IMPLICATIONS OF ENERGY AND CARBON POLICIES FOR THE AGRICULTURE AND FORESTRY SECTORS

BIO-BASED ENERGY
ANALYSIS GROUP

AGRICULTURAL POLICY
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November 2010

By

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BACKGROUND-Energy and carbon policies could have considerable sector wide impacts on agriculture and on greenhouse gas emissions from agriculture. With this policy consideration, key questions arise regarding how various energy and carbon policy instruments might impact the agricultural and forestry sectors. The 25x'25 Alliance asked the University of Tennessee's Bio-Based Energy Analysis Group (BEAG) to analyze how several proposed policy instruments might impact land use change, feedstock production, feedstock prices, and farm income, as well as carbon costs and payments for producers. Results in this report focus on agriculture and forestry sector analysis; providing potential impacts on agriculture and forestry as a result of the establishment of a national Renewable Electricity Standard (RES) and the allowance of carbon capture and sequestration payments. This study also evaluates the potential impacts of the carbon policies on the nation's economy through the agriculture sector impacts.

ABOUT BEAG-The Bio-Based Energy Analysis Group, located at the University of Tennessee, is an inter-disciplinary research and outreach group which strives to provide decision makers in government and industry with the most up to date economic and environmental analysis of the bio-based energy industry at the state, regional, and national levels. In 2006, BEAG assessed the ability of the agriculture and forestry sectors to produce 25 percent of the energy consumed by the nation by 2025 while continuing to produce safe, abundant and affordable food, feed and fiber. An additional study was conducted in 2009. Among the key findings, the study found that America's farms, forests and ranches can play a significant role in meeting the country's renewable energy needs, that the 25x'25 goal is achievable and that it can be met without compromising the ability of the agricultural sector to reliably produce food, feed and fiber at reasonable prices. These reports can be viewed at **BEAG.ag.utk.edu**

ABOUT 25x'25-25x'25 is a renewable energy initiative backed by organizations and individuals united by a common interest in making America's energy future more secure, affordable and environmentally sustainable. Through its diverse alliance of agricultural, forestry, environmental, conservation and other organizations and businesses, 25x'25 partners have been working collaboratively since 2005 to advance the goal of securing 25 percent of the nation's energy needs from renewable sources by the year 2025. 25x'25 is led by a national steering committee composed of volunteer leaders from the agricultural, forestry and renewable energy communities. The initiative is supported by the Energy Future Coalition. More on 25x'25 can be found at **www.25x25.org**

PREVIOUS REPORT - ***Analysis of the Implications of Climate Change and Energy Legislation to the Agriculture Sector*** In November 2009, BEAG provided 25x'25 with an analysis of several agricultural offsets scenarios under a cap and trade mechanism. Including a scenario in which emissions, including those from agriculture are regulated by the U.S. Environmental Protection Agency (EPA) and no offsets are included. This analysis projected that under EPA regulation, net farm income would fall below the established baseline, and that the agriculture sector would be subject to higher input costs with no opportunity to be compensated for GHG reduction services. Under a scenario with multiple offsets the income from offsets and from market revenues is higher than any potential increase in input costs including energy and fertilizer, and net returns to the agriculture sector are projected to be positive and exceed the baseline projections for eight of nine crops analyzed.

The current analysis incorporates a carbon policy scenario from this November 2009 report. The carbon sequestration and capture scenario is combined with a renewable electricity standard and compared to the implementation of a renewable electricity standard alone. This analysis also includes a broader range of woody biomass feedstocks in the scenario building.

The study has been funded by The Energy Foundation. An electronic copy of the report can be viewed and downloaded at **www.25x25.org** and at **BEAG.ag.utk.edu**

EXECUTIVE SUMMARY

This study developed policy scenarios to project how meeting potential energy and carbon policies might impact the U.S. agriculture and forestry sectors. The Renewable Fuels Standard (RFS) established by The Energy Independence and Security Act (EISA) of 2007 is assumed to be continued into the future for the purposes of this analysis and serves as the baseline for comparison. Policy instruments considered in these scenarios include a renewable electricity standard (RES) and a carbon policy including carbon payments to producers. In total, including the baseline, three scenarios are considered:

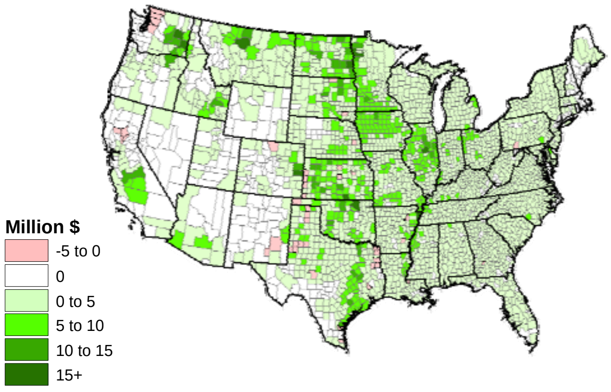
1) The ***EISA* (*Baseline)*** Scenario in which the renewable fuels standard (RFS) that was established under EISA is met;

2) The ***EISA+RES*** Scenario under which the RFS that was established under EISA is met and a renewable electricity standard (RES) is met; and

3) The ***EISA+RES+CPAY*** Scenario*,* which meets the RFS established under EISA, meets a RES, and incorporates a payment system for carbon based environmental services. (These services include conservation tillage, bioenergy crops production, afforestation, grasslands management, and methane capture).

KEY FINDINGS – *EISA+RES* Scenario

The results of this study show that with a properly designed Renewable Electricity Standard (RES), economic returns to the agriculture and forestry sectors are significant and are projected to be widespread across the United States. Implementation of an RES would significantly add to the national economy and create over 700,000 jobs. Demand and production of biomass feedstocks in the form of dedicated energy crops are expected to increase to meet the renewable fuels standard established under EISA and to meet the renewable electricity standard (RES), but there would not be significant changes to commodity cropland use, or crop and livestock prices. With an RES carbon emissions from agricultural lands are reduced by 2025, but not as significantly as when an RES is combined with a carbon capture and sequestration payment program or in the baseline scenario without an RES.



Under the EISA+RES Scenario, in 2025, positive agricultural net returns are scattered across the United States.

- Economic net returns to agriculture are projected to be positive in the ***EISA+RES*** Scenario compared with the baseline; including up to $14 billion in accumulated additional revenues for agriculture and forestry compared with EISA; these increases in net returns are projected to be widespread across the U.S.;

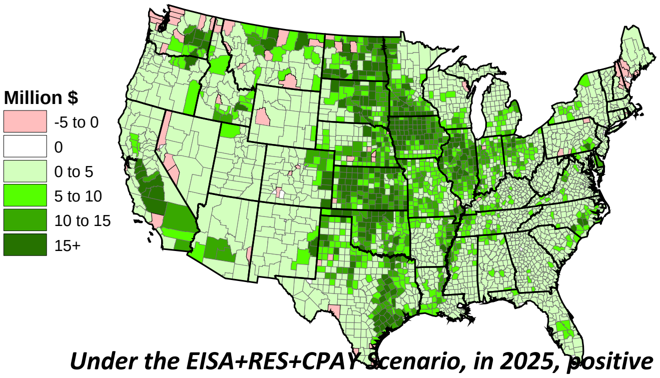
- Positive national economic impacts are projected to occur as a result of the ***EISA+RES*** Scenario, including $215 billion of additional economic activity, the creation of over 700,000 jobs, and $84 billon added to the nation's GDP;

- Net carbon emissions are reduced under the ***EISA+RES*** Scenario, but the environmental performance with regard to carbon is slightly less effective than under ***EISA*** alone;
- Bioenergy feedstock production increases in the form of dedicated energy crops;
- Demand for bioenergy feedstocks will cause shifts to more intensely managed pasture land; forest residues, thinnings and short rotation woody biomass crops will play a significant role in meeting feedstock demands;
- Major shifts in commodity cropland use do not occur;
- Major crop and livestock prices are not disrupted;
- Both prices and production increase over time for beef, pork, and poultry; thus increasing gross returns for all three scenarios.

KEY FINDINGS – *EISA+RES+CPAY* Scenario

A properly designed RES and carbon pricing mechanism, which allows for carbon payments, while limiting agricultural residue removals to appropriate levels, can produce significant reductions in carbon emissions from agriculture. Implementation of these policies would provide positive economic returns to the agriculture and forestry sectors, while simultaneously strengthening the national economy and creating new jobs. Similar to the implementation of an RES alone, the demand and production of biomass feedstocks will increase in the form of dedicated energy crops without significantly changing commodity cropland use and without affecting crop and livestock prices.

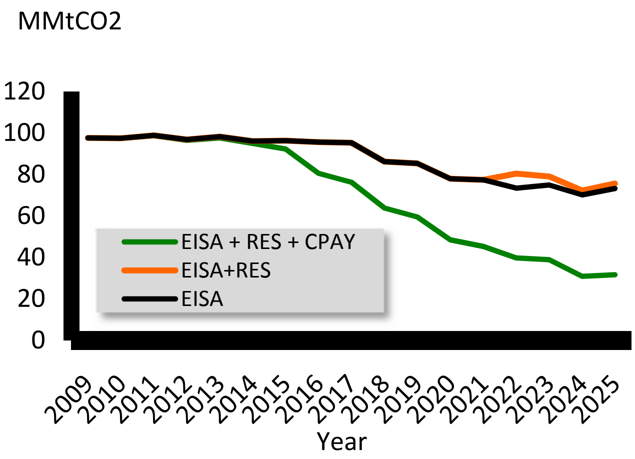
- Economic net returns to agriculture are projected to be positive in the ***EISA+RES+CPAY*** Scenario compared with the baseline, including up to $57 billion in accumulated additional revenues for agriculture and forestry compared with EISA; these increases in net returns are projected to be widespread across the U.S.;



Under the EISA+RES+CPAY Scenario, in 2025, positive agricultural net returns are scattered across the United States.

- Positive national economic impacts are projected to occur as a result of the ***EISA+RES+CPAY*** Scenario, and are greater than in the ***EISA+RES*** Scenario. When including multiplier effects through the economy, there is an additional $226 billion in economic activity, an addition of over 800,000 jobs and $87 billion added to the nation's GDP;

- Income from carbon payments and from market revenues are higher than any potential increase in the cost of inputs such as energy and fertilizer;
- Biomass feedstock production creates significant direct and indirect reduction in greenhouse gases (GHG) in the ***EISA+RES+CPAY*** scenario; Net carbon emissions are reduced 76 million tons of carbon dioxide equivalents;
- Bioenergy feedstock production would increase in the form of dedicated energy crops;
- Demand for bioenergy feedstocks will cause shifts to more intensely managed pasture land; forest residues, thinnings and tree harvest will play a significant role in meeting feedstock demands;
- Major shifts in commodity cropland use do not occur;
- Major crop and livestock prices are not disrupted;
- Prices and production increase over time for beef, pork, and poultry; thus increasing gross returns for all three scenarios. Adding the carbon policy to increased energy feedstock demands is projected to decrease production of the three livestock sectors by less than 1 percent each.



Net carbon emissions from agricultural lands are significantly reduced in the EISA+RES+CPAY Scenario.

OVERVIEW OF POLICY IMPACTS, 2010 - 2025

Policy Scenarios	*Economic Net Returns (Accumulated 2010-2025)*	*Climate Net Carbon Flux[*] (Accumulated 2010-2025)*	*Feedstock Max. Price*	*Renewable Energy Production (2025)*	*Change in Total Industry Output Compared with **EISA** in 2025*	*Change in Number of Annual Jobs Compared with **EISA** in 2025*
	Billion $	*MMTCE****	*$/dry ton*	*Quad BTU*	*Billion $*	*(1000)*
EISA	2,960	386	45.00	4.21	-------[**]	--------
EISA+RES	2,974	394	50.00	4.78	$215	723
EISA+RES+CPAY	3,017	310	51.00	4.96	$227	805

*Carbon flux is amount of carbon dioxide (CO_2) released over a specific time interval.

**Many of the impacts reported in this document are estimated by comparing the scenario of interest to the baseline. The baseline contains EISA but no additional energy or carbon policy. Therefore, the impacts of EISA are not included in the impacts reported in this report.

*** Million Metric Tons of Carbon Equivalent

KEY STUDY ASSUMPTIONS

- The ***EISA*** Scenario contains the RFS, which requires 36 billion gallons of renewable fuels by 2022, with 21 billion gallons coming from cellulosic ethanol and/ or advanced biofuels and one billion gallons from biodiesel by 2012.
- The ***EISA+RES*** and ***EISA+RES+CPAY*** Scenarios contain an RES that requires electric utilities with some exceptions to generate 25% of their electricity from renewable energy resources by 2025.
- The ***EISA+RES+CPAY*** Scenario encompasses a carbon policy which entails several distinct policy instruments:
    - **Carbon Price** – It is assumed that carbon use will result in increased costs at a rate of up to $27/ton by 2030.
    - **Agricultural Environmental Services** – Agriculture will be paid for environmental carbon capture and sequestering services (conservation tillage, bioenergy crops production, afforestation, grasslands, and methane capture).
    - **Residue Removal** – Crop residue removals fields is limited to both a carbon neutral level and a soil erosion limit. The baseline and the ***EISA + RES*** Scenario limits residue removal to soil erosion control only.
    - **Fertilizer Exemption** – the energy that is used to produce fertilizer is exempt from carbon pricing.
- The study used POLYSYS, an agricultural policy simulation model of the U.S. agricultural sector, to project the impacts to the agricultural sector from these potential policy scenarios, while IMPLAN is used to project the economic impacts.
- No attempts have been made to estimate the changes in infrastructure requirements to move renewable electricity from where it’s produced to population centers where it can be used nor are the costs or investments of moving cellulose to meet the EISA and RES demands incorporated. Therefore, the costs, investments that would be required, and the impacts to the economy of transporting feedstocks or transmitting electricity are not included in the economic impacts of this analysis.

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STUDY PURPOSE AND BACKGROUND

The purpose of this study is to project how proposed energy and carbon policies that increase the use of renewable energy and reduce greenhouse gas emissions (GHG) might affect the U.S. agricultural sector. At the time of our analysis, the Energy Independence and Security Act of 2007 (EISA) was in place. The law established a renewable fuels standard (RFS) requiring the production of 36 billion gallons of renewable fuels by 2022 (U.S. Congress, 2007). During the 111th U.S. Congress several energy and/or climate bills were proposed. While differences in proposed legislation exist, many contained one or both of two key energy policy instruments: a renewable electricity standard (RES) and a carbon policy that establishes a price for carbon and allows for carbon payments to agriculture. This study examines several policy scenarios that would result from the varying application of these policy instruments.

A renewable electricity standard (RES)—also referred to as a renewable portfolio standard (RPS)—requires certain electricity retailers to provide a minimum specified share of their total electricity sales from qualifying renewable power generation. RES policies can incorporate market-based mechanisms that enable obligated entities to buy or sell tradable renewable energy certificates (RECs) to demonstrate compliance (Sullivan, Logan, Bird, and Short, 2009).

In the agriculture and forestry sectors, carbon payment mechanisms are designed to reduce greenhouse gas emissions and reward farmers for good practices. These may be established through various policy and market avenues. Past policies have included a pricing mechanism for carbon emissions and allow for offsets. Emissions sources with excess allowances (i.e., sources with more allowances than emissions) would be allowed to trade or sell those offsets to other regulated or non-regulated entities to meet their reduction targets. Carbon projects that capture and sequester carbon would receive a payment for those services. In this analysis, conservation tillage, bioenergy crop production, afforestation, grassland management and methane capture are included as carbon capture and sequestering activities that are eligible for carbon payments. However, these carbon payments could also come through other mechanisms such as tax credits, voluntary carbon markets, and USDA run incentive programs similar to the Conservation Reserve Program

By examining three scenarios: 1) EISA as a baseline; 2) EISA and an RES; and 3) EISA, an RES and carbon payments, this study seeks to project how the policy instruments of an RES and carbon price mechanism with multiple allowable carbon capture and sequestering practices might impact the agricultural sector and generate climate benefits, as measured by changes to net carbon flux (net carbon flux represents the amount of carbon leaving a system). Information on how legislative changes will impact land use change, feedstock production, feedstock prices, farm income, carbon costs, payments for producers, and resulting national economic impacts is provided.

