25% Renewable Energy for the United States By 2025: Agricultural and Economic Impacts

25x'25

by

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Executive Summary

This study was designed to determine the feasibility of America's farms, forests and ranches providing 25 percent of U.S. total energy needs while continuing to produce safe, abundant and affordable food, feed and fiber. In addition, the analysis looks at the associated impacts of achieving the goal on the agricultural sector and the nation's overall economy. The 25x'25 Project Steering Committee established the "25x'25" vision and, along with Energy Future Coalition and the Energy Foundation, financed the study. The analysis was conducted by a team of professors and analysts from the University of Tennessee (UT) during 2005-2006

According to the U.S. Dept. of Energy (DOE), estimated energy use in 2005 was 100.5 quads. Based on DOE estimates and a recent RAND study, the nation will annually consume about 117.7 quads of energy by 2025. A quad is a quadrillion BTUs. To put a quad in perspective, about 4.4 million households would consume a quad of energy through electricity and gasoline use in one year.

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. Based on 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.

A second scenario examining the impacts of producing 25% of the nation's electric power and motor vehicle fuels (hereafter the "EPT" scenario) was also performed, to parallel the findings of the RAND report. This scenario produced smaller benefits than the "All Energy" case, with smaller effects on land use and feed crop prices.

Key findings in this analysis:
- **America's farms, forests and ranches can play a significant role** in meeting the country's renewable energy needs.

- **The 25x'25 goal is achievable**. Continued yield increases in major crops, strong contributions from the forestry sector, utilization of food processing wastes, as well as the use of over one hundred million acres of dedicated energy crops, like switchgrass, will all contribute toward meeting this goal. A combination of all of these new and existing sources can provide sufficient feedstock for the additional 15.45 quads of renewable energy needed.

- **The 25x'25 goal can be met while allowing** the ability of the agricultural sector to reliably produce food, feed and fiber at reasonable prices.

- **Reaching the goal would have an extremely favorable impact on rural America and the nation as a whole**. Including multiplier effects through the economy, the projected annual impact on the nation from producing and converting feedstocks into energy would be in excess of $700 billion in economic activity and 5.1 million jobs in 2025, most of that in rural areas.

- **By reaching the 25X'25 energy goal**, **the total addition to net farm income could reach $180 billion**, as the market rewards growers for producing alternative energy and enhancing

our national security. In 2025 alone, net farm income would increase by $37 billion compared with USDA baseline projections.

- **Reaching the goal would also have significant positive price impacts on crops.** In the year 2025, when compared with USDA baseline projections, national average per bushel crop prices are projected to be $0.71 higher for corn, $0.48 higher for wheat, and $2.04 higher for soybeans.

- **With higher market prices, an estimated cumulative savings in government payments of $15 billion could occur**. This does not include potential savings in fixed/direct or Conservation Reserve Program (CRP) payments.

- **In the near term, corn acres are projected to increase**. As cellulosic ethanol becomes commercially viable after 2012, the analysis predicts major increases in acreage for a dedicated energy crop like switchgrass.

- **The higher feed crop prices do not result in a one-to-one increase in feed expenses for the livestock industry**. Increases in ethanol and biodiesel production result in more distillers dried grains (DDG's) and soybean meal, which partially compensate for increased corn prices. Moreover, the integrated nature of the industry allows for the adjustment of animal inventories as a way to adjust to the environment and increase net returns. In addition, the production of energy from manure and tallow could provide additional value for the industry.

- **Contributions from America's fields, farms and forests could result in the production of 86 billion gallons of ethanol and 1.2 billion gallons of biodiesel**, which has the potential to decrease gasoline consumption by 59 billion gallons in 2025. **The production of 14.19 quads of energy from biomass and wind sources** could replace the growing demand for natural gas, diesel, and/or coal generated electricity. These renewable energy resources could significantly decrease the nation's reliance on foreign oil, fossil fuels, and enhance the national security of all Americans.

Methodology:

This type of cutting-edge research on the economics of alternative energy required the UT to combine two computer models in order to provide a comprehensive outlook at both the agricultural sector and the national and state economic impacts. A computer simulation model, POLYSYS, and an input-output model, IMPLAN, were used for the study. POLYSYS has been used for a number of national agricultural studies that require projections on the impacts on agricultural acreages and production by U.S. Agricultural Statistical Districts as the result of federal farm policy changes. IMPLAN contains state level input-output models that provide an accounting of each state's economy.

Forest residues, mill wastes and small diameter feedstock (from thinning forests to reduce fuel for fires) comprise the woody biomass feedstocks evaluated in the study. The nation has over 400 million acres of privately owned forest land, with over 40 million of these acres in plantation forests. This forest resource could provide additional woody feedstocks. A study focusing on these additional feedstocks should be conducted.

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I. Introduction

This study was designed to determine the feasibility of America's farms, forests and ranches providing 25 percent of U.S. total energy needs while continuing to produce safe, abundant and affordable food, feed and fiber. In addition, the analysis looks at the associated impacts of achieving the goal on the agricultural sector and the nation's overall economy. The 25x'25 Working Group established the "25x'25" vision and, along with Energy Future Coalition and The Energy Foundation, financed the study. The analysis was conducted by a team of professors and analysts from the University of Tennessee (UT) during 2005-2006

Several policy initiatives to spur the development and use of bioenergy and bioproducts using starch, cellulose, oil, etc., have been enacted in recent years.

- President Bill Clinton signed Executive Order 13134 calling for tripling the use of bioproducts and bioenergy in the U.S. by 2010. The Agricultural Risk Protection Act of 2002 provided for the research and development of biobased industrial products.

- The Farm Security and Rural Investment Act of 2002 established, among other provisions, a Federal agency program to purchase bioproducts, provide biorefinery grants to support development of bioproducts and fuels, extend the termination date of the Biomass Research and Development Act of 2000, and expand the feedstocks list for use of Commodity Credit Corporation (CCC) payments to eligible producers to purchase biomass feedstocks.

- President George Bush signed the Energy Policy Act of 2005, encouraging the development of more renewable energy and expediting the development of environmentally responsible renewable energy projects on federal lands. In addition, the Act established a renewable fuel requirement for the nation, mandating 7.5 billion gallons of renewable fuels by 2012. Ethanol and biodiesel were defined as eligible renewable fuels.

- In 2006, U.S. Secretary of Energy Samuel Bodman set a goal of making cellulosic ethanol a practical and cost-competitive alternative by 2012 (at $1.07/gal) and displacing 30 percent (60 billion gallons) of gasoline by 2030.

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. This approach accounts for the identification and adoption of short-term requirements that a market or policy incentive mechanism must meet for agriculture to remain a reliable source of feedstocks for bioenergy without imposing significant costs to consumers.

Agriculture is uniquely positioned among the current renewable energy sources (Figure 1) 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 (Figure 2) 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.
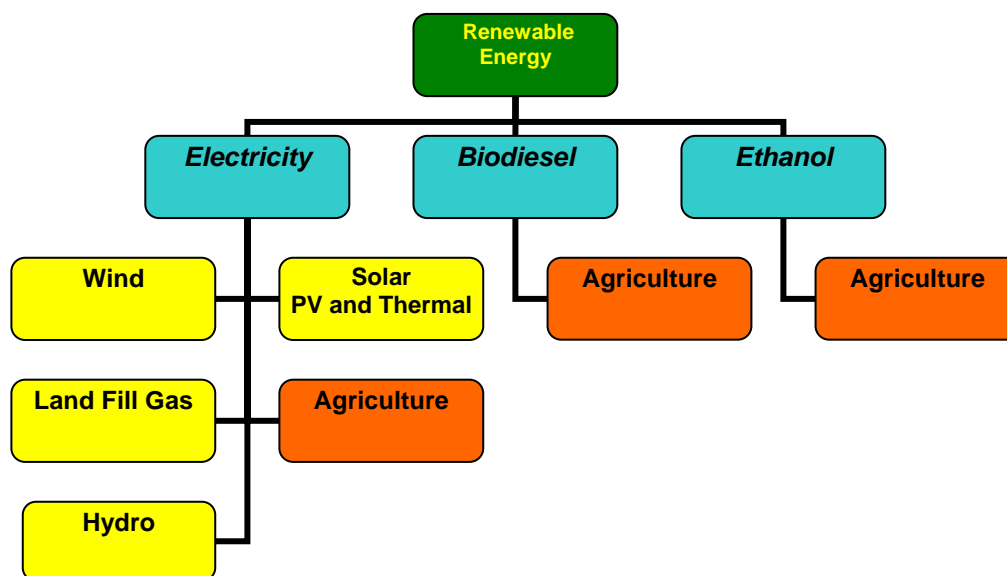
Figure 1. Renewable Energy Sources.
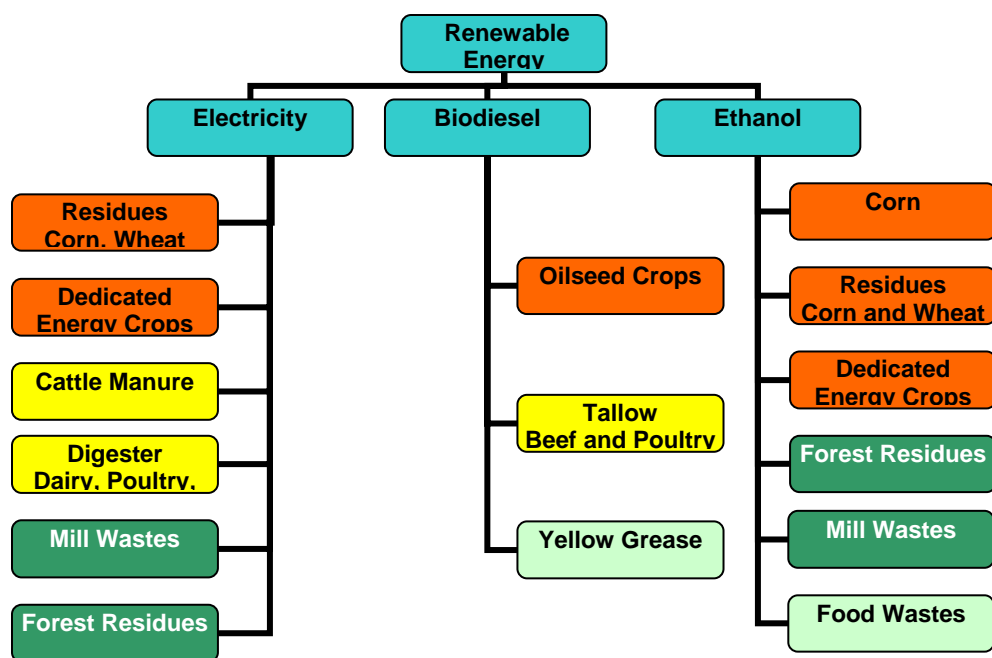
Figure 2. Bioenergy Sources.

Increasing renewable energy to meet 25 percent of the nation's energy needs 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.

II. Objectives

The goal of this study was 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 was 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 was 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.

III. Methodology

The methodology, schematically displayed in Figures 3 and 4, responds to the need to perform an in-depth analysis of the agricultural sector's ability to be a significant source of energy. Figure 3 is a schematic of the process to achieve the first objective that 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 POLYSYS 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 second diagram, Figure 4, reflects the process to estimate the overall economic impacts of producing renewable energy, from agricultural feedstock but also from solar and wind sources. 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.
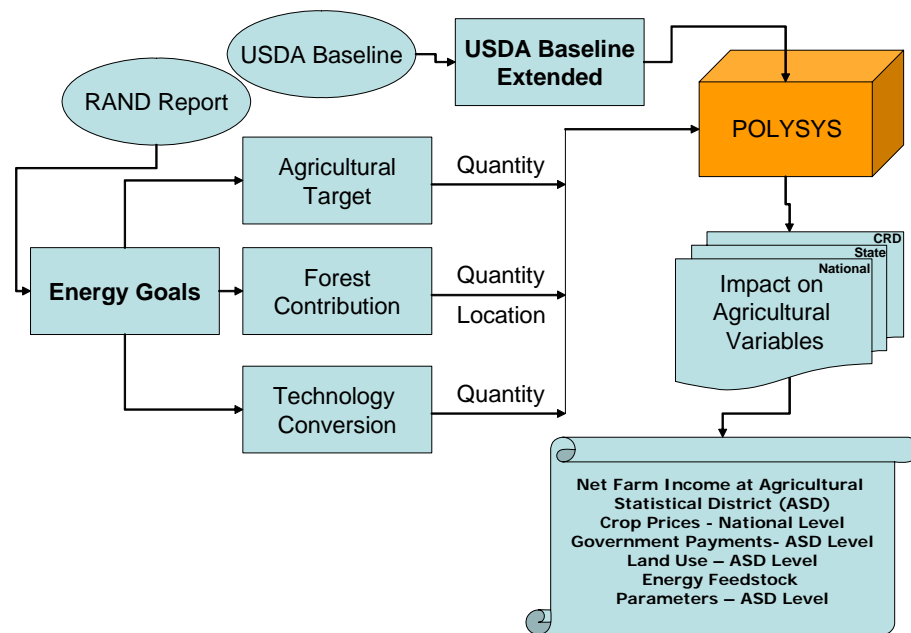
Figure 3. Process for Definition of Renewable Energy Targets and Impacts on Agricultural Variables.
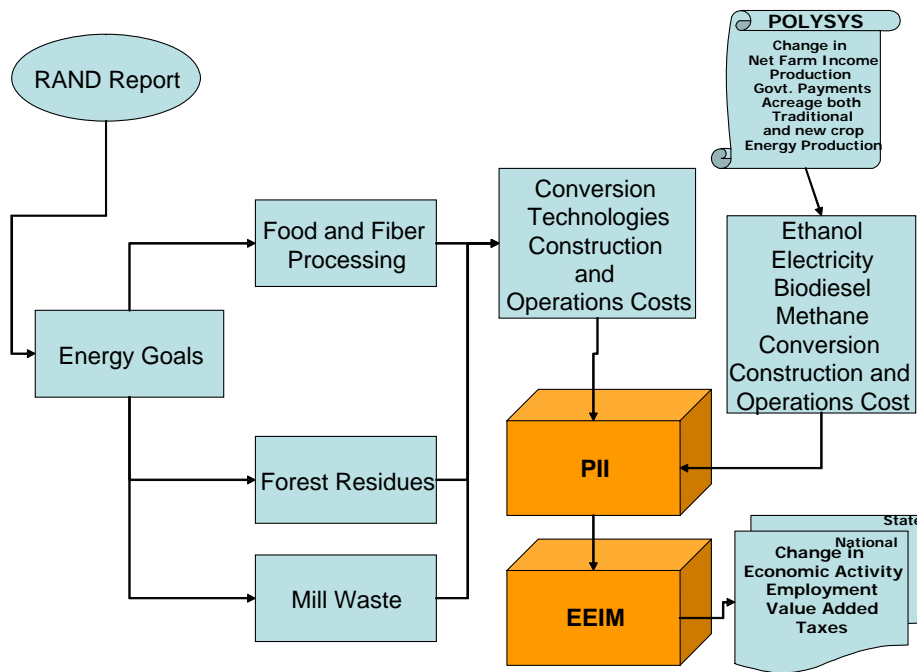
Figure 4. Process to Estimate the Economic Impacts of Producing Renewable Energy.

From the diagrams it is clear that 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.

There are four major methodological steps before the analytical tool kit can be utilized to obtain the estimates defined in the objectives. These are:

1. **Renewable Energy Goals**-Definition of renewable energy goals, including bioenergy,

2. **Conversion Technologies**-Collection of the data on the conversion technologies available,

3. **POLYSYS**-Update and expansion of POLYSYS, and

4. **PII/IMPLAN**-Update and expansion of PII to modify IMPLAN.

3.1. Renewable Energy Goals

3.1.1. Overall Goals

The Energy Information Administration (EIA) projected in its 2006 *Annual Energy Outlook* the amount of energy that will be needed annually through the year 2030 (DOE, 2006). The analysis indicates that by 2025, 126.99 quadrillion BTUs of energy (quads) will be needed to meet demand, with 9.6 quads of energy coming from renewable resources (Table 1).

In 2004, there were 6.02 quads of energy produced from renewable resources of which about 1.87 quads are derived from biomass feedstocks. In addition, there was some non-marketed energy use. However, since non-marketed energy use is not estimated by EIA, it is not included in this analysis.

Table 1. Total Energy and Renewable Energy Consumption Projections Through the Year 2025.

	2004	2010	2015	2020	2025
			Quads		
Total Energy Consumption	99.68	107.87	114.18	120.63	126.99
Marketed Renewable Energy-Base Case[a]	6.02	7.73	8.30	8.96	9.60

[a] Includes ethanol production of 0.23 in 2003, 0.28 in 2004, 0.66 in 2010, 0.87 in 2015, 0.96 in 2020, and 1 quad in 2025.
Source: DOE, 2006.

By the year 2025, EIA projects that electric power and motor vehicle fuels will account for 81.62 quads, or 64% of primary energy use. Thus, 20.41 quads of renewable energy would be required to supply 25% of that demand. A recent report by the RAND Corporation (RAND, 2006) analyzed the impact of such a shift on net U.S. energy expenditures.

Table 2. Sectoral Energy Projections.

Sector	2004	2010	2015	2020	2025
			Quads		
Residential	21.04	22.99	24.07	25.17	25.88
Commercial	17.37	19.51	21.23	23.02	24.82
Industrial	33.27	34.46	35.60	36.95	38.77
Transportation	28.00	30.90	33.29	35.50	37.52
Total	99.68	107.87	114.18	120.63	126.99
Electric Power	38.67	42.82	45.38	48.24	50.86
Motor Vehicle Fuels	22.84	25.15	27.02	28.86	30.76
Total	61.51	67.97	72.40	77.10	81.62

Source: DOE, 2006

In addition to biofuels used in transportation, the renewable resource portfolio includes residential wood use, commercial and industrial biomass, electric power generated from hydroelectric, geothermal, biomass (either through co-fired or dedicated plants), solar thermal

and photovoltaic, and wind. Table 3 contains EIA's estimates of renewable energy production in the reference case scenario.

Table 3. Renewable Energy Consumption by Sector and Source.

	2005	2010	2015	2020	2025
			Quads		
Residential (wood)	0.40	0.44	0.43	0.43	0.42
Commercial (biomass)	0.09	0.09	0.09	0.09	0.09
Industrial	1.59	1.79	1.90	2.01	2.14
Conventional Hydroelectric	0.04	0.04	0.04	0.04	0.04
Municipal Solid Waste	0.01	0.01	0.01	0.01	0.01
Biomass	1.53	1.74	1.84	1.96	2.09
Transportation	0.23	0.66	0.87	0.96	1.00
Ethanol used in Gasoline Blending	0.23	0.65	0.87	0.95	0.99
Electric Power	3.62	4.76	5.01	5.47	5.95
Conventional Hydroelectric	2.77	2.98	2.99	2.99	2.99
Geothermal	0.30	0.39	0.57	0.92	1.33
Municipal Solid Waste	0.30	0.33	0.35	0.36	0.37
Biomass	0.12	0.52	0.52	0.57	0.58
Dedicated Plants	0.12	0.11	0.10	0.14	0.24
Cofiring	0.00	0.41	0.42	0.43	0.34
Solar Thermal	0.01	0.01	0.01	0.02	0.02
Solar Photovoltaic	0.00	0.00	0.00	0.00	0.00
Wind	0.11	0.52	0.58	0.62	0.65
Total Marketed Renewable Energy	5.93	7.73	8.30	8.96	9.60

Source: DOE, 2006

This study assessed the potential contribution of biomass feedstocks from agricultural sources such as those from traditional crops (corn and soybeans), energy crops such as switchgrass, and agricultural byproducts (corn stover, wheat straw, animal waste and fats, forest residues, mill wastes, and food processing wastes). Not included was an assessment of wood harvested for energy use.

Other sources of renewable electricity include energy derived from geothermal, solar photovoltaic, hydroelectric power, and wind. The RAND study projects 2.08 quads of energy for geothermal, 0.69 quads from solar photovoltaic, 4.04 quads from wind, and 3.10 quads from hydro (Table 4).

The RAND analysis also assessed the use of biomass for electric power generation and for the production of motor vehicle fuels (ethanol and biodiesel), concluding that 5.64 quads and 5.92 quads, respectively, would be consumed for each purpose. Combined with 9.91 quads from other renewable electricity sources, this would bring total renewable energy use in the U.S. in 2025 to 21.47 quads. Because the displacement of coal-based electricity has a ripple effect – two-thirds of the energy in coal is lost in making electric power – the economy needs less total energy in the RAND scenario, 117.7 quads with 81.62 quads alone required meeting electric power and transportation needs.

Table 4. Selected Renewable Energy Projections.

	RAND	2006 EIA Base Case
	Quads	
Geothermal	2.08	1.33
Solar Photovoltaic	0.69	0.00
Solar Thermal	0	0.02
Wind	4.04	0.65
Hydro	<u>3.10</u>	<u>3.03</u>
Total	9.91	5.03

Therefore, two renewable energy goals are evaluated in this analysis based on RAND projections. The first goal is meeting 25 percent of the total projected energy of 117.7 quads (All Energy (AE) Scenario) with renewable energy. The second goal is meeting 25 percent of the electric power and transportation (EPT Scenario) needs of 81.62 quads with renewable energy.

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.

3.1.2. The Contribution of Biomass

The purpose of this study was to assess 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, therefore, was to evaluate the ability of production agriculture to contribute to this goal.

The RAND analysis concluded that biomass could contribute 11.56 quads of energy by 2025, but did not assess the impact of that level of consumption on the agricultural sector. This study attempts to maximize production of biomass for energy without distorting agricultural markets. To achieve the objectives of this study, a single crop is chosen as a model dedicated energy crop. The selection of this crop was based on information developed over several decades by the Department of Energy at national laboratories such as the Oak Ridge National Laboratory. In 1975, the Department of Energy initiated a feedstock program. The initial decade of this program focused on short rotation woody crops. In 1983, the program began focusing on herbaceous crops. Following a set of experiments, the program, for a number of reasons (i.e., native grass, high productivity, and adapted to a large growing area of the United States), decided to focus on switchgrass in 1993.

Switchgrass is a perennial native grass that has a large native range. Switchgrass can be grown from Colorado to the East Coast of the U.S. and from the Gulf Coast into Canada. Switchgrass yields in some areas can exceed 10 tons per acre and does not require large amounts

of inputs. Other crops such as Hybrid Poplar, Energy Cane, Giant Reed, Giant Miscanthus, and Napier Grass could provide higher yields at a lower cost in some areas of the country.

Forest residues, wood from fuel reduction forest management practices, and mill wastes are included in the analysis (Figures 5-7). However, the potential for forestry is understated in this analysis. Standing timber is not incorporated into the potential supplies of cellulosic materials. The nation has over 400 million acres of privately owned forest land, with over 40 million of these acres in plantation forests. This forest resource could provide additional woody feedstocks.

In the South, where pulpwood stumpage fees are on the decline and an additional market for these managed forests is being sought, this acreage will likely play a role in meeting the nation's renewable energy needs. With 33 percent of the United States' land area in forests and with 58 percent of the forest land in non-industrial private land ownership, the use of that land for energy conversion would impact the degree of change in crop acreages and, no doubt, other study outcomes.

