2000; California Energy Commission, 2001; Energy Information Administration, 2001a,b; Mann and Spath, 2001; Urbanchuk, 2001; Collins, 2002; McLaughlin *et al.*, 2002; Shapouri *et al.*, 2002; Sheehan, 2002; Sheehan *et al.*, 2002; De La Torre Ugarte *et al.*, 2003; and Walsh *et al.*, 2003). Previous economic modeling evaluating agriculture feedstocks for energy has been conducted in the context of carbon displacement potential (Adams *et al.*, 1992, 1999; McCarl *et al.*, 2000, 2001) 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 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 (De La Torre Ugarte *et al.*, 1998; Ray *et al.*, 1998a,b; De La Torre Ugarte and Ray, 2000). 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 help 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 quadrillion British thermal units (quads) of energy or 4.5% of projected energy demands through use of residues (stover and straw), crops such as corn and soybeans and dedicated energy crops (using switchgrass, *Panicum virgatum*, as a model crop) as feedstocks in the production of electricity, ethanol, biodiesel and selected bioproducts.

Previous economic impact modeling using IMPLAN® to analyze agricultural feedstocks for energy has evaluated the: 1) economic impacts of using alternative feedstocks for coal-fired plants in the southeastern United States (English *et al.*, 2004a), 2) economic impacts of producing switchgrass and crop residues for use as a bioenergy feedstock (English *et al.*, 2004b) and 3) potential regional economic impacts of converting corn stover to ethanol (English, *et al.*, 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% of America's energy needs with renewable energy by the year 2025 (25 x'25), while continuing to produce safe, abun-

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dant 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 US 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.

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 derived 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 an input-output (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 I/O 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 US 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 US 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 by exogenously estimating three variables – exports, yields and population. Exports and yields beyond 2015 are determined by extending the trend in the final three years of USDA baseline outward. The population of the United States is extended out using 2006 US Census Bureau estimates (http://www.census.gov/ipc/www/usinterimproj/).

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 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 calculate 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/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 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 (bu) of corn grain (56 pounds (lb)) used in ethanol production, 18.3 lb 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 bu 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% for beef production and 10% 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 resulting from 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 the effects on a state or 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 that changes in policy have on the US 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, *et al.*, 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

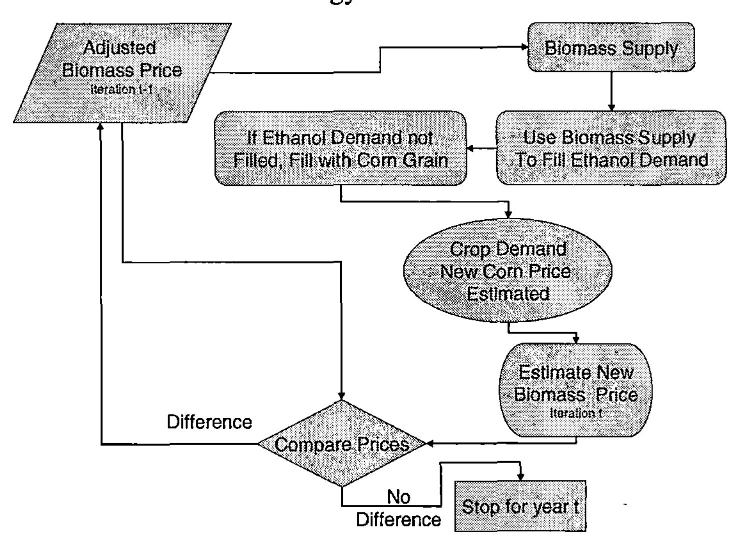

Figure 1: Schematic of the Methods Employed to Determine Feedstock Price Required to Meet Energy Demand.

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 *et al.*, 2004).