STUDY ASSUMPTIONS

SCENARIO DEVELOPMENT

The impacts of two key policy instruments are examined in this study; these instruments are a RES and pricing system for carbon. Hence, the focus of the analysis is on both energy use and carbon policy and analysis scenarios are developed accordingly (Table 1). Three scenarios are evaluated in this analysis:

- The baseline is formed by taking a USDA projection and extending it to 2025 and requiring not only the 15 million gallons of ethanol from corn demand but also the rest of the EISA fuel mandate. In the baseline, the use of crop residues is allowed when soil erosion concerns are met;
- In the second scenario, a renewable electricity standard must also be met, and the use of crop residues is the same as the baseline; and
- In the third scenario, a carbon pricing strategy (and the related carbon payments) is added along while increasing the constraint on crop residue removal. Crop residues cannot be removed if soil carbon levels cannot be maintained. Fertilizers are exempt from carbon pricing.

Table 1. Changes in Variables of the Policy Scenarios Analyzed

Scenarios	Feedstock Production	Carbon Price	Allowable Carbon Capture and Sequestering Activities	Crop Residues Constrained	Fert-ilizers Exempt
1. EISA (Baseline)	Meet EISA	None	None	Soil erosion	NA
2. EISA+RES	EISA+RES	None	None	Soil erosion	NA
3. ***EISA+RES+CPAY***	EISA+RES	Up to $27	1. Conservation Tillage 2. Bioenergy Crops 3. Afforestation 4. Grasslands 5. Methane capture	Soil carbon neutral	Yes

ENERGY USE POLICY

With regard to energy use, the current RFS policy is embedded into an extended agricultural baseline that is provided by USDA. The USDA agricultural baseline provides long run projections for the farm sector for a 10 year period. The annual projections include agricultural commodities, agricultural trade, and aggregate indicators of the sector, such as farm income and food prices (ERS, 2010). The USDA baseline is extended beyond the 10 year span, with the extended baseline running to 2025. The extended baseline also incorporates cellulosic ethanol expansion, as well as extending yield growth and commodity per capita demand. This baseline is referred to throughout the document as the ***EISA*** Scenario. This scenario contains the RFS which requires 36 billion gallons of renewable fuels by 2022, with 21 billion gallons coming from cellulosic ethanol and/or advanced fuels and one billion gallons from biodiesel by 2012.

The impacts of two other scenarios are compared with the ***EISA*** Scenario. Energy use in these scenarios will increase incorporating a renewable electricity standard. ***EISA+RES*** and ***EISA+RES+CPAY*** contain an RES that requires electric utilities to generate 25% of their electricity from renewable energy sources by 2025.

CARBON POLICY

These scenarios include combinations of energy and carbon policies. None of the scenarios are designed to represent a specific piece of legislation. Rather, they are created to look at general impacts of policy instruments that have been proposed. In ***EISA*** and ***EISA+RES***, no carbon policy is applied. Hence, ***EISA+RES*** enables comparison of the effects of an RES without carbon policies in place. ***EISA+RES+CPAY*** incorporates a carbon policy. The carbon policy will entail several distinct policy instruments.

- The first is the pricing mechanism of carbon. It is assumed that carbon use will result in increased costs at a rate of up to $27/ton by 2030 (Figure 1). As a result of this increase in carbon prices, the price of electricity is projected to increase 14 percent and petroleum price 4.7 percent from the baseline in 2025 by EPA (USDA/ERS, 2009).
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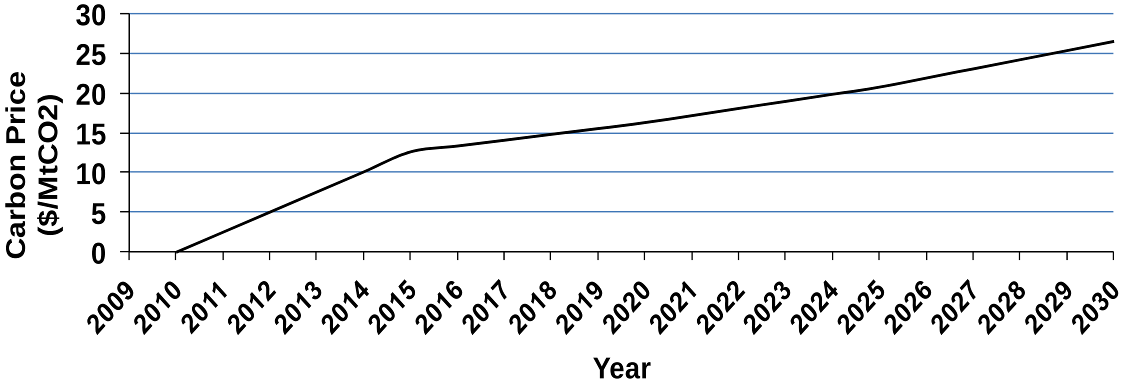


Figure 1. Carbon Costs, by Year

(Source: US/EPA, 2009a)

- The second is the ability of agriculture to sell or receive payment for environmental carbon capture and sequestering services. These services include conservation tillage, bioenergy crops production, afforestation, grasslands, and methane capture. Payments are priced at the same level as allowances, but after discounts for transaction costs and the expected program discounts for unintentional reversals, the net receipts per ton will be reduced. The net receipts as a portion of the carbon prices employed for each activity type are: 40 percent for a change in tillage practices, 30 percent for afforestation, 20 percent for methane capture, and 20 percent for production of bioenergy crops (Table 2)(De La Torre Ugarte, 2009).

- A third requirement is that the amount of crop residue that can be removed from fields is limited to both a carbon neutral level, a level where carbon stored does not decrease, and a soil erosion limit. The baseline and the ***EISA+RES*** Scenario limits residue removal to soil erosion control only. The payment for carbon capture and sequestration services is reduced from the carbon price reflecting market transaction costs, aggregator costs, and verification costs (see Table 2).

Table 2. Payment Level Reductions Across Practices

Practices	Value Reduced (%)	Practices	Value Reduced (%)
Conservation Tillage	40	Grassland Establishment	20
Bioenergy Crops Production	20	Methane Capture	20
Afforestation	30		

(Source: 25x ’25 Economic Planning Team)

RENEWABLE ENERGY GOALS

Legislation proposed in Congress called for a national Renewable Electricity Standard (RES). The RES proposed in this analysis would establish that 25 percent of energy produced by retail electricity producers will come from renewable energy sources by 2025. However, there are some exemptions. In April 2009, EIA provided an analysis of a renewable electricity standard that was initially proposed by Congressman Markey and modified by the U.S. House of Representatives. EIA estimated that, given exceptions to small power retailers, hydro sales, municipal solid waste (MSW) sales, and states taking allowable energy efficiency credits,

In this analysis, renewable energy can be generated using the following technologies: non-agricultural includes new hydro (pre 2001 is defined as old hydro), solar, land fill gases, and geothermal; renewable energy development likely to occur on the nation’s productive farm, forest, and range lands includes wind and biomass.

the effective RES rate would be approximately 17 percent by 2025 (Table 3). This percentage progression in the RES forms the basis for the level of power requirements in ***EISA+RES*** and **EISA+RES+CPAY** and is the first step in defining the energy goal for the scenarios ***EISA+RES*** and ***EISA+RES+CPAY***.

To project requirements from renewable energy under the policy scenarios evaluated, projected values for energy consumption must first be obtained. Information from both the 2009 and 2010 Annual Energy Outlooks were used to develop the energy requirements for each of the scenarios. The Energy Information Administration (EIA) projected in the 2010 *Annual Energy Outlook* the amount of energy that will be needed annually through the year 2035 (USDOE/EIA, 2010a). The analysis indicates that by 2025, 108.3 quadrillion BTUs of energy (Quads) will be needed to meet demand. In 2009, the United States consumed 100.1 Quads of energy.

It is estimated that the United States electricity consumption by 2025 would equal nearly 12 Quads of energy or 4,577 billion kWh of electricity by 2025. By the year 2025, under a renewable portfolio or electricity standard, the United States could be required to produce 918 billion kWh in electricity from renewable sources (EIA, 2009) (Figure 2).

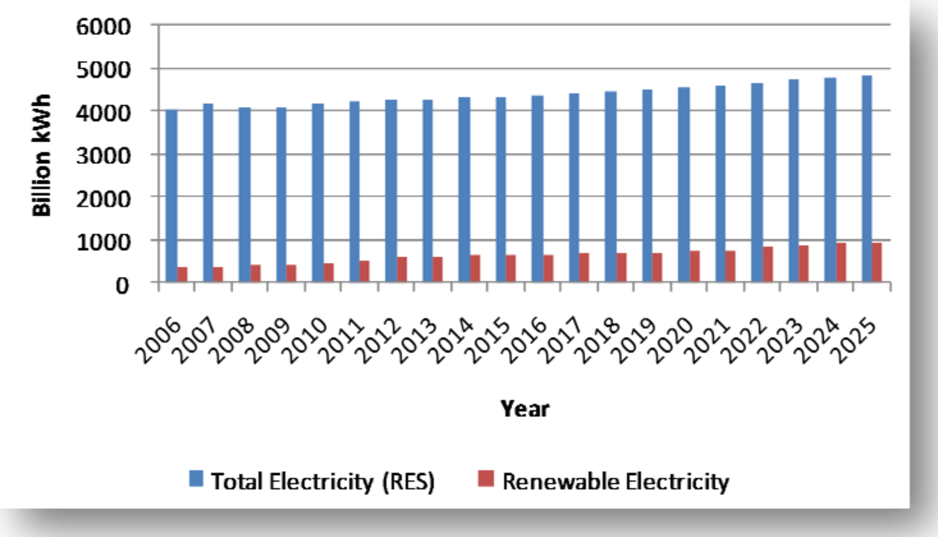


Figure 2. Projected Electricity Consumption and Renewable Electricity Standard, 2009 - 2030 (Department of Energy, 2009)

Table 3. Provisions of the Proposed Renewable Electricity Standards

		Annual Percentage Excluding:		
Calendar Year	Production Percentage	Small Power Retailers	Small Power Retailers, Hydro Sales, and MSW Sales	Small Power Retailers, Hydro Sales, MSW Sales and States Taking Allowable Energy Efficiency Credits
		Percent		
2012	6	5.28	5.04	3.4272
2013	6	5.28	5.04	3.4272
2014	8.5	7.48	7.14	4.8552
2015	8.5	7.48	7.14	4.8552
2016	11	9.68	9.24	6.2832
2017	11	9.68	9.24	6.2832
2018	14	12.32	11.76	7.9968
2019	14	12.32	11.76	7.9968
2020	17.5	15.4	14.7	9.996
2021	17.5	15.4	14.7	9.996
2022	21	18.48	17.64	11.9952
2023	21	18.48	17.64	11.9952
2024	23	20.24	19.32	13.1376
2025	25	22	21	17

(Source: USDOE/EIA, 2009)

The second step is to separate the contributions of different types of renewable energy. Renewable energy can come from a variety of sources such as solar, land fill, geothermal, additional hydro, wind, and biomass. In 2009, the United States consumed 100.1 Quads of energy. Of this, 8.65 came from renewable energy with 0.91 Quads from ethanol and biodiesel. The electric power sector produced 3.65 quads of electricity from renewable energy sources and the industrial sector used 2.53 Quads of renewable generated electricity (Figure 3). Much of this energy was in hydro and biomass.

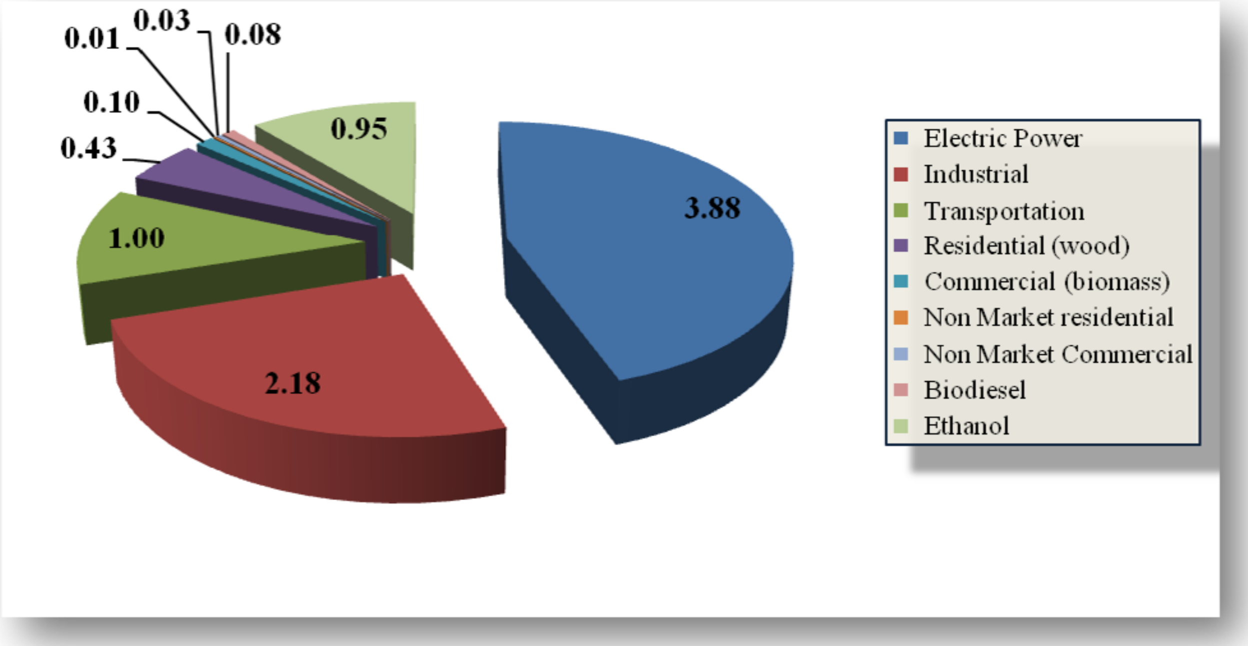


Figure 3. Quads of Renewable Energy Generated in the United States, 2009

(Source: Department of Energy, Energy Information Administration, 2010)

To estimate electricity required from biomass, the amount of electricity from other renewable sources is first estimated based on the reference case levels of production of the various types of renewable electricity. For hydro, the amount of kWh produced in 2006 was subtracted from the production values for each year (2009 through 2030) to obtain the additional renewable electricity projected from hydro for each year. The EIA Reference Case splits solar production into two types -- solar photovoltaic and solar thermal. Using the ratio of a solar technology to the total solar electricity used, an estimate of the proportion for each solar technology is obtained (Table 4).

The infrastructure requirements to move renewable electricity from where its produced to population centers where it can be used is not incorporated in this study nor are the costs or investments of moving cellulose to meet the EISA and RES demands. Therefore, the costs, investments that would be required, and the impacts to the economy of transporting feedstocks or transmitting electricity are not incorporated.

Table 4. Estimated Additional Renewable Electricity Production by Technology Required to Meet the RES, 2010-2030

	Year:			
Renewable Electricity Production Technology	2010	2015	2020	2025
	Billion kWh			
Solar Photovoltaic	0.39	2.03	3.99	5.40
Solar Thermal	2.78	12.42	15.17	14.72
Land Fill	6.72	8.72	8.72	8.72
Geothermal	3.21	7.28	7.29	7.31
Additional Hydro	(18.61)	9.54	9.62	10.19
Wind	85.42	176.31	176.82	180.67
Additional Biomass	2.33	(16.58)	212.29	553.80
Total Additional Renewable Electricity	82.25	199.72	433.91	780.81

MAJOR ASSUMPTIONS

THE CONTRIBUTION OF BIOMASS

This study will assess the potential contribution of biomass feedstocks from agricultural sources such as those from traditional crops (corn and soybeans), dedicated herbaceous energy crops, dedicated short rotation woody crops such as willow and hybrid poplar, agricultural byproducts (corn stover, wheat straw, animal waste and fats, forest residues, mill wastes, and food processing wastes), and trees harvested for energy use.

DEDICATED HERBACEOUS ENERGY CROP YIELDS

There are numerous potential dedicated energy crops that may contribute to the nation’s energy supply. In this analysis, switchgrass is used as an example of an herbaceous dedicated energy crop. 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 5). 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 5. Changes in Dedicated Energy Crop Yields, Through 2025, by Region

			Projected Yields	
REGION	Base Yield	Annual Breeding Gains	10 Years	15 Years
		Tons/Acre		
North East	4.87	5.0%	7.3	9.7
Appalachia	5.84	5.0%	8.8	11.7
Corn Belt	5.98	5.0%	9.0	12.0
Lakes States	4.8	5.0%	7.2	9.6
Southeast	5.49	5.0%	8.2	11.0
Southern Plains	4.3	5.0%	6.5	8.6
North Plains	3.47	5.0%	5.2	6.9

(Source: Hellwinckel and De La Torre Ugarte, 2005).