More than 30 percent of the pines under private ownership in the South are planted pines. With state of the art silviculture, managed stands can produce three cords per acre per year, or approximately eight tons per acre per year. On stands that are managed intensively with advanced tree improvements, vegetative control and fertilizers, the level of output can perhaps be doubled (Haney, 2006). If planted forests were used, this could double the forest feedstock contribution toward meeting the goal.
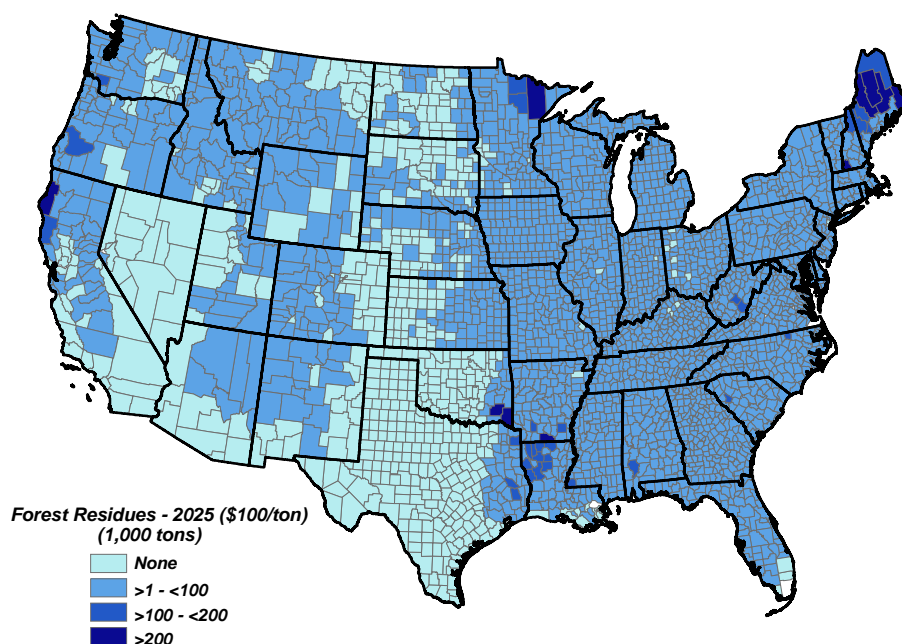
Figure 5. Location of Forest Residues Used in the POLYSYS Model.

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Mill Residues - 2025 ($100/ton)
(1,000 tons)

- None
- >1 - <100
- >100 - <200
- >200 - <500
- >500
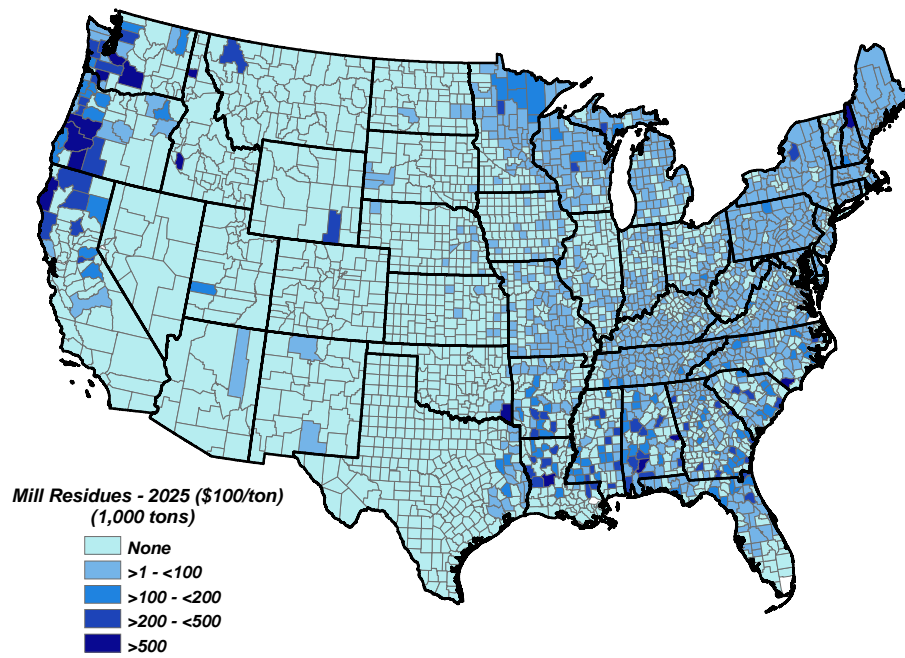
Figure 6. Location of Mill Wastes Used in the POLYSYS Model.

Forest Thinnings
(1,000 tons)

- None
- >1 - <100
- >100 - <200
- >200
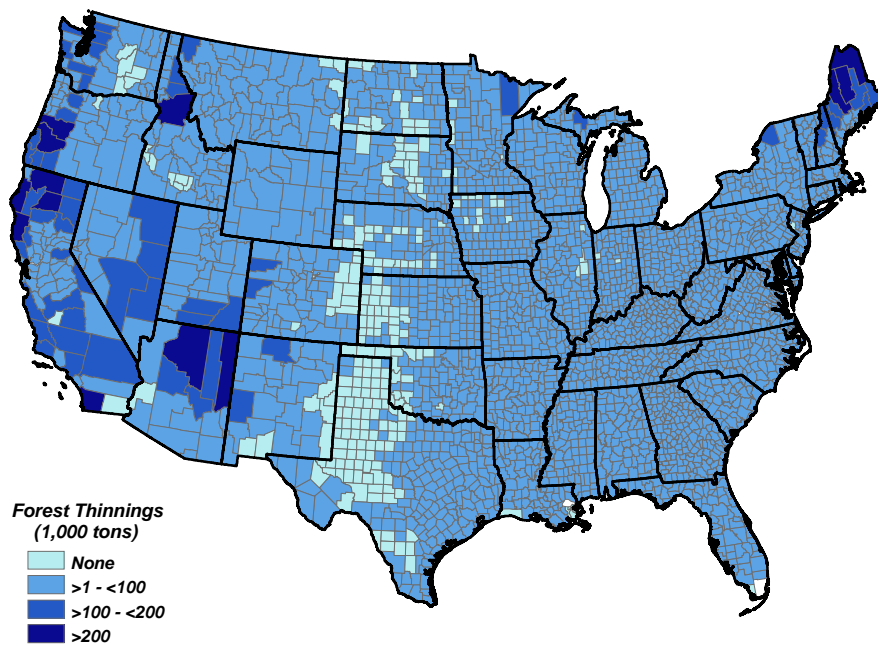
Figure 7. Location of Forest Thinnings and Fuel Treatments Used in the POLYSYS Model.

3.2. Conversion Technologies

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 Table 5, while detailed examples for each conversion technology are presented in Appendix A. The projections of electricity generation for the representative facilities contained in Appendix A are not adjusted with capacity factors. However, these adjustments were made in the model.

Detailed illustrations of the renewable technologies used in this analysis are presented in Appendix A. Example energy prices are used in calculating Total Industry Output in each of the appendix tables. Total Industry Output (TIO), an IMPLAN term, represents the annual dollar value of production of an industry. It is calculated using energy price multiplied by the facility's production (for example, price of ethanol per gallon x the gallon capacity of the plant). It should be noted that these are merely examples.

For the IMPLAN calculations, state energy prices are used. In the actual state-by-state analysis, electricity prices vary by state. The state electricity average prices per kWh used in the actual analysis are from the Department of Energy's Annual Electric Industry Power Database for 2004 (DOE, 2004). State averages of ethanol and biodiesel were developed from several sources. For ethanol, where splash prices were available, the state average price per gallon was taken. For states where the average was not available, the average of the states in the region is used. For regions where data were not available, the average of nearby regions is used. For states where the spot was available, but not rack, the spot is multiplied by 1.04, which is the average ratio of rack to spot prices for certain available cities (OPIS, 2005).[1] The same procedure was used for estimating state-by-state wholesale prices for B-100. The price data are for April 2005.

Cellulosic feedstock costs for ethanol presented in Appendix A are assumed to be $30.00 per ton. This is for illustrative purposes only since POLYSYS will provide the estimated prices used in the analysis. Likewise, for co-firing of cellulosic residues with coal, the feedstock cost is for corn stover and would change if wheat, rice, switchgrass, forest, poplar, mill, and urban residues were used.

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[1] Rack price is the wholesale price at the point of primary storage. Spot price is the current value of a product on a volume basis at a given market. Splash price is a rack price sold in small quantities.

Table 5. 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

Table 5. 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 (40,000 head)	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.

3.3. POLYSYS

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 presented in Appendix B.

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 bioproducts module which fills exogenous demands from the feedstock sources. The bioproducts module captures the dynamics of corn grain and cellulosic feedstocks competing to fill ethanol demand by using a searching by iteration method to find the optimal allocation of feedstocks to satisfy these demands.

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 8). Of this 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.

**Private Land Base
938 Million Acres**

**Total Cropland
434 Million Acres**

Private Land Base legend:
- Cropland
- Pasture/range
- Woodland
- Other

Values: 76, 33, 434, 395

Total Cropland legend:
- POLYSYS Planted Cropland
- Cropland Pasture
- CRP
- Other

Values: 33, 34, 61, 307
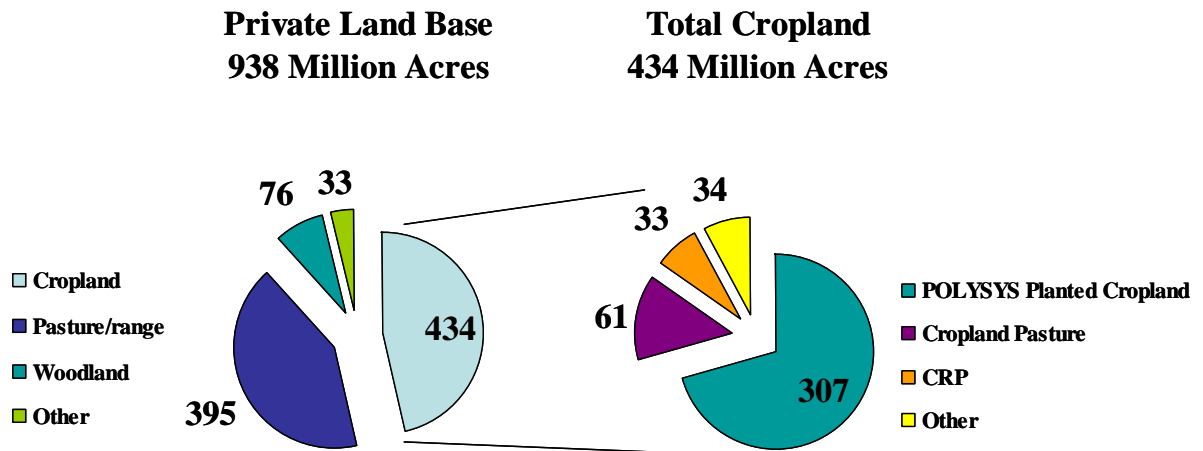
Source: USDA, National Agricultural Statistical Service, 2004.

Figure 8. Land Use by Major Use Category, 2002.

3.3.1. Crop Supply Module

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.

Regional baseline acreage is anchored to a national baseline, which is disaggregated to a regional level based on historical crop production and supply patterns. Once the total acreage available for crop production in each ASD is determined, the supply module allocates acres to competing crops using a linear programming model that maximizes expected returns using the previous year's estimated prices.

Production from each of the 305 ASDs is determined independently and aggregated to obtain national production. Allocation rules are utilized to limit the acreage that can switch from production of one crop to another or removed from production in each ASD. These allocation rules simulate the inelastic nature of agricultural supply. 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).

In regions where switchgrass is determined to be profitable, some pasture can be made available to both switchgrass and any other crop. Additionally, in order for pasture acreage to come into production, the loss of regional forage production must be replaced with new regional

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hay production. The Agricultural Census of 2002 (USDA, 2004) lists 61 million acres as "crop acreage in pasture". This application makes these lands available to be converted into other crop production. A condition for this to occur is that hay acreage must replace the lost forage productivity regionally of the lost pasture acreage. Regional pasture yields are taken from English, et al, 1989. For each region annually, the amount of pasture that can potentially switch into other crops is determined by:

$$P_{out} = \%H_{avail} * H_{acres} * H_{yield} / P_{yield}$$
$$H_{in} = P_{out} * P_{yield} / H_{yield}$$
$$NG_{pot} = P_{out} - H_{in}$$

where:

P_{out} is the amount of pasture that can come out of pasture if available,
$\%H_{avai}$ is the percentage of current hay total acreage that can expand,
H_{acres} is the current hay total acreage,
H_{yield} is the yield per acre of hay,
P_{yield} is the yield per acre of pasture,
H_{in} is the acres of hay that will come in to replace $P_{out,}$ and
NG_{pot} is the potential net gain in acreage.

The actual net gain in land available to other crops from pastureland is constrained through several mechanisms: 1) only pasture classified as historical cropland is available, 2) pasture can only come in at the rate at which hay acreage can grow, 3) hay lands must replace lost forage production at regional hay yield levels, and 4) there must be a crop with positive net expected income to absorb the new land available. Through this filtering process, substantially less than the 56 million acres of "crop acreage in pasture" actually comes into production and less still into production of other crops besides hay.

3.3.2. Crop Demand Module

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, 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 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, cash receipts, production expenses, government outlays, net returns, and net realized farm income are expressed in nominal terms through 2015. Beyond 2015, these variables are expressed in 2015 dollars.

3.3.3. Livestock Module

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. Livestock production levels are a function of lagged livestock and feed own and cross prices, as well as the

baseline levels and exogenously determined variables such as livestock exports. The livestock sector is linked to the supply and demand modules principally through the feed grain component. Livestock quantities affect feed grain demand and price, and feed grain prices and supply affect livestock production decisions. Exports and imports of livestock products are exogenous to the model.

3.3.4. Biomass Feedstock Sources

3.3.4.1. Switchgrass

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.

In this application, switchgrass is not available in the first two years of simulation. Currently, in the United States, switchgrass is not produced as a dedicated energy feedstock, although it is grown on some CRP acres and on hay acres as a forage crop. The lack of large-scale commercial production and the lack of switchgrass seed necessitates a lag time before switchgrass can become a feedstock for ethanol or other bioproduct production. A minimum of two years to begin large scale switchgrass production is assumed.

Switchgrass expected prices are a function of one year lagged market prices. Once planted, the expected yields for switchgrass remain fixed for the life of the production rotation. Also, once acres are planted into switchgrass, they remain in switchgrass through the end of the simulation.

3.3.4.2. Crop Residues

To evaluate the potential of crop residues to provide feedstocks to the bioproduct markets, POLYSYS includes corn stover and wheat straw response curves that estimate stover and straw quantities (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).

The choice of whether residues are harvested from a particular county is determined by figuring the difference between the cost of collecting residues to the edge-of-field and the market revenue generated. If positive, the residues are harvested from all county corn or wheat acres. Expected prices are current year residue prices. Current year prices are used because the choice to harvest residues can be made on already planted acres.

3.3.4.3. Wood Residues

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.

3.3.4.4. Animal Manure

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.

3.3.4.5. Yellow Grease

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.

3.3.5. Optimal Feedstock Allocation

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 9 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

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grain is used to figure a corresponding price for biomass that would produce ethanol at the equivalent price. The corresponding price of biomass is derived by the following equation:

$$CORPRC_{biomass} = (Pcorn / TECH_{corn} + CONV_{corn} - CONV_{biomass}) * TECH_{biomass}$$

Where:

$CORPRC_{biomass}$	is the corresponding price of biomass,
P_{corn}	is the price of corn grain,
$TECH_{corn}$	is gallons of ethanol per bushel of corn grain,
$CONV_{corn}$	is the conversion cost of corn grain to ethanol per gallon,
$CONV_{biomass}$	is the conversion cost of biomass to ethanol per gallon, and
$TECH_{biomass}$	is the gallons of ethanol per dry ton of biomass.
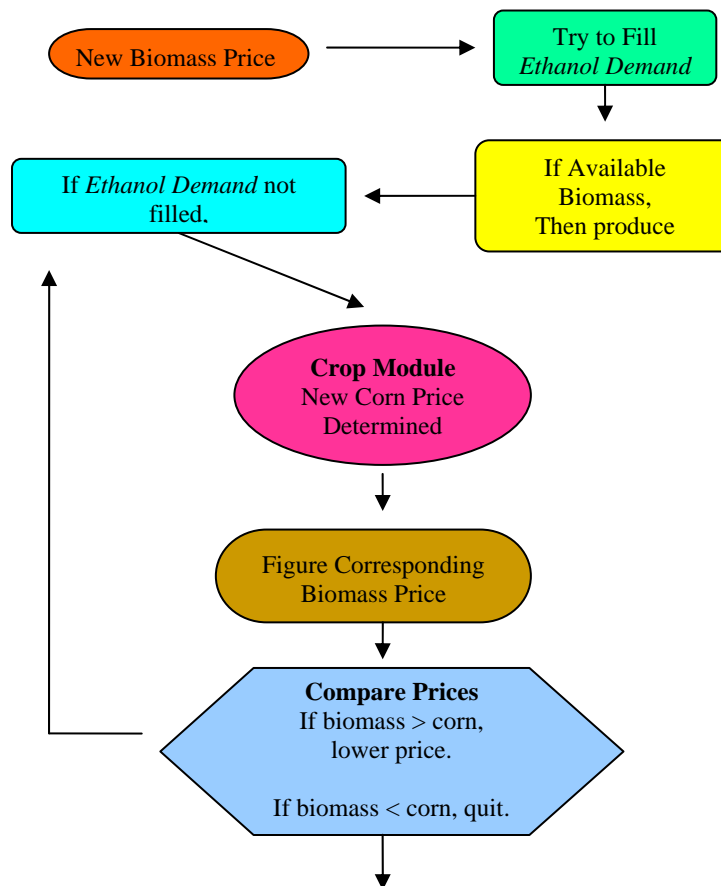
Figure 9. Schematic of the Methods Employed to Determine Feedstock Price Required to Meet Energy Demand.

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 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. But if biomass price can continue to drop below the corresponding corn price and still fill ethanol demand, it is allowed to do so. In this situation, corn grain use for ethanol cannot fall below the previous year's use. This results in biomass filling all increases in ethanol production because it can produce ethanol cheaper than corn grain.

Because ethanol is the dominate bioproduct that can use either biomass or corn grain, its feedstock allocation determines market prices. In instances where the iterative solution results in a price that brings in slightly more biomass than is necessary to fill ethanol demand, the excess is used in electricity production.

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.

Credit from the market revenue of DDG's to the production of ethanol reduced total production costs of ethanol. The market price of DDG's is estimated by the following equation:

$$DDG_{prc} = 22.7 + 30.80 * (Corn_{prc})$$

$$(R^2 = .96)$$

Where:
DDG_{prc} is the price per ton of distillers dry grains, and
$Corn_{prc}$ is the price per bushel of corn grain.

For every bushel of soybeans (60 pounds) used in biodiesel production, 45.5 pounds of soybean meal are produced. The soybean meal byproduct enters into the POLYSYS soybean product module where price are endogenously determined. The revenue from the sale of soybean meal is credited to the production of biodiesel and acts to reduce the total production costs.

3.3.6. Conversion Costs and Coefficients

The conversion costs and technical coefficients used in the model are listed in Table 6. Full documentation of sources or estimation of the data through 2015 can be found in our previous document for the NRI entitled, *Economic Implications to the Agricultural Sector of Increasing the Production of Biomass Feedstocks to Meet Biopower, Biofuels, and Bioproduct Demands* (De La Torre Ugarte et. al., 2006).

A few technical improvements are assumed for the extension through 2025. Conversion coefficients of cellulose to ethanol were increased linearly for stover, straw and switchgrass from 2015 to 2025 to final coefficients of 87.9, 83.2 and 90.2 gals per ton respectively. The conversion of corn grain to ethanol is assumed to increase from 2.7 gals per bushel in 2014 to 3.0 gals per bushel in 2019, and thereafter remain steady. Biodiesel is also assumed to increase from 1.4 gals per bushel in 2014 to 1.5 gals per bushel in 2019 and thereafter remain steady.

Wood residue is also added as a feedstock for conversion to electricity and ethanol. Wood residue technical coefficients were derived by adjusting switchgrass coefficients by the difference in BTU content. The ratio of switchgrass to wood BTU content is assumed at 1.0625.

3.4. PII / IMPLAN

3.4.1. IMPLAN

IMPLAN employs a regional social accounting system and can be used to generate a set of balanced economic/social accounts and multipliers (MIG, 2006). The social accounting system is an extension of input-output analysis[2]. The model uses regional purchase coefficients generated by econometric equations that predict local purchases based on a region's characteristics. Output from the model includes descriptive measures of the economy including total industry output, employment, and value-added for over 500 industries in state's economy. Total industry output is defined as the value of production by industry per year. Total industry output and value added are expressed in 2005 dollars.

The model also can be used for predictive purposes, by providing estimates of multipliers. Multipliers measure the response of the economy to a change in demand or production. Multiplier analysis generally focuses on the impacts of exogenous changes on: a) output of the sectors in the economy, b) income earned by households because of new outputs, and c) jobs that are expected to be generated because of the new outputs. The notion of multipliers rests upon the difference between the initial impact of an exogenous change in final demand (final use and purchases of goods and services produced by industries) and the total impacts of the change.

Direct impacts measure the response of a given industry to a change in final demand for the industry. Indirect impacts represent the response by all industries in the economy to a change in final demand for a specific industry. Induced impacts represent the response by all industries in the economy to increased expenditures of new household income and inter-institutional transfers generated from the direct and indirect impacts of the change in final demand for a specific industry.

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[2] Input-output (I-O) analysis, also know as inter-industry analysis, is the name given to an analytical work conducted by Wassily Leontief (1936) in the late 1930's. The fundamental purpose of the I-O framework is to analyze the interdependence of industries in an economy through market-based transactions.

Table 6. Baseline Conversion Costs and Technical Coefficients.

Conversion Costs	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Biomass to Elect($/KWH)*	0.0036	0.0035	0.0035	0.0034	0.0033	0.0033	0.0033	0.0032	0.0032	0.0032
Biomass to Ethanol ($ per gal)	1.398	1.324	1.249	1.175	1.101	1.027	0.953	0.878	0.804	0.730
Corn Grain to Ethanol ($ per gal)	0.551	0.551	0.551	0.551	0.551	0.551	0.551	0.551	0.551	0.551
Soybeans to Biodiesel ($ per gal)	0.436	0.436	0.436	0.436	0.436	0.436	0.436	0.436	0.436	0.436
Wood to Elect($/kwh)	0.0038	0.0038	0.0037	0.0036	0.0035	0.0035	0.0035	0.0034	0.0034	0.0034
Wood to Ethanol($/gal)	1.485	1.406	1.327	1.249	1.170	1.091	1.012	0.933	0.854	0.776
Beef Cattle Manure to Elect ($/kwh)	0.0104	0.0104	0.0104	0.0104	0.0104	0.0104	0.0104	0.0104	0.0104	0.0104
Poultry Manure to Elect ($/kwh)	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080
Swine Manure to Elect ($/kwh)	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080
Dairy Manue to Elect ($/kwh)	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040

* Incremental costs associated with co-firing relative to no co-fire.