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

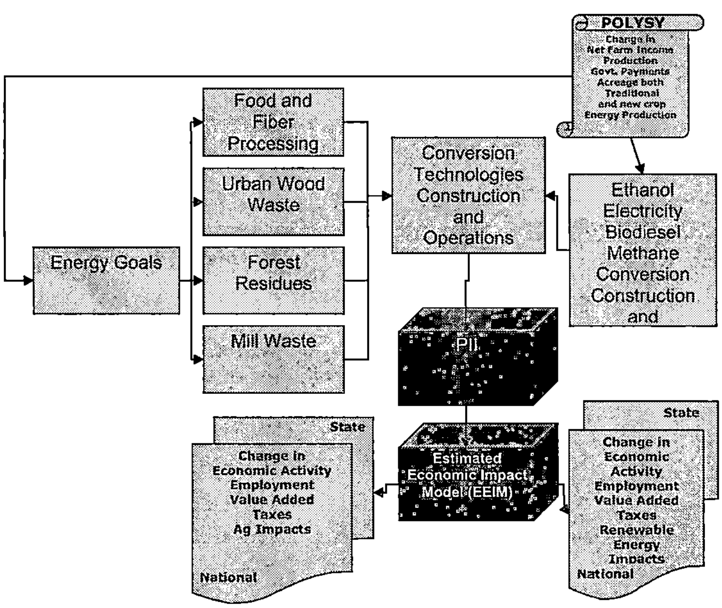

Figure 2: Schematic of PII, the Link between POLSYS and IMPLAN®.

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 US 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. In addition, of the remaining 67 million acres of cropland including Conservation Reserve Program (CRP), idle lands, etc., 15 million acres are 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. 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 that irrigation is needed in regions where irrigated hay production exceeds dryland hay production, 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, 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 in 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 switchgrass as a feedstock 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 (dt)/acre depending on location. Switchgrass is not a feasible crop option without irrigation 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/acre) as a function of corn and wheat grain yields, plus stover and straw production costs as a function of yields of removable residue (dt/acre). 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 takes into considerations the 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 and Lamb, 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 (bu/acre) are converted to biomass quantities (dt/acre) 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 Technology 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/acre).

Forest residues, mill wastes, fuel treatments and forestland thinnings are included in the model as wood residues for conversion to bioenergy (Figure 4). We assume 46 dt of forest residues, 67 million dt of mill residues, 60 million dt of fuel treatments and 52 million dt of forestlands thinnings are available for a total of 352 million dt (Walsh *et al.*, 2003). The price at which these feedstocks come into use is determined by regional harvesting costs plus transportation costs.

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 (Moser *et al.*, 1998; Sweeten *et al.*, 2002).

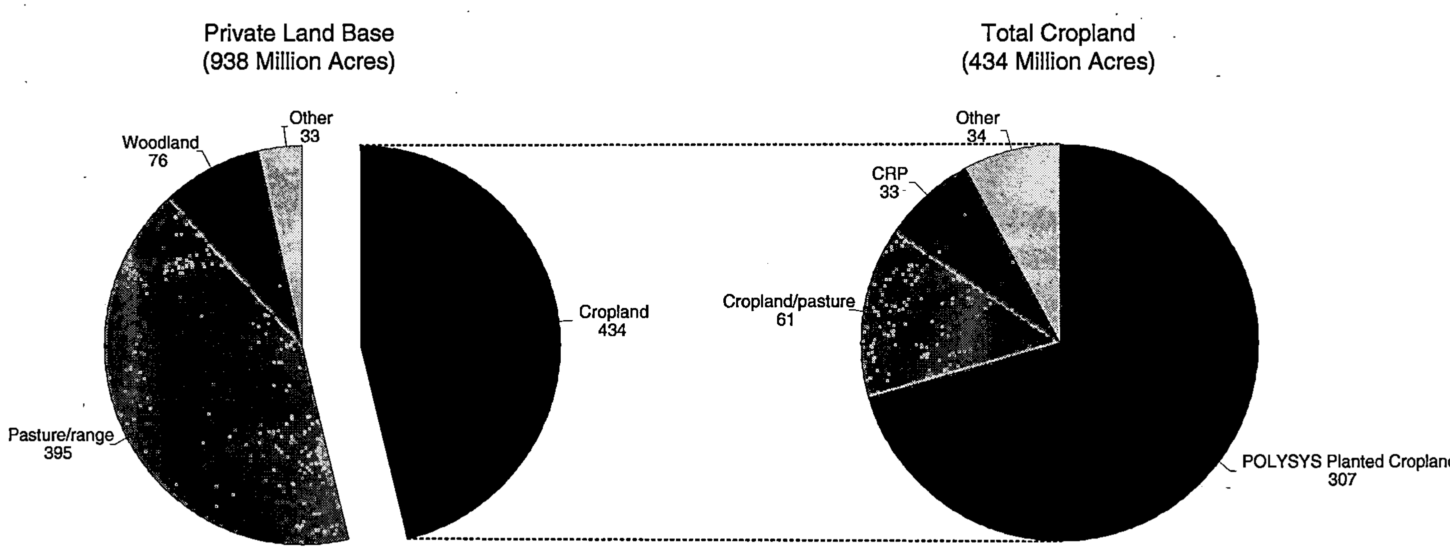

Figure 3: Land Use by Major Use Category, 2002.
Source: National Agricultural Statistics Service, 2004.