SHORT ROTATION WOODY BIOMASS

Woody cellulosic feedstocks are considered in the model, including coppice (e.g., willow) and non-coppice (e.g., poplar and pine) woody crops. Feedstock yields and costs of production are unique to the county level (Perlack *et al.*, 2010). Woody crops have an average growth rate of 5 Mg C per hectare annually, and we assume a 5 percent growth rate per year on new plantings to account for future advances in breeding and selection.

CURRENT STANDING FOREST

The current industrial and nonindustrial private forest stand is growing at a certain rate which depends on species and location. This rate has been estimated by the US Forest Service and is contained in the Forest Inventory Assessment data. While this rate can be altered over a period of time by adding new genetic material or by changing management practices, it is assumed that over the next 15 years the current growth rate is not significantly impacted.

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 increase availability without affecting the amount of residues that need to be left in the ground for erosion control and soil sustainability. In the ***EISA*** Scenario, from 2010 to 2030, no-till is allowed to change at ½ the rate of change in acres between 1994 and 2006. This tillage trend changes from the baseline due to changes in incentives (increased carbon costs and increased value of carbon sequestration) that are reflected in the policy runs. Conservation tillage practice does not change as a result of changes in the incentives.

AUGMENT THE LANDBASE

This study focuses on the use of crop and forest lands, 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 (USDA-NASS, 2009). 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 (Figure 4). Not all of these lands will be available for conversion to cropland. Two major assumptions limit pastureland conversion. First, currently irrigated pastureland cannot be converted to biomass crops. If investments have been made in irrigating pastureland, low-input non-irrigated biomass crops would not likely supplant the existing land use. Second, we

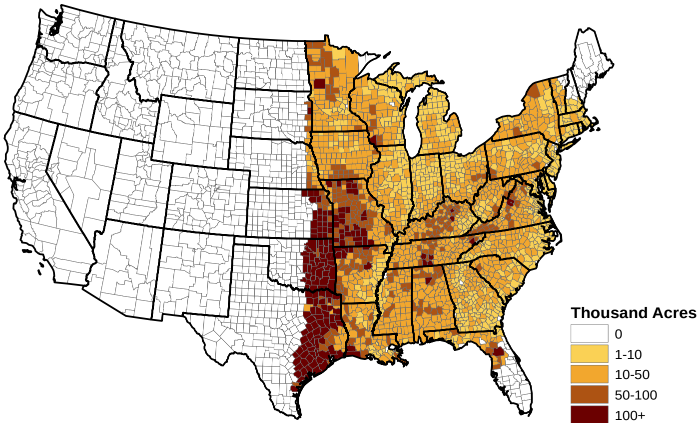


Figure 4. Location of Pasture/Rangeland Available for Conversion

limit pastureland conversion to land east of the meridian passing through Omaha, Nebraska. We assume that pastureland intensification can make up for displaced forage from pasture converted to biomass crops. In more arid regions, the yield benefits of pastureland intensification are not realized. Although ranchers have had success with management intensive grazing out to the 100th meridian (central Nebraska), we move the line of delineation eastward to be conservative in our estimation. These assumptions limit total potential pastureland conversion to less than 68 million acres. If pastureland is converted to energy crops, then an equal amount of regional pastureland must be intensified. We assume that the forage yields on this land can double through intensified management. This requirement results is the same amount of roughage being available for the beef industry.

YIELDS OF TRADITIONAL COMMODITIES

Yields of traditional crops are also assumed to increase over time as projected in the USDA Baseline through to year 2018. For years after 2018, we extend the projected yield increase from the last three. Yield growth rates range from 0.43 percent for cotton to 1.13 percent for corn (Table 6). These yields were used in all three scenarios.

Table 6. Yields of the Eight Major U.S. Crops

	Annual Change in Yields	
Crop (unit)	2009-2018	2019-2025
	Percent Change	
Corn (bushels)	1.23	1.13
Sorghum (bushels)	0.16	0.16
Oats (bushels)	0.65	0.61
Barley (bushels)	0.95	0.88
Wheat (bushels)	0.85	0.88
Soybeans (bushels)	0.99	0.93
Cotton (pounds)	1.24	0.43
Rice (pounds)	1.06	0.79

RESULTS

OVERALL RANKINGS BY CRITERIA

Four criteria were used in evaluating the performance of the various policy scenarios. These criteria were economic (net returns), climate effects (net carbon flux), feedstock value (maximum price), and bioenergy production (quadrillion BTUs of energy). As can be seen in Table 7, the ***EISA+RES+CPAY*** Scenario produces the highest net returns of the three scenarios. In addition, this scenario produces the lowest net carbon flux. It also produces the highest level of bioenergy production. However, the scenario also produces the highest feedstock price.

The ***EISA+RES+CPAY*** scenario produces the highest net returns of the three scenarios. In addition, this scenario produces the lowest net carbon flux.

Overall, the results in this table reflect that increasing bioenergy production increases net returns to the agricultural sector and the availability of carbon payments significantly improve the environmental performance of the sector, while only increasing the feedstock costs by a small amount. Energy demands were met using a variety of feedstocks and technologies.

Table 7. Scenarios Ranking by Objective

	Indicator Objective*			
Scenarios	*Economic Net Returns* (Accumulative 2010-2025)	*Climate Net Carbon Flux* (Accumulative 2010-2025)	*Feedstock Max. Price*	Energy Production (2025)
	Billion $	*MMTCE*	*$/dt*	*Quads*
EISA	2,960	386	45.00	4.21
EISA+RES	2,974	394	50.00	4.78
EISA+RES+CPAY	3,017	310	51.00	4.96

*MMTCE stands for Million Metric Tons of Carbon Equivalent, and $/dt is the abbreviation for dollars per dry ton.

NET RETURNS TO AGRICULTURE

Displayed in Figure 5, the net returns to crops and livestock sectors, increase as the bioenergy demanded increases. The ***EISA+RES*** and the ***EISA+RES+CPAY*** Scenarios both show increased income above the ***EISA*** Scenario. During the initial 3 years, there are small changes; however, the increase becomes larger over time as renewable energy demand for electricity increases. As carbon payments are made available, additional improvements in net returns accrue. Regional net returns from the agricultural and forest sectors are widespread across the nation (Figure 6). However, the Great Plains, Southern Plains, Corn Belt, and Delta regions appear to obtain the greatest benefits in t

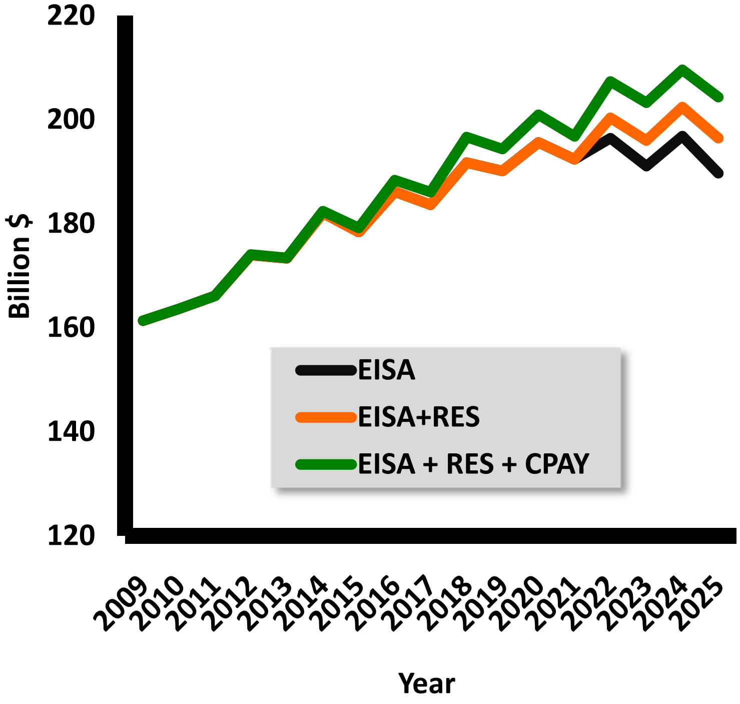
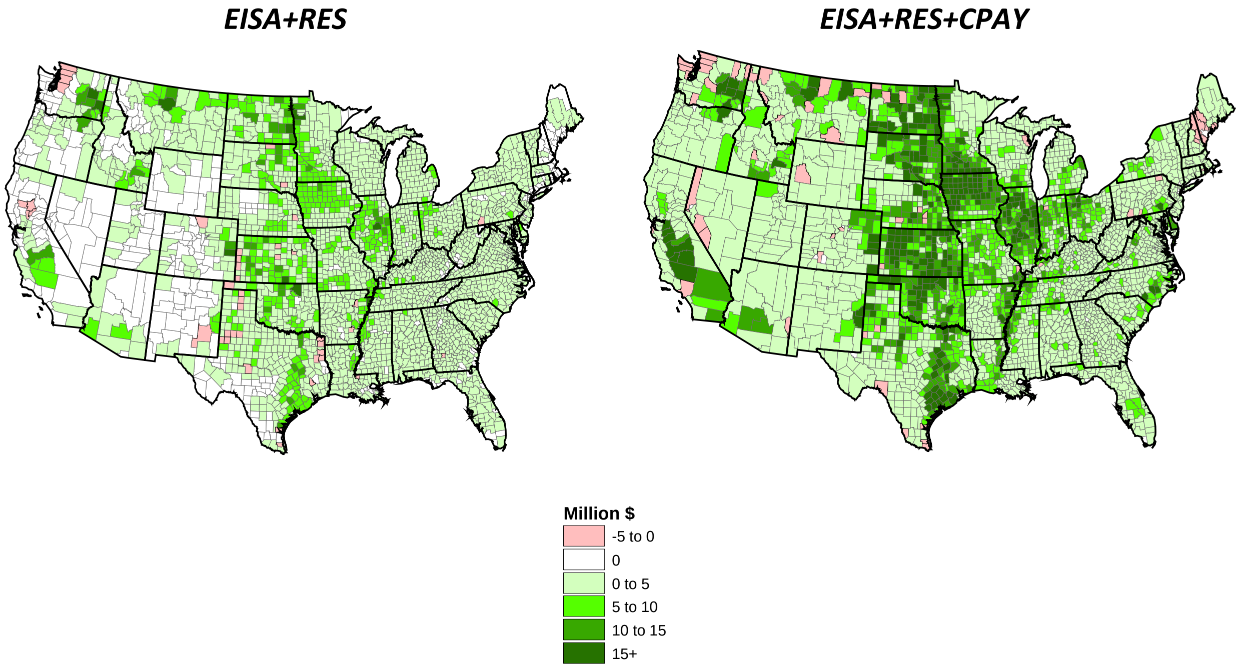


Figure 5. Agricultural Net Returns by Scenario, 2010-2025

CROP RETURNS

The first column of Table 8 shows the net returns by crop under ***EISA*** (Baseline), while columns 2 and 4 show the average change in crop net returns away from ***EISA***, for ***EISA+RES*** and ***EISA+RES+CPAY***, respectively. Columns 3 and 5 show the net contributions of carbon payments to these returns (the net incorporates not only carbon payments, but also increased costs of operation). Corn under the ***EISA+RES+CPAY*** increases $1.7 billion, with $170 million coming from net carbon payments. Wheat net returns increase $669 million and soybeans $531 million. In all cases, the crop net returns increase in the ***EISA+RES*** and the ***EISA+RES+CPAY*** Scenarios compared with ***EISA***.


EISA+RES

EISA+RES+CPAY

Figure 6. Net Returns to Agriculture and Forest Sectors Under the *EISA+RES* and *EISA+RES+CPAY* Scenarios, 2025

Table 8. Net Returns by Major Crops, by Scenario 2025

	EISA	*EISA+RES*		*EISA+RES+CPAY*	
Crop	Crop Net Returns	Change Crop Net Returns	Net Carbon Payments	Change Crop Returns	Net Carbon Payments
			(million $)		
Corn	29,548	535	-	1,686	170
Grain Sorghum	411	13	-	37	4
Oats	68	4	-	13	4
Barley	472	12	-	46	6
Wheat	7,150	202	-	669	94
Soybeans	20,613	118	-	531	210
Cotton	503	59	-	92	3
Rice	1,359	8	-	26	1

LIVESTOCK RETURNS

In 2007, livestock including cattle and calves, hogs, and poultry grossed $61, $18, and $37 billion, respectively (USDA/NASS, 2009). In the ***EISA*** Scenario or the baseline, the farm price for beef is projected to initially increase from about $90 per one hundred pounds (cwt) in 2010 to the low $100/cwt in the 2020's. A similar path is projected for both the ***EISA+RES*** and the ***EISA+RES+CPAY*** Scenarios. For hogs and pigs, the estimated farm price per cwt in the ***EISA*** moves from $45 in 2010 to the low $60's in 2022 through 2025. The projected broiler (poultry) price fluctuates between $43/cwt to $65/cwt during the period of analysis. Production also shifts. Total production of beef moves from 24.8 billion pounds in 2010 to 29.7 billion pounds in 2025. Hog production increases from 20.6 to 26.5 billion pounds and broiler production increases from 35 to 47 billion pounds.

Both prices and production are increasing over time for the three major livestock types. However, expenses are also increasing. The cost of grazing increases as does the cost of other feedstocks. For acres in pasture to transition to herbaceous/wood energy crop production, the management of a share of the remaining pasture acres requires intensification. To achieve intensification, an increase in forage productivity through fertilization, re-seeding legume-grass mixture or more intensive grazing management could be adopted. It is estimated that forage productivity could double at a cost between $40 and $80/acre (Barnhart, Duffy, and Smith, 2008). For instance if forage value equal 1 ton per acre, then after intensification 2 tons of forage would be available at double the cost per acre. Since the increase in the cost of feed grains is an expected event, it is assumed that the sector would gradually adjust its size to maintain similar levels of profitability. This assumption would not prevail under large unexpected shocks to the system. Production of beef, pork, and poultry is not impacted when comparing the ***EISA+RES*** to the ***EISA*** Scenario. However, the carbon policy does reduce the amount of inventory of all three livestock types. By 2025, the beef cow herd is reduced by 187,000 head, hog inventory changes by 346,000 head, and poultry production is reduced by 40 million pounds. This amounts to a 0.78 percent, 0.38 percent and a 0.11 percent reduction in beef, pork, and poultry, respectively (Figure 7).

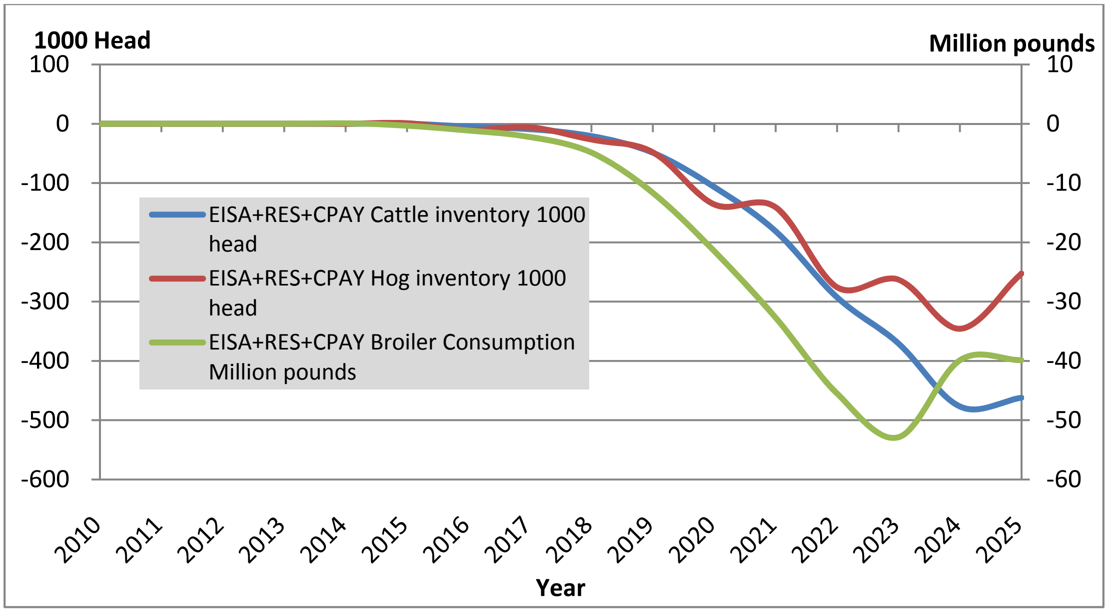


Figure 7. Estimated Change in Inventory or Production Levels, Cattle, Hogs, and Poultry, 2010-2025, *EISA+RES+CPAY*

Apparent from Figure 8, cash returns from cow-calf operations may experience a larger adjustment than hog or poultry operations. This occurs as the speed in adjustment in the livestock takes more time than the other sectors; a result of its natural cycle. The impacts of increased prices accumulate in the case of the scenario with ***EISA+RES+CPAY***, the sector slowly adjust to get back to the baseline level of returns by 2025. In any case, the key message from this figure is that for scenarios under consideration, the behavior of all the livestock sectors is similar to the ***EISA*** alone scenario. The reduction in cash returns occurs earlier in the case of the scenario with ***EISA+RES+CPAY***.