Technical Coefficients										
Electricity (Co-fire)	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Corn Stover(KWH/DT)	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494
Wheat Straw(KWH/DT)	1424	1424	1424	1424	1424	1424	1424	1424	1424	1424
Switchgrass(KWH/DT)	1532	1532	1532	1532	1532	1532	1532	1532	1532	1532
Wood(KWH/DT)	1576	1576	1576	1576	1576	1576	1576	1576	1576	1576
Ethanol										
Corn Stover(gal/ton)	69.6	70.5	71.5	72.5	73.4	74.4	75.3	76.3	77.3	78.2
Wheat Straw(gal/ton)	65.9	66.8	67.7	68.6	69.6	70.5	71.4	72.3	73.2	74.1
Switchgrass(gal/ton)	71.4	72.4	73.4	74.4	75.3	76.3	77.3	78.3	79.3	80.3
Wood(gal/ton)	73.3	74.3	75.3	76.3	77.3	78.3	79.3	80.4	81.4	82.4
Corn Grain(gal/bu)	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.8
Distillers Dried Grains(lbs/bu)	18.31	18.31	18.31	18.31	18.31	18.31	18.31	18.31	18.31	18.31
CREDITS										
stover elect from ethanol production (kwh/dt)	200	200	200	200	200	200	200	200	200	200
straw elect from ethanol production (kwh/dt)	185	185	185	185	185	185	185	185	185	185
switchgrass elect from ethanol production (kwh/dt)	210	210	210	210	210	210	210	210	210	210
Bio-Diesel										
Soybeans(gal/bu)	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.42
Oil biprod (lbs/bu)	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0
Meal biprod (lbs/bu)	45.5	45.5	45.5	45.5	45.5	45.5	45.5	45.5	45.5	45.5

Table 6 continued.

Conversion Costs	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Biomass to Elect($/KWH)*	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032
Biomass to Ethanol ($ per gal)	0.730	0.730	0.730	0.730	0.730	0.730	0.730	0.730	0.730	0.730
Corn Grain to Ethanol ($ per gal)	0.551	0.551	0.551	0.551	0.551	0.551	0.551	0.551	0.551	0.551
Soybeans to Biodiesel ($ per gal)	0.436	0.436	0.436	0.436	0.436	0.436	0.436	0.436	0.436	0.436
Wood to Elect($/kwh)	0.0034	0.0034	0.0034	0.0034	0.0034	0.0034	0.0034	0.0034	0.0034	0.0034
Wood to Ethanol($/gal)	0.776	0.776	0.776	0.776	0.776	0.776	0.776	0.776	0.776	0.776
Beef Cattle Manure to Elect ($/kwh)	0.0104	0.0104	0.0104	0.0104	0.0104	0.0104	0.0104	0.0104	0.0104	0.0104
Poultry Manure to Elect ($/kwh)	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080
Swine Manure to Elect ($/kwh)	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080
Dairy Manue to Elect ($/kwh)	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040

* Incremental costs associated with co-firing relative to no co-fire.

Technical Coefficients	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Electricity (Co-fire)										
Corn Stover(KWH/DT)	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494
Wheat Straw(KWH/DT)	1424	1424	1424	1424	1424	1424	1424	1424	1424	1424
Switchgrass(KWH/DT)	1532	1532	1532	1532	1532	1532	1532	1532	1532	1532
Wood(KWH/DT)	1576	1576	1576	1576	1576	1576	1576	1576	1576	1576
Ethanol										
Corn Stover(gal/ton)	79.2	80.2	81.1	82.1	83.1	84.0	85.0	86.0	86.9	87.9
Wheat Straw(gal/ton)	75.0	75.9	76.8	77.8	78.7	79.6	80.5	81.4	82.3	83.2
Switchgrass(gal/ton)	81.3	82.3	83.3	84.2	85.2	86.2	87.2	88.2	89.2	90.2
Wood(gal/ton)	83.4	84.4	85.4	86.5	87.5	88.5	89.5	90.5	91.5	92.5
Corn Grain(gal/bu)	2.8	2.9	2.9	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Distillers Dried Grains(lbs/bu)	18.31	18.31	18.31	18.31	18.31	18.31	18.31	18.31	18.31	18.31
CREDITS										
stover elect from ethanol production (kwh/dt)	200	200	200	200	200	200	200	200	200	200
straw elect from ethanol production (kwh/dt)	185	185	185	185	185	185	185	185	185	185
switchgrass elect from ethanol production (kwh/dt)	210	210	210	210	210	210	210	210	210	210
Bio-Diesel										
Soybeans(gal/bu)	1.44	1.46	1.48	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Oil biprod (lbs/bu)	11	11	11	11	11	11	11	11	11	11
Meal biprod (lbs/bu)	45.5	45.5	45.5	45.5	45.5	45.5	45.5	45.5	45.5	45.5

This study uses Type I and Type SAM (Social Accounting Matrix) multipliers. Type I multipliers are calculated by dividing direct plus indirect impacts by the direct impacts. Type SAM multipliers are calculated by adding direct, indirect, and induced impacts and then dividing by the direct impacts. The Type SAM multipliers take into account the expenditures resulting from increased incomes of households as well as inter-institutional transfers resulting from the economic activity. Therefore, Type SAM multipliers assume that, as final demand changes, incomes increase along with inter-institutional transfers. Increased expenditures by people and institutions lead to increased demands from local industries.

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.

Switchgrass, an energy feedstock, is not currently produced as a dedicated energy source in the United States, although it is grown on some CRP acres and on hay acres as a forage crop. The lack of large-scale commercial production results in switchgrass not being identified in the IMPLAN model. Thus, its production must be added to the IMPLAN state models if POLYSYS projects switchgrass production to occur in that particular state. This is achieved through a weighted aggregation scheme. Expenses by IMPLAN sector are summed over each region within a state and divided by total sales of switchgrass using the following equation:

$$GAC_{m,i,j} = \sum_{j=1}^{n}(COST_{i,j,k} * ACRE_{m,j,k}) / \sum_{j=1}^{n}(Q_{m,j} * P)$$

i = 1 to 48 for the number of states,
j = 1 to n for the number of ASD's with in a state,
k = 1 to 509 for the number of IMPLAN sectors,
m = POLYSYS' solution year – 2005 through 2013,

where:

$GAC_{m,i,j}$ is the gross absorption coefficient representing the amount spent in year (m) in sector (k) in state (i) per dollar of output,

$COST_{i,j,k}$ is the amount spent in IMPLAN sector (k) in state (i) and ASD (j) in dollars per acre,

$ACRE_{m,j,k}$ is the acres planted in switchgrass in state (i) and ASD (j),

$Q_{m,j}$ is the quantity of switchgrass produced in state (i) and ASD (j) in tons, and

P is the national price for switchgrass in dollars per ton.

These coefficients represented a state's biofeedstock production function and are inserted into a blank industrial sector in IMPLAN. The state model is then solved with a biofeedstock

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total industry output equaling the gross returns determined from the POLYSYS solution for each ASD aggregated to the state.

3.4.2. POLYSYS/IMPLAN Integrator (PII)

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 program, the POLYSIS/IMPLAN Integrator (PII), developed at The University of Tennessee, takes POLYSYS acreage, price, change 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.

The integrator, PII, written in Visual Basic and taking advantage of IMPLAN's data structure, provides the user a means to solve IMPLAN at the state level and determine regional economic impacts as a result of changes in agricultural production practices, policies, prices, government payments, and/or technology adoption. The resulting reports generated from the analysis summarize, via graphs and maps, the economic impacts as measured by changes in total industry output, employment, and value added. In addition, tabular information is presented for use in the analysis. For the purposes of this report, three impacts are reported: a) the impacts to the agricultural sector, b) the impacts to the renewable energy sector, and c) the impacts that occur as a result of interstate commerce. The impacts that occur from interstate commerce can not be allocated to any particular state and, consequently, the maps do not incorporate these impacts. They occur as a result of input purchases across state lines, as well as the impacts that occur as a result of a flow of income from one state to another.

3.4.2.1. Impacts to the Agricultural 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).

3.4.2.2. Impacts to the Renewable Energy Sector

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.

3.4.2.3. Impacts That Occur As A Result Of Interstate Commerce

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.

3.4.3. Scenarios

The focus of the analysis is on comparing two scenarios in which 25 percent of either AE or EPT Scenarios are met with renewable energy at improved crop yields with a scenario which extends the 2006 USDA baseline to 2025 (USDAExt). The results from the extension of the 2006 USDA baseline, USDAExt, are provided in Appendix B. Sensitivity to crop yields is investigated by evaluating the price impacts when the improved crop yield assumption is removed from EPT. Since the objective of the study is to assess agriculture's ability as energy source, no specific assumptions are made about the mechanisms to achieve the renewable energy demand. The basic purpose is to estimate the impacts to the agricultural sector and each states economy if the target is achieved.

To adequately interpret the results coming from POLYSYS, it is important to refer the simulation values to the baseline scenario (USDAExt). The baseline represents the best estimate of what would be occur without meeting the expanded energy goals. The simulation results – i.e, AE or EPT- indicate what would be the impacts of introducing the specific changes described by the scenario, leaving all other macroeconomic assumptions constant. Comparing a variable value projected by the scenario against the baseline, provides an accurate measure of the impact. In this way even if the baseline does not completely reflect what is occurring in a particular time, like corn price in December of 2006 above $3.00 per bushel, the value simulated stills provides an accurate measure of the dimension of the change with respect to the baseline situation.

3.4.3.1. AE Scenario

This scenario provides information on the impacts of meeting 25 percent of total energy requirements with renewable energy sources by the year 2025. 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, in addition to the previous discussion on how different feedstocks are included in POLYSYS, five 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 crops dedicated for bioenergy, using switchgrass as a model crop[3]. 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). The fourth assumption is augmentation of land available for crops. Finally, the fifth assumption is with respect to future yields of traditional agricultural commodities. These assumptions are discussed below.

Switchgrass Yields

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). The rates of yield increase vary regionally (Table 7). 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 7. Changes in Switchgrass Yield Assumed Through the Year 2025.

REGION	Base Yield	Annual Breeding Gains	Projected Yields 10 Years	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.

Adoption of Reduced-till and No-till Practices

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

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[3] 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.

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 8.

Table 8. 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

Augment the Landbase

A fourth assumption has to do with the availability of land. 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.

Yields of Traditional Commodities

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 9 lists the annual rate of

growth in yields under the USDAExt and the AE scenarios. The change in the annual rate of growth in yields under the AE scenario takes effect in the year 2016 and beyond.
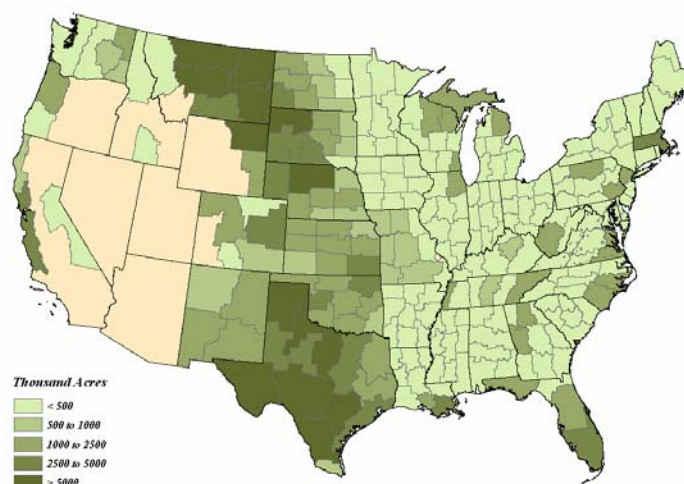
Figure 10. Location Of Pasture/Range Land Available For Conversion.

Table 9. Crop Yields under USDAExt and AE and EPT Scenarios.

Crop (unit)	Projected % Annual Growth in Yields		National Average Projected Yields Under the AE and EPT Scenarios	
	USDAExt	AE and EPT Scenarios*	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 percent increase in the rate of growth of yields over time for the AE Scenario.

This scenario provides information on the impacts of meeting 25 percent of the energy requirements with renewable energy sources by the year 2025. Pursuing the renewable energy goal will require political and commercial support to develop and establish feedstock production and conversion capabilities that will not only use corn and soybeans, but will also use cellulosic materials to generate electricity and produce ethanol.

3.4.3.2. EPT Scenario

The EPT scenario has similar assumptions as the AE scenario with the exception of land availability. In this scenario, no pasture/range lands are available for conversion and no additional land from CRP or idle lands are available. Cropland in pasture can be converted to alternative crops if the feed supplied by that pasture is supplemented through additional hay production. For this scenario, the impacts of not having increased yield growth rates on meeting the EPT goal are also investigated. Results are presented for impacts on agricultural prices and government payments.

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. Throughout the discussion of the results, comparisons will be made with USDAExt. The first section will report the projected impacts of both the AE and the EPT scenarios on agriculture. In addition, the commodity price impacts of EPT are compared with impacts assuming no increase in the yield growth rate. The second section will report on the economic impacts both at the national and state level. Both sections will report on the impacts for the simulated years of 2010, 2015, 2020, and 2025, and the information from the agricultural sector will also report the initial simulation year 2007.

4.1. Renewable Energy Production Projections

There are two energy goals incorporated into the analysis. Both the goal expressed in the EPT scenario of 20.4 quads of renewable energy by the year 2025 (Table 10), as well as the goal of 29.43 quads of renewable energy by the year 2025 as reflected in the AE scenario were achieved in the analysis. 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 10. Projected Renewable Energy Production by Feedstock Under the AE and EPT Scenarios, 2025.

Type of Energy [a]	Units	Quantity	BTU's/unit	Quads
			Billion Units	
AE:				
Ethanol	Gallons	86.9	84,600	7.35
Biodiesel	Gallons	1.1	136,000	0.15
Electricity from Biomass	kWh	962.0	8,266	7.95
Wind	kWh	606.5	10280	6.24
EPT:				
Ethanol	Gallons	87.8	84,600	7.43
Biodiesel	Gallons	1.1	136,000	0.12
Electricity from Biomass	kWh	277.0	8,266	2.29
Wind	kWh	274.8	10,280	2.83

[a] Also included in the analysis are the RAND projected levels for solar, hydro, and geothermal.

By 2025, in the EPT scenario, 9.84 Quads of energy was produced in the agricultural sector. This includes 87.8 billion gallons of ethanol, 1.1 billion gallons of biodiesel, and 277 billion kWh of electricity excluding wind (Table 11). The period of 2010-2015 corresponds to the time in which the cellulosic-to-ethanol conversion is expected to be introduced, and consequently, reflects the period of steepest relative growth. The results also indicate the relative importance of ethanol as the main bioenergy source contributing to reach the energy goal under the EPT scenario.

Table 11. Projected Bioenergy Production for the Years 2007, 2010, 2015, 2020, and 2025 Under AE and EPT Scenarios.

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**
EPT:						
Ethanol	Bil. Gallons	5.80	8.10	31.60	60.00	87.80
Biodiesel	Bil. Gallons	0.16	0.22	0.45	0.72	1.10
Electricity	Bil. kWh	87.00	89.00	148.00	231.00	277.00
Total Energy	Quads	**1.23**	**1.45**	**3.95**	**7.07**	**9.84**

Under the 25X'25 energy scenario (AE), 15.45 quads of energy are produced from our nation's agricultural lands. While ethanol production is slightly less than in the EPT goal, electricity production from cellulosic materials increases to 962 billion kWh.

4.2. 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 either the AE or the EPT goal from agriculture. It is also evident that these goals can be reached at a much lower impact on agricultural prices when yields of traditional crops increase at a rate greater than that reflected in USDAExt. Given current yield trends, continued investment in research, and expected advancements in technology, yields could substantially increase above the trend line.

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.

4.2.1. 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 11). Other sources of cellulosic feedstock contributing to overall supply are wheat straw and wood and forest residues. The Administration's Healty Forest Initiative has the potential of providing critical forestry-based feedstocks. While the contribution of soybeans represents a seven fold increase from 2007, it is a relatively minor contributor to the availability of feedstock.

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 12). 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

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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.

AE Scenario

EPT Scenario

Legend:
- ☐ Soybeans
- ☐ Corn Grain
- ■ Wood Residue
- ☐ Straw
- ■ Stover
- ■ Ded. Energy Crops
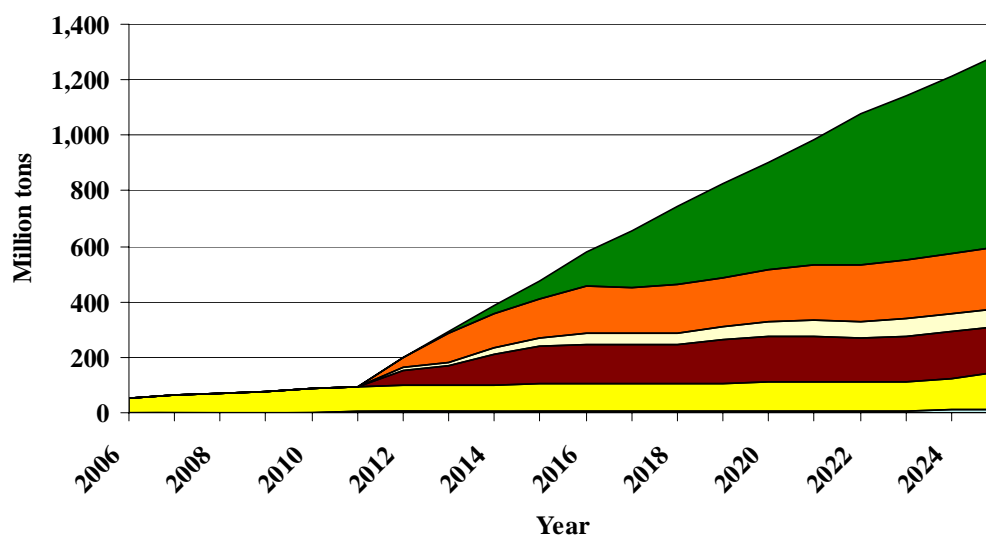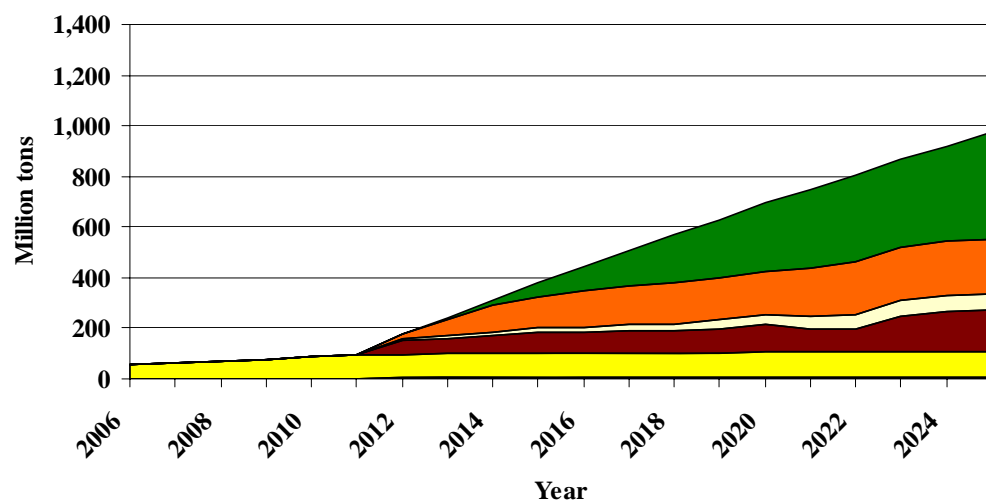
Figure 11. Total Energy Feedstock Quantities Used in the AE and the EPT Scenarios.

AE Scenario

Million Acres (y-axis: 0 to 900)

Year (x-axis): 2007, 2010, 2015, 2020, 2025

Category	2007	2010	2015	2020	2025
Idle and CRP	66.7	58.9	55.8	53.8	52.9
Ded. Energy Crop				56.8	105.8
Pasture	451.5	451.5	367.8	303.6	279.2
Hay	62.8	63.3	129.6	176.9	167.8
Wheat	58.6	58.8	58.3	54.0	49.4
Soybeans	73.4	72.2	72.2	59.1	53.3
Corn	81.9	85.4	85.2	82.9	78.7

EPT Scenario

Million Acres (y-axis: 0 to 900)

Year (x-axis): 2007, 2010, 2015, 2020, 2025

Category	2007	2010	2015	2020	2025
Idle and CRP	66.7	66.7	66.7	66.7	66.7
Ded. Energy Crop				36.8	59.2
Pasture	451.5	451.5	439.1	424.9	418.0
Hay	62.4	62.4	65.4	67.2	67.2
Wheat	58.0	57.5	57.1	53.6	49.5
Soybeans	73.3	71.3	69.3	62.5	57.3
Corn	81.0	84.9	85.6	83.8	76.7

Legend:
- Corn
- Soybeans
- Wheat
- Other Crops
- Hay
- Pasture
- Ded. Energy Crop
- Idle and CRP

Figure 12. Changes in Land Use for Selected Simulated Years under the AE and the EPT 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.

While there is no recent literature on the use of cropland for pasture, a 2005 study of producers in Tennessee reported that at about $55 per ton for switchgrass, producers would be willing to convert acreage equivalent to about 12 percent of the state's pastureland into energy dedicated crops (Jensen, et al, 2005). At about $84 per ton, the amount of acreage producers would be willing to convert to switchgrass would total over 16 percent of the state's pastureland. Furthermore, the findings from the Tennessee study suggested availability of information about energy dedicated crops expands; producers' willingness to convert acreage to switchgrass would increase. This finding suggests that as information about energy dedicated crops expands, and a bioenergy cellulosic based industry expands and becomes part of the agricultural sector, the acres of pasture will shift into dedicated energy crops.

4.2.3. 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 12). 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 both the AE and EPT scenarios are within price ranges experienced in the last decade.

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.

4.2.4. 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. Figures 13 and 14 indicate the distribution of the cellulosic feedstock production. The first map in both Figures 13 and 14 reflects no use of cellulosic feedstock occurring before 2012.

Thereafter, the other three maps 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.

Table 12. Impact on the Average Crop Price by Scenario for Selected Simulated Years.

Crop and Scenario	Projected for the Year:				
	2007	2010	2015	2020	2025
	$/bushel				
Corn:					
AE	2.13	2.76	2.62	2.67	3.17
EPT	2.21	2.83	2.77	2.48	2.78
USDAExt	2.20	2.60	2.60	2.51	2.46
EPT (without increases in yield growth rates)	2.21	2.83	2.77	2.79	4.05
Wheat:					
AE	3.06	3.13	3.32	3.83	3.94
EPT	3.10	3.27	3.66	3.85	4.00
USDAExt	3.10	3.25	3.55	3.50	3.46
EPT (without increases in yield growth rates)	3.10	3.27	3.66	3.99	5.08
Soybeans:					
AE	5.46	6.04	6.26	7.54	7.73
EPT	5.47	6.21	6.60	6.83	7.21
USDAExt	5.40	5.95	6.10	5.85	5.69
EPT (without increases in yield growth rates)	5.47	6.21	6.60	7.20	8.03
Cotton	$/pound				
AE	0.51	0.51	0.62	0.63	0.63
EPT	0.51	0.51	0.61	0.61	0.62
USDAExt	0.51	0.51	0.57	0.57	0.58
EPT (without increases in yield growth rates)	0.51	0.51	0.61	0.61	0.61
Switchgrass:	$/dry ton				
AE	0.0	0.0	46.85	60.90	81.85
EPT	0.0	0.0	36.4	40.0	55.3
USDAExt	0	0	0	0	0
EPT (without increases in yield growth rates)	0.0	0.0	36.4	40.8	55.2

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. By 2025, in both renewable energy scenarios, the Midwest portion of the country is supplying the bulk of bioenergy materials. A comparison of Figures 13 and 14 shows that the primary difference between the two renewable energy goals is the level of cellulosic feedstock production.