Fats and oils 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, number of employees and cost information sources is presented in Appendix A.

Renewable Energy Scenario

To meet the 25 x'25 vision, 25% 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 25 x'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 several 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 US 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.[2] 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).

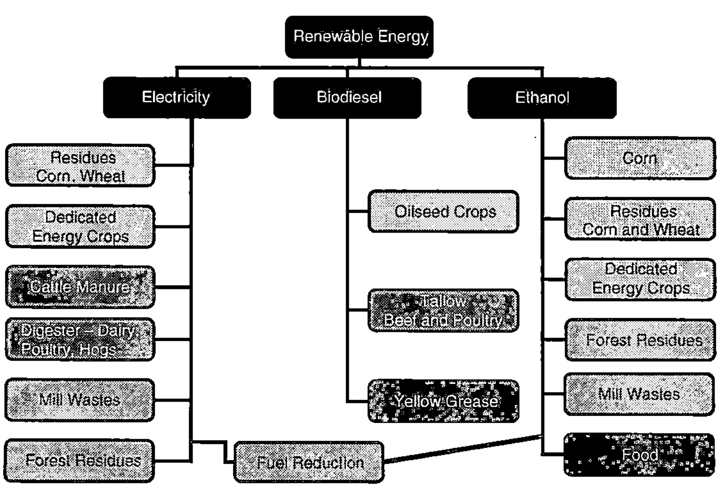

Figure 4: Feedstock and Energy Services in POLYSYS/IMPLAN®.

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% compared with the yield growth rate in the USDAExt scenario (Table 1).

To date, 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% 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 the baseline to increase reduced and no-till for corn and wheat following the path listed in Table 3.

Results

To attain 15.45 quads of energy, the analysis indicates that 86.9 billion gallons (gal) of ethanol, 1.1 billion gal of biodiesel and 962 billion kilowatt-hours (kWh) of electricity will be produced for biomass sources by 2025 (Table 4).

[2] 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		National Average Projected Yields Under the AE Scenario	
	USDAExt	AE Scenario*	2015	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% 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: Hellwinkel and De La Torre Ugarte (2005).

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

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	Billion Gallons	5.83	8.09	30.41	57.97	86.86
Biodiesel	Billion Gallons	0.16	0.22	0.45	0.72	1.10
Electricity	Billion kWh	87.00	89.00	379	698	962
Total Energy	Quads	1.23	1.45	5.77	10.77	15.45

The projected results that occur as a result of producing these levels of energy are provided in two major sections. The first section discusses the impacts in the agricultural sector and the economic impacts to each state and the nation are discussed.

Agricultural Sector Impacts

The results from the analysis indicate that reaching the 25 x '25 energy goal is a plausible target if, in addition to the 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, only 172 million acres are used 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. The conversion of cellulosic feedstocks (crop residues, switchgrass, wood residues) is essential for 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 feedstocks in the form of corn residues. The gains in net revenues indicate that income rises in all areas of the country. Finally, higher commodity prices cause government program payments to decline, significantly lowering the cost of commodity programs.

Feedstock Utilization

Bioenergy production is derived from several feedstocks (Figure 5). 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 feedstocks. 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 feedstocks. Attaining the goal is also dependent on the successful introduction of bioenergy dedicated crops such as switchgrass and conversion of wood to ethanol. As the year 2025 approaches, the contribution of dedicated crops is over 50% 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 total feedstock supply.

Changes in Land Use

To support the level of feedstocks 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 US agriculture, with 105.8 million acres planted. Significant shifts from current uses 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 would occur, as acreage becomes constrained and more energy per acre is required to achieve the target reflected in both scenarios.