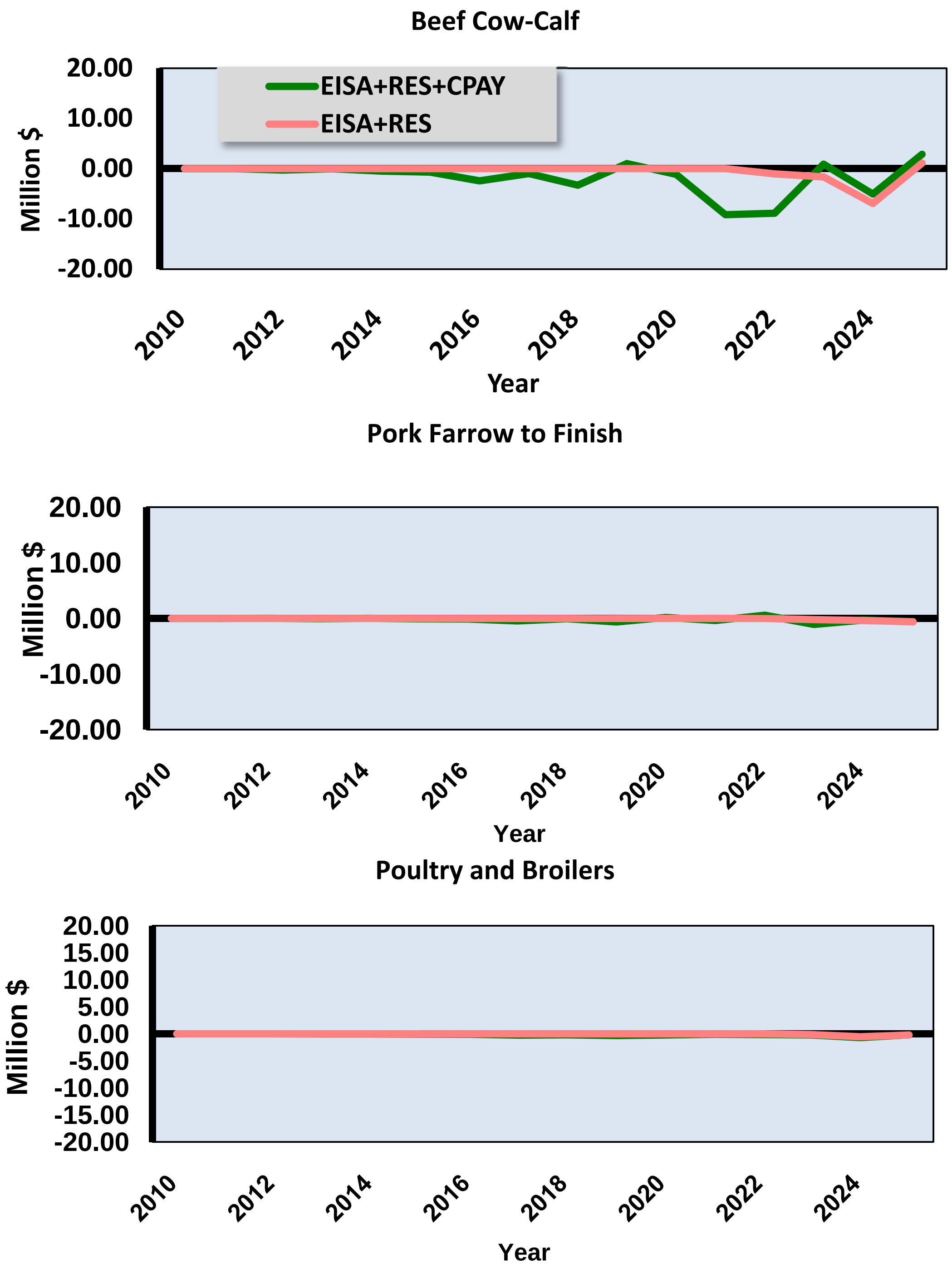


Figure 8. Livestock Average Cash Returns, By Scenario, 2010 – 2025

LAND USE

As energy production from biomass sources expands, when comparing the ***EISA+RES*** Scenario to ***EISA*** alone, the acreage in total major crops decreases about 5.57million acres; corn changes very little, wheat decreases 1.5 million acres (3 percent), and soybeans decrease 0.6 million acres (1 percent) (Table 9). A total of 45 million acres of dedicated energy crops are produced in the ***EISA+RES*** Scenario in 2025, with 9 million in woody crops and the remainder in herbaceous energy crops. To achieve this increase in acres, 5 million acres of pasture are management intensified in addition to the changes in major crop acres.

Table 9. Estimated Land Use by Scenario, 2025

	EISA	***EISA+RES***	***EISA+RES+CPAY***
		(million acres)	
Corn	87.91	88.18	87.75
Soybeans	65.17	64.43	62.25
Wheat	51.47	49.92	46.45
Cotton	8.57	8.54	7.05
Rice	2.67	2.71	2.64
Total Major Crops	**228.54**	**222.97**	**218.04**
Energy Crops	31.02	36.21	61.79
Energy Woody Crops	7.72	9.34	10.47
Total Energy Crops	**38.74**	**45.55**	**72.26**
Hay	61.18	61.18	61.18
Intensive Pasture	**11.78**	**16.58**	**32.29**
Pasture	**372.11**	**362.74**	**328.69**
TOTAL LAND	712.35	709.02	712.46
Pasture Converted	32.52	41.91	76.02

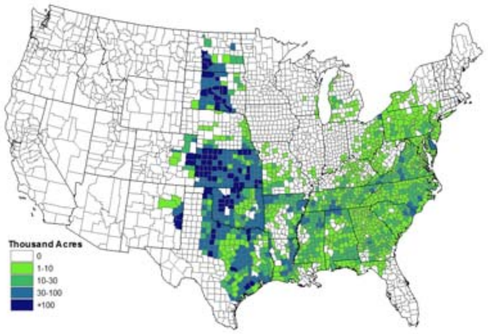
Adding the carbon payments plus restricting the amount of crop residues coming from major crops results in 72 million acres of dedicated energy crops or an additional 33.5 million acres from the ***EISA*** baseline. To achieve this, an additional 21 million acres of intensified pasture is needed and with an accompanying shift of 10 million acres in land currently planted in major crops. Production of dedicated energy crops is geographically widespread (Figures 9 and 10). Herbaceous dedicated energy crop acreage is concentrated in the Plains States with significant additional acreage occurring in the Mid-South. Woody crops acreage from poplars is concentrated the upper Midwest and the Delta States plus Florida, while acreage of willows occurs primarily in New England and the northernmost parts of Michigan, Minnesota, and Wisconsin. Dedicated energy crops are not grown in the Midwest as land rental prices are much higher compared to other states surrounding them.

Private industrial and non industrial forests also provide feedstock for bioenergy. In the ***EISA+RES*** Scenario, slightly more than 215,000 acres of hardwood timberland are harvested for biomass by 2025 along with 44,000 acres of pine (Figure 11). If under a carbon policy in addition to EISA and RES, nearly 340,000 acres of forest are projected to be harvested annually to supply cellulose either to be converted to a liquid fuel or to meet the RES by 2025. The difference between the two scenarios occurs as a result of the carbon harvest limit placed on crop residues as well as the carbon capture and sequestering practices placed on agricultural lands.

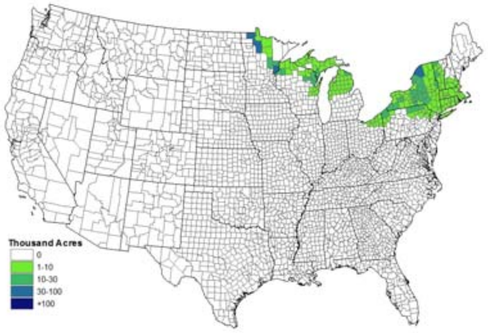
COMMODITY PRICES

The aforementioned changes in land use, do not significantly impact agricultural markets (Table 10). For example, all projected price changes commodity crops are 10 percent or less except for wheat in 2025 under the ***EISA+RES+CPAY*** Scenario. Most price changes reflected in the table are 5 percent or less.

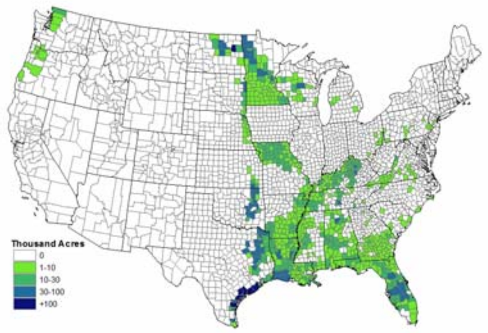
Herbaceous



Short Rotation Willow



Short Rotation Poplar

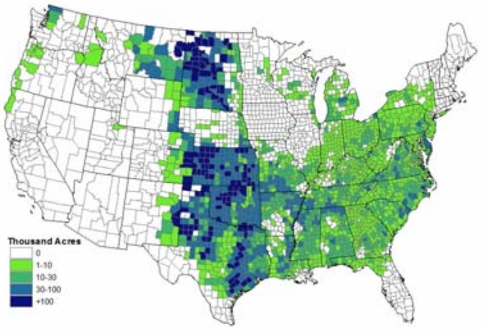


Thousand Acres

⬜	0
🟩	1–10
🟩	10–30
🟦	30–100
🟦	+100

Figure 9. Regional Land Use by Herbaceous and Woody Dedicated Energy Crops, *EISA+RES* Scenario, 2025

Herbaceous



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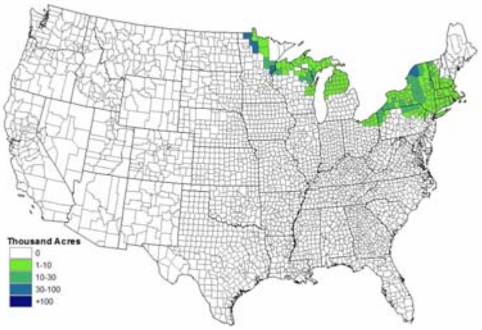

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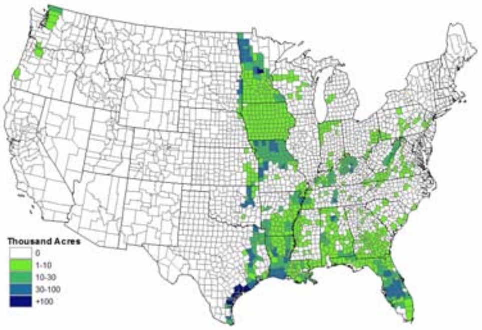
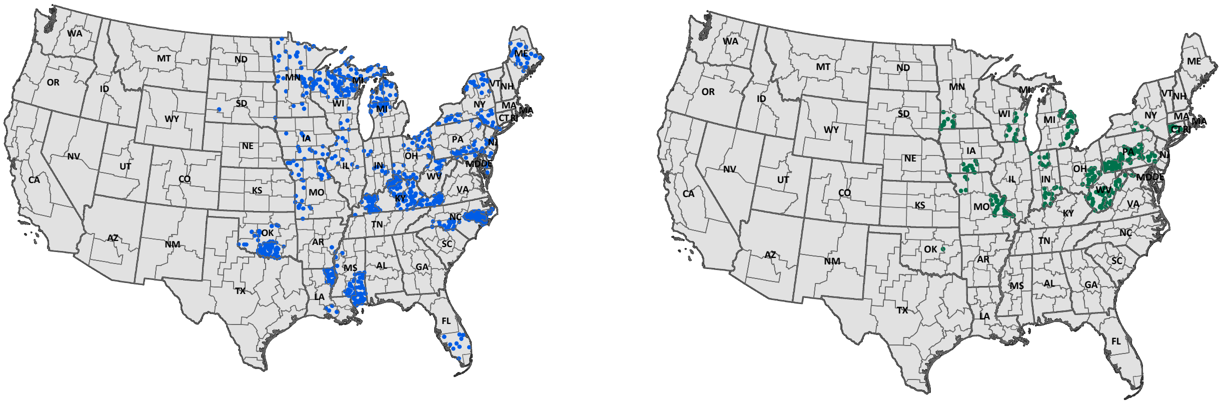


Thousand Acres
⬜ 0
🟩 1-10
🟩 10-30
🟦 30-100
🟦 +100

Figure 10. Regional Land Use by Herbaceous and Woody Dedicated Energy Crops, *EISA+RES+CPAY* Scenario, 2025

Hardwoods (1 Dot = 500 acres) **Pine (1 Dot = 300 acres)**

EISA+RES



EISA+RES+CPAY

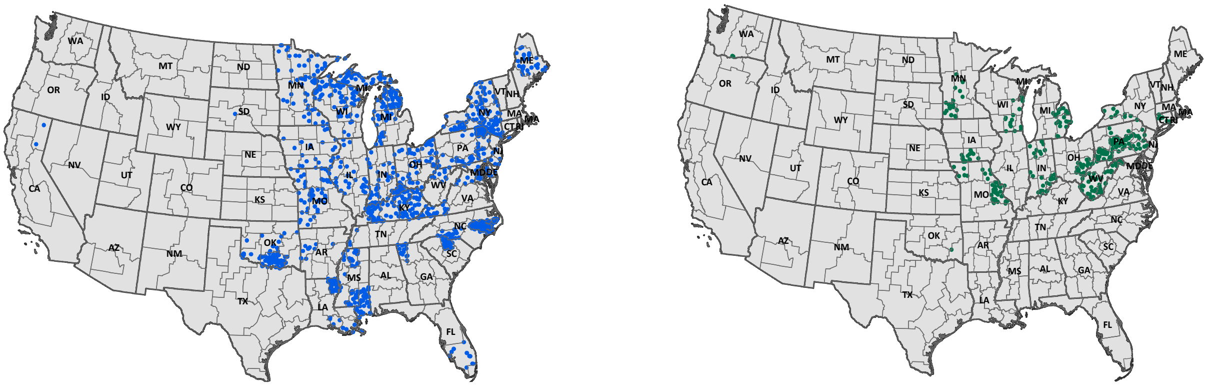


Figure 11. Additional Acres of Standing Forest Hardwoods and Pine Needed to Meet the *EISA+RES* or the *EISA+RES+CPAY* Scenario, 2025

Table 10. Prices of Selected Major Commodities, by Scenario, 2015, 2020, and 2025

	2015		2020		2025	
	Price	Change from Baseline	Price	Change from Baseline	Price	Change from Baseline
Corn ($/bu)						
EISA	3.61		4.13		3.68	
EISA+RES	3.61	0.0%	4.13	0.0%	3.70	0.5%
EISA+RES+CPAY	3.64	0.8%	4.33	4.8%	3.78	2.7%
Soybeans ($/bu)						
EISA	10.63		9.45		9.79	
EISA+RES	10.63	0.0%	9.45	0.0%	10.23	4.5%
EISA+RES+CPAY	10.67	0.4%	9.45	0.0%	10.73	9.6%
Wheat ($/bu)						
EISA	5.88		6.63		6.59	
EISA+RES	5.88	0.0%	6.63	0.0%	7.15	8.5%
EISA+RES+CPAY	5.94	1.0%	7.24	9.2%	7.58	15.0%
Cotton ($/lb)						
EISA	0.64	0.0%	0.69	0.0%	0.70	0.0%
EISA+RES	0.64	0.0%	0.69	0.0%	0.73	4.0%
EISA+RES+CPAY	0.64	0.8%	0.72	4.2%	0.74	5.5%

BIOMASS PRICE

Notably, as can be seen in Figure 12, biomass feedstock price does not vary greatly by scenario. In each case, the feedstock price increases from $30 per dry ton to above $45 per dry ton. As bioenergy demand increase over time, the price of the biomass feedstock increases as would be expected.