Within both renewable energy scenarios, nearly all regions within all states supply some cellulosic feedstock by the year 2020. Since both scenarios paint a similar picture, only maps displaying the distribution for the AE Scenario are covered in this section. By 2015, cellulosic

material is produced throughout the United States with the exception of the western most part of the Great Plains and east of the Rockies (Figure 15).

2010

2015

2020

2025

Dry Tons
- zero
- up to 500 thousand
- up to 1 million
- up to 2 million
- up to 4 million
- over 4 million
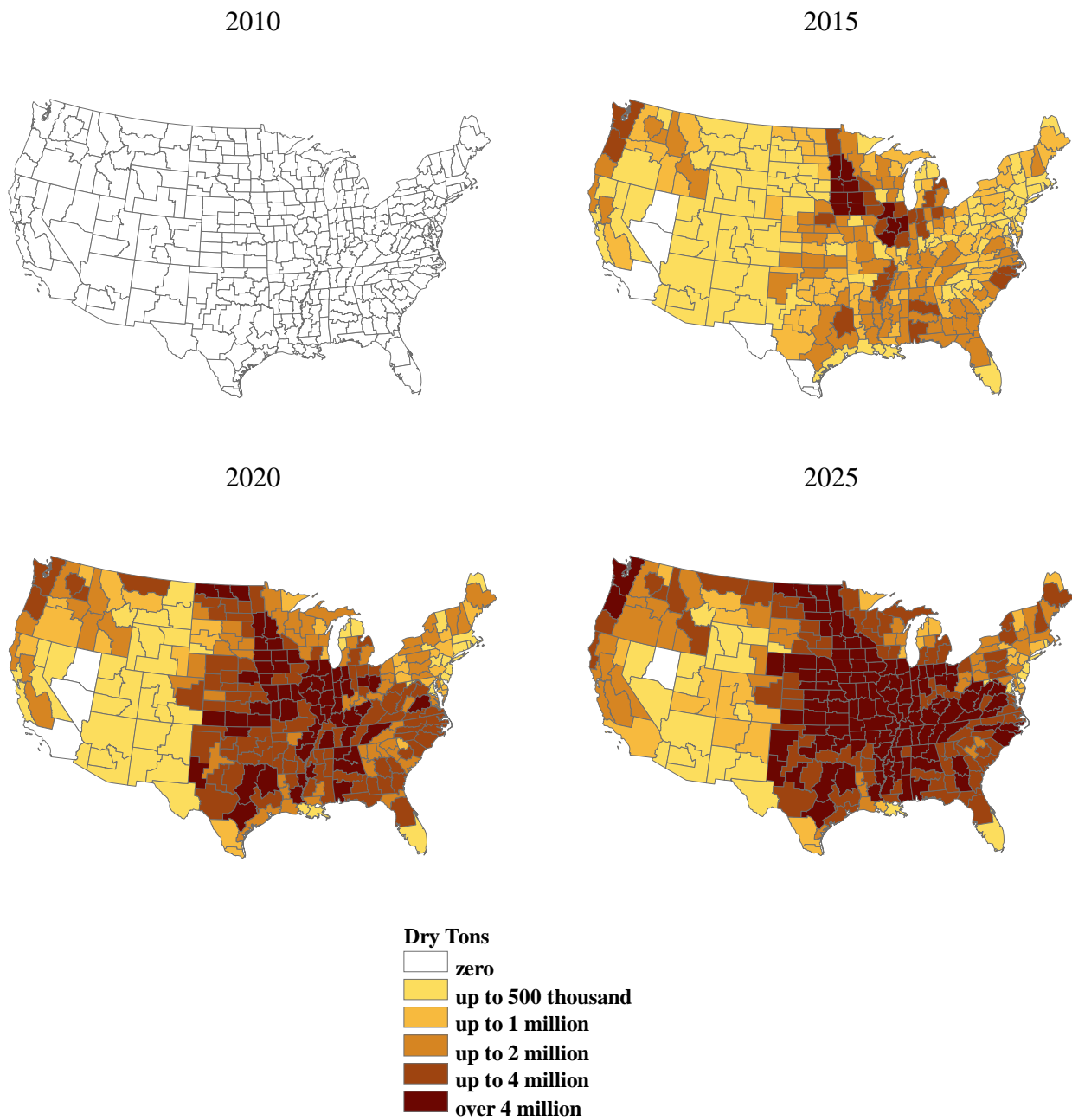
Figure 13. Distribution of All Cellulosic Feedstock (Crop Residues, Dedicated Energy Crops, Forest Residues, Mill Wastes, and Wood from Fuel Reduction), AE Scenario.

2010

2015

2020

2025

Dry Tons

- zero
- up to 500 thousand
- up to 1 million
- up to 2 million
- up to 4 million
- over 4 million
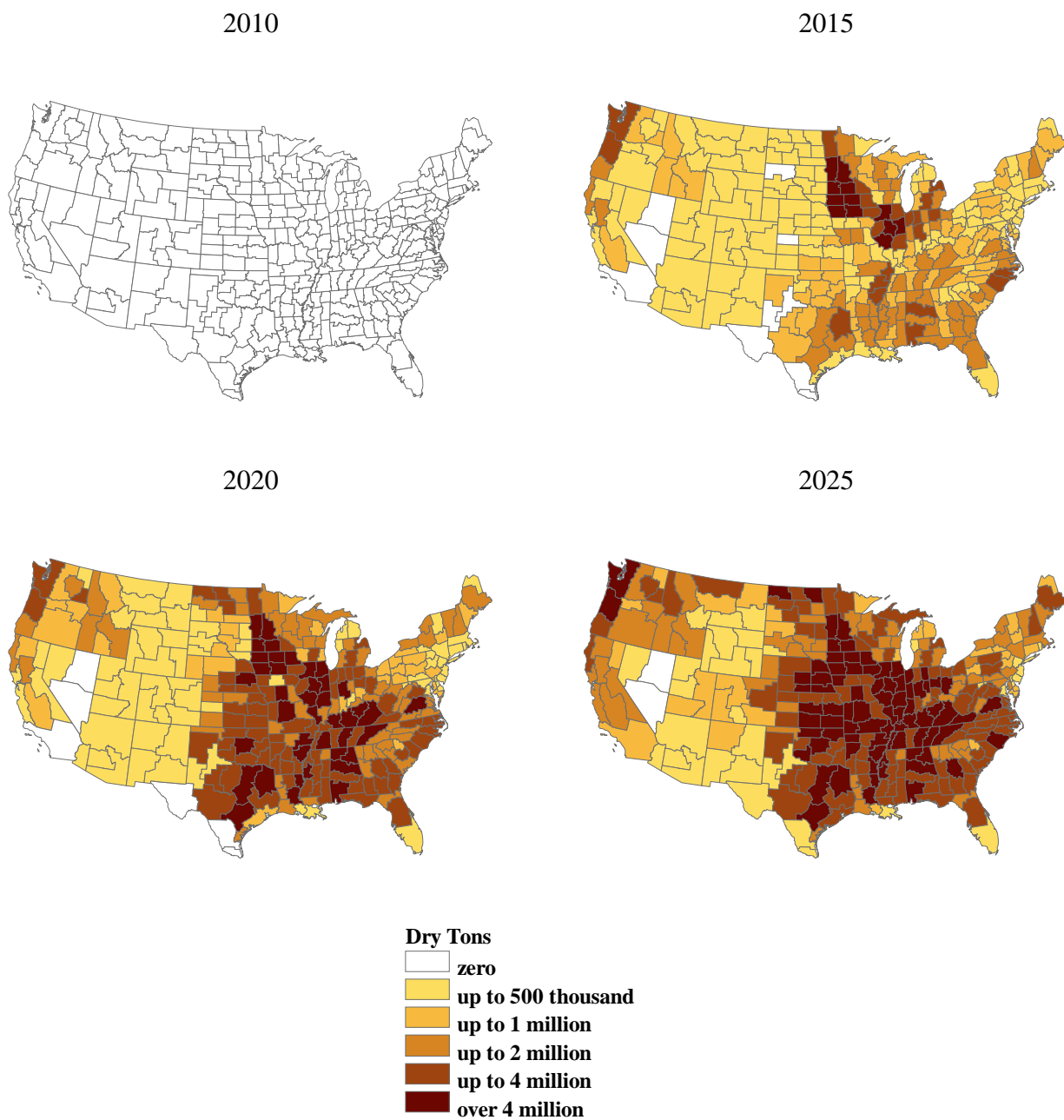
Figure 14. Distribution of All Cellulosic Feedstock (Crop Residues, Dedicated Energy Crops, Forest Residues, Mill Wastes, and Wood from Fuel Reduction), EPT Scenario.
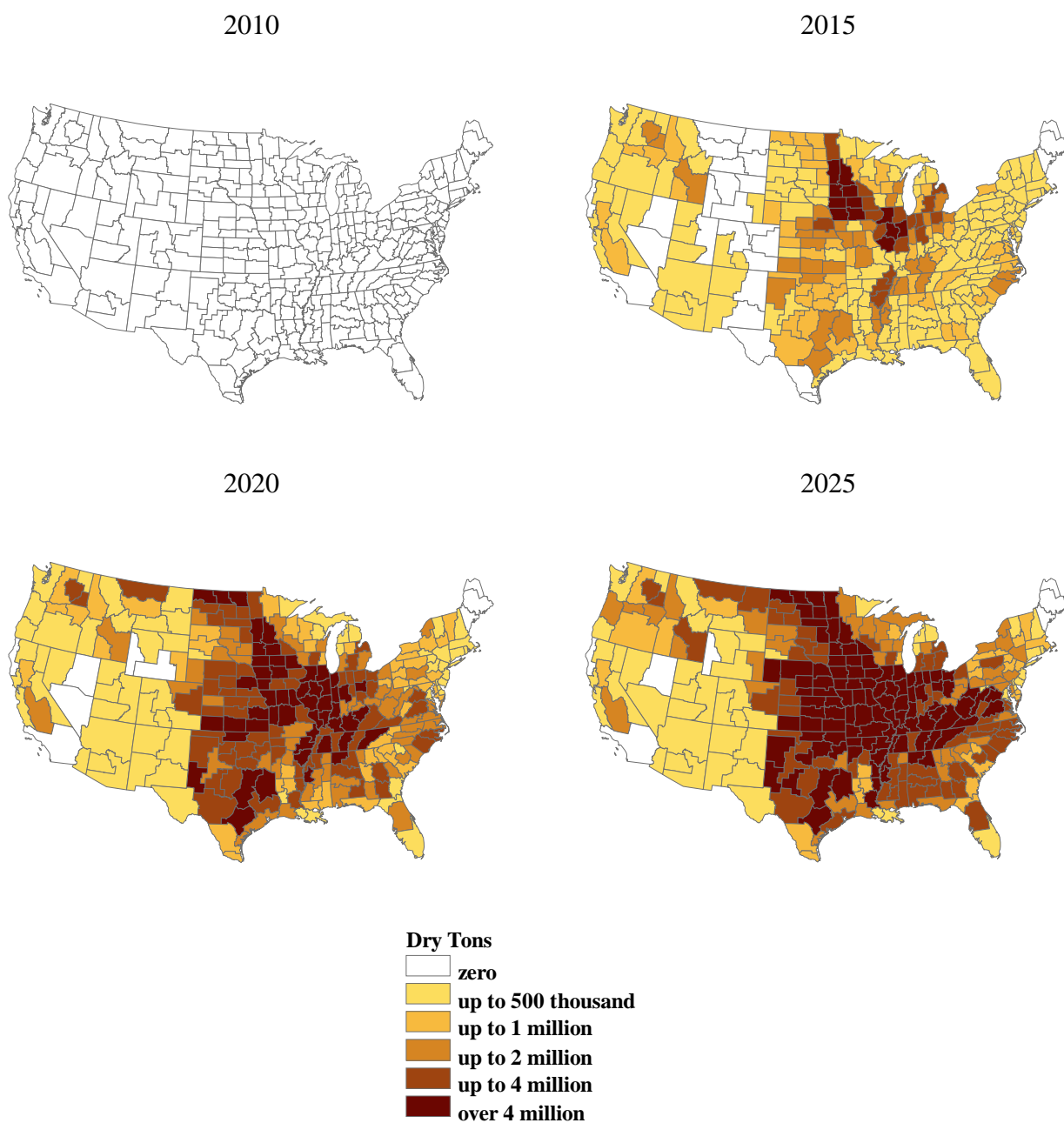
Figure 15. Distribution of Cellulosic Feedstock from Crop Residues and Dedicated Energy Crops, AE Scenario.

In 2015, dedicated energy crops, are supplied from western Tennessee, eastern Texas, and other parts of the Southeastern United States, plus parts of North and South Dakota, Minnesota, Michigan, and northern New York, and the New England States (Figure 16). 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.

2010

2015

2020

2025

Dry Tons
- zero
- up to 500 thousand
- up to 1 million
- up to 2 million
- up to 4 million
- over 4 million
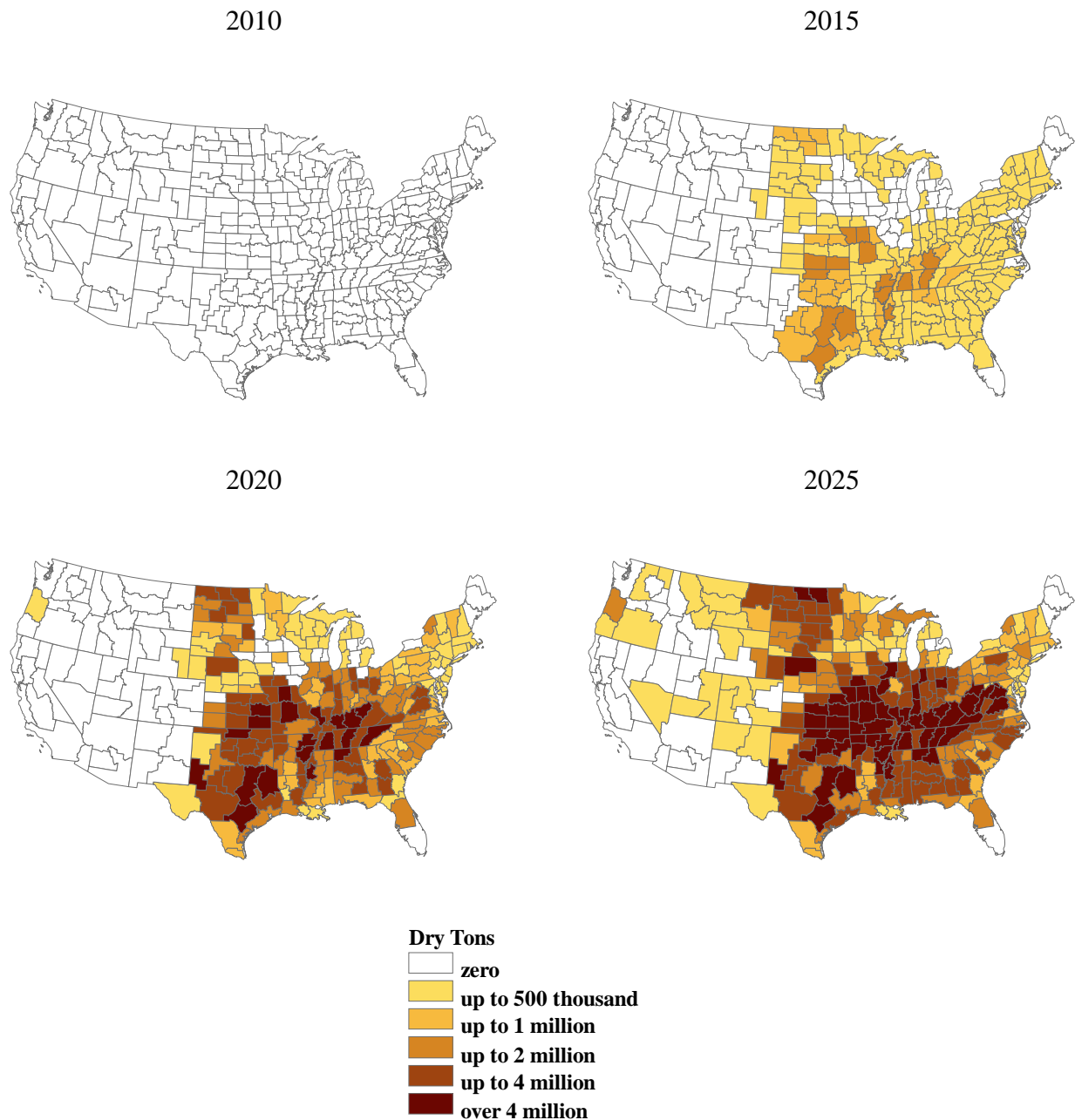
Figure 16. Distribution of Cellulosic Feedstock from Dedicated Energy Crops, AE Scenario.

A 16.5 percent increase occurs in realized net returns occurs to the agricultural sector when meeting the AE energy goal. In the USDAext 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. In 2025, for instance, a gain of $37 billion is projected.

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The same direction in impacts on realized net farm income occurs when meeting the EPT goal. Under the EPT goal, a cumulative increase in realized net farm income of $66 billion, compared with USDAext baseline scenario, is projected to occur over the period of analysis. In 2025, nearly $21 billion increase is projected.

Another significant regional impact is the distribution of the gains in net returns. For both renewable energy scenarios, 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 17 and 18). 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

4.2.5. Change in Export Volume and Value

Increasing the renewable energy goal to 29.4 quads (AE) and adding the possibility of converting land currently in pasture/range land to cropland results in further decrease in exports over the 2006 to 2025 time frame. Corn decreases by 2.2 billion bushels when compared to the USDAext scenario over the time frame analyzed (Table 13). Soybeans exports are estimated to decrease by 4.1 billion bushels over the time frame showing a decline of 618 million bushels in 2025 alone.

In the EPT scenario, there are few impacts in the volume of exports, except in the case of soybeans. For corn, wheat, and cotton, the increase in yield compensates for the loss in acreage, hence price changes are modest and exports impacts are small. In addition, in the case of corn, there is potential for future export market development for distiller's dry grains. This future market potential is not modeled as part of the current analysis. For soybeans, the decrease of about 16 million acres by 2025 and the consequent price increase results in a 40 percent reduction in export volume.

Table 14 contains the resulting export value impacts of the analysis. As energy produced from agriculture increases from those levels reflected in the USDAext scenario to those in AE scenario, total value of exports decreases by $3 billion in the year 2025. Corn and wheat increase in value by $461 and $81 million, respectively, while soybeans and cotton decline by $2.5 and $1.0 billion respectively.

Since for corn, wheat, and cotton the volume of exports is relatively unaffected and these crops experience increases in average market prices, the value of the exports shows a slight increase under the EPT scenario. However, the loss in the volume of soybeans is not offset by the increase in soybean prices so the total value of the soybeans exports decline by about $2.3 billon. Consequently the total value of exports is projected to decline by an estimated $2.2 billion by the end of the period of this analysis under the EPT scenario.

2010

2015

2020

2025

Dollars

	zero
	up to 25 million
	up to 50 million
	up to 100 million
	over 100 million
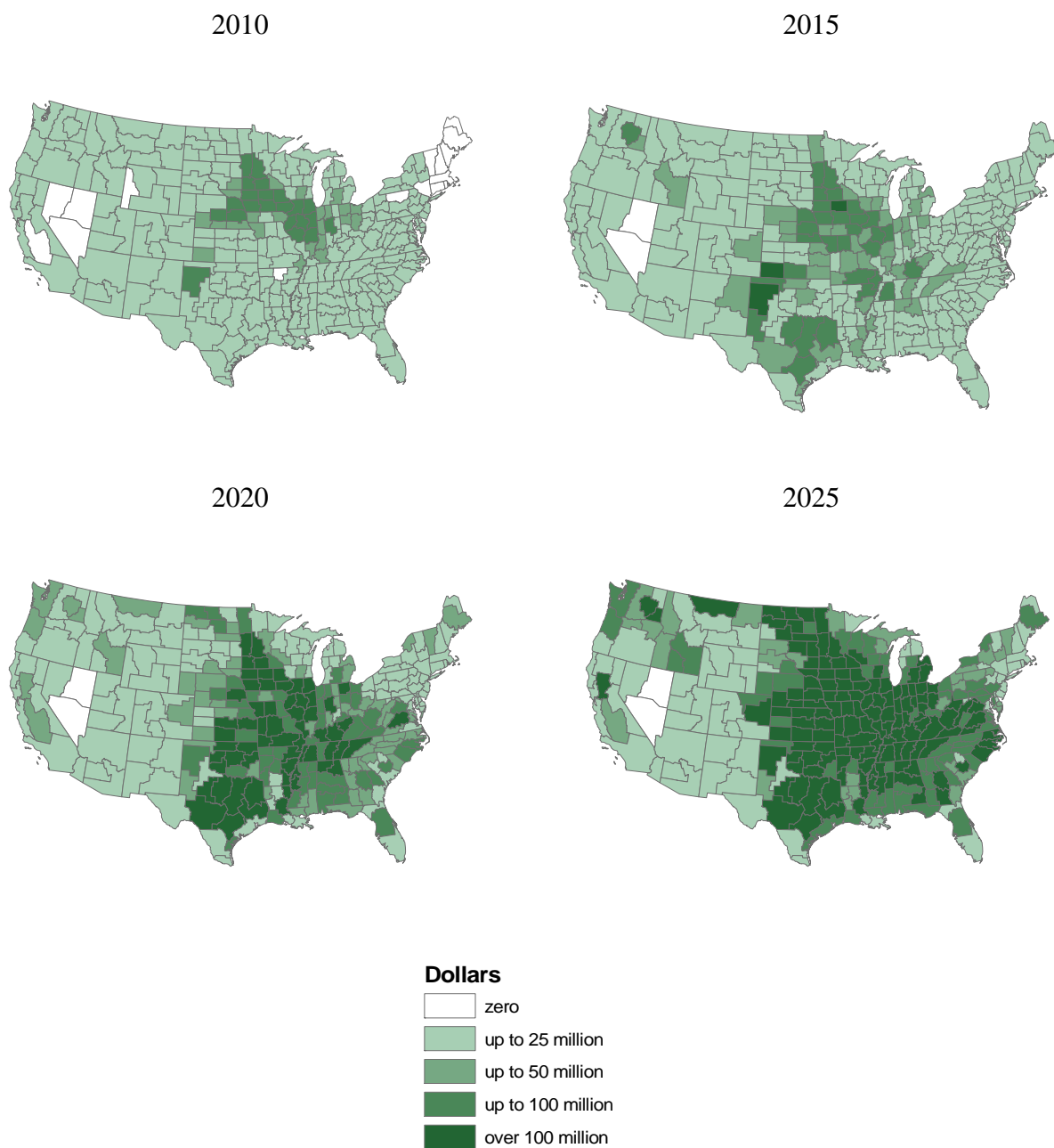
Figure 17. Distribution of Changes in Net Returns, AE Scenario, 2010, 2015, 2020, and 2025.