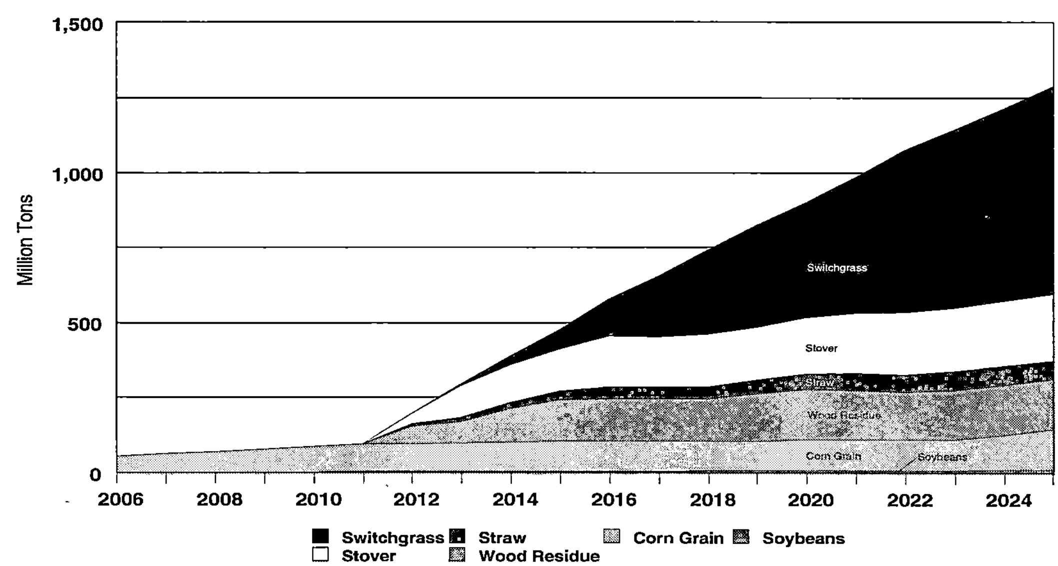

Figure 5: Projected Use of Feedstock for Energy.

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

Crop and Scenario	Projected for the Year: 2007	2010	2015	2020	2025
			Dollars/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			Dollars/Pound		
AE	0.51	0.51	0.62	0.63	0.63
USDAExt	0.51	0.51	0.57	0.57	0.58
Switchgrass:			Dollars/Dry ton		
AE	0.0	0.0	46.85	60.90	81.85
USDAExt	0.0	0.0	0.0	0.0	0.0

Perhaps the most significant projected change is the shift of pastureland/rangeland and cropland in pasture, hereafter the sum of both referred to as pastureland, towards the production of dedicated energy crops, 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. Since it is well recognized that pasture and grassland are significantly underutilized, this increase in management intensity is likely to occur at a very low additional cost. While causing changes in the livestock industry, the welfare of livestock producers is not expected to be significantly impacted.

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 dedicated energy crops, an overall increase in commodity prices is projected (Table 5). Notably, when compared with

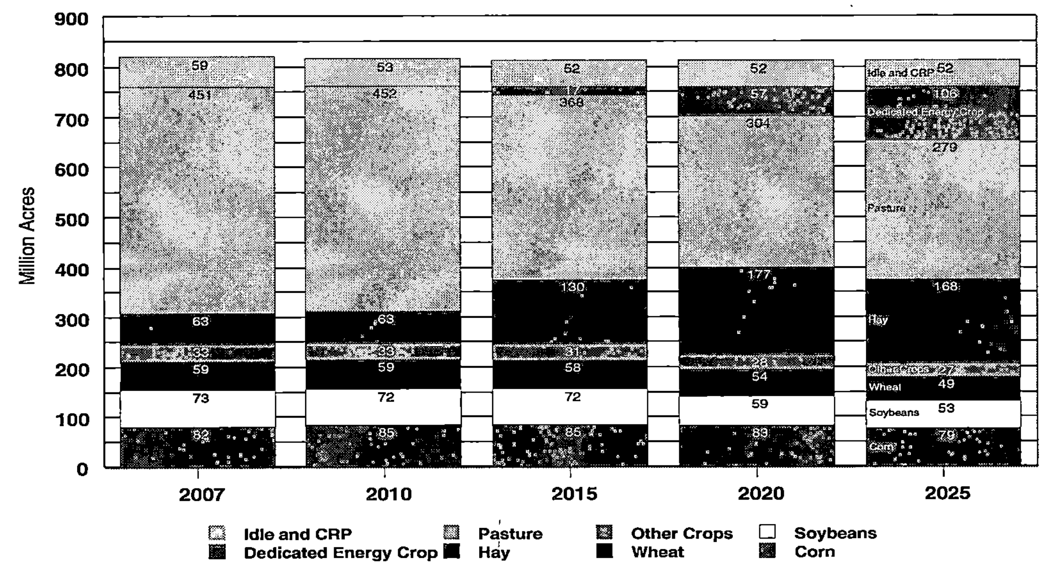

Figure 6: Projected Changes in Land Use.