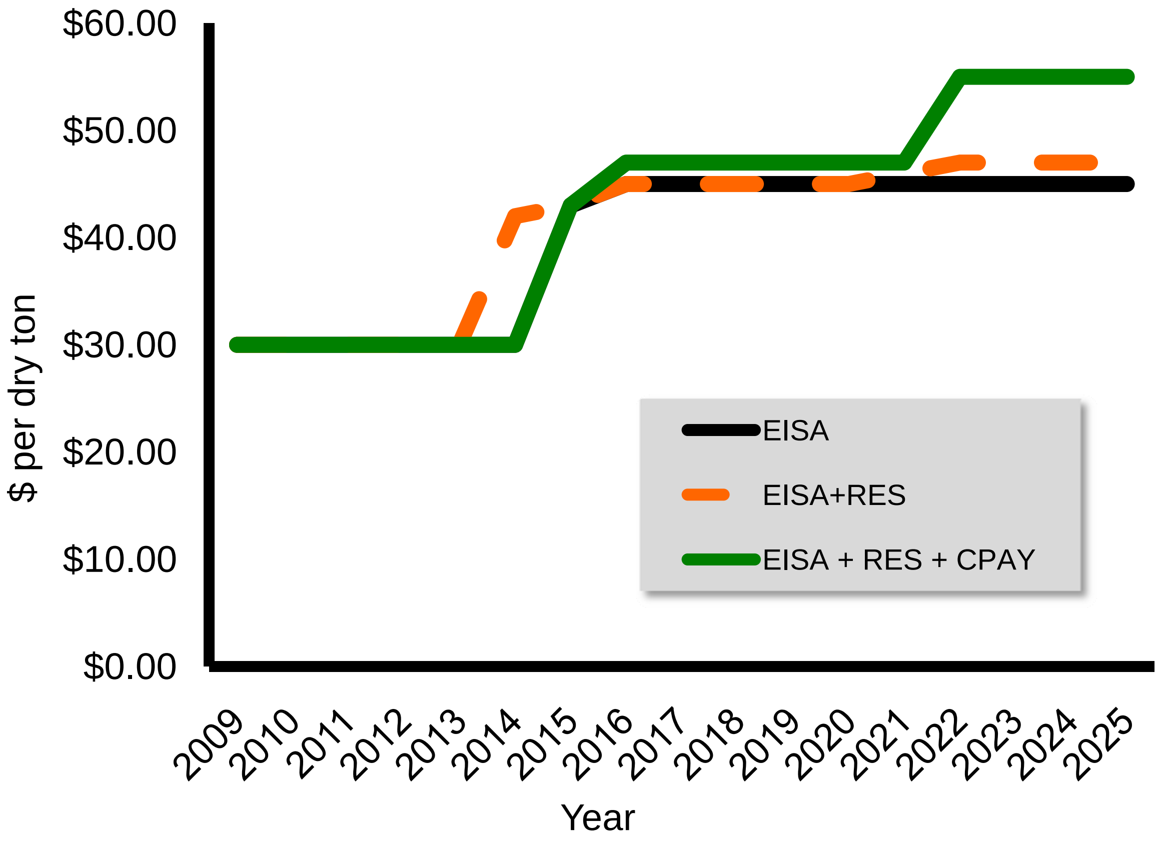
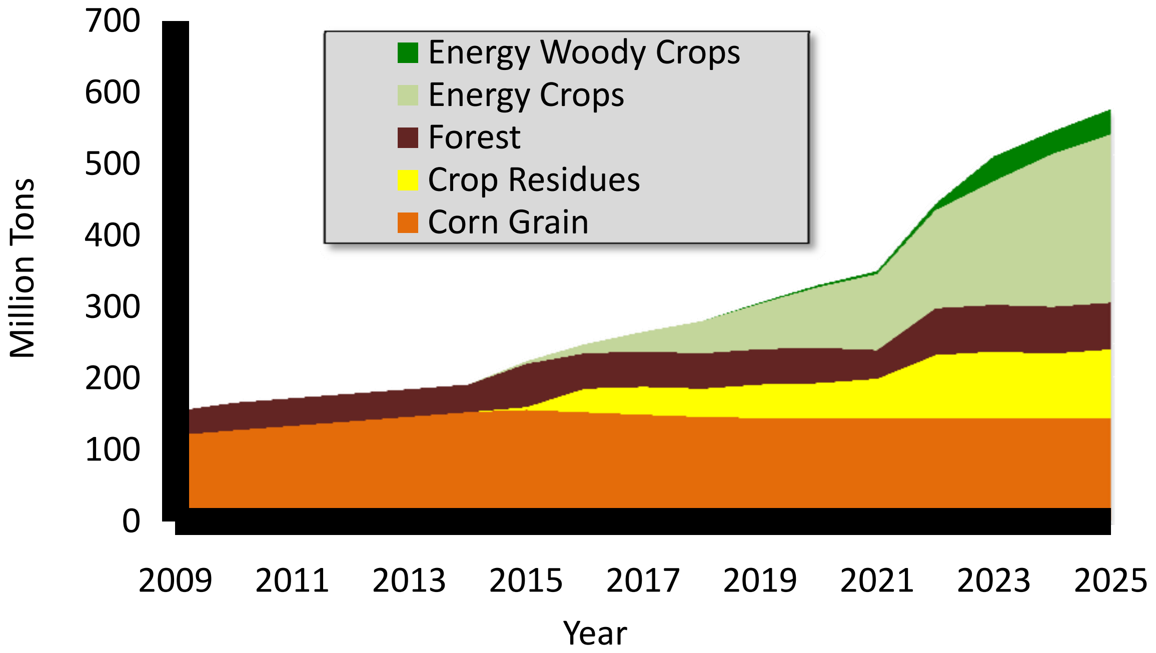


Figure 12. Biomass Feedstock Price, by Scenario, 2010 - 2025

BIOMASS FEEDSTOCKS

Figure 13 shows the feedstock supply composition for both the ***EISA+RES*** and the ***EISA+RES+CPAY*** Scenarios for the year 2025. Initially, feedstock demand is met by corn grain and forest feedstocks. Over time, herbaceous energy crops are produced and provide supplies for bioenergy, with this increasing to the majority share by 2025. In 2021, both woody dedicated energy crops and crop residues are required. The largest difference between the two scenario is the contribution of crop residues. In the EISA+RES Scenario, crop residues play a significant role in feedstock supply whereas in the EISA+RES+CPAY where crop residues are restricted to carbon neutral levels they are less significant.

EISA+RES



EISA+RES+CPAY

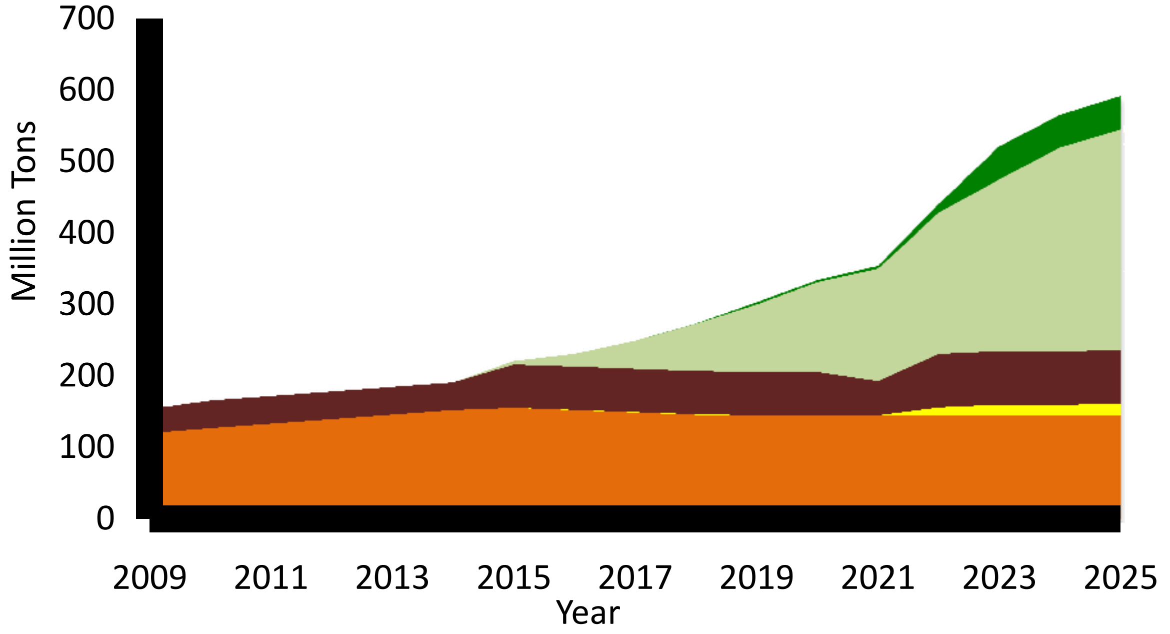


Figure 13. Feedstock by Source, *EISA+RES and EISA+RES+CPAY* Scenarios, 2010-2025

As cellulose is demanded, either for the production of electricity or liquid transportation fuels, 30 million dry tons of residues from logging operations and material from thinnings from forest management activities are supplied. In 2015, as the demands from renewable energy increases, about 20 million dry tons from whole tree forest operations are supplied. This increases to about 35 million dry tons by 2023 in the ***EISA+RES+CPAY*** Scenario and stays at 20 million dry tons in the ***EISA+RES*** Scenario. In total, an estimated 75 million dry tons per year will be supplied from our nation's timberlands in the ***EISA+RES+CPAY*** Scenario.

Contributions from forests are spread throughout the nation as shown in Figure 14. Trees are harvested primarily in the North Central Region and the New England states. Wastes and residues come from the Southeast and Pacific regions in addition to the North Central and New England states**.**

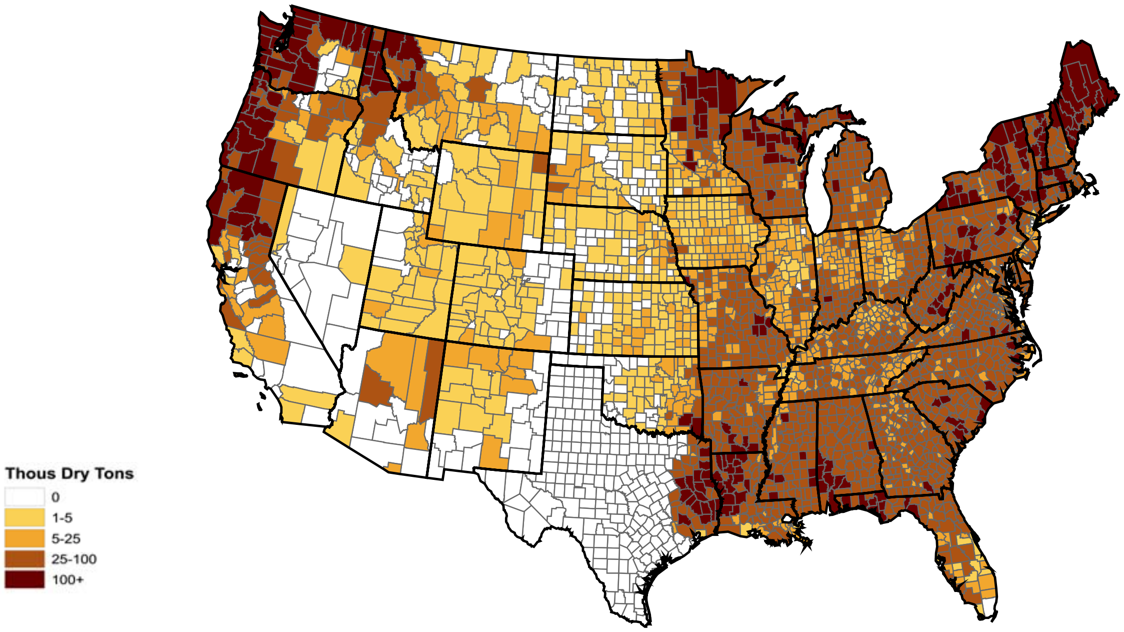


Figure 14. Forest Feedstock: Standing Forest, Wastes, & Residues, *EISA+RES+CPAY* Scenario, 2025, Thousand Dry Tons

CARBON EMISSIONS

All three scenarios show reductions in carbon emissions from agricultural and forest lands (Figure 15). Notably, the addition of the carbon payments provides 10 million metric tons of additional reductions. Tying energy independence to a well-constructed carbon policy that contains payments for agricultural producers to capture and sequester carbon will reduce the carbon footprint of agriculture significantly. A reduction of carbon emissions from agricultural lands of 76 million tons of carbon equivalent is projected under the ***EISA+RES+CPAY*** Scenario.

Tying energy independence to a well-constructed carbon policy that contains payments for agricultural producers to capture and sequester carbon will reduce the carbon footprint of agriculture significantly—76 million tons of carbon equivalent under the ***EISA+RES+CPAY*** Scenario.

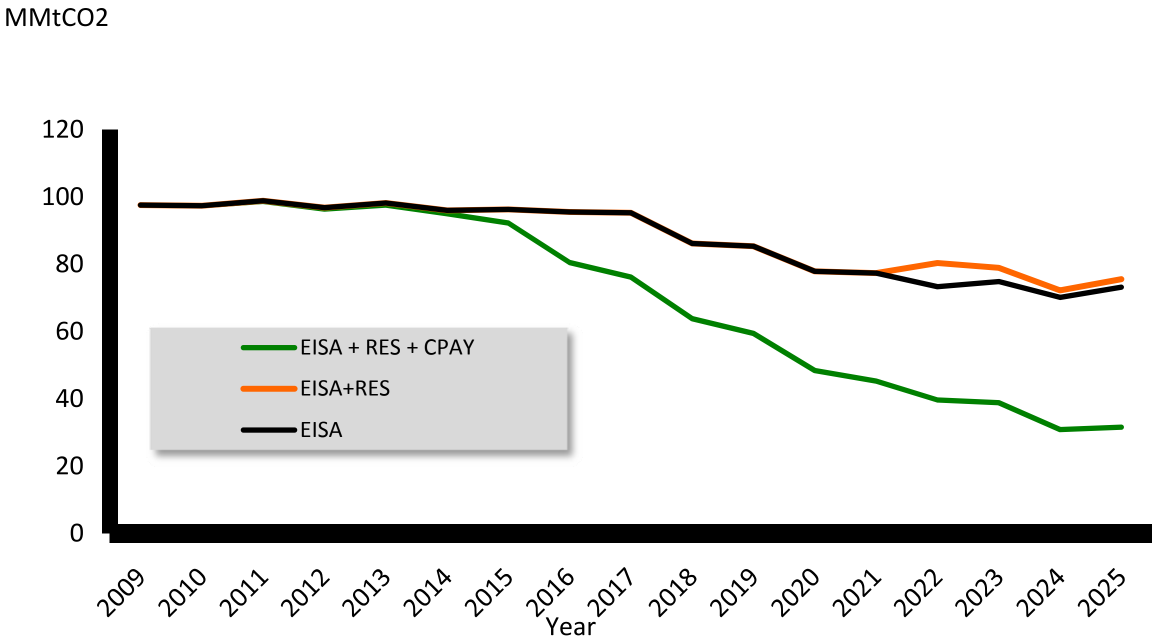


Figure 15. Changes in Carbon Emissions from Agricultural Lands, 2010-2025

In the ***EISA+RES*** Scenario, agricultural activity, including additional landuse, is required to meet the new demands placed on the sector as a result of the RES. This has the effect of increasing carbon emissions above the ***EISA*** alone scenario.[1]

Carbon policy modeled in the ***EISA+RES+CPAY*** Scenario results in two types of impacts to agricultural producers. The first impact occurs as a result of increased costs of energy and, hence, increases the cost of production. The second impact occurs as a result of the five carbon and sequestering practices modeled in the analysis. Once dedicated energy crops become viable, the returns from employing the practices exceed the costs of increased energy (Figure 16).

By 2025, the net revenue gained from carbon policy exceeds $1.0 billion. Aggregated over the 15 years, the net gain for agriculture is estimated at $ 5.7 billion ($15 billion in carbon payment income and -9.3 billion in increased energy costs) as a result of the increased price of carbon. Net revenue as a result of carbon policy is slightly negative for first 5 years. While these negative returns to agriculture are projected in the first several years, in subsequent years the returns exceed the costs imposed from increased energy costs.