2010

2015

2020

2025

Dollars

- zero
- up to 25 million
- up to 50 million
- up to 100 million
- over 100 million
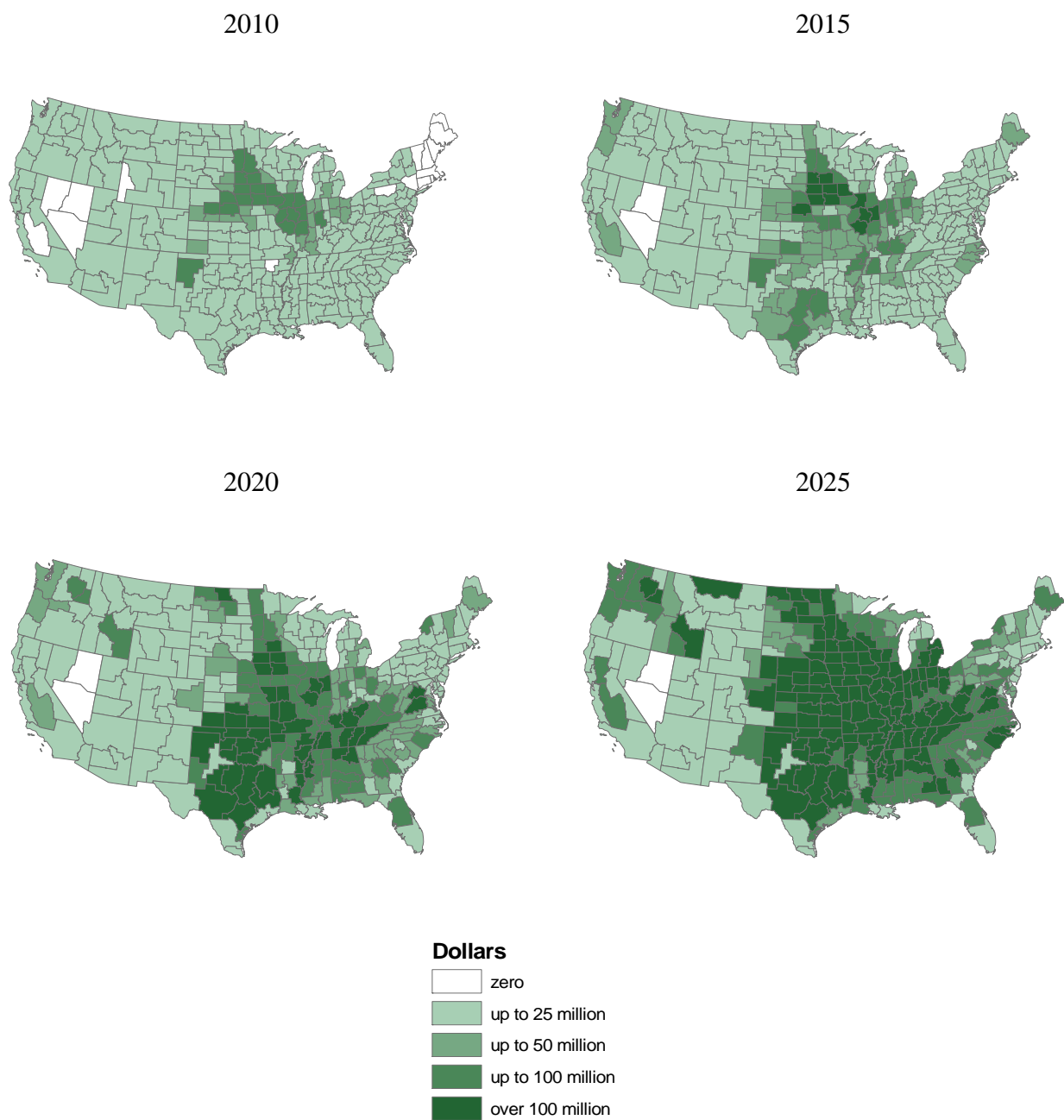
Figure 18. Distribution of Changes in Net Returns, EPT Scenario, 2010, 2015, 2020, and 2025.

Table 13. Projected Volume of Exports for Selected Years and Scenario.

Crop and Scenario	Projected for the Year:				
	2007	2010	2015	2020	2025
Corn:	Million Bushels				
AE	2,047	2,100	2,392	2,406	2,310
EPT	2,023	2,048	2,234	2,470	2,601
USDAExt	2,025	2,125	2,375	2,575	2,789
Wheat:					
AE	953	1,030	1,212	1,122	1,141
EPT	950	1,003	1,111	1,089	1,120
USDAExt	950	1,000	1,125	1,193	1,273
Soybeans:					
AE	1,071	1,008	934	650	481
EPT	1,070	978	838	782	629
USDAExt	1,080	1,030	975	1,034	1,099
Cotton:	Million Bales				
AE	15	16	14	13	13
EPT	15	16	14	15	15
USDAExt	15	16	16	17	18

The significance and importance of the export market has varied according to the specific commodity and has generally been stagnant or declining during the past decade, except in the case of soybeans. As important as exports are, their key role is to provide a reliable market for U.S. agricultural commodities. If domestic demand coming from a dynamic bioenergy sector proves to be more reliable and stable, then this shift in demand from exports to domestic market is a step forward in the economic performance of the agricultural sector.

4.2.6. 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 15). 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. By 2025, under the assumption of the EPT scenario, the cost of a gallon of ethanol would be $1.46 and the cost of biodiesel would be $2.23 per gallon.

Table 14. Projected Value of Agricultural Exports for Corn, Wheat, Soybeans, and Cotton by Selected Year and Scenario.

Crop and Scenario	Projected for the year:				
	2007	2010	2015	2020	2025
Corn:	Million Dollars				
AE	4,353	5,801	6,275	6,429	7,315
EPT	4,463	5,787	6,188	6,126	7,241
USDAExt	4,455	5,525	6,175	6,474	6,854
Wheat:					
AE	2,917	3,222	4,024	4,293	4,494
EPT	2,946	3,283	4,068	4,198	4,481
USDAExt	2,945	3,250	3,994	4,174	4,410
Soybeans:					
AE	5,845	6,086	5,843	4,904	3,715
EPT	5,849	6,073	5,534	5,343	4,538
USDAExt	5,832	6,128	5,947	6,055	6,253
Cotton:					
AE	3,731	3,893	4,188	4,047	4,022
EPT	3,731	3,866	4,137	4,279	4,300
USDAExt	3,731	3,868	4,460	4,798	5,067
Total:					
AE	18,148	20,392	21,910	21,202	21,213
EPT	18,297	20,399	21,482	21,479	22,313
USDAExt	18,271	20,162	22,179	23,220	24,420

Table 15. 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
EPT	1.37	1.60	1.38	1.32	1.45
Biodiesel [a]:					
AE	1.80	2.57	2.50	2.74	2.74
EPT	1.81	2.63	2.61	2.53	2.58

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

4.2.7. 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 small (Figure 19). Consequently, the savings in either type of payment

are relatively minor (Table 16). The majority of changes in the AE scenario reflect the decrease in CRP payments that occur as contracts expire and landowners who are attracted by higher crop prices voluntarily move land into production (an aggregated $28 billion over the 20 year analysis period).
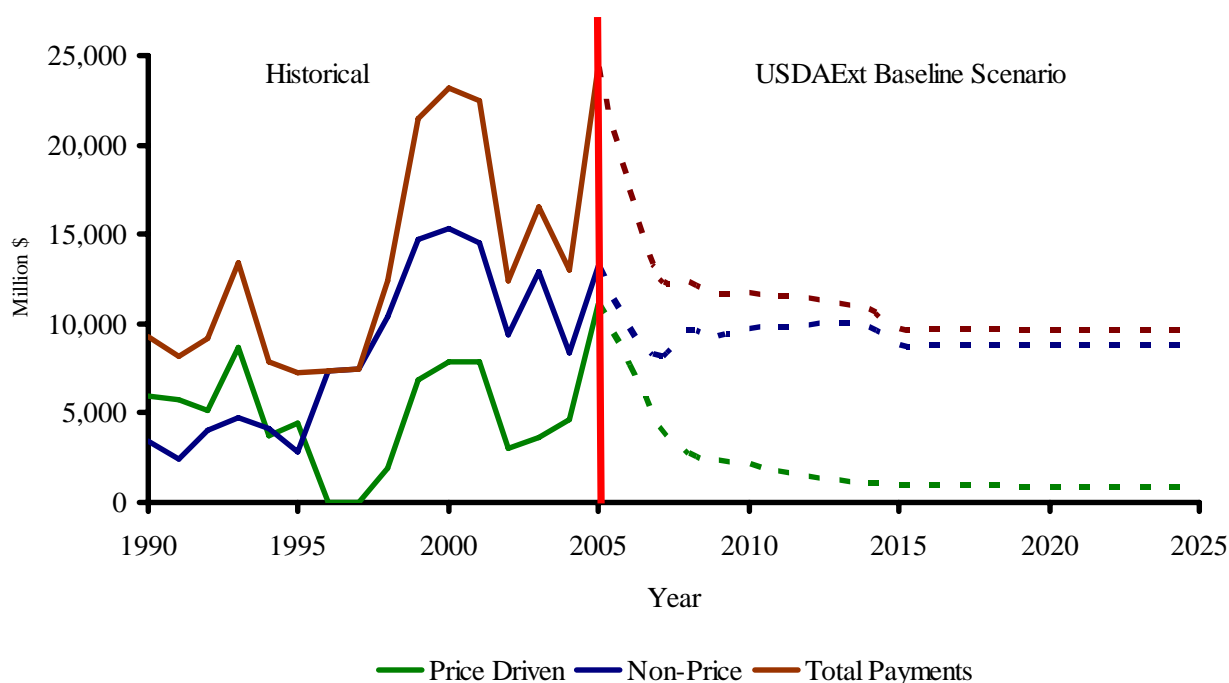
Figure 19. Historical And Projected UsdaExt Baseline Scenario Government Payments.

In the EPT scenario, most of the government savings projected to occur in the model are counter cyclical payments, about $4.3 billion. The larger payment categories are the direct payments and the payments for Conservation Reserve contracts. In aggregate, $15.2 billion in government payments are saved over the 20 year period. In the EPT scenario, the CRP program was assumed to continue so those payments remain at the same level as those reflected in USDAExt. The direct payments made to farmers are assumed at levels under the 2002 Farm Bill. However, it should be noted that under future policies these direct payments could change as net farm income changes. Aggregate government payments under the EPT scenario decrease by $4.5 billion relative to the baseline.

The changes projected for realized net farm income resulting from expanding the role of agriculture as an energy source are displayed in Figure 20. 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. In the EPT scenario, the gains are available in the initial years of the analysis when the demand for energy is first increased. This difference in the results is largely a result of the land base available for crop production. By allowing the use of additional land beyond cropland that is in pasture, significant resources become available. This impacts commodity prices. In the final years of the study period, the increase in net farm income is the steepest as the final push for reaching the renewable energy goals reflected in AE and EPT.

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More pasture is brought into production of bioenergy and prices of the crops continue to increase. Figure 20 also indicates the potential savings in government payments.

Table 16. Estimated Level of Government Payments by Government Program.

Government Program and Scenario	Projected for the Year:					Total
	2007	2010	2015	2020	2025	
	Million Dollars					
Loan Deficiency :						
AE	1,035	428	15	0	0	5,734
EPT	816	357	0	0	0	4,988
USDAExt	816	360	0	0	0	5,069
EPT (without increases in yield growth rates)	816	357	0	0	0	4,988
Contract:						
AE	4,249	5,168	5,168	5,168	5,168	101,993
EPT	4,249	5,168	5,168	5,168	5,168	101,993
USDAExt	4,249	5,168	5,168	5,168	5,168	101,993
EPT (without increases in yield growth rates)	4,249	5,168	5,168	5,168	5,168	101,993
Counter Cyclical:						
AE	4,196	1,995	603	313	223	26,862
EPT	3,408	1,661	461	478	402	24,184
USDAExt	3,458	1,714	868	832	819	28,584
EPT (without increases in yield growth rates)	3,408	1,661	461	480	429	24,088
Other:						
AE	3,152	3,035	2,020	2,020	2,020	51,831
EPT	3,950	4,490	3,610	3,610	3,610	80,420
USDAExt	3,950	4,490	3,610	3,610	3,610	80,420
EPT (without increases in yield growth rates)	3,950	4,490	3,610	3,610	3,610	80,420
Total Payments:						
AE	12,226	10,626	7,806	7,501	7,411	172,918
EPT	12,423	11,677	9,239	9,256	9,181	211,588
USDAExt	12,474	11,732	9,646	9,610	9,597	216,068
EPT (without increases in yield growth rates)	12,423	11,677	9,239	9,258	9,207	211,490

AE Scenario
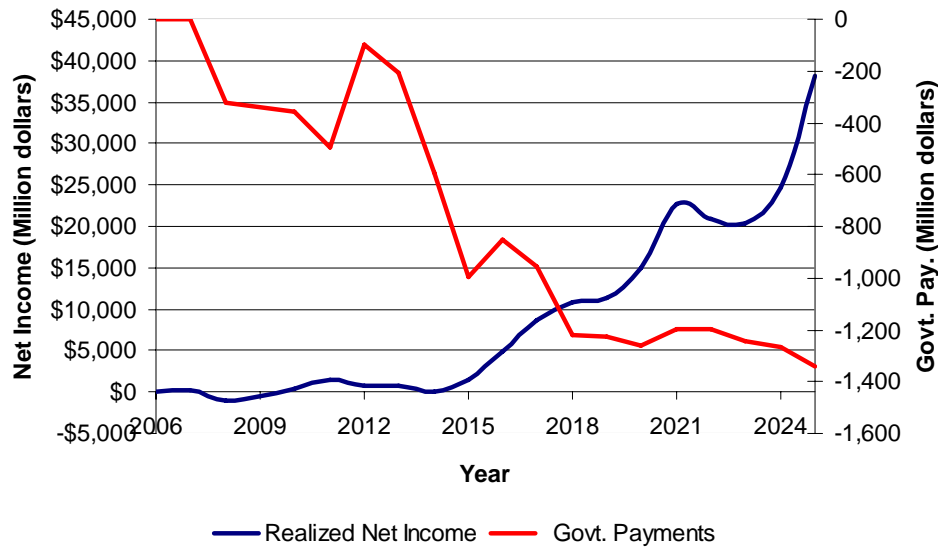
EPT Scenario
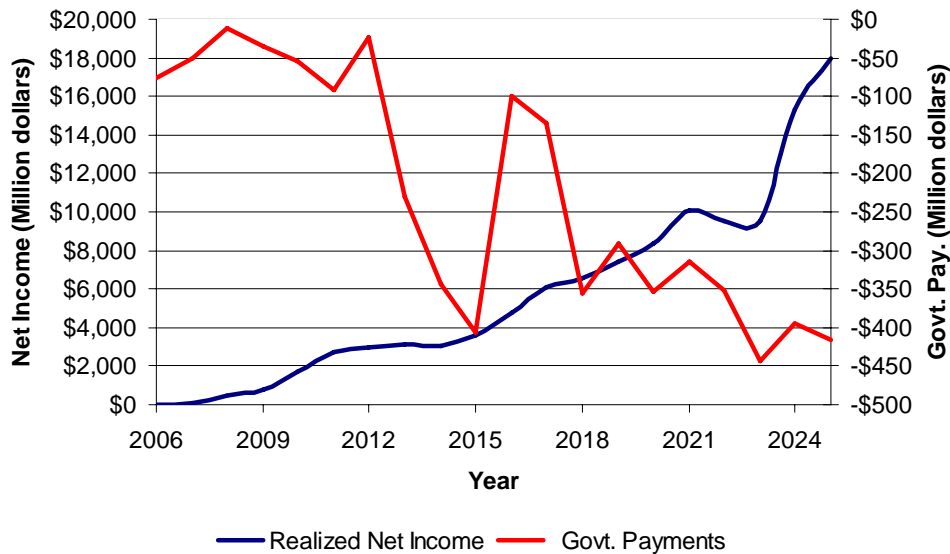
Figure 20. Changes in Net Farm Income (NFI) and Government Payments Under the AE and EPT Scenarios.

4.2.8. Land Values

Given the changes in net farm income, it is anticipated that land values would also experience a significant change. While returns to agricultural activity are a key determinant of land values, there is also an important element that responds to how agricultural production is

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organized and also as a speculative element. The estimate of land values reported in the Table 17 reflect changes in net returns and are defined in terms of percentage changes from the USDAExt scenario.

Table 17. Change in Land Values From the USDAExt Baseline.

	Projected for the Year:				
	2007	2010	2015	2020	2025
AE	0%	0%	18%	71%	155%
EPT	0%	2%	29%	76%	144%

Figure 21 depicts the changes in land values from the USDAExt scenario by state in the year 2025 for both renewable energy scenarios. The states with the larger increases are those in which feedstock production is concentrated, as well as those which would experience the largest gains in net returns - that is the Southern Plains, the Midwest, and then the Southeast. The states along the East Coast and Western states are not projected to experience a significant increase in land values, as they are not large suppliers of agricultural feedstock, or significant growers of the major commodities.

AE   EPT

0% - 49%
50% - 99%
100% - 199%
Over 200%
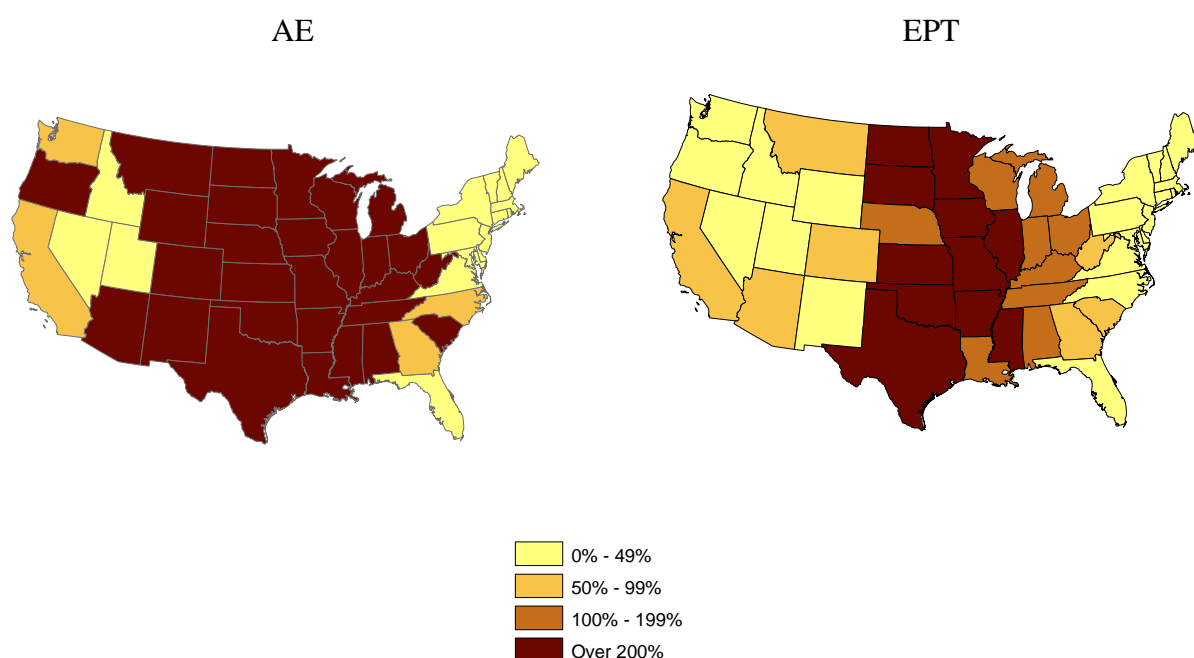
Figure 21.   Percentage Change in Land Values from the USDAExt Scenario in the AE and the EPT Scenarios, 2025.

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 and the EPT are presented in Table 18. As is expected, the larger impacts correspond to the more aggressive scenario. In the AE scenario, 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.

Although there is a large decline in soybean acreage, the soybean meal supply, a key feed ingredient, does not change significantly. This is due to two major reasons – decreased exports of soybeans and a large influx of soybean meal byproduct from biodiesel production. By 2025, soybean acreage drops quite significantly from 66.9 million acres to 53.3 million acres, a loss of 13.6 million acres resulting in a production drop of 437 million bushels. Increased soybean prices cause exports to decline from 1,099 million bushels to 481 million bushels, a drop of 618 million bushels. Biodiesel production demands 276 million bushels. Soybean crush demand (independent of biodiesel) drops by 138 million bushels. The soybean meal supply actually increases slightly due to 6,284 thousand tons of byproduct from biodiesel production. This causes soybean meal price to increases slightly from $177 per ton to $180 per ton. Note that as the use of soybeans for biodiesel increases, the driving product in the soybeans complex shifts from the meal value of the soybeans to the oil value of the soybeans.

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. Table 18 indicates that, by 2025, cash receipts from cattle increase $532 million over baseline. Feed costs increase $115 million over baseline and net returns increase by $417 million, which is about a 3.9 percent gain in total net returns to cattle. It is important to note that increased costs incurred as a result of more intensive roughage management are not accounted for in the livestock analysis.

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 increase in feed expenses by 2025 in both industries is above a billion dollars, mostly in the poultry sector. 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.[4] 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

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[4] 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.

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.

Table 18. Change in Livestock Sector Costs and Returns, AE and EPT Scenarios.

Costs and Returns by Livestock Type	2008	2010	2015	2020	2025
			Million Dollars		
AE Scenario					
Cattle:					
Expenses	-$19	$30	-$83	$10	$115
Cash Receipts	-$107	$62	-$154	$322	$532
Net Returns	-$88	$32	-$71	$312	$417
% Change Net Returns	-1.0%	0.4%	-0.8%	2.9%	3.9%
Hogs:					
Expenses	-$74	$39	-$135	$254	$331
Cash Receipts	-$2	-$24	-$3	$35	$104
Net Returns	$73	-$63	$132	-$219	-$227
% Change Net Returns	3.6%	-4.4%	7.1%	-10.9%	-11.0%
Chickens:					
Expenses	-$149	$182	-$230	$600	$732
Cash Receipts	-$1	-$6	-$13	$38	$191
Net Returns	$149	-$187	$217	-$562	-$541
% Change Net Returns	2.1%	-2.7%	2.7%	-6.8%	-6.6%
EPT Scenario					
Cattle:					
Expenses	$9	$30	-$20	-$45	$28
Cash Receipts	$35	$157	$210	$132	$150
Net Returns	$26	$126	$229	$177	$122
% Change Net Returns	0.3%	1.5%	2.7%	1.7%	1.2%
Hogs:					
Expenses	$27	$149	$154	$49	$168
Cash Receipts	-$1	$6	$78	$47	$20
Net Returns	-$28	-$143	-$76	-$3	-$148
% Change Net Returns	-1.5%	-9.0%	-4.3%	-0.1%	-6.7%
Chickens:					
Expenses	$66	$305	$295	$223	$421
Cash Receipts	$1	$16	$52	$32	$4
Net Returns	-$66	-$289	-$243	-$190	-$417
% Change Net Returns	-1.0%	-4.2%	-3.0%	-2.3%	-5.0%

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.

4.3. Impacts on the Nation's Economy

While the above impacts compare an alternative scenario to a baseline, these impacts are estimated based on a comparison between the scenario goals and the amount of energy from ethanol and wood energy currently supplied. In other words, the estimates measure the impacts of the energy sector growth beyond the 2005 level as determined from the projected amounts from the POLYSYS AE and EPT Scenarios. The impacts on the economy are spread throughout the United States. 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 (Figure 22). An estimated $533.8 billion dollars is generated annually in the conversion of renewables to energy under the AE scenario. 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 (Figure 23). 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.

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 19). 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.