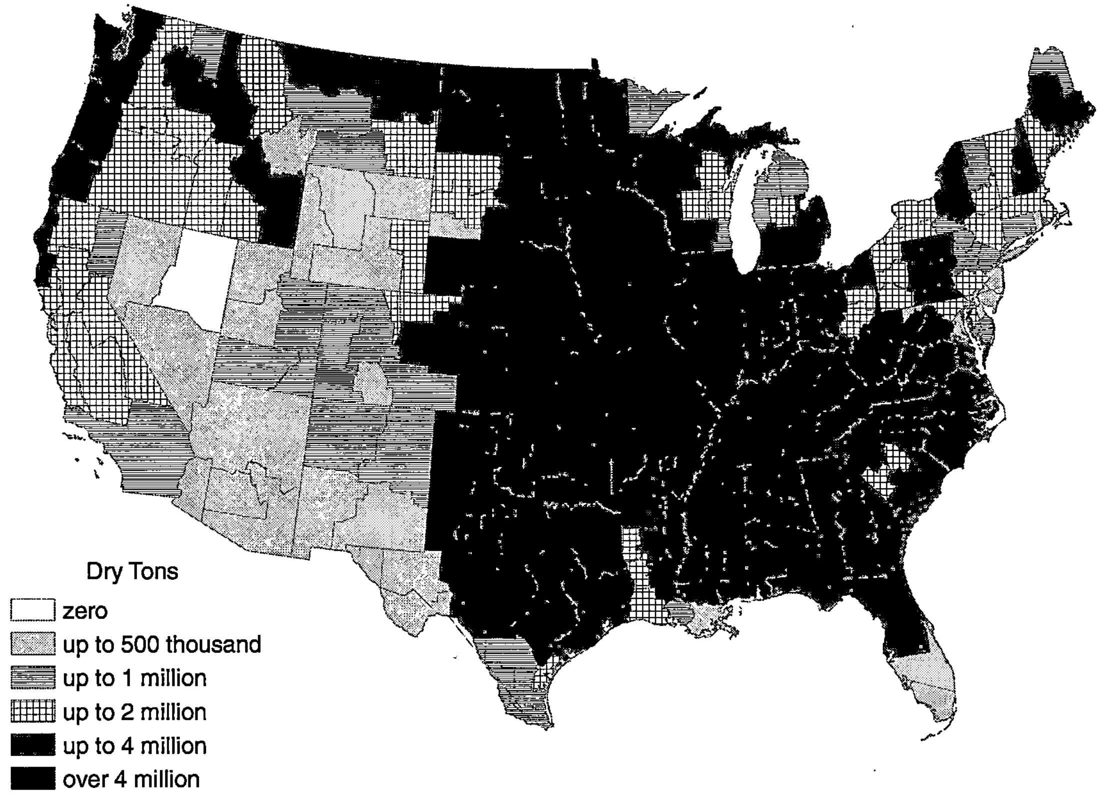

Figure 7: Distribution of All Cellulosic Feedstock (Crop Residues, Dedicated Energy Crops, Forest Residues, Mill Wastes and Wood from Fuel Reduction), AE Scenario.