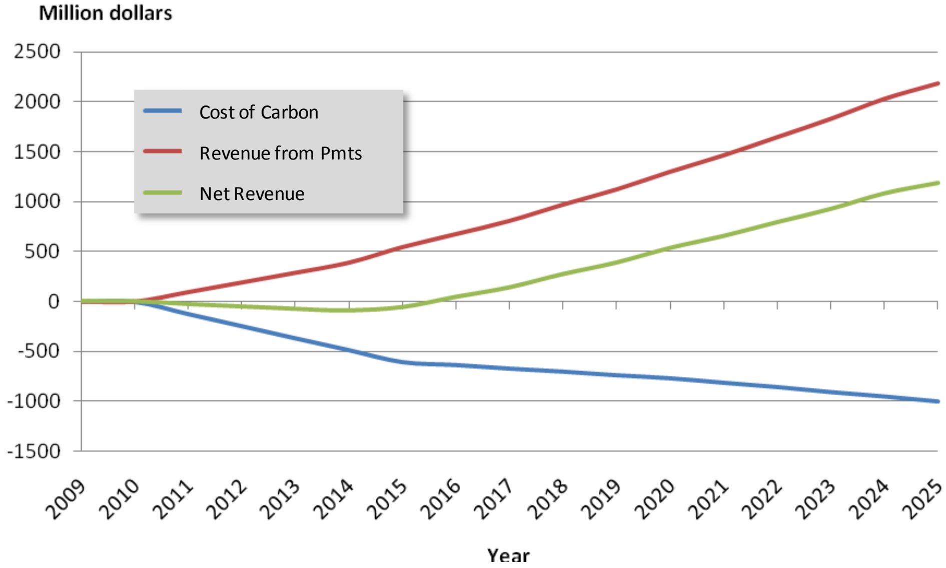


Figure 16. Direct Impact of the Carbon Policy, Increased Cost of Production, Economic Value of Carbon Payments, and the Net Impact, 2025, *EISA+RES+CPAY* Scenario

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[1] Measurements of carbon emissions in this analysis do not include the reduction of emissions that might occur as a result of fossil fuel replacement. If these reductions were taken into account, then the ***EISA+RES*** Scenario would likely result in carbon emission reductions below the ***EISA*** Scenario.

ECONOMIC IMPACTS

Total economic impacts are divided into three areas, the impacts caused by the investment and operation of the renewable energy sector, the impacts as a result of changes to the agricultural sector, and the impacts as a result of an energy price increase as a result of requiring more expensive energy from renewable sources. The total annual impact of these changes to the economy when compared to the ***EISA*** Scenario are estimated to be $227 billion of added economic activity for the ***EISA+RES+CPAY*** Scenario when compared to ***EISA*** and $214.3 billion when comparing ***EISA+RES*** to the base scenario (Table 11). These increases in economic impacts would be reduced as a result of increased consumer electricity prices.

Total jobs created by adding the RES and the carbon policy increase by 732,000 in 2025 when comparing the ***EISA+RES +CPAY*** to the ***EISA*** Scenario. This does not include those one time jobs created as a result of investment nor does it include additional jobs generated in the transportation sector moving the cellulose to the renewable energy sector or the investments required to develop additional transmission lines.

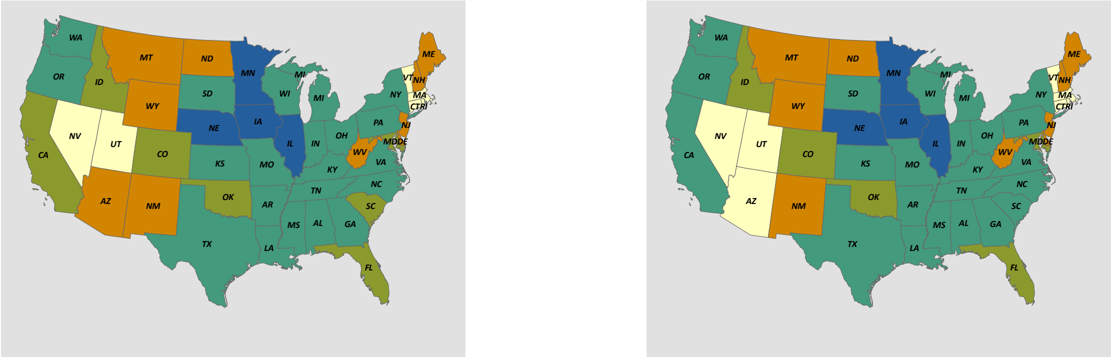
Table 11. Annual Economic Impact of Changes in the Nation's Economy Compared to the *EISA* Scenario Not Including Investment and Impact of Increased Electricity Prices

	2015	2020	2025
TIO:		Million $	
EISA+RES	$106,184.7	$166,264.6	$214,287.6
EISA+RES+CPAY	$106,576.6	$172,890.9	$227,486.5
Jobs:		(1000 jobs)	
EISA+RES	291	531	723
EISA+RES+CPAY	292	549	805

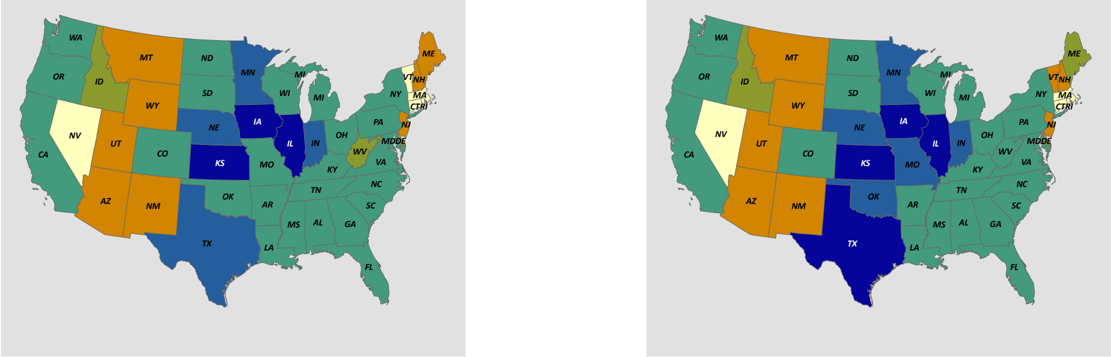
In the ***EISA+RES*** and the ***EISA+RES+CPAY*** Scenarios, all states show a positive total economic impact (Figure 17). States located in the Great Plains and the Corn Belt appear to receive the greatest benefits in terms of economic impacts.

EISA+RES ***EISA+RES+CPAY***

2015



2025



🟨 **$1.0 - $100.0**
🟧 **$100.0 - $500.0**
🟩 **$500.0 - $1,000.0**
🟩 **$1,000.0 - $5,000.0**
🟦 **$5,000.0 - $10,000.0**
🟦 **> $10,000.0**

Figure 17. State Economic Impacts Compared to EISA Scenario, 2015 and 2025, for the *EISA+RES* and *EISA+RES+CPAY* Scenarios

IMPACTS OCCURING AS A RESULT OF THE DEVELOPMENT OF A RENEWABLE ENERGY SECTOR

Table 12 shows the economic impacts of the renewable energy sector from the two policy scenarios, the ***EISA+RES*** and the ***EISA+RES+CPAY***, compared with ***EISA*** alone. Both results from year-to-year operations and from investment in facilities and equipment are presented.

By 2025, the ***EISA+RES+CPAY*** Scenario is projected to result in $93.4 billion in total industry output (TIO) directly through annual operations, and $207.9 billion including multiplier effects (defined in Appendix, Page 76) through the economy. With the ***EISA+RES+CPAY*** policy, it is projected that in 2025, over 35,000 jobs are projected to be added directly through annual operations, and nearly 682,000 jobs are projected to be added when multiplier effects are included. In addition, in 2025, the ***EISA+RES+CPAY*** Scenario is projected to produce $21.2 billion in Gross Domestic Product (GDP) directly through operations, and $79.7 billion with multiplier effects.[2] For each measure, TIO, employment, and GDP, the operations under the ***EISA+RES+CPAY*** Scenario produce greater economic impacts than from operations under the ***EISA+RES*** Scenario.

When projected investment impacts are examined, it can be seen that under the ***EISA+RES+CPAY Scenario***, in the 15 years, $91.5 billion are added directly through this investment, and nearly $293 billion in TIO is added when the multiplier effects are considered. Nearly 548,000 jobs are added directly and 1.76 million jobs are added including multiplier effects. About $41 billion can be attributed to GDP directly, and when including multiplier effects, GDP is projected to change by $145 billion over the 15 year period. For each measure, TIO, employment, and GDP, the operations under the ***EISA+RES+CPAY*** Scenario produce greater economic impacts from investment than the ***EISA+RES*** Scenario.

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[2] Using an income approach to calculating GDP approximates the value that is added in the process of production. The Income Approach sums the amounts in 5 categories Wages and Salaries, Profits, Interest and income from unincorporated businesses and investments plus indirect business taxes. This is approximated by value added estimated in IMPLAN.

Table 12. Projected Changes in Economic Impacts from Renewable Energy Operations and Investment from the *EISA* Scenario, by Scenario, 2015, 2020, and 2025

Type of Impact by Scenario	Year					
	Total Industry Output (TIO)					
	2015		**2020**		**2025**	
			Million $2010			
Operations	**Direct**	**Total**	**Direct**	**Total**	**Direct**	**Total**
EISA+RES	$53,590	$105,756	$77,534	$166,171	$93,080	**$206,153**
EISA+RES+CPAY	$53,651	$106,084	$78,004	$168,141	$93,448	**$207,929**
	2010-2015		**2010-2020**		**2010-2025**	
Investment	**Direct**	**Total**	**Direct**	**Total**	**Direct**	**Total**
EISA+RES	$50,747	$164,119	$72,018	$230,514	$88,369	**$282,036**
EISA+RES+CPAY	$51,419	$166,359	$74,917	$240,151	$91,536	**$292,559**
	Jobs					
	2015		**2020**		**2025**	
			Number			
Operations	**Direct**	**Total**	**Direct**	**Total**	**Direct**	**Total**
EISA+RES	17,563	290,398	28,435	517,525	35,285	**672,514**
EISA+RES+CPAY	17,573	292,224	28,503	527,687	35,349	**681,982**
	2010-2015		**2010-2020**		**2010-2025**	
Investment	**Direct**	**Total**	**Direct**	**Total**	**Direct**	**Total**
EISA+RES	336,514	1,028,952	420,000	1,373,913	508,768	**1,672,538**
EISA+RES+CPAY	344,903	1,047,800	455,735	1,454,523	547,926	**1,760,735**
	Gross Domestic Product					
	2015		**2020**		**2025**	
			Million $2010			
Operations	**Direct**	**Total**	**Direct**	**Total**	**Direct**	**Total**
EISA+RES	$2,937	$29,568	$14,426	$59,509	$21,659	**$79,346**
EISA+RES+CPAY	$2,828	$29,615	$14,151	$60,084	$21,223	**$79,704**
	2010-2015		**2010-2020**		**2010-2025**	
Investment	**Direct**	**Total**	**Direct**	**Total**	**Direct**	**Total**
EISA+RES	$23,507	$82,585	$31,809	$113,968	$38,923	**$139,318**
EISA+RES+CPAY	$23,950	$83,870	$33,705	$119,482	$41,059	**$145,345**

The geographic dispersion of economic impacts (TIO) across the nation can be seen in Figure 18. In 2015, adding the RES to current policy as is represented by the ***EISA+RES*** Scenario does not create many impacts across the nation. However, adding CPAY have much larger positive ramifications on each state's economy. While additions to economic activity are experienced widely across the United States, the states experiencing the greatest additions to TIO are Iowa, Minnesota, Illinois, Nebraska, Kansas, and Texas when comparing the ***EISA+RES+CPAY*** Scenario to the ***EISA*** Scenario.

IMPACTS OCCURING AS A RESULT OF CHANGES IN THE AGRICULTURAL SECTOR

Economic impacts resulting from changes in the agricultural sector incorporate economic returns from changes in agricultural operations including commodity price changes, shifts in land use, and changes in government payments; changes in forest operations; changes in consumption patterns resulting from wind leases; and in the ***EISA+RES+CPAY*** Scenario the impact of carbon policy on energy costs as well as carbon payments. In the ***EISA+RES*** Scenario, the total change in the nation's economy is estimated at $8.1 billion with $7.7 billion occurring from changes in agricultural operations, $0.3 billion in forest operations[3] (Table 13).

The addition of an RES to EISA could result in the creation of an estimated 18,300 direct jobs and 50,500 total jobs. When carbon policy is incorporated into the mix, jobs increase to nearly 123,000. In 2015, however, the job picture is mixed with a loss of 952 direct jobs and a slight increase (156) in the total economic employment picture. This occurs primarily as a result of changes in the grains and beans that are projected to occur (wheat and soybean acreage) as residues are reduced requiring additional acres of dedicated energy crops (***EISA+RES+CPAY***). Note that jobs as a result of increased transportation demands as a result of the establishment of an RES are not included.

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[3] The $1.6 billion only includes the changes that occur as a result of forest proprietors' income increasing from offset payments measured by the difference between the market price of the biomass and the cost of biomass removal and delivery. This value does not include the impacts from operations of equipment in the forest to remove feedstocks. That value is included in the renewable energy sector.

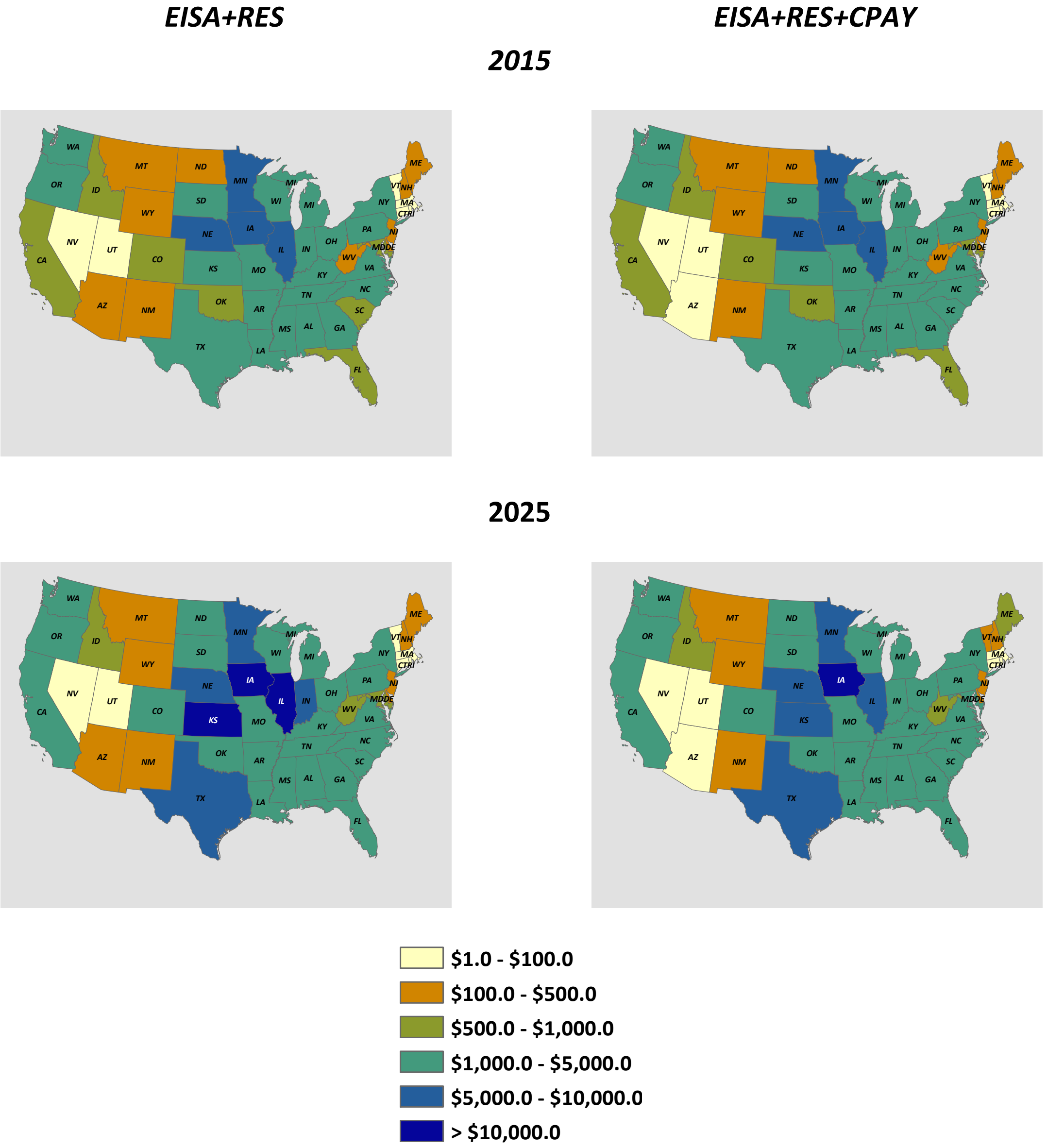

Figure 18. State Economic Impacts compared to EISA Scenario, 2015 and 2025, for the *EISA+RES* and *EISA+RES+CPAY* Scenarios as a Result of the Operations of the Renewable Energy Sector

Table 13. Projected Economic Impacts from Changes in the Agricultural Sector Compared to *EISA*, by Scenario, 2015, 2020, and 2025

	Total Industry Output (TIO)					
	2015		**2020**		**2025**	
Scenario and Sector Impact	**Direct**	**Total**	**Direct**	**Total**	**Direct**	**Total**
EISA+RES			***Million 2010 $***			
Agriculture Operations	0.0	(0.0)	0.0	21.9	4.401.9	7.760.2
Forest Operations	-	-	-	-	186.2	305.2
Wind Lease Payments	73.6	100.3	52.8	71.9	50.6	69.0
TOTAL	73.6	100.3	93.9	4,638.8	4,638.8	8,134.5
EISA+RES+CPAY						
Agriculture Operations	120.0	145.0	1.854.4	3.464.3	8.920.5	16.147.1
Net Carbon Returns	$153	$219	$850	$1,182	$1,637	$2,263
Forest Operations	$0	$0	0.0	0.0	616.1	995.3
Wind Lease Payments	94.1	128.3	76.0	103.7	111.6	152.2
TOTAL	367.2	492.2	2,780.7	4,750.4	11,284.9	19,557.7

	Jobs					
	2015		**2020**		**2025**	
	Direct	**Total**	**Direct**	**Total**	**Direct**	**Total**
EISA+RES			***Number***			
Agriculture Operations	0	6	0	178	17,467	48,537
Forest Operations	0	0	0	0	675	1,617
Wind Lease Payments	344	575	247	412	237	396
TOTAL	344	575	247	590	18,379	50,550
EISA+RES+CPAY						
Agriculture Operations	-2,005	-1,652	-734	14,360	38,346	104,197
Net Carbon Returns	613	1,072	3,846	6,551	7,507	12,721
Forest Operations	0	0	0	0	2,226	5,197
Wind Lease Payments	440	736	355	594	522	873
TOTAL	-952	156	3,467	21,505	48,601	122,988

Table 13. Continued.