AE Scenario   **EPT Scenario**

Total Industry Output

Agricultural Generated Economic Acitivity
Direct - $113.6 Billion
Total - $170.5 Billion

($ Millions)

⧄ *None*	🟧 *$5,0001 - $10,000*
$1 - $100	🟧 *$10,001 - $15,000*
$101 - $1,000	🟫 *> $15,000*
$1,001 - $5,000	

Agricultural Generated Economic Acitivity
Direct - $51.8 Billion
Total - $78.0 Billion

Employment

Agricultural Generated Economic Acitivity
Direct - 1,171,760
Total - 1,749,625

(Number)

⧄ *None*	🟦 *10,001 - 25,000*
1 - 1,000	🟦 *25,001 - 60,000*
1,001 - 10,000	🟦 *60,001 - 90,000*
10,001 - 25,000	🟦 *> 90,000*

Agricultural Generated Economic Acitivity
Direct - 476,022
Total - 749,803

Figure 22. Estimated Impacts to the National Economy as a Result of Changes in Agricultural Production, Prices, and Government Payments in the AE and the EPT Scenarios.

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AE Scenario   **EPT Scenario**

Total Industry Output

Renewable Energy Sector Generated Economic Activity
Direct - $138.7 Billion
Total - $533.8 Billion

Renewable Energy Sector Generated Economic Activity
Direct - $132.3 Billion
Total - $509.3 Billion

($ Millions)

None	$5,0001 - $10,000
$1 - $100	$10,001 - $15,000
$101 - $1,000	> $15,000
$1,001 - $5,000	

Employment

Renewable Energy Sector Generated Economic Acitivity
Direct - 93,390
Total - 3,415,909

Renewable Sector Generated Economic Acitivity
Direct - 91,701
Total - 3,281,356

(Number)

None	10,001 - 25,000
1 - 1,000	25,001 - 60,000
1,001 - 10,000	60,001 - 90,000
10,001 - 25,000	> 90,000

Figure 23. Estimated Impacts to the National Economy as a Result of Establishing a Larger Renewable Energy Sector in the AE and EPT Scenarios.

Table 19. Estimated Annual National Impacts Under the AE and EPT Scenarios, 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				
2010:				
Agricultural Production Sector	$2,844.6	$4,647.7	24,753.7	43,858.4
Renewable Energy Sector	$14,171.0	$29,910.9	6,412.3	141,956.6
Interstate Commerce	$0.0	$26,454.1	0.0	201,925.3
Total	$17,015.6	$61,012.7	31,166.0	387,740.3
2015:				
Agricultural Production Sector	$16,742.0	$27,596.9	162,960.1	274,602.6
Renewable Energy Sector	$50,044.5	$104,275.1	31,324.1	537,274.2
Interstate Commerce	$0.0	$95,419.3	0.0	737,830.8
Total	$66,786.4	$227,291.4	194,284.2	1,549,707.6
2020:				
Agricultural Production Sector	$56,844.9	$86,012.0	536,493.1	828,569.8
Renewable Energy Sector	$93,007.9	$189,137.0	61,892.1	980,656.6
Interstate Commerce	$0.0	$173,503.0	0.0	1,340,315.5
Total	$149,852.8	$448,652.0	598,385.3	3,149,541.9
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
EPT Scenario:				
2010:				
Agricultural Production Sector	$3,270.30	$4,797.50	17,340.00	33,374.10
Renewable Energy Sector	$4,204.70	$8,943.00	1,902.00	43,678.00
Interstate Commerce	$0.00	$7,700.30	0	59,288.50
Total	$7,475.00	$21,440.80	19,242.00	136,340.60
2015:				
Agricultural Production Sector	$11,855.00	$20,574.70	103,223.30	192,375.00
Renewable Energy Sector	$41,510.00	$86,288.00	27,647.00	452,430.00
Interstate Commerce	$0.00	$79,335.20	0	618,470.00
Total	$53,365.00	$186,197.90	130,870.30	1,263,275.00
2020:				
Agricultural Production Sector	$27,070.40	$42,393.90	264,176.00	414,943.00
Renewable Energy Sector	$86,264.20	$175,076.30	59,432.00	920,801.00
Interstate Commerce	$0.00	$162,072.00	0	1,254,184.00
Total	$113,334.60	$379,542.20	326,608.00	2,589,928.00

Table 19. Continued

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	
2025:				
Agricultural Production Sector	$51,629.20	$78,540.00	476,022.00	749,803.00
Renewable Energy Sector	$132,358.20	$267,215.30	91,701.30	1,403,603.60
Interstate Commerce	$0.00	$242,070.00	0	1,877,752.50
Total	$183,987.40	$587,825.30	567,723.30	4,031,159.10

Under the EPT scenario, $184 billion is directly generated in the economy purchasing inputs, adding value to those inputs and supplying the energy. Including the multiplier effects, the total impact to the nation's economy is estimated at $587 billion or slightly more than a half trillion dollars creating an estimated 4.0 million jobs.

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.

Under the AE scenario, changes in the agricultural sector results in impacts occur in virtually all sectors of the economy. As shown in Figure 24, in the year 2025, the impact to sectors supplying cellulosic materials is estimated at $50 billion, primary crop agricultural sector increases $8 billion, and services increase by over $20 billion.

Changes in the renewable energy sector also results in impacts occur in virtually all sectors of the economy. Agricultural processing increases by nearly $150 billion as residues, grain, and dedicated energy crops are converted to energy by 2025 (Figure 25). Similar to the sectors impacted by the Agricultural sector, the service sectors also show significant gains ($40 billion). It is important to remember that the impacts to the primary agricultural sectors are displayed in the previous chart and to display them in this sector would be double counting these impacts.

Figure 24. Estimated Impacts to the Nation's Economy by Sector as a Result of Changes in the Agricultural Sector, AE Scenario, 2025.

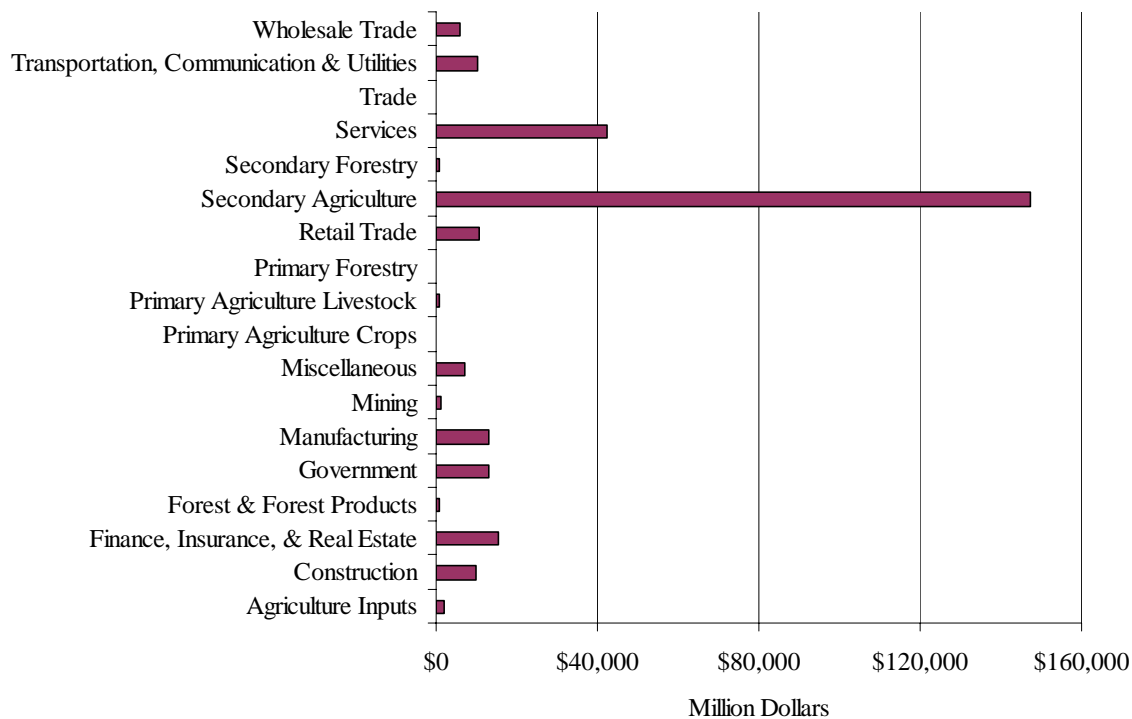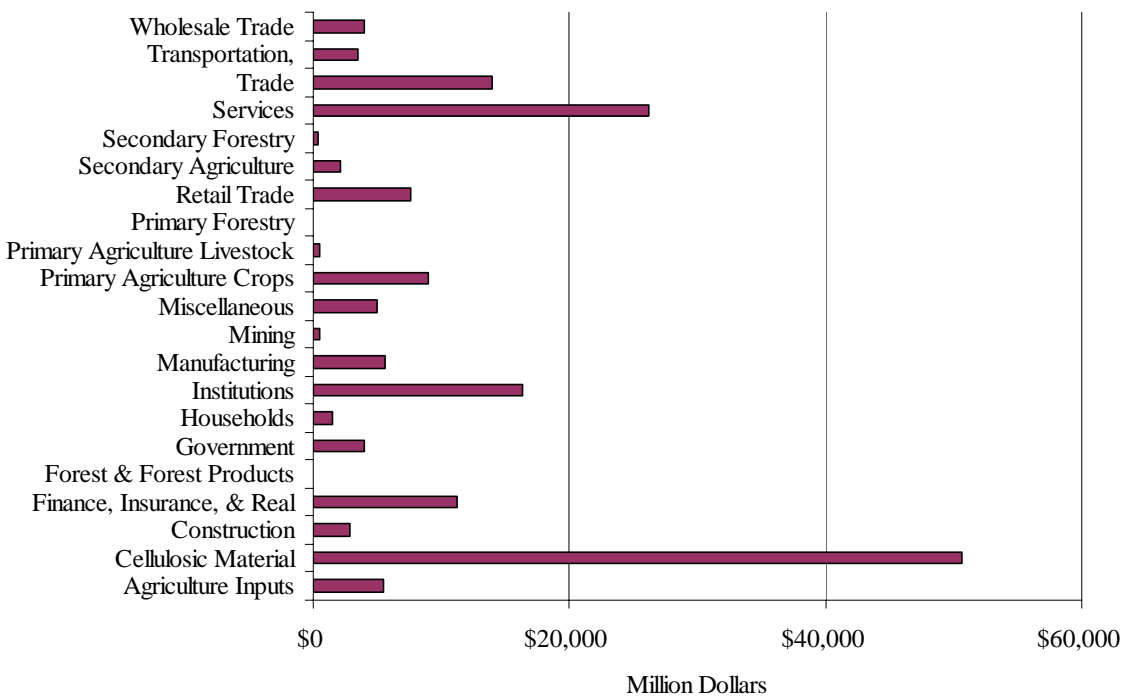**Figure 25. Estimated Impacts to the Nation's Economy by Sector as a Result of Changes in the Renewable Energy Sector, AE Scenario, 2025.**

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. These sources are projected to be coupled with over 606 billion kWh of wind generated electricity to meet the overall renewable energy goal.

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.

Among traditional crops, only the volume of exports of soybeans would be significantly affected. While exports provide key markets for agricultural commodities, a dynamic bioenergy sector could strengthen domestic demand for selected commodities. In 2025, land values are expected to be 155 percent above the baseline. 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.

In this study, forest residues, mill wastes and small diameter feedstock that results from thinning forests to reduce fuel for fires were included as woody feedstocks. However, it should be noted that the nation has over 400 million acres of privately owned forest land, with over 40 million of these acres in plantation forests. This forest resource could potentially provide

additional woody feedstocks. Future analysis should investigate the feasibility and economic impacts from using additional woody feedstock sources.

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. The production of 12.83 quads of electricity from biomass and wind sources could replace the growing demand for natural gas, diesel or coal generated electricity. These new sources of renewable energy could significantly decrease the nation's reliance on foreign oil, fossil fuels, and enhance the national security of all Americans.

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APPENDIX A: Renewable Conversion Technologies — Illustrative Examples of Expenditures Used in IMPLAN

Notes for Appendix A Tables

For each renewable energy conversion technology, examples of expenditures on inputs and services associated with the energy conversion technology and the related IMPLAN sectors are presented. At the top of each table, the conversion technology is listed, along with the total industry output for a particular type and size of facility and the number of employees. The source from which the example expenditure data are constructed is also listed.

Each table provides example information regarding expenditures on investment, operating, depreciation, and byproducts. The IMPLAN sector in which the expenditure would be made to produce the particular type of energy and the sector description are provided in each table. In the far right hand column of each table, the dollar amount of the expenditure in a given sector is shown. The allocation of expenditures to each of the sectors listed is based on engineering cost data provided from the studies sourced at the top of each table. When prices of energy change, expenditures for value added (employee compensation, proprietary income, other property income, and indirect business taxes) change. Since prices vary by state, expenditures for value added are excluded from the tables. In addition, since IMPLAN is linked to POLYSYS, feedstock prices change reflecting those estimated prices provided by POLYSYS. In the conversion technologies presented and for illustrative purposes, the example prices per gallon for ethanol and biodiesel were $2.11/gallon and $2.52/gallon respectively. For electricity, an example wholesale price used is $.088 per kWh. The actual average state prices were below this price.

In the future, other types of feedstocks may become valuable options for the livestock industry. Currently, methane digesters are options for dairy, swine, and poultry manures. For cattle feedlot biomass, co-firing is also an option for the future. Feedlots in the U.S. are increasing in size and capacity, creating the need to find environmentally-friendly manure disposal options.

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Conversion Technology: Ethanol from Shelled Corn (Dry Mill)
Facility Size: 48 MM Gal/year
Total Industry Output: $101,280,000
Employees: 36
Source: 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

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Table A.1. IMPLAN Expenditures for Ethanol from Shelled Corn (Dry Mill)

Type	IMPLAN Sector	IMPLAN Sector Description	Expenditures
Investment	239	Metal Tank, Heavy Gauge, Manufacturing (Saccharification, Storage/Load Out))	$5,527,361
Investment	269	All Other Industrial Machinery Manufacturing (Fermentation, Distillation, Solid/Syrup Separation/Drying)	$30,910,641
Investment	289	Air & Gas Compressor Manufacturing (Air Compressor)	$152,294
Investment	292	Feedstock Handling	$3,932,322
Investment	460	Waste Management & Remediation Services (Wastewater Treatment)	$1,522,182
Operating	2	Grain Farming (Feedstock)	$33,427,796
Operating	30	Power Generation & Supply (Electricity)	$1,739,332
Operating	31	Natural Gas Distribution (Natural Gas)	$16,923,254
Operating	32	Water, Sewage, & Other Systems (Makeup Water, Steam, CT Water, Cool Water)	$268,729
Operating	84	All Other Food Manufacturing (Yeast)	$1,023,390
Operating	150	Other Basic Inorganic Chemical Manufacturing (Caustic)	$1,138,713
Operating	151	Other Basic Organic Chemical Manufacturing (Gluco-Anylase)	$2,186,330
Operating	390	Wholesale Trade (Denaturant (Gasoline))	$1,125,885
Operating	411	Miscellaneous Store Retailers (Operating Supplies)	$624,329
Operating	425	Banking (Interest Expense)	$2,316,760
Operating	427	Insurance Carriers (Insurance & Local Taxes)	$266,321
Operating	451	Management of Companies & Enterprises (Consulting Services)	$623,246
Operating	485	Commercial Machinery Repair & Maintenance (Maintenance Supplies)	$550,941
Depreciation	239	Metal Tank, Heavy Gauge, Manufacturing (Saccharification, Storage/Load Out))	$552,736
Depreciation	269	All Other Industrial Machinery Manufacturing (Fermentation, Distillation, Solid/Syrup Separation/Drying)	$3,091,064
Depreciation	289	Air & Gas Compressor Manufacturing (Air Compressor)	$15,229
Depreciation	292	Feedstock Handling	$393,232
Byproduct	47	Other Animal Food Manufacturing (DDGS)	$12,315,927

Expenditure Summary for Ethanol from Shelled Corn

Expenditure Type	Total $	$/Gallon
Investment	$42,044,801	$0.88
Operating	$62,215,026	$1.30
Operating w/out Feedstock Expenditure	$28,787,230	$0.60
Depreciation	$4,052,262	$0.08
Byproduct	$12,315,927	$0.26

Conversion Technology: Ethanol from Cellulosic Residues (Stover, Switchgrass, Rice Straw, and Wheat Straw)
Facility Size: 69.3 MM Gal/year
Total Industry Output: $146,223,000
Employees: 77
Source: 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).

Table A.2. IMPLAN Expenditures for Ethanol from Cellulosic Residues (Stover, Switchgrass, Rice Straw, and Wheat Straw).

Type	IMPLAN Sector	IMPLAN Sector Description	Expenditures
Investment	37	Manufacturing & Industrial Buildings (Concrete Feedstock-Storage Slab)	$1,014,619
Investment	150	Other Basic Inorganic Chemical Manufacturing (Hydrazine Addition, Ammonia Addition, & Phosphatic Addition Packages)	$56,097
Investment	171	Other Miscellaneous Chemical Product Manufacturing (Biogas Emergency Flare)	$15,449
Investment	238	Power Boiler & Heat Exchanger Manufacturing (Condensors, Feed Economizers & Interchangers, Evaporators)	$10,592,600
Investment	239	Metal Tank, Heavy Gauge, Manufacturing (Mixing Tanks, Water Tanks, Filtrate Tanks, Storage Tanks)	$9,014,827
Investment	240	Metal Can, Box, & Other Container Manufacturing (Storage Bins & Drums)	$584,479
Investment	255	Miscellaneous Fabricated Metal Product Manufacturing (Corn Stover Wash Table)	$506,357
Investment	257	Farm Machinery & Equipment Manufacturing (Shredder)	$1,698,900
Investment	269	Other Industrial Machinery Manufacturing (Mixers, Agitators, & Fermentors)	$8,881,329
Investment	273	Other Commercial & Service Industry Machinery Manufacturing (Hot Process Water Softener System)	$1,486,715
Investment	275	Air Purification Equipment Manufacturing (Filters & Scrubbers)	$14,123,771
Investment	276	Industrial & Commercial Fan & Blower Manufacturing (Blowers & Instrument Air Dryer)	$246,726
Investment	277	Heating Equipment except Warm Air Furnaces (Heaters & Reboilers)	$1,016,025

Table A.2. IMPLAN Expenditures for Ethanol from Cellulosic Residues (Stover, Switchgrass, Rice Straw, and Wheat Straw).

Type	IMPLAN Sector	IMPLAN Sector Description	Expenditures
Investment	278	AC Refrigeration & Forced Air Heating (Coolers & Cooling Tower System)	$3,053,855
Investment	285	Turbine & Turbine Generator Set Units Manufacturing (Turbine/Generator)	$11,497,789
Investment	288	Pump & Pumping Equipment Manufacturing (Pumps)	$6,794,254
Investment	289	Air & Gas Compressor Manufacturing (Plant Air Compressor)	$1,111,595
Investment	292	Conveyor & Conveying Equipment Manufacturing (Conveyors, Feed Systems, & Screws)	$20,540,498
Investment	294	Industrial Truck, Trailer, & Stacker Manufacturing (Bale Moving Forklift)	$165,413
Investment	301	Scales, Balances, & Miscellaneous General Purpose Machinery (Truck Scales & Bar Screen)	$298,873
Investment	316	Industrial Process Variable Instruments (Magnetic Separator, Thickener, & Clarifiers)	$593,929
Investment	460	Waste Management & Remediation Services (Digesters & Waste Basins)	$22,853,455
Operating	2	Grain Farming (Feedstock)	$23,444,607
Operating	32	Water, Sewage, & Other Systems (Makeup Water)	$414,876
Operating	150	Other Basic Inorganic Chemical Manufacturing (Clarifier Polymer, Sulfuric Acid, Boiler Chemicals, Cooling Tower Chemicals, Waste Water Chemicals/Polymers)	$1,716,182
Operating	151	Other Basic Organic Chemical Manufacturing (Corn Steep Liquor & Purchased Cellulase)	$9,176,952
Operating	157	Phosphatic Fertilizer Manufacturing (Ammonium Phosphate)	$214,630
Operating	196	Lime Manufacturing (Hydrated Lime)	$1,570,267
Operating	427	Insurance Carriers (Insurance)	$672,365
Operating	438	Accounting Bookkeeping Services (Taxes, etc.)	$671,514
Operating	460	Waste Management & Remediation Services (Steam, etc.)	$2,079,300
Operating	485	Commercial Machinery Repair & Maintenance	$2,375,777
Depreciation	37	Manufacturing & Industrial Buildings (Concrete Feedstock-Storage Slab)	$50,731
Depreciation	150	Other Basic Inorganic Chemical Manufacturing (Hydrazine Addition, Ammonia Addition, & Phosphatic Addition Packages)	$5,610
Depreciation	171	Other Miscellaneous Chemical Product Manufacturing (Biogas Emergency Flare)	$1,545
Depreciation	238	Power Boiler & Heat Exchanger Manufacturing (Condensors, Feed Economizers & Interchangers, Evaporators)	$1,059,260
Depreciation	239	Metal Tank, Heavy Gauge, Manufacturing (Mixing Tanks, Water tanks, Filtrate Tanks,	$901,483

Table A.2. IMPLAN Expenditures for Ethanol from Cellulosic Residues (Stover, Switchgrass, Rice Straw, and Wheat Straw).

Type	IMPLAN Sector	IMPLAN Sector Description	Expenditures
		Storage Tanks)	
Depreciation	240	Metal Can, Box, & Other Container Manufacturing (Storage Bins & Drums)	$58,448
Depreciation	255	Miscellaneous Fabricated Metal Product Manufacturing (Corn Stover Wash Table)	$50,636
Depreciation	257	Farm Machinery & Equipment Manufacturing (Shredder)	$169,890
Depreciation	269	Other Industrial Machinery Manufacturing (Mixers, Agitators, & Fermentors)	$888,133
Depreciation	273	Other Commercial & Service Industry Machinery Manufacturing (Hot Process Water Softener System)	$148,672
Depreciation	275	Air Purification Equipment Manufacturing (Filters & Scrubbers)	$1,412,377
Depreciation	276	Industrial & Commercial Fan & Blower Manufacturing (Blowers & Instrument Air Dryer)	$24,673
Depreciation	277	Heating Equipment except Warm Air Furnaces (Heaters & Reboilers)	$101,603
Depreciation	278	AC Refrigeration & Forced Air Heating (Coolers & Cooling Tower System)	$305,386
Depreciation	285	Turbine & Turbine Generator Set Units Manufacturing (Turbine/Generator)	$1,149,779
Depreciation	288	Pump & Pumping Equipment Manufacturing (Pumps)	$679,425
Depreciation	289	Air & Gas Compressor Manufacturing (Plant Air Compressor)	$111,160
Depreciation	292	Conveyor & Conveying Equipment Manufacturing (Conveyors, Feed Systems, & Screws)	$2,054,050
Depreciation	294	Industrial Truck, Trailer, & Stacker Manufacturing (Bale Moving Forklift)	$16,541
Depreciation	301	Scales, Balances, & Miscellaneous General Purpose Machinery (Truck Scales & Bar Screen)	$29,887
Depreciation	316	Industrial Process Variable Instruments (Magnetic Separator, Thickener, & Clarifiers)	$59,393
Byproduct	30	Power Generation & Supply (Electricity Credit)	$6,544,130

Expenditure Summary for Ethanol from Cellulosic Residues

Expenditure Type	Total $	$/Gallon
Investment	$116,147,555	$1.68
Operating	$42,336,470	$0.61
Operating w/out Feedstock Expenditure	$18,891,864	$0.27
Depreciation	$9,278,682	$0.13
Byproduct	$6,544,130	$0.09

Table A.3. IMPLAN Expenditures for Ethanol from Food Residues.