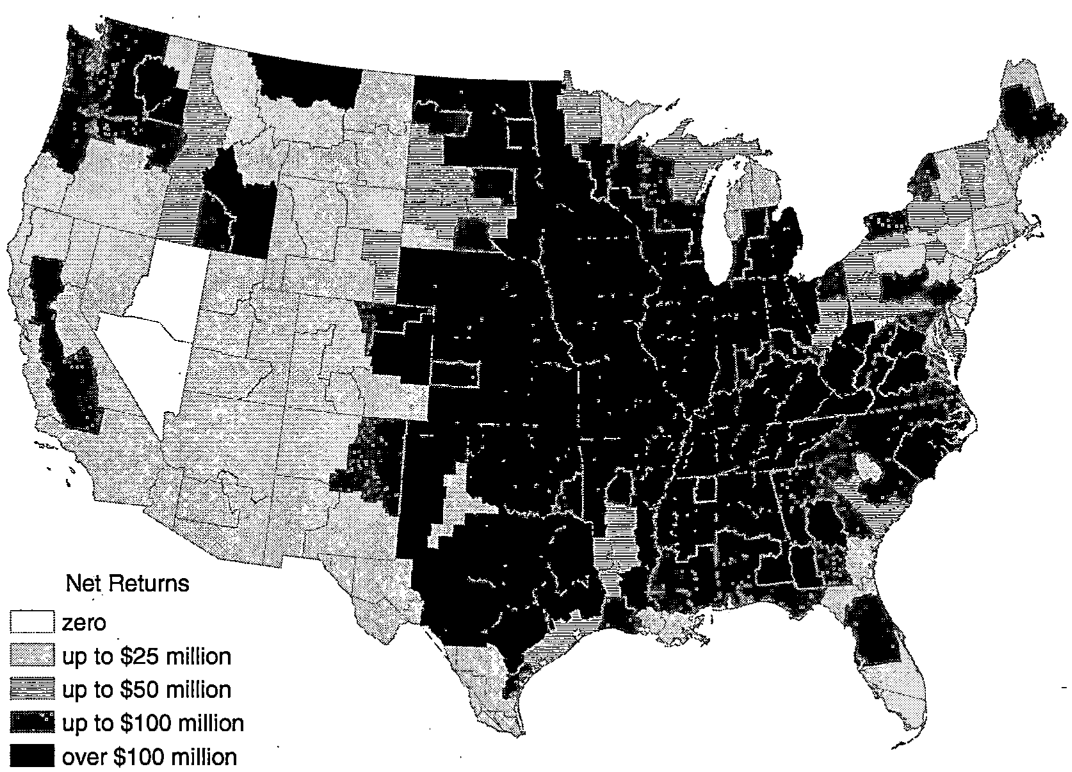

Figure 8: Distribution of Net Returns, AE Scenario.

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

	Projected for the Year:				
	2007	2010	2015	2020	2025
Ethanol:			(Dollars/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 included.

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.

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 indicates the geographic distribution of the cellulosic feedstock production. The results indicate that the cellulosic feedstocks (crop residues, wood residues and thinnings) are initially concentrated in the corn growing areas of the Midwest. Then, feedstock production expands towards the Southern Plains and the Southeast. Importantly, cellulosic feedstock production expands 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 thinnings. It is important to reiterate that no forest is specifically harvested for energy purposes in these scenarios. Although, the addition of forest resources could have substantial impacts on bioenergy markets and should be the subject of future research.

By 2025, many of the ASDs 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 yield performance in the South and faces less competition from traditional Midwest corn and soybean production.

A 16.5% increase occurs in realized net returns to the agricultural sector when meeting the AE energy goal. The gains are distributed across the 48 contiguous US states. 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 in net returns also triggers expansion to all areas of the country (Figure 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 significant growth in feedstock production.

Cost of Ethanol and Biodiesel

Increasing the demand for renewable energy to the level reflected in AE results in an increase in feedstock costs, as the price of feedstocks rise, particularly for biodiesel. (Table 6). 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 $0.20.

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 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 small.

In the AE Scenario, over the entire 20 year period, producers could expect 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.

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%

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 9 also indicates the potential savings in government payments.

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 the 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 ac, an increase of 100 million ac. 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 the feed ration, and consequently the increase in the cost of feed results in a noticeable drop in net returns. The model results indicate that the production adjustment and increase in prices