	Gross Domestic Product (GDP)					
	2015		2020		2025	
	Direct	Total	Direct	Total	Direct	Total
EISA+RES			***Million 2010$***			
Agriculture Operations	0.0	0.0	25.7	38.6	834.3	2.832.3
Forest Operations	-	-	-	-	42.9	98.4
Wind Lease Payments	22.1	37.4	15.8	26.8	15.2	25.7
TOTAL	22.1	37.4	41.5	65.4	892.5	**2,956.4**
EISA+RES+CPAY						
Agriculture Operations	56.20	79.38	367.39	1.335.10	1.355.37	5.530.72
Net Carbon Returns	49.1	88.8	262.9	454.9	503.6	864.4
Forest Operations	0.0	0.0	0.0	0.0	143.1	317.4
Wind Lease Payments	28.2	47.8	22.8	38.6	33.5	56.7
TOTAL	133.6	216.0	653.1	1,828.6	2,035.5	**6,769.2**

Results of the state impacts are somewhat mixed (Figure 19). In 2015, under the ***EISA+RES+CPAY***, much of the western United States and the South incur some negative impacts to their economies when compared to the ***EISA*** Scenario. This result occurs as crop residue harvests are decreased with shifts to production of dedicated energy crops. However, as the demand for renewable energy from cellulosic feedstocks increases the picture changes to one where most states receive a positive impact from agricultural operations.

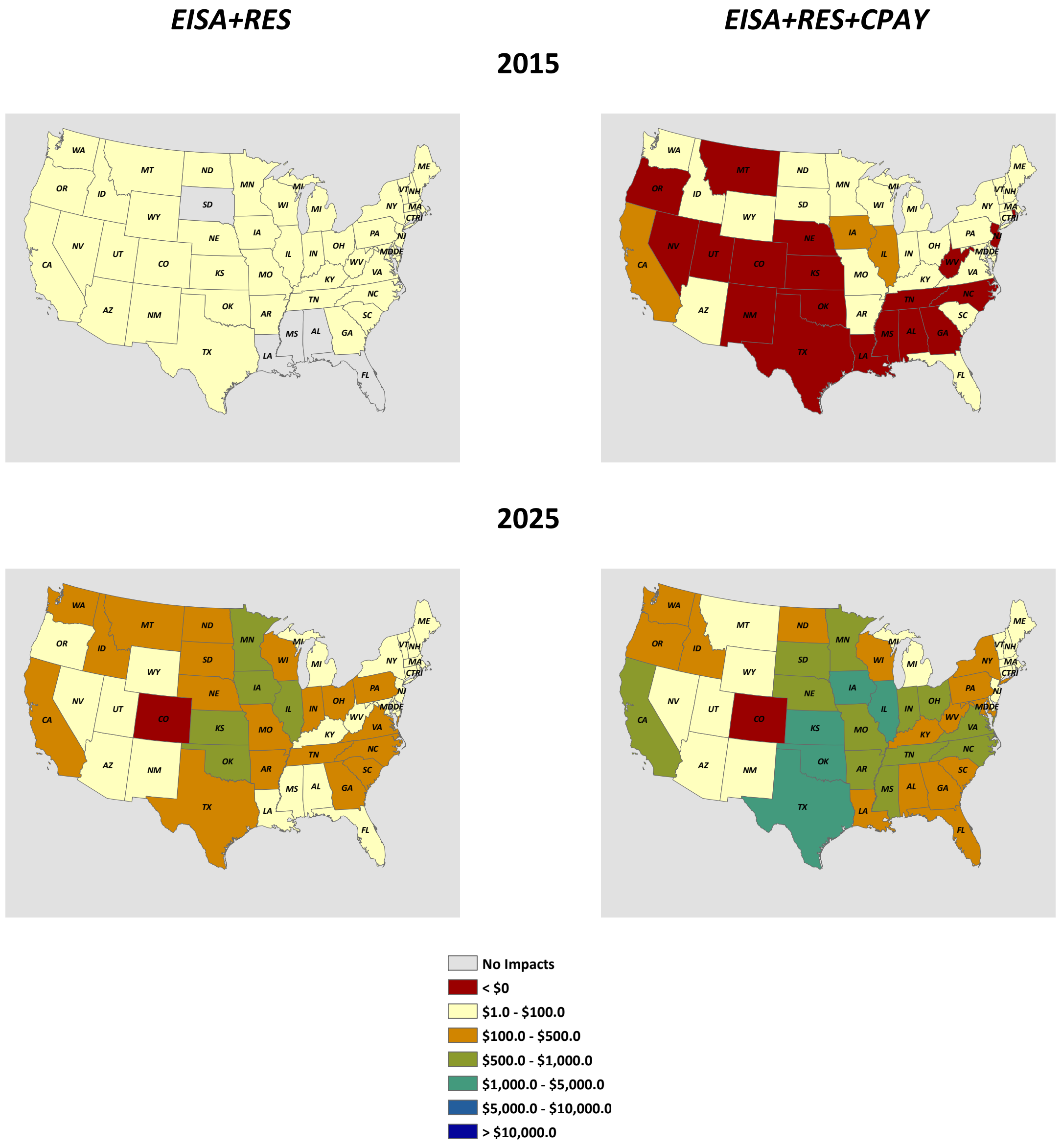

Figure 19. State Economic Impacts compared to *EISA* Scenario, 2015 and 2025, for the *EISA+RES* and *EISA+RES+CPAY* Scenarios as a Result of Changes in Land Use, Commodity Prices, Wind Leases, Forest Operations, and Government Payments

IMPACTS OCCURING AS A RESULT OF CHANGES IN THE ELECTRICITY PRICES

Consumers spent $360.5 billion on electricity in 2008 (USDOE/EIA, 2010b). Increased production of renewable electricity will increase current electricity prices. According to EIA, average US price for electricity is $0.098/kWh. Of that, approximately $0.031/kWh occurs as a result of transmission and distribution costs leaving $0.067/kWh to cover production costs. This production cost of $0.067 is compared to the breakeven costs estimated for each of the renewable technologies modeled. An increase in cost of $0.0036, $0.007, and $0.0104/kWh are estimated for the 2015, 2020, and 2025 solutions of the ***EISA+RES*** Scenario, respectively and $0.0036, 0.007, and 0.0105/kWh in 2015, 2020, and 2025 for the ***EISA+RES+OFFESTS*** Scenario, respectively. There is very little difference between scenarios (Table 14). Consumers could expect to pay an additional $45 billion for electricity in 2025 under the ***EISA+RES+CPAY*** Scenario and slightly more in the ***EISA+RES*** Scenario when compared to the ***EISA*** alone scenario. Assuming that a household's electricity consumption is equivalent to 11,040 kWh/year, the increase in household expenditures would be around $3.30/month in 2015 and $9.50/month in 2025. The ***EISA+RES+CPAY*** Scenario would have slightly higher increases in household expenditures than the ***EISA+RES*** Scenario.

Table 14. Economic Impacts as a Result of Increased Electricity Prices

	Total Industry Output					
	2015		**2020**		**2025**	
	Direct	Total	Direct	Total	Direct	**Total**
			Million $ (2010)			
EISA+RES	-$15,617	-$48,843	-$25,045	-$68,705	-$45,442	**-$124,661**
EISA+RES+CPAY	-$15,659	-$42,957	-$24,931	-$68,394	-$45,063	**-$123,620**

CONCLUSIONS

Energy to supply an RES would come from a variety of sources; however, biomass is projected to supply about 71 percent of the energy. Hence, America's rural areas would provide a key role in supplying feedstocks to meet an RES. Feedstocks to supply this RES would come from several sources including herbaceous dedicated energy crops, woody dedicated energy crops, forest and wood residues, and crop residues. Over the 2010-2025 time period, the role of corn grain's contribution to energy feedstocks remains relatively stable, while the role of herbaceous energy crops increase dramatically. Accumulated net returns to agriculture over the 2010 to 2025 time span are projected at $14 billion above EISA when an RES is adopted, while the additions to net returns are $57 billion when carbon payments are adopted in addition to the RES. Because of the contribution of a variety of feedstocks, increases in net returns are geographically widespread across the nation.

The results from this study suggest that adoption of an RES in conjunction with the already existing RFS could occur without making significant changes in major crop planting patterns. Supplying this level of feedstock without shifting major crop patterns would require intensification of grazing patterns and expansion of hay acreage. Projected land use shifts for major crops appear to be minimal with a decrease in acres of major crops of 2.4 percent when meeting the ***EISA+RES*** Scenario and 4.6 percent under the ***EISA+RES+CPAY*** Scenario. This occurs as dedicated energy crops increase 17 and 87 percent for the ***EISA+RES*** and the ***EISA+RES+CPAY*** Scenarios respectively. To acquire the necessary land for dedicated energy crops, while the nation experiences a minimal shift in major crops, intensive pasture increases from nearly 12 million acres in the baseline to 16.5 and 32.3 million acres in the ***EISA+RES*** and ***EISA+RES+CPAY*** Scenarios respectively.

Expansion of the renewable energy industry, including both feedstock production and energy conversion, can add significantly to the overall economy. In 2025, with an RES, a projected $8.1 billion in output is projected to come from America's farms, fields, and forests, with a projected addition of 50,550 jobs, many of which would be located in rural areas. The conversion of these feedstocks into electricity and fuels would add $206.1 billion in economic activity and 672, 514 jobs to the economy. In total, the economic impacts with an RES compared with EISA, are about $214 billion and over 723,000 jobs. When a carbon capture and sequestering payment system is added to the RES, the economic impacts are even greater, with $227 billion in total industry output, and over 805,000 jobs. Under this policy scenario, about $19.6 billion in output and 122,988 jobs are added from production of feedstocks, and $207.9

billion 681,982 jobs are added from conversion. It should be noted that the RES would contribute nearly 90% of the jobs overall under this combined policy scenario.

Findings from this study suggest expansion of the renewable energy industry under an RES could make significant contributions to the America's rural economies, without disruption of traditional crop markets. Furthermore, rewarding environmental performance, while expanding the renewable energy industry, could reduce CO_2 emissions and also add to net returns to agriculture and the renewable energy industry.

In closing, the projections in this study are reliant on yield growth, and, hence, to increase agriculture's contribution to energy security, it is critical that a national commitment to continuing research and extension investments in major crops and bioenergy feedstocks be made. It should also be noted that many of the impacts reported in this document are estimated by comparing the scenario of interest to the baseline. The baseline contains EISA but no additional energy or carbon policy. Therefore, the impacts of EISA are not included in the impacts reported in this report.

REFERENCES CITED

Aden, A., M. Ruth, K. Ibsen, J. Jechura, K. Nerves, J. Sheehan, B. Wallace, L. Montague, A. Slayton, and J. Lukas. 2002. *Lignocelluloses 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).

Alexander, R. and B. English. 1988. "Micro-Oriented Sediment Simulator Version 2.1 User's Manual". Research Report 88 – 21. Department of Agriculture and Resource Economics, The University of Tennessee, Institute of Agriculture.

Barnhart, S., M. Duffy, and D. Smith. 2008. "Estimated Costs of Pasture and Hay Production". Ag Decision Maker, Iowa State University, Ames, IA. Accessed June, 2010 at http://www.extension.iastate.edu/agdm/crops/pdf/a1-15.pdf.

BBI International. 2002. "State of Maine Ethanol Pre-Feasibility Study". Prepared for Finance Authority of Maine. Accessed June, 2010 at http://www.famemaine.com/files/Content/Publications/FAME-Final_Report_10-24.pdf.

Borenstein, S. 2008. "The Market Value and Cost of Solar Photovoltaic Electricity Production". Center for the Study of Energy Markets (CSEM), University of California Energy Institute, University of California, Berkeley. CSEM WP 176. Available at http://www.ucei.berkeley.edu/PDF/csemwp176.pdf.

Bullock, D. 2006. "Cross-Hedging Distillers Dried Grains (DDG) Using U.S. Corn Futures". Available at http://www.mda.state.mn.us/riskmgmt/crosshedgingdistillers.pdf (Accessed May 9, 2006).

Clark, E., J. Haverkamp, and W. Chapman. 1985. *Eroding Soils: The Off-Farm Impacts*. Washington, DC: The Conservation Foundation.

Conservation Tillage Information Center. 2004. National Crop Residue Management Survey Data. West Lafayette, IN: Conservation Technology Information Center. Available at http://www.ctic.purdue.edu/Core4/CT/CT.html.

Conservation Tillage Information Center. 2007. National Crop Residue Management Survey Data. West Lafayette, IN: Conservation Technology Information Center. Available at http://www.ctic.purdue.edu/Core4/CT/CT.html.

Dager, C. Personal Communication. River Operations, Navigation and Hydraulic Engineering, Tennessee Valley Authority, November 2005.

De La Torre Ugarte, D., B. English, C. Hellwinckel, J. Menard, and M. Walsh. 2007. "Economic Implications to the Agricultural Sector of Increasing the Production of Biomass Feedstocks to Meet Biopower, Biofuels, and Bioproduct Demands". Department of Agricultural and Resource Economics, Institute of Agriculture, The University of

Tennessee. Research Series 08-01. Available at http://beag.ag.utk.edu/pp/Webbio productNRI.pdf.

De La Torre Ugarte, D., D. Ray, and K. Tiller. 1998. "Using the POLYSYS Modeling Framework to Evaluate Environmental Impacts on Agriculture." *Evaluating Natural Resource Use in Agriculture*. T. Robertson, B.C. English, and R.R. Alexander, eds. Ames, Iowa: Iowa State University Press.

De La Torre Ugarte, D.G., M.E. Walsh, H. Shapouri, and S.P. Slinsky. 2003. "The Economic Impacts of Bioenergy Crop Production on U.S. Agriculture". Report Prepared for the U.S. Department of Agriculture and U.S. Department of Energy. Accessed June, 2010 at http://www.usda.gov/oce/reports/energy/AER816Bi.pdf.

Daniel de la Torre Ugarte, Burton C. English,Chad Hellwinckel, Tristram O. West, Kimberly L. Jensen, Christopher D. Clark, and R. Jamey Menard, 2009. Analysis of the Implications of Climate Change and Energy Legislation to the Agricultural Sector, Department of Agricultural Economics, Institute of Agriculture, The University of Tennessee, last accessed November 2010 at http://beag.ag.utk.edu/pp/UT_Climate_energy%20report_25x'25Nov30.pdf

Eidman, V. Personal Communication (e-mail). University of Minnesota, Department of Applied Economics, January 2006.