Type	IMPLAN Sector	IMPLAN Sector Description	Expenditures
Investment	37	Manufacturing & Industrial Buildings (Concrete Feedstock-Storage Slab)	$1,014,619
Investment	150	Other Basic Inorganic Chemical Manufacturing (Hydrazine Addition, Ammonia Addition, & Phosphatic Addition Packages)	$56,097
Investment	171	Other Miscellaneous Chemical Product Manufacturing (Biogas Emergency Flare)	$15,449
Investment	238	Power Boiler & Heat Exchanger Manufacturing (Condensors, Feed Economizers & Interchangers, Evaporators)	$10,592,600
Investment	239	Metal Tank, Heavy Gauge, Manufacturing (Mixing Tanks, Water Tanks, Filtrate Tanks, Storage Tanks)	$9,014,827
Investment	240	Metal Can, Box, & Other Container Manufacturing (Storage Bins & Drums)	$584,479
Investment	255	Miscellaneous Fabricated Metal Product Manufacturing (Wash Table)	$506,357
Investment	257	Farm Machinery & Equipment Manufacturing (Shredder)	$1,698,900
Investment	269	Other Industrial Machinery Manufacturing (Mixers, Agitators, & Fermentors)	$8,881,329
Investment	273	Other Commercial & Service Industry Machinery Manufacturing (Hot Process Water Softener System)	$1,486,715
Investment	275	Air Purification Equipment Manufacturing (Filters & Scrubbers)	$14,123,771
Investment	276	Industrial & Commercial Fan & Blower Manufacturing (Blowers & Instrument Air Dryer)	$246,726
Investment	277	Heating Equipment except Warm Air Furnaces (Heaters & Reboilers)	$1,016,025
Investment	278	AC Refrigeration & Forced Air Heating (Coolers & Cooling Tower System)	$3,053,855
Investment	285	Turbine & Turbine Generator Set Units Manufacturing (Turbine/Generator)	$11,497,789

Table A.3. IMPLAN Expenditures for Ethanol from Food Residues.

Type	IMPLAN Sector	IMPLAN Sector Description	Expenditures
Investment	288	Pump & Pumping Equipment Manufacturing (Pumps)	$6,794,254
Investment	289	Air & Gas Compressor Manufacturing (Plant Air Compressor)	$1,111,595
Investment	292	Conveyor & Conveying Equipment Manufacturing (Conveyors, Feed Systems, & Screws)	$20,540,498
Investment	294	Industrial Truck, Trailer, & Stacker Manufacturing (Forklift)	$165,413
Investment	301	Scales, Balances, & Miscellaneous General Purpose Machinery (Truck Scales & Bar Screen)	$298,873
Investment	316	Industrial Process Variable Instruments (Magnetic Separator, Thickener, & Clarifiers)	$593,929
Investment	460	Waste Management & Remediation Services (Digesters & Waste Basins)	$22,853,455
Operating	32	Water, Sewage, & Other Systems (Makeup Water)	$414,876
Operating	150	Other Basic Inorganic Chemical Manufacturing (Clarifier Polymer, Sulfuric Acid, Boiler Chemicals, Cooling Tower Chemicals, Waste Water Chemicals/Polymers)	$1,716,182
Operating	151	Other Basic Organic Chemical Manufacturing (Corn Steep Liquor & Purchased Cellulase)	$9,176,952
Operating	157	Phosphatic Fertilizer Manufacturing (Ammonium Phosphate)	$214,630
Operating	196	Lime Manufacturing (Hydrated Lime)	$1,570,267
Operating	427	Insurance Carriers (Insurance)	$672,365
Operating	438	Accounting Bookkeeping Services (Taxes, etc.)	$671,514
Operating	460	Waste Management & Remediation Services (Steam, etc.)	$2,079,300
Operating	485	Commercial Machinery Repair & Maintenance	$2,375,777
Depreciation	37	Manufacturing & Industrial Buildings (Concrete Feedstock-Storage Slab)	$50,731
Depreciation	150	Other Basic Inorganic Chemical Manufacturing (Hydrazine Addition, Ammonia Addition, & Phosphatic Addition Packages)	$5,610
Depreciation	171	Other Miscellaneous Chemical Product Manufacturing (Biogas Emergency Flare)	$1,545
Depreciation	238	Power Boiler & Heat Exchanger Manufacturing (Condensors, Feed Economizers & Interchangers, Evaporators)	$1,059,260
Depreciation	239	Metal Tank, Heavy Gauge, Manufacturing (Mixing Tanks, Water tanks, Filtrate Tanks, Storage Tanks)	$901,483
Depreciation	240	Metal Can, Box, & Other Container Manufacturing (Storage Bins & Drums)	$58,448
Depreciation	255	Miscellaneous Fabricated Metal Product Manufacturing (Wash Table)	$50,636

Table A.3. IMPLAN Expenditures for Ethanol from Food Residues.

Type	IMPLAN Sector	IMPLAN Sector Description	Expenditures
Depreciation	257	Farm Machinery & Equipment Manufacturing (Shredder)	$169,890
Depreciation	269	Other Industrial Machinery Manufacturing (Mixers, Agitators, & Fermentors)	$888,133
Depreciation	273	Other Commercial & Service Industry Machinery Manufacturing (Hot Process Water Softener System)	$148,672
Depreciation	275	Air Purification Equipment Manufacturing (Filters & Scrubbers)	$1,412,377
Depreciation	276	Industrial & Commercial Fan & Blower Manufacturing (Blowers & Instrument Air Dryer)	$24,673
Depreciation	277	Heating Equipment except Warm Air Furnaces (Heaters & Reboilers)	$101,603
Depreciation	278	AC Refrigeration & Forced Air Heating (Coolers & Cooling Tower System)	$305,386
Depreciation	285	Turbine & Turbine Generator Set Units Manufacturing (Turbine/Generator)	$1,149,779
Depreciation	288	Pump & Pumping Equipment Manufacturing (Pumps)	$679,425
Depreciation	289	Air & Gas Compressor Manufacturing (Plant Air Compressor)	$111,160
Depreciation	292	Conveyor & Conveying Equipment Manufacturing (Conveyors, Feed Systems, & Screws)	$2,054,050
Depreciation	294	Industrial Truck, Trailer, & Stacker Manufacturing (Forklift)	$16,541
Depreciation	301	Scales, Balances, & Miscellaneous General Purpose Machinery (Truck Scales & Bar Screen)	$29,887
Depreciation	316	Industrial Process Variable Instruments (Magnetic Separator, Thickener, & Clarifiers)	$59,393
Byproduct	30	Power Generation & Supply (Electricity Credit)	$6,544,130

Expenditure Summary for Ethanol from Food Residues

Expenditure Type	Total $	$/Gallon
Investment	$116,147,555	$1.68
Operating	$18,891,863	$0.27
Depreciation	$9,278,682	$0.13
Byproduct	$6,544,130	$0.09

Table A.4. IMPLAN Expenditures for Ethanol from Wood Residues.

Type	IMPLAN Sector	IMPLAN Sector Description	Expenditures
Investment	37	Manufacturing & Industrial Buildings (Plant Engineering & Construction)	$137,568,289
Investment	150	Other Basic Inorganic Chemical Manufacturing (Inventory - Chemicals & Denaturant)	$265,846
Investment	151	Other Basic Organic Chemical Manufacturing (Inventory - Ethanol & Lignin Residue)	$1,111,099
Investment	292	Conveyor & Conveying Equipment Manufacturing (Spare Parts)	$293,934
Investment	356	Railroad Rolling Stock Manufacturing (Rolling Stock & Shop Equipment)	$147,356
Investment	425	Banking (Startup Costs, Working Capital, capitalized Fees & Interest)	$10,154,237
Investment	431	Real Estate (Land)	$194,991
Investment	437	Legal Services (Permits, Legal & Miscellaneous)	$290,676
Investment	451	Management of Companies & Enterprises (Organizational Costs)	$293,052
Operating	14	Logging (Feedstock)	$14,580,764
Operating	30	Power Generation & Supply (Electricity)	$884,912
Operating	32	Water, Sewage & Other Systems (Steam & Fresh Water)	$11,623,994
Operating	150	Other Basic Inorganic Chemical Manufacturing	$5,642,213
Operating	390	Wholesale Trade (Denaturants)	$1,060,416
Operating	411	Miscellaneous Store Retailers (Office/Lab Supplies & Expenses)	$72,074
Operating	425	Banking (Interest - Senior Debt)	$6,881,729
Operating	437	Legal Services (Legal & Accounting/Community Affairs)	$35,579
Operating	451	Management of Companies & Enterprises (Consulting Services)	$23,913
Operating	456	Travel Arrangement & Reservation Services (Travel, Training & Miscellaneous)	$29,902
Operating	458	Services to Buildings & Dwellings (Maintenance Materials & Services)	$2,008,746
Operating	460	Waste Management & Remediation Services (Wastewater Effluent Treatment & Solid Waste Disposal)	$892,591
Operating	499	Other State & Local Govt. Enterprises (Property	$1,986,679

Table A.4. IMPLAN Expenditures for Ethanol from Wood Residues.

Type	IMPLAN Sector	IMPLAN Sector Description	Expenditures
		Taxes & Insurance)	
Depreciation	37	Manufacturing & Industrial Buildings (Plant Engineering & Construction)	$6,878,414
Depreciation	150	Other Basic Inorganic Chemical Manufacturing (Inventory - Chemicals & Denaturant)	$26,585
Depreciation	151	Other Basic Organic Chemical Manufacturing (Inventory - Ethanol & Lignin Residue)	$111,110
Depreciation	292	Conveyor & Conveying Equipment Manufacturing (Spare Parts)	$29,393
Depreciation	356	Railroad Rolling Stock Manufacturing (Rolling Stock & Shop Equipment)	$14,736
Depreciation	431	Real Estate (Land)	$9,750
Byproduct	148	Industrial Gas Manufacturing (Carbon Dioxide)	$955,767
Byproduct	151	Other Basic Organic Chemical Manufacturing (Lignin Residue)	$7,497,280

Expenditure Summary for Ethanol from Wood Residues

Expenditure Type	Total $	$/Gallon
Investment	$150,319,480	$4.64
Operating	$45,723,512	$1.41
Operating w/out Feedstock Expenditure	$31,142,748	$0.96
Depreciation	$7,069,988	$0.22
Byproduct	$8,453,047	$0.26

Table A.5. IMPLAN Expenditures for Biodiesel from Soybeans.

Type	IMPLAN Sector	IMPLAN Sector Description	Expenditures
Investment	30	Power Generation & Supply (Utilities)	$1,241,521
Investment	37	Manufacturing & Industrial Bldgs. (Buildings, Civil/Mechanical/Electrical, Land/Prep/Trans Access)	$7,157,477
Investment	150	Other Basic Inorganic Chemical Manufacturing (Solvent Extraction)	$6,868,171
Investment	239	Metal Tank, Heavy Gauge, Manufacturing (Preparation and Mill Feed/Meal Sizing)	$5,079,026
Investment	269	All Other Industrial Machinery Manufacturing (Peripherals)	$2,985,735
Investment	292	Conveyor & Conveying Equipment Manufacturing (Feedstock & Product Storage and Handling)	$11,742,001
Investment	425	Banking (Contingency (10%))	$1,701,107
Investment	431	Real Estate (Land)	$194,991
Investment	439	Architectural & Engineering Services (Engineering/Permitting)	$334,672
Investment	451	Management of Companies & Enterprises (Set-up Consulting)	$5,206
Operating	1	Oilseed Farming (Feedstock)	$41,988,192
Operating	30	Power Generation & Supply	$338,482
Operating	32	Water, Sewage & Other Systems	$891,995
Operating	148	Industrial Gas Manufacturing	$35,677
Operating	150	Other Basic Inorganic Chemical Manufacturing	$261,496
Operating	151	Other Basic Organic Chemical Manufacturing	$921,664
Operating	425	Banking	$1,543,306
Operating	427	Insurance Carriers	$276,737
Operating	438	Accounting	$1,627,729
Operating	485	Commercial Machinery Repair & Maintenance	$353,271
Depreciation	30	Power Generation & Supply (Utilities)	$121,987
Depreciation	37	Manufacturing & Industrial Bldgs. (Buildings, Civil/Mechanical/Electrical, Land/Prep/Trans Access)	$349,696
Depreciation	150	Other Basic Inorganic Chemical Manufacturing (Solvent Extraction)	$705,300
Depreciation	239	Metal Tank, Heavy Gauge, Manufacturing (Preparation and Mill Feed/Meal Sizing)	$508,700
Depreciation	269	All Other Industrial Machinery Manufacturing	$305,000

Table A.5. IMPLAN Expenditures for Biodiesel from Soybeans.

Type	IMPLAN Sector	IMPLAN Sector Description	Expenditures
Depreciation	292	(Peripherals) Conveyor & Conveying Equipment Manufacturing (Feedstock & Product Storage and Handling)	$1,198,434
Depreciation	431	Real Estate (Land)	$10,000
Byproduct	151	Glycerine Credit	$6,972,756
Byproduct	163	Soapstock Credit	$129,604

Expenditure Summary for Biodiesel from Soybeans

Expenditure Type	Total $	$/Gallon
Investment	$37,309,907	$2.87
Operating	$48,238,549	$3.71
Operating w/out Feedstock Expenditure	$6,250,356	$0.48
Depreciation	$3,199,117	$0.25
Byproduct	$7,102,361	$0.55

> **Conversion Technology**: Biodiesel from Yellow Grease
> **Facility Size**: 10.0 MM Gal/year
> **Total Industry Output**: $25,192,000
> **Employees**: 10
> **Source**: 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.

Table A.6. IMPLAN Expenditures for Biodiesel from Yellow Grease.

Type	IMPLAN Sector	IMPLAN Sector Description	Expenditures
Investment	37	Manufacturing & Industrial Buildings (Building)	$287,772
Investment	41	Other New Construction (Civil and site work)	$570,715
Investment	239	Metal Tank, Heavy Gauge, Manufacturing (Storage Tanks)	$676,812
Investment	292	Conveyor & Conveying Equipment Manufacturing (Transesterfication Machinery)	$5,179,308
Investment	425	Banking (Working Capital)	$1,328,593
Investment	431	Real Estate (Land)	$64,991
Investment	439	Architectural & Engineering Services (Permits/misc.)	$138,373
Operating	30	Power Generation & Supply (Electricity)	$1,711
Operating	31	Natural Gas Distribution (Natural Gas/diesel)	$530,040
Operating	32	Water, Sewage, & Other Systems (Water)	$10,352
Operating	37	Manufacturing & Industrial Buildings (Building)	$15,441
Operating	54	Fats & Oils Refining & Blending (Yellow Grease)	$12,912,929
Operating	150	Other Basic Inorganic Chemical Manufacturing (Catalyst)	$296,096
Operating	151	Other Basic Organic Chemical Manufacturing (Methanol)	$1,088,151
Operating	239	Metal Tank, Heavy Gauge, Manufacturing (Storage Tanks)	$45,514
Operating	292	Conveyor & Conveying Equipment Manufacturing (Equipment)	$538,271
Operating	392	Rail Transportation (Rail Transportation)	$466,382
Operating	425	Banking (Interest Expense)	$139,026
Operating	427	Insurance Carriers (Insurance)	$222,796
Operating	439	Architectural & Engineering Services (Permits)	$27,675
Operating	451	Management of Companies & Enterprises (Marketing)	$93,359
Operating	460	Waste Management & Remediation Services (Waste Disposal & Waste Water Treatment)	$40,145
Operating	485	Commercial Machinery Repair & Maintenance (Maintenance)	$88,217
Depreciation	37	Manufacturing & Industrial Buildings (Building)	$14,389
Depreciation	41	Other New Construction (Civil and site work)	$28,536
Depreciation	239	Metal Tank, Heavy Gauge, Manufacturing (Storage Tanks)	$67,681

Table A.6. IMPLAN Expenditures for Biodiesel from Yellow Grease.

Type	IMPLAN Sector	IMPLAN Sector Description	Expenditures
Depreciation	292	Conveyor & Conveying Equipment Manufacturing (Transesterfication Machinery)	$517,931
Depreciation	431	Real Estate (Land)	$3,250
Byproduct	151	Glycerine	$2,405,777
Byproduct	163	Soap Stock	$38,246

Expenditure Summary for Biodiesel from Yellow Grease

Expenditure Type	Total $	$/Gallon
Investment	$8,246,564	$0.82
Operating	$16,516,104	$1.65
Operating w/out Feedstock Expenditure	$3,603,176	$0.36
Depreciation	$631,787	$0.06
Byproduct	$2,444,023	$0.24

Table A.7. IMPLAN Expenditures for Horizontal Axis Wind Turbine Power Plant.

Type	IMPLAN Sector	IMPLAN Sector Description	Expenditures
Investment	41	Other New Construction (Foundations, Civil engineering, Installation & Commissioning, etc.)	$3,241,835
Investment	285	Turbine & Turbine Generator Set Units Manufacturing (Tower, Wind Turbine/Generator, Power Collection System)	$5,924,837
Investment	316	Industrial Process Variable Instruments (Electrical/Controls/Instrumentation)	$2,722,123
Investment	334	Motor & Generator Manufacturing (Rotor Assembly)	$3,467,286
Investment	394	Truck Transportation (Transportation & Freight)	$858,590
Investment	437	Legal Services (Due Diligence, Permitting, Legal)	$1,409,573
Investment	439	Architectural & Engineering Services (Engineering)	$113,634
Investment	442	Computer Systems Design Services (SCADA & Communications)	$100,169
Investment	499	Other State & Local Govt. Enterprises (Tax and Fees)	$2,964,391
Operating	485	Commercial Machinery Repair & Maintenance (includes Turbines, BOP, insurance, admin.)	$472,157
Depreciation	41	Other New Construction (Foundations, Civil engineering, Substation, Metering, Interconnection, Sensors, etc.)	$149,182
Depreciation	285	Turbine & Turbine Generator Set Units Manufacturing (Tower, Wind Turbine/Generator, Power Collection System)	$592,484
Depreciation	316	Industrial Process Variable Instruments (Electrical/Controls/Instrumentation)	$272,212
Depreciation	334	Motor & Generator Manufacturing (Rotor Assembly)	$346,729

Expenditure Summary for Horizontal Axis Wind Turbine Power Plant

Expenditure Type	Total $	$/kWh
Investment	$20,802,438	$0.16
Operating	$472,157	$0.00
Depreciation	$1,360,607	$0.01

Conversion Technology: Solar Thermal Technology (Parabolic Trough)
Conversion Technology: Solar Thermal Technology (Parabolic Trough)
Facility Size: 700,800,000 kWh/year
Total Industry Output: $61,670,400
Employees: 36
Source: Electric Power Research Institute & BBF Consult. 2004. "Renewable Energy Technical Assessment Guide – TAG-RE: 2004". Technical Report – 1008366

Table A.8. IMPLAN Expenditures for Solar Thermal Technology (Parabolic Trough).

Type	IMPLAN Sector	IMPLAN Sector Description	Expenditures
Investment	41	Other New Construction (Structures & Improvements)	$6,804,503
Investment	285	Turbine & Turbine Generator Set Units Manufacturing (Steam Generator)	$65,159,350
Investment	311	Semiconductors & Related Device Manufacturing (Heliostats, Collectors, & Concentrators)	$102,423,530
Investment	425	Banking (Project & Process Contingency)	$29,812,341
Investment	439	Architectural & Engineering Services (General Facilities & Engineering Fees)	$14,941,503
Investment	442	Computer System Design Services (Balance of Plant)	$17,498,052
Investment	451	Management of Companies & Enterprises (Owner costs)	$5,626,593
Operating	485	Commercial Machinery Repair & Maintenance	$4,633,694
Depreciation	41	Other New Construction	$340,225
Depreciation	285	Turbine & Turbine Generator Set Units Manufacturing	$6,515,935
Depreciation	311	Semiconductors & Related Device Manufacturing	$10,242,353

Expenditure Summary for Solar Thermal Technology

Expenditure Type	Total $	$/kWh
Investment	$242,265,872	$0.35
Operating	$4,633,694	$0.01
Depreciation	$17,098,513	$0.02

Conversion Technology: Utility Scale Solar Photovoltaic Power Plant (One-Axis Tracking)	
Facility Size: 438,000,000 kWh/year	
Total Industry Output: $38,544,000	
Employees: 5	
Source: Electric Power Research Institute & BBF Consult. 2004. "Renewable Energy Technical Assessment Guide – TAG-RE: 2004". Technical Report – 1008366	

Table A.9. IMPLAN Expenditures for Utility Scale Solar Photovoltaic Power Plant (One-Axis Tracking).

Type	IMPLAN Sector	IMPLAN Sector Description	Expenditures
Investment	311	Semiconductors & Related Device Manufacturing (Heliostats, Collectors, & Concentrators)	$191,420,610
Investment	425	Banking (Project & Process Contingency)	$24,914,363
Investment	439	Architectural & Engineering Services (General Facilities & Engineering Fees)	$23,342,405
Investment	442	Computer System Design Services (Balance of Plant)	$57,621,107
Investment	451	Management of Companies & Enterprises (Owner costs)	$8,544,805
Operating	485	Commercial Machinery Repair & Maintenance	$344,338
Depreciation	311	Semiconductors & Related Device Manufacturing	$19,142,061
Depreciation	439	Architectural & Engineering Services (General Facilities & Engineering Fees)	$2,566,244
Depreciation	442	Computer System Design Services (Balance of Plant)	$5,762,111

Expenditure Summary for Solar Photovoltaic Technology

Expenditure Type	Total $	$/kWh
Investment	$305,843,290	$0.70
Operating	$344,338	$0.001
Depreciation	$27,470,416	$0.06

Conversion Technology: Wood Fired Power Plant
Facility Size: 219,000,000 kWh/year
Total Industry Output: $19,272,000
Employees: 26
Source: Electric Power Research Institute & BBF Consult. 2004. "Renewable
Energy Technical Assessment Guide – TAG-RE: 2004". Technical Report – 1008366

Table A.10. IMPLAN Expenditures for Wood Fired Power Plant.

Type	IMPLAN Sector	IMPLAN Sector Description	Expenditures
Investment	37	Manufacturing & Industrial Buildings (Concrete Substructures, Piping, Electrical, Insulation, Process Structural, Stack)	$9,517,751
Investment	161	Paint & Coating Manufacturing (Paint)	$122,147
Investment	203	Iron & Steel Mills (Structural Steel)	$2,450,137
Investment	240	Metal can, box, & Other Container Manufacturing (Receiving Hopper/Magnet, Reclaim Hopper, Feed Bin)	$18,941
Investment	259	Construction Machinery Manufacturing (Hammer Mill/Hopper, Dozer 1, & Dozer 2)	$989,168
Investment	273	Other Commercial & Service Industry Machinery Manufacturing (Demineralizer Plant)	$145,076
Investment	277	Heating Equipment, except Warm Air Furnaces (No. 2 Oil Burners (4X))	$531,944
Investment	278	AC, Refrigeration, & Forced Air Heating (Cooling Tower)	$2,321,209
Investment	285	Turbine & Turbine Generator Set Units Manufacturing (Stoker Steam Generator, Steam Turbine/Generator Set)	$16,337,749
Investment	292	Conveyor & Conveying Equipment Manufacturing (Rotary Disc Screen/Hopper, RDS Conveyor, HM Conveyor, Reclaim Conveyor, Feed Conveyor)	$206,477
Investment	315	Automatic Environmental Control Manufacturing (NOx Control _SNCR, CEMS)	$1,351,409
Investment	316	Industrial Process Variable Instruments (Instrumentation)	$1,923,392
Investment	346	Motor Vehicle Body Manufacturing (Truck Scale/Unloader)	$97,022
Investment	425	Banking (Contingency Fee)	$10,569,619
Investment	451	Management of Companies & Enterprises (Home Office Expense (w/Overhead), Field Expenses (w/Overhead), Contractor Fees)	$14,194,612
Operating	14	Logging (Feedstock)	$3,190,445
Operating	485	Commercial Machinery Repair & Maintenance (Maintenance)	$1,830,044

Table A.10. IMPLAN Expenditures for Wood Fired Power Plant.