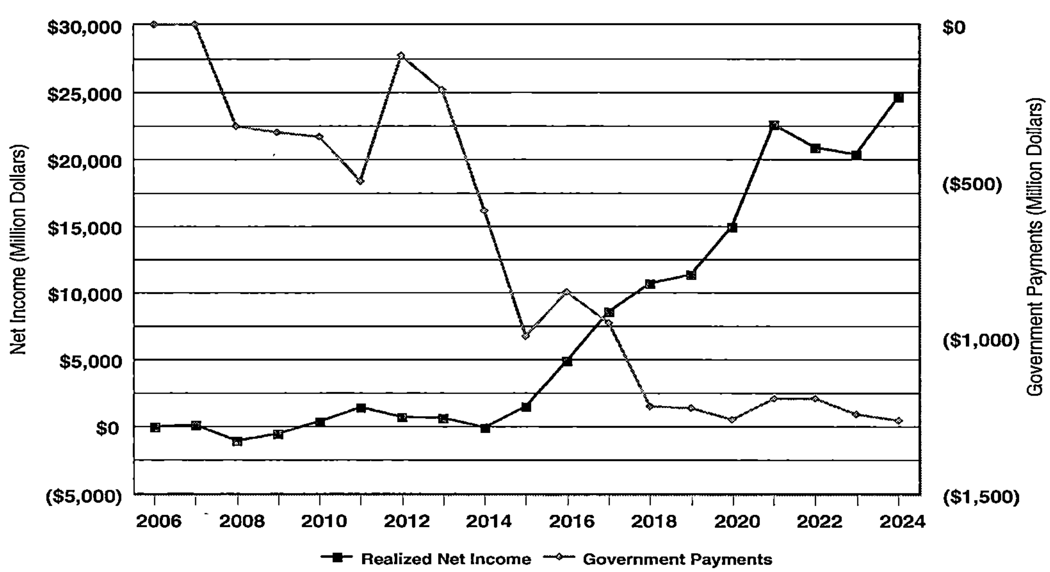

Figure 9: Changes in Net Farm Income (NFI) and Government Payments Under AE Scenario.

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

are not large enough to compensate for the increase in feed expenditures. However, it is very important to emphasize that the model is capable of fully capturing the high degree of vertical coordination in the poultry and hog industry.[3] 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%. 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 reduced 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 analysis period.

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 US 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 US 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. How-

[3] 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.

ever, states receiving over ten billion dollars in increased economic activity in the renewable energy sector 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.

Conclusions

This study projected the potential impacts on agriculture and the economy from meeting the 25x'25 renewable energy goal. Based on existing conversion technologies, an assessment of the impacts on the economics of the agricultural sector associated with bioenergy production 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 United States, 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 gal 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 a dedicated energy crop economy with 105.8 million planted acres. This acreage is projected to come into 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

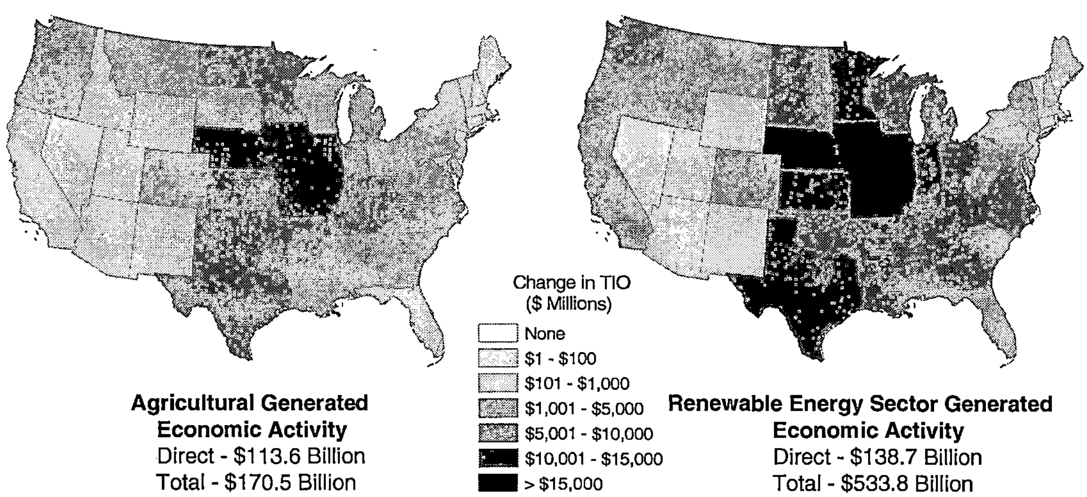

Figure 10: Estimated Impacts to the US Economy as a Result of Scenario AE.