Type	IMPLAN Sector	IMPLAN Sector Description	Expenditures
Depreciation	37	Manufacturing & Industrial Buildings (Concrete Substructures, Piping, Electrical, Insulation, Process Structural, Stack)	$475,888
Depreciation	161	Paint & Coating Manufacturing (Paint)	$12,215
Depreciation	203	Iron & Steel Mills (Structural Steel)	$122,507
Depreciation	240	Metal can, box, & Other Container Manufacturing (Receiving Hopper/Magnet, Reclaim Hopper, Feed Bin)	$1,894
Depreciation	259	Construction Machinery Manufacturing (Hammer Mill/Hopper, Dozer 1, & Dozer 2)	$98,917
Depreciation	273	Other Commercial & Service Industry Machinery Manufacturing (Demineralizer Plant)	$14,508
Depreciation	277	Heating Equipment, except Warm Air Furnaces (No. 2 Oil Burners (4X))	$53,194
Depreciation	278	AC, Refrigeration, & Forced Air Heating (Cooling Tower)	$232,121
Depreciation	285	Turbine & Turbine Generator Set Units Manufacturing (Stoker Steam Generator, Steam Turbine/Generator Set)	$1,633,775
Depreciation	292	Conveyor & Conveying Equipment Manufacturing (Rotary Disc Screen/Hopper, RDS Conveyor, HM Conveyor, Reclaim Conveyor, Feed Conveyor)	$20,648
Depreciation	315	Automatic Environmental Control Manufacturing (NOx Control _SNCR, CEMS)	$135,141
Depreciation	316	Industrial Process Variable Instruments (Instrumentation)	$192,339
Depreciation	346	Motor Vehicle Body Manufacturing (Truck Scale/Unloader)	$9,702

Expenditure Summary for Wood Fired Power Plant

Expenditure Type	Total $	$/kWh
Investment	$60,776,653	$0.28
Operating	$5,020,489	$0.02
Operating w/out Feedstock Expenditure	$1,830,044	$0.01
Depreciation	$3,002,849	$0.01

> **Conversion Technology**: Co-fire (15%) of Cellulosic Residues (Corn, Wheat, Rice, Switchgrass, Forest, Poplar, Mill, and Urban) with Coal
> **Facility Size**: 137,313,000 kWh/year
> **Total Industry Output**: $12,083,544
> **Employees**: 7
> **Source**: 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".

Table A.11. IMPLAN Expenditures for: Co-fire (15%) of Cellulosic Residues (Corn, Wheat, Rice, Switchgrass, Forest, Poplar, Mill, and Urban) with Coal.

Type	IMPLAN Sector	IMPLAN Sector Description	Expenditures
Investment	41	Other New Construction (Biomass Handling System Installation, Civil Structural, Electrical)	$1,850,692
Investment	232	Prefabricated Metal Buildings and Components (Wood Silo with Live Bottom)	$47,684
Investment	292	Conveyor & Conveying Equipment Manufacturing (Conveyor #1, Radial Stacker, Radial Screw, Conveyor #2, etc.)	$474,775
Investment	298	Industrial Process Furnace & Oven Manufacturing (Modification at Burners)	$33,982
Investment	316	Industrial Process Variable Instruments (Controls)	$156,794
Investment	346	Motor Vehicle Body Manufacturing (Truck Tipper with Hopper and Feeder)	$107,035
Investment	425	Banking (Contingency (30%))	$906,470
Investment	439	Architectural & Engineering Services (Engineering @ 10%)	$363,337
Operating	2	Grain Farming (Feedstock)	$2,207,703
Operating	485	Commercial Machinery Repair & Maintenance	$212,420
Depreciation	41	Other New Construction (Biomass Handling System Installation, Civil Structural, Electrical)	$185,069
Depreciation	232	Prefabricated Metal Buildings and Components (Wood Silo with Live Bottom)	$2,384
Depreciation	292	Conveyor & Conveying Equipment Manufacturing (Conveyor #1, Radial Stacker, Radial Screw, Conveyor #2, etc.)	$47,478
Depreciation	298	Industrial Process Furnace & Oven Manufacturing (Modification at Burners)	$3,398
Depreciation	316	Industrial Process Variable Instruments (Controls)	$15,679
Depreciation	346	Motor Vehicle Body Manufacturing (Truck Tipper with Hopper and Feeder)	$10,703

Expenditure Summary for Co-fire (15%) of Cellulosic Residues (Corn, Wheat, Rice, Switchgrass, Forest, Poplar, Mill, and Urban) with Coal

Expenditure Type	Total $	$/kWh
Investment	$3,940,769	$0.03
Operating	$2,420,123	$0.02
Operating w/out Feedstock Expenditure	$212,420	$0.00
Depreciation	$264,711	$0.00

Table A.12. IMPLAN Expenditures for Co-fire (10%) of Cattle Feedlot Biomass with Coal (Feedlot Size 45,000 head).

Type	IMPLAN Sector	IMPLAN Sector Description	Expenditures
Investment	41	Other New Construction (Biomass Handling System Installation, Civil Structural, Electrical)	$1,850,692
Investment	232	Prefabricated Metal Buildings and Components (Wood Silo with Live Bottom)	$47,684
Investment	292	Conveyor & Conveying Equipment Manufacturing (Conveyor #1, Radial Stacker, Radial Screw, Conveyor #2, etc.)	$474,775
Investment	298	Industrial Process Furnace & Oven Manufacturing (Modification at Burners)	$33,982
Investment	316	Industrial Process Variable Instruments (Controls)	$156,794
Investment	346	Motor Vehicle Body Manufacturing (Truck Tipper with Hopper and Feeder)	$107,035
Investment	425	Banking (Contingency (30%))	$906,470
Investment	439	Architectural & Engineering Services (Engineering @ 10%)	$363,337
Operating	18	Agriculture & Forestry Support Activities	$156,615
Operating	407	Gasoline Stations (Fuel/Lube)	$68,698
Operating	425	Banking (Depreciation & Capital)	$296,974
Operating	485	Commercial Machinery Repair & Maintenance (Repair)	$621,944
Depreciation	41	Other New Construction (Biomass Handling System Installation, Civil Structural, Electrical)	$185,069
Depreciation	232	Prefabricated Metal Buildings and Components (Wood Silo with Live Bottom)	$2,384
Depreciation	292	Conveyor & Conveying Equipment Manufacturing (Conveyor #1, Radial Stacker, Radial Screw, Conveyor #2, etc.)	$47,478
Depreciation	298	Industrial Process Furnace & Oven Manufacturing (Modification at Burners)	$3,398
Depreciation	316	Industrial Process Variable Instruments (Controls)	$15,679
Depreciation	346	Motor Vehicle Body Manufacturing (Truck Tipper with Hopper and Feeder)	$10,703

Expenditure Summary for Co-fire (10%) of Cattle Feedlot Biomass with Coal (Feedlot Size 45,000 head)

Expenditure Type	Total $	$/kWh
Investment	$3,940,769	$0.03
Operating	$1,144,231	$0.01
Depreciation	$264,711	$0.00

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Conversion Technology: Landfill Gas
Facility Size: 34,457,555 kWh/year
Total Industry Output: $3,032,265
Employees: 30
Source: Environmental Protection Agency, Landfill Methane Outreach Program.
2005. Documents, Tools, and Resources. Energy Project Landfill Gas Utilization
Software (E-Plus).

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Table A.13. IMPLAN Expenditures for Landfill Gas.

Type	IMPLAN Sector	IMPLAN Sector Description	Expenditures
Investment	41	Other New Construction (Electricity Generation Installation & Other Costs, Gas Treatment Installation & Other Costs, Inter Connect Installation & Other Costs)	$1,774,789
Investment	205	Iron, Steel Pipe & Tube from Purchased Steel (Pipe)	$1,381,823
Investment	239	Metal Tank, Heavy Gauge, Manufacturing (Condensate Knockout)	$103,351
Investment	261	Oil & Gas Field Machinery & Equipment (Well & Well Heads)	$682,411
Investment	275	Air Purification Equipment Manufacturing (Filters)	$14,601
Investment	276	Industrial & Commercial Fan and Blower Manufacturing (Blowers)	$45,216
Investment	277	Heating Equipment, except Warm Air Furnaces (Radiator Costs)	$215,082
Investment	289	Air & Gas Compressor Manufacturing (Compressor)	$81,196
Investment	298	Industrial Process Furnace & Oven Manufacturing (Flares)	$68,444
Investment	316	Industrial Process Variable Instruments (Monitor)	$933
Investment	333	Electric Power & Specialty Transformer Manufacturing (Substation Costs & Intertie Wiring Costs)	$284,078
Investment	336	Relay & Industrial Control Manufacturing (Protective Relays Costs)	$42,670
Investment	341	Wiring Device Manufacturing (System Disconnect Costs)	$86,237
Investment	350	Motor Vehicle Parts Manufacturing (IC Low Engine & Engineer Wiring Costs)	$1,995,465
Investment	442	Computer Systems Design Services (Substation Telemetry Costs)	$9,120
Operating	485	Commercial Machinery Repair & Maintenance (Collection System Variable O&M, Compression System Variable O&M,)	$797,365
Depreciation	41	Other New Construction (Electricity Generation Installation & Other Costs, Gas Treatment	$177,479

Table A.13. IMPLAN Expenditures for Landfill Gas.

Type	IMPLAN Sector	IMPLAN Sector Description	Expenditures
		Installation & Other Costs, Inter Connect Installation & Other Costs)	
Depreciation	205	Iron, Steel Pipe & Tube from Purchased Steel (Pipe)	$138,182
Depreciation	239	Metal Tank, Heavy Gauge, Manufacturing (Condensate Knockout)	$10,335
Depreciation	261	Oil & Gas Field Machinery & Equipment (Well & Well Heads)	$68,241
Depreciation	275	Air Purification Equipment Manufacturing (Filters)	$1,460
Depreciation	276	Industrial & Commercial Fan and Blower Manufacturing (Blowers)	$4,522
Depreciation	277	Heating Equipment, except Warm Air Furnaces (Radiator Costs)	$21,508
Depreciation	289	Air & Gas Compressor Manufacturing (Compressor)	$8,120
Depreciation	298	Industrial Process Furnace & Oven Manufacturing (Flares)	$6,844
Depreciation	316	Industrial Process Variable Instruments (Monitor)	$93
Depreciation	333	Electric Power & Specialty Transformer Manufacturing (Substation Costs & Intertie Wiring Costs)	$28,408
Depreciation	336	Relay & Industrial Control Manufacturing (Protective Relays Costs)	$4,267
Depreciation	341	Wiring Device Manufacturing (System Disconnect Costs)	$8,624
Depreciation	350	Motor Vehicle Parts Manufacturing (IC Low Engine & Engineer Wiring Costs)	$199,547

Expenditure Summary for Landfill Gas

Expenditure Type	Total $	$/kWh
Investment	$6,785,416	$0.20
Operating	$797,365	$0.02
Depreciation	$677,630	$0.02

Conversion Technology: Warm Climate Methane Digester for Swine (4,000 Sow Farrow to Wean Pig with Pit Recharge)
Facility Size: 438,000 kWh/year
Total Industry Output: $38,544
Employees: 1
Source: 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.

Table A.14. IMPLAN Expenditures for Warm Climate Methane Digester for Swine (4,000 Sow Farrow to Wean Pig with Pit Recharge).

Type	IMPLAN Sector	IMPLAN Sector Description	Expenditures
Investment	41	Other New Construction (Excavation, Engine-generator building, heat loop, electrical)	$94,504
Investment	101	Textile Bag & Canvas Mills (Digester Cover)	$60,714
Investment	173	Plastic Pipe, Fittings, and Profile Shapes (Manure Transfer Pipe)	$3,753
Investment	277	Heating Equipment, except Warm Air Furnaces (Gas/hot water piping, boiler & hot water storage, hot water use equipment)	$28,245
Investment	288	Pump & Pumping Equipment Manufacturing (Gas pump, meter)	$3,551
Investment	333	Electric Power & Specialty Transformer Manufacturing (Engine-generator)	$96,503
Investment	439	Architectural & Engineering Services (Engineering)	$28,045
Operating	485	Commercial Machinery Repair & Maintenance (Engine Maintenance)	$14,408
Depreciation	41	Other New Construction (Excavation, Engine-generator building, heat loop, electrical)	$4,725
Depreciation	101	Textile Bag & Canvas Mills (Digester Cover)	$6,071
Depreciation	173	Plastic Pipe, Fittings, and Profile Shapes (Manure Transfer Pipe)	$375
Depreciation	277	Heating Equipment, except Warm Air Furnaces (Gas/hot water piping, boiler & hot water storage, hot water use equipment)	$2,824
Depreciation	288	Pump & Pumping Equipment Manufacturing (Gas pump, meter)	$355
Depreciation	333	Electric Power & Specialty Transformer Manufacturing (Engine-generator)	$9,650
Byproduct	30	Power Generation & Supply (Electricity)	$37,596
Byproduct	142	Petroleum Refineries (Value of reduced propane use)	$10,579

Expenditure Summary for Warm Climate Methane Digester for Swine (4,000 Sow Farrow to Wean Pig with Pit Recharge)

Expenditure Type	Total $	$/kWh
Investment	$315,315	$0.72
Operating	$14,408	$0.03
Depreciation	$24,000	$0.05
Byproduct	$48,175	$0.11

> **Conversion Technology**: Cool Climate Methane Digester for Swine (5,000 Sow Farrow to Finish Operation)
> **Facility Size**: 525,600 kWh/year
> **Total Industry Output**: $46,253
> **Employees**: 1
> **Source**: 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.

Table A.15. IMPLAN Expenditures for Cool Climate Methane Digester for Swine (5,000 Sow Farrow to Finish Operation).

Type	IMPLAN Sector	IMPLAN Sector Description	Expenditures
Investment	41	Other New Construction (Secondary Storage Basin)	$10,666
Investment	101	Textile Bag & Canvas Mills (Miscellaneous)	$4,909
Investment	239	Metal Tank, Heavy Gauge, Manufacturing (Complete Mix Digester)	$139,285
Investment	288	Pump & Pumping Equipment Manufacturing (Special Equipment (pumps, valves, meters))	$60,921
Investment	333	Electric Power & Specialty Transformer Manufacturing (Engine/generator Costs)	$119,104
Investment	439	Architectural & Engineering Services (Engineering)	$51,847
Operating	485	Commercial Machinery Repair & Maintenance (Engine Maintenance)	$10,977
Depreciation	41	Other New Construction (Secondary Storage Basin)	$1,067
Depreciation	101	Textile Bag & Canvas Mills (Miscellaneous)	$491
Depreciation	239	Metal Tank, Heavy Gauge, Manufacturing (Complete Mix Digester)	$13,929
Depreciation	288	Pump & Pumping Equipment Manufacturing (Special Equipment (pumps, valves, meters))	$6,092
Depreciation	333	Electric Power & Specialty Transformer Manufacturing (Engine/generator Costs)	$11,910
Byproduct	30	Power Generation & Supply (Electricity)	$40,928

Expenditure Summary for Cool Climate Methane Digester for Swine (5,000 Sow Farrow to Finish Operation)

Expenditure Type	Total $	$/kWh
Investment	$386,732	$0.74
Operating	$10,977	$0.02
Depreciation	$33,489	$0.06
Byproduct	$40,928	$0.08

Conversion Technology: Methane Digester for Dairy (1,000 head)
Facility Size: 1,080,000 kWh/year
Total Industry Output: $95,040
Employees: 1
Source: Nelson, C. and J. Lamb. 2002. "Final Report: Haubenschild Farms
Anaerobic Digester Updated". The Minnesota Project 2002.

Table A.16. IMPLAN Expenditures for Methane Digester for Dairy (1,000 head).

Type	IMPLAN Sector	IMPLAN Sector Description	Expenditures
Investment	41	Other New Construction (Cement Work, Piping Installation, Excavating/Grading, Building, Component Installation)	$80,688
Investment	101	Textile Bag & Canvas Mills (Cover)	$8,354
Investment	239	Metal Tank, Heavy Gauge, Manufacturing (Digester Tank)	$88,979
Investment	277	Heating Equipment, except Warm Air Furnaces (Heating & Gas Pipes)	$22,669
Investment	288	Pump & Pumping Equipment Manufacturing (Manure Pump & Gas Pump/Meter)	$13,969
Investment	333	Electric Power & Specialty Transformer Manufacturing (Engine-generator/hot water recovery)	$110,178
Investment	439	Architectural & Engineering Services (Engineering)	$42,374
Operating	485	Commercial Machinery Repair & Maintenance (Engine Maintenance)	$14,021
Depreciation	41	Other New Construction (Cement Work, Piping Installation, Excavating/Grading, Building, Component Installation)	$4,034
Depreciation	101	Textile Bag & Canvas Mills (Cover)	$835
Depreciation	239	Metal Tank, Heavy Gauge, Manufacturing (Digester Tank)	$8,898
Depreciation	277	Heating Equipment, except Warm Air Furnaces (Heating & Gas Pipes)	$2,267
Depreciation	288	Pump & Pumping Equipment Manufacturing (Manure Pump & Gas Pump/Meter)	$1,397
Depreciation	333	Electric Power & Specialty Transformer Manufacturing (Engine-generator/hot water recovery)	$11,018
Byproduct	30	Power Generation & Supply (Electricity)	$83,883
Byproduct	142	Petroleum Refineries (Offset Heating Costs - Propane)	$4,057

Expenditure Summary for Methane Digester for Dairy (1,000 head)

Expenditure Type	Total $	$/kWh
Investment	$367,211	$0.34
Operating	$14,021	$0.01
Depreciation	$28,449	$0.03
Byproduct	$87,940	$0.08

Table A.17. IMPLAN Expenditures for Methane Digester for Poultry (40,000 head).

Type	IMPLAN Sector	IMPLAN Sector Description	Expenditures
Investment	41	Other New Construction (Excavation, Engine-generator building, heat loop, electrical)	$94,504
Investment	101	Textile Bag & Canvas Mills (Digester Cover)	$60,714
Investment	173	Plastic Pipe, Fittings, and Profile Shapes (Manure Transfer Pipe)	$3,753
Investment	277	Heating Equipment, except Warm Air Furnaces (Gas/hot water piping, boiler & hot water storage, hot water use equipment)	$28,245
Investment	288	Pump & Pumping Equipment Manufacturing (Gas pump, meter)	$3,551
Investment	333	Electric Power & Specialty Transformer Manufacturing (Engine-generator)	$96,503
Investment	439	Architectural & Engineering Services (Engineering)	$28,045
Operating	485	Commercial Machinery Repair & Maintenance (Engine Maintenance)	$14,408
Depreciation	41	Other New Construction (Excavation, Engine-generator building, heat loop, electrical)	$4,725
Depreciation	101	Textile Bag & Canvas Mills (Digester Cover)	$6,071
Depreciation	173	Plastic Pipe, Fittings, and Profile Shapes (Manure Transfer Pipe)	$375
Depreciation	277	Heating Equipment, except Warm Air Furnaces (Gas/hot water piping, boiler & hot water storage, hot water use equipment)	$2,824
Depreciation	288	Pump & Pumping Equipment Manufacturing (Gas pump, meter)	$355
Depreciation	333	Electric Power & Specialty Transformer Manufacturing (Engine-generator)	$9,650
Byproduct	30	Power Generation & Supply (Electricity)	$37,596
Byproduct	142	Petroleum Refineries (Value of reduced propane use)	$10,579

Expenditure Summary for Methane Digester for Poultry (40,000 head)

Expenditure Type	Total $	$/kWh
Investment	$315,315	$0.72
Operating	$14,408	$0.03
Depreciation	$24,000	$0.05
Byproducts	$48,175	$0.11

APPENDIX B: 2006 USDA Baseline Extended to 2025 (USDAExt)

POLYSYS is initially anchored to the 2006 USDA baseline, which contains projections values for agricultural variables from 2006 through the year 2015. Because the time horizon of the study goes to 2025, the 2006 USDA baseline is extended to 2025 by exogenously estimating three variables. These variables are export changes, yield changes, and population changes. All other variables are solved endogenously from these changes.

Exports

Exports beyond 2015 (the final year of USDA baseline) are determined by extending the trend in the final three years of USDA baseline outward. Corn and wheat export trends are reduced 50%. The resulting export projections are used to 'shock' the model in the first iteration and thereafter solving to an endogenous equilibrium. The baseline exports are listed in Table B.1 along with the annual rate of change.

Yields

The last three years of USDA baseline trend in yields are extended beyond 2015 to 2025. The resulting baseline yields are listed in Table B.2 along with the annual rates of change for the individual crops.

Population

Population of the U.S. is extended out using U.S. Census Bureau 2006 estimates. (http://www.census.gov/ipc/www/usinterimproj/). Population estimates affect food demand and therefore crops prices and production. Table B.3 gives the Census Bureau estimates for population in the US.

In addition, commodity programs were kept under the same legislation and instrument levels prevailing in 2006 and the Conservation Reserve Program contracts were extended to the year 2025.

Table B.1. Export Projections for Estimated Baseline, USDAExt.

	2006	**2010**	**2015**	**2020**	**2025**	**Change**
Corn (mil bu)	2,100	2,125	2,375	2,576	2,791	1.78%
Grain Sorghum	175	155	165	170	172	0.89%
Oats	3	3	3	3	3	0.00%
Barley	20	20	20	21	23	0.61%
Wheat	1,000	1,000	1,125	1,192	1,272	1.33%
Soybeans	1,095	1,030	975	1,036	1,100	1.05%
Cotton (mil bales)	15	16	16	17	18	1.26%
Rice (mil cwt)	116	117	123	134	145	1.62%

*Shocked model with USDA baseline trend to all except corn and wheat, where shock factor =50% of USDA baseline trend.

Table B.2. Yield Projections for Estimated Baseline, USDAExt.

	2006	2010	2015	2020	2025	Rate of Change
Corn(bu/ac)	147.7	154.9	163.9	173.3	183.3	1.13%
Sorghum	65.0	66.8	69.0	71.6	74.2	0.76%
Oats	62.8	64.4	66.4	68.4	70.6	0.61%
Barley	64.4	66.8	69.8	72.9	76.2	0.88%
Wheat	42.7	44.3	46.3	48.4	50.5	0.88%
Soybeans	40.7	42.3	44.3	46.4	48.5	0.93%
Cotton(lbs/ac)	760.0	780.0	805.0	830.6	857.1	0.43%
Rice(lbs/ac)	6,917.0	7,184.0	7,477.0	7,771.0	8,076.5	0.79%

*USDA baseline trends extended beyond 2014 to 2025

Table B.3. Population Projections for Estimated Baseline, USDAExt.

	Projected to the Year:				
Item	2005	2010	2015	2020	2025
Population (000)	295,530.5	308936.0	322,302.0	335,846.0	349,758.0

U.S. Bureau of Census, 2006

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