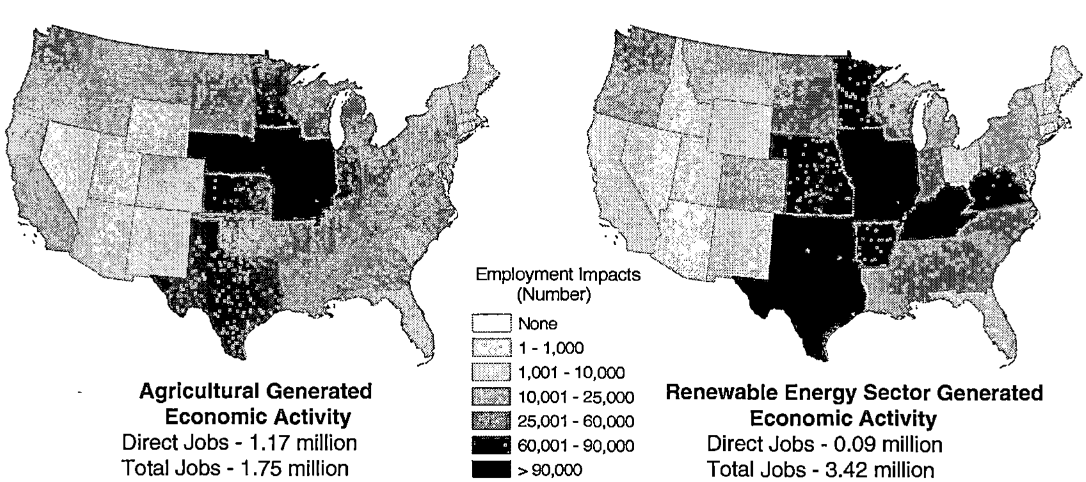

Figure 11: Estimated Impacts in Employment Generation as a Result of AE Scenario.

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/gal and of $2.74/gal 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 US economy.

Finally, since ethanol's British thermal unit (Btu) content is approximately 67% that of gasoline, consumption of 86.9 billion gal of ethanol has the potential to decrease gasoline consumption by 59 billion gal or more[4] in 2025. This reduction in gasoline consumption could significantly decrease the nation's reliance on foreign oil.

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[4] As ethanol becomes a fuel of choice and blended with gasoline at higher concentrations, engine manufactures are likely to design engines so that they more efficiently utilize ethanol as a fuel. This would increase the replacement of 59 billion gallons.

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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 *et al.*, 2000; Eidman, 2006.
Ethanol from Cellulosic Residues (Stover, Switchgrass, Rice Straw, and Wheat Straw)	69.3 MM gal/year	Stover 772,333 dry tons Switchgrass 984,375 dry tons Rice Straw 670,573 dry tons Wheat Straw 1,061,538 dry tons	Aden *et al.*, 2002.
Ethanol from Food Residues	69.3 MM gal/year	984,375 dry tons	Aden *et al.*, 2002.
Ethanol from Wood Residues	32.4 MM gal/year	500,036 dry tons	BBI International, 2002.
Biodiesel from Soybeans	13.0 MM gal/year	9,000,000 bushels	English *et al.*, 2002.
Biodiesel from Yellow Grease	10.00 MM gal/year	80,000,000 pounds	Fortenberry, 2005.
Horizontal Axis Wind Turbine Power Plant	131,400,000 kWh/year	NA	Electric Power Research Institute and BBF Consult., 2004.
Solar Thermal Technology (Parabolic Trough)	700,800,000 kWh/year	NA	Electric Power Research Institute and BBF Consult., 2004.
Utility Scale Solar Photovoltaic Power Plant (One-Axis Tracking)	438,000,000 kWh/year	NA	Electric Power Research Institute and BBF Consult., 2004.
Wood Fired Power Plant	219,000,000 kWh/year	110,500 dry tons	Electric Power Research Institute and BBF Consult., 2004.
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 *et al.*, 2004.
Co-fire (10%) of Cattle Feedlot Biomass with Coal (Feedlot Size 45,000 head)	137,313,000 kWh/year	NA	Sweeten *et al.*, 2002; English *et al.*, 2004.
Landfill Gas	34,457,555 kWh/year	NA	US Environmental Protection Agency, 2005.
Warm Climate Methane Digester for Swine (4,000 Sow Farrow to Wean Pig with Pit Recharge)	438,000 kWh/year	NA	Moser *et al.*, 1998.
Cool Climate Methane Digester for Swine (5,000 Sow Farrow to Finish Operation)	525,600 kWh/year	NA	McNeil Technologies, Inc., 2000.
Methane Digester for Dairy (1,000 head)	1,080,000 kWh/year	NA	Nelson and Lamb, 2002.
Methane Digester for Poultry (40,000 head)	438,000 kWh/year	NA	Moser *et al.*, 1998.

MM = million
NA = not available