Electric Power Research Institute (EPRI). 2007. *Renewable Energy Technical Assessment Guide – TAG-RE: 2006*. Technical Report – 1012722.

English, B., J. Menard, B. Wilson, and D. De La Torre Ugarte. 2004a. "Integrating IMPLAN With a National Agricultural Policy Model". 2004 National IMPLAN User's Conference Proceedings, Eastern Management Development Center, Shepherdstown, West Virginia, October 6-8. Available at https://implan.com/v3/?searchword=conference& searchphrase=all&limit= &ordering=popular&view=search&Itemid=99999999 &option=com_search.

English, B., J. Menard, M. Walsh, and K. Jensen. 2004b. "Economic Impacts of Using Alternative Feedstocks in Coal-Fired Plants in the Southeastern United States". Accessed June, 2010 at http://beag.ag.utk.edu/pp/New%20Cofire%20Study%20Doc.pdf.

English, B., K. Jensen, and J. Menard in cooperation with Frazier, Barnes & Associates, Llc. 2002. "Economic Feasibility of Producing Biodiesel in Tennessee". Accessed June, 2010 at http://beag.ag.utk.edu/pp/biodiesel.pdf.

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. Available at http://www.aae.wisc.edu/pubs/sps/pdf/ stpap481.pdf.

Frazier, Barnes & Associates, LLC. 2004. "Feasibility Study for Use of Poultry Litter to Create Biomass Energy Final Report". Prepared for Michigan Biomass Energy Program. Available at http://www.michigan.gov/documents/cis/CIS_EO_Poultry_CoGen_Report_180812_7.pdf.

Goebel, J. Personal Communication. USDA-National Resource Conservation Service, April/June 2007.

Graham, R., L. Allison, and D. Becker. 1996. The Oak Ridge Crop County Level Database. Environmental Sciences Division, Bioenergy Feedstock Development Program, Oak Ridge National Laboratory, December 1996. Available at http://bioenergy.ornl.gov/papers/bioen96/graham2.html.

Gupta, C., C. Onstad, and W. Larson. 1979. “Predicting the Effects of Tillage and Crop Residue Management on Soil Erosion”. *Journal of Soil and Water Conservation* 34(1979):77-79.

Heid, W., Jr. 1984. *Turning Great Plains Crop Residues and Other Products into Energy*. Washington, DC: U.S. Department of Agriculture, Economic Research Service, Agricultural Economic Report No. 523.

Hellwinckel, C. and D. De La Torre Ugarte. 2005. “Peak Oil and the Necessity of Transitioning to Regenerative Agriculture”. Farm Foundation Report. Available at http://www.farmfoundation.org/news/articlefiles/1718-Hellwinckel%20and%20De%20La%20Torre%20Ugarte.pdf.

Jager, H., L. Baskaran, C. Brandt, E. Davis, C. Gunderson, and S. Wullschleger. 2010. “Empirical Geographic Modeling of Switchgrass Yields in the United States”. *Bioenergy* 2(5):248-257.

La Capra Associates, Inc., GDS Associates, Inc., and Sustainable Energy Advantage, LLC. 2006. *Analysis of a Renewable Portfolio Standard for the State of North Carolina, Technical Report*. Prepared for the North Carolina Utilities Commission. Available at http://www.lacapra.com/downloads/NC_RPS_Report.pdf.

Marland, G., T. West, B. Schlamadinger, and L. Canella. 2003. “Managing Soil Organic Carbon in Agriculture: The Net Effect on Greenhouse Gas Emissions”. *Tellus B* 55(2):613-621.

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.

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.

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.

Nelson, R. 2002. "Resource Assessment and Removal Analysis for Corn Stover and Wheat Straw in the Eastern and Midwestern United States—Rainfall and Wind Induced Soil Erosion Methodology". *Biomass and Bioenergy* 22(5):349-363.

Nelson, C. and J. Lamb. 2002. "Final Report: Haubenschild Farms Anaerobic Digester Updated". The Minnesota Project 2002. Available at http://www.mnproject.org/pdf/Haubyrptupdated.pdf.

Nelson, R., C. Hellwinckel, C. Brandt, T. West, D. De La Torre Ugarte, and G. Marland. 2009. "Energy Use and Carbon Dioxide Emissions from Cropland Production in the United States, 1990-2004". *Journal of Environmental Quality* 38(2):418-425.

Niessen, W., C. Markes, R. Sommerlad. 1996. *Evaluation of Gasification and Novel Thermal Processes for the Treatment of Municipal Solid Waste*. Golden, CO: U.S. Department of Energy, National Renewable Energy Laboratory, TP-430-21612. Available at http://www.nrel.gov/docs/legosti/fy96/21612.pdf.

Olson, D. and S. Lindall. 1999. "IMPLAN Professional Software, Analysis, and Data Guide". Minnesota IMPLAN Group, Inc., 502 2nd Street, Suite 301, Hudson, WI, 54016. Available at http://www.implan.com./

Perlack, R., L. Wright, L. Easton, and B Stokes. Forthcoming. 2010. "Woody Biomass for Energy Applications: State of Technology". Oak Ridge National Laboratory.

Pew Center for Global Climate Change. 2010. "Short Summary of the American Power Act (Kerry-Lieberman)". Accessed June, 2010 at http://www.pewclimate.org/federal/analysis/congress/111/summary-american-power-act-kerry-lieberman.

Ribaudo, M. 1986. *Reducing Soil Erosion: Offsite Benefits*. Washington, DC: U.S. Department of Agriculture, Economic Research Service, Economics Report No. 561.

Skog, K. Personal Communication. USDA Forest Service, March 2010.

Sullivan, Patrick, Jeffrey Logan, Lori Bird, and Walter Short, Comparative Analysis of Three Proposed Federal Renewable Electricity Standards, National Renewable Energy Laboratory, *Technical Report,* NREL/TP-6A2-45877, May 2009.

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.

U.S. Congress. 2007. *Energy Independence And Security Act Of 2007*. Public Law 110–140—DEC. 19, 2007. 110th Congress. Available at http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=110_cong_public_laws&docid=f:publ140.110.pdf.

U.S. Department of Agriculture, Agricultural Marketing Service. 2005. "Grain Transportation Report". December 8. Accessed September, 2010 at http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELDEV3100987.

U.S. Department of Agriculture, Economic Research Service. 2009. "A Preliminary Analysis of the Effects of HR 2454 on US Agriculture". Office of the Chief Economist, July 22, 2009. Accessed August 10, 2010 at http://www.usda.gov/oce/newsroom/archives/releases/2009files/HR2454.pdf.

U.S. Department of Agriculture, Economic Research Service. 2010. Agricultural Baseline Projections. Briefing Room. Accessed October 19, 2010 at http://www.ers.usda.gov/Briefing/Baseline/.

U.S. Department of Agriculture, National Agricultural Statistics Service (NASS). 2009. "2007 Census of Agriculture". Accessed June, 2010 at http://www.agcensus.usda.gov/Publications/2007/Full_Report/index.asp.

U.S. Department of Agriculture, National Agricultural Statistics Service (NASS). 2010. Data and Statistics. "Pre-Extracted Data by Year and by Crop". Available at http://www.nass.usda.gov/Data_and_Statistics/Pre-Extracted_Data/Year/index.asp.

U.S. Department of Agriculture, National Resource Conservation Service. 1994. *State Soil Geographic (STATSGO) Data Base—Data Use Information*. Washington, DC: Miscellaneous Publication Number 1492. Available at http://www.nrcs.usda.gov/technical/techtools/statsgo_db.pdf.

U.S. Department of Agriculture, National Resource Conservation Service. 2007a. National Resources Inventory. Washington DC: USDA National Resource Conservation Service. 1997 and 2003 Data sets on CD. Available at http://www.nrcs.usda.gov/technical/NRI/.

U.S. Department of Agriculture, National Resource Conservation Service. 2007b. Watersheds, Hydrologic Units, Hydrologic Unit Codes, Watershed Approach, and Rapid Watershed Assessments. Available at http://www.nrcs.usda.gov/programs/rwa/Watershed_HU_HUC_ WatershedApproach_defined_6-18-07.pdf.

U.S. Department of Energy, Energy Information Administration. 2009*. Impacts of a 25-Percent Renewable Electricity Standard as Proposed in the American Clean Energy and Security Act Discussion Draft*. SR/OIAF/2009-04. Accessed September 2010 at http://www.eia.doe.gov/oiaf/servicerpt/acesa/pdf/sroiaf(2009)04.pdf.

U.S. Department of Energy, Energy Information Administration. 2010a. Annual Energy Outlook 2010. Report #: DOE/EIA-0383(2010). Accessed June, 2010 at http://www.eia.doe.gov/oiaf/aeo/.

U.S. Department of Energy, Energy Information Administration. 2010b. State Energy Data System, Updates by Energy Source. "Table F13b: Electricity Price and Expenditure Estimates by Sector, 2008". Accessed August 2, 2010 at http://www.eia.doe.gov/emeu/states/hf.jsp?incfile=sep_fuel/html/fuel_pr_es.html.

U.S. Department of Energy, Office of Utility Technology, Energy Efficiency and Renewable Energy. 1997. *Renewable Energy Technology Characterizations*. Topical Report 109496. Available at http://www1.eere.energy.gov/ba/pba/pdfs/techchar.pdf.

U.S. Environmental Protection Agency (EPA). 2005. Landfill Methane Outreach Program. Documents, Tools, and Resources. Energy Project Landfill Gas Utilization Software (E-Plus).

U.S. Environmental Protection Agency (EPA). 2008. *Advance Notice of Proposed Rulemaking: Regulating Greenhouse Gas Emissions under the Clean Air Act*. EPA-HQ-OAR-2008-0318, July 11. "Supplemental: Inter-Agency Review Comments". Accessed September 2010 at http://www.epa.gov/climatechange/emissions/downloads/ANPRPreamble4.pdf**.**

U.S. Environmental Protection Agency (EPA). 2009a. "EPA Analysis of the American Clean Energy and Security Act of 2009 H.R. 2454 in the *111th Congress,* June 23, 2009. Available at http://www.epa.gov/climatechange/economics/pdfs/HR2454_Analysis.pdf.

U.S. Environmental Protection Agency (EPA). 2009b. "Proposed Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act; Proposed Rule." *Federal Register* 74(78): 18886-18910 (April 24, 2009b). Available at http://www.epa.gov/climatechange/endangerment/downloads/EPA-HQ-OAR-2009-0171-0001.pdf.

U.S. Supreme Court, 2007. Massachusetts, et al. v. Environmental Protection Agency, et al., No. 05–1120. Argued November 29, 2006—Decided April 2, 2007, accessed at http://www.supremecourt.gov/opinions/06pdf/05-1120.pdf

Vogelmann, J., S. Howard, L. Yang, C. Larson, B. Wylie, and N. Van Driel. 2001. "Completion of the 1990s National Land Cover Data Set for the Conterminous United States from Landsat Thematic Mapper Data and Ancillary Data Sources". *Photogrammetric Engineering and Remote Sensing* 67(June):650-662.

Walsh, M., D. De La Torre Ugarte, H. Shapouri, and S. Slinsky. 2003. "Bioenergy Crop Production in the United States Potential Quantities, Land Use Changes, and Economic Impacts on the Agricultural Sector". *Environmental and Resource Economics* 24(4): 313-333.

Weimar, M. and R. Stillman. 1990. "A Long Term Forecasting Model of the Livestock and Poultry Sectors". NCR-134 Conference Proceedings on Applied Commodity Price Analysis, Forecasting, and Market Risk Management, Chicago, Illinois.

West, T. and G. Marland. 2002. "A Synthesis of Carbon Sequestration, Carbon Emissions, and Net Carbon Flux in Agriculture". *Agriculture, Ecosystems, and Environment* 91(1-3):217-232.

West, T. and W. Post. 2002. "Soil Organic Carbon Sequestration Rates by Tillage and Crop Rotation: A Global Analysis". Soil *Science Society of America Journal* 66:1930-1946.

West, T., C. Brandt, B. Wilson, C. Hellwinckel, D. Tyler, G. Marland, D. De La Torre Ugarte, J. Larson, M. Mueller, and R. Nelson. 2008. "Estimating Regional Changes in Soil Carbon with High Spatial Resolution: Integrating Field Measurements, Inventory Data, and Remote Sensing Products". *Soil Science Society of American Journal* 72(2):285-294.

West, T., G. Marland, A. King, W. Post, A. Jain, and K. Andrasko. 2004. "Carbon Management Response Curves: Estimates of Temporal Soil Carbon Dynamics". *Environmental Management* 33(4): 507-518.

Williams, J. and H. Berndt. 1977. "Sediment Yield Prediction Based on Watershed Hydrology". *Trans. Am. Soc. Agric. Eng.*, 20(6):1100-1104.

Wischmeier, W. and D. Smith. 1965. *Predicting Rainfall Erosion Losses from Cropland East of the Rocky Mountains*. Agricultural Handbook No. 282. Washington, DC: USDA ARS in Cooperation with Purdue Agricultural Experiment Station.

Wischmeier, W. and D. Smith. 1978. *Predicting Rainfall Erosion Losses – A guide to Conservation Planning*. Agriculture Handbook No. 537. Washington, DC: USDA in Cooperation with Purdue Agricultural Experiment Station.

Yoder, D., D. McCool, G. Weesies, G. Foster, and K. Renard. 1997. *Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE)*. Agricultural Handbook No. 703. Washington, DC: USDA ARS.

Zhu, S., J. Buongiorno, J. Turner, R. Raunikar. 2010. "Using the Global Forest Products Model (GFPM version 2009)". Department of Forest and Wildlife Ecology, University of Wisconsin-Madison, Madison, WI. Staff Paper Series #66, May 2010. Available at http://forestandwildlifeecology.wisc.edu/facstaff/Buongiorno/book/GFPM.htm.

GLOSSARY OF TERMS

ASD	Agricultural Supply Districts are areas of agricultural production across the United States, totaling 305 in all.
Baseline	The Baseline is a scenario which uses the USDA agricultural baseline projections and extends them. In this scenario, the EISA is assumed to continue.
BEAG	Bio-Based Energy Analysis Group at the University of Tennessee
EIA	Energy Information Administration
EISA	Energy Independence and Security Act of 2007. This Act expanded the renewable fuel standard to 36 billion gallons by 2022, and required a certain portion of this amount come from advanced renewable fuels (21 billion gallons), including cellulosic fuels (16 billion gallons). The Renewable Fuel Standard (RFS) portion of EISA 2007 is contained in Sections 201 - 248 of the Act.
EPA	Environmental Protection Agency
GDP	Gross Domestic Product
GHG	Greenhouse Gas Emissions
H.R. 2454	American Clean Energy and Security Act of 2009
HYDRO	Hydroelectric power
IMPLAN	IMPLAN is an economic input-output modeling system with which the U.S., state, region, or county economies can be modeled. IMPLAN includes the capability to generate multipliers and projecting impacts by applying final demand changes to the model.
MSW	Power from metropolitan solid waste
CPAY	A carbon payment is a financial instrument to help reduce GHG emissions which is measured in metric tons of carbon dioxide-equivalent (CO_2e). One carbon payment is equivalent to one metric ton of carbon dioxide or its equivalent in other GHG. In the case of this study, potential carbon payments are considered for conservation tillage, bioenergy crop production, afforestation, grasslands management, and agricultural methane capture.
PII	PII is the POLYSYS/IMPLAN Integrator, a linking program and modification of IMPLAN (to accommodate biomass feedstock production and biofuels conversion industries, and scenarios development
POLYSYS	POLYSYS is a dynamic agricultural sector model.
Quads	Quadrillion BTU's of energy.
RES	A Renewable Electricity Standard is a standard that requires a certain percentage of electricity be met from renewable sources.
RFS	A Renewable Fuel Standard is a standard that requires an amount of fuel

GLOSSARY OF TERMS

	produced come from renewable sources.
Stumpage Costs	Stumpage costs are the costs incurred by companies or operators to harvest timber
TIO	Total industry output is represents the value of production across all industries in a region.
25x’25	A renewable energy initiative backed by organizations and individuals united by a common interest in making America’s energy future more secure, affordable and environmentally sustainable. Their goal is to advance securing 25 percent of the nation’s energy needs from renewable sources by the year 2025.

APPENDIX

MODELING PROCESS

Figure A.1 is a schematic of the modeling process to arrive at projections of impacts on the agricultural sector from use of the energy and climate change policy instruments. Achieving the first objective begins with the definition of the energy targets for various sources of renewable energy, including that produced from agricultural feedstocks, under an RFS, RES, or both. 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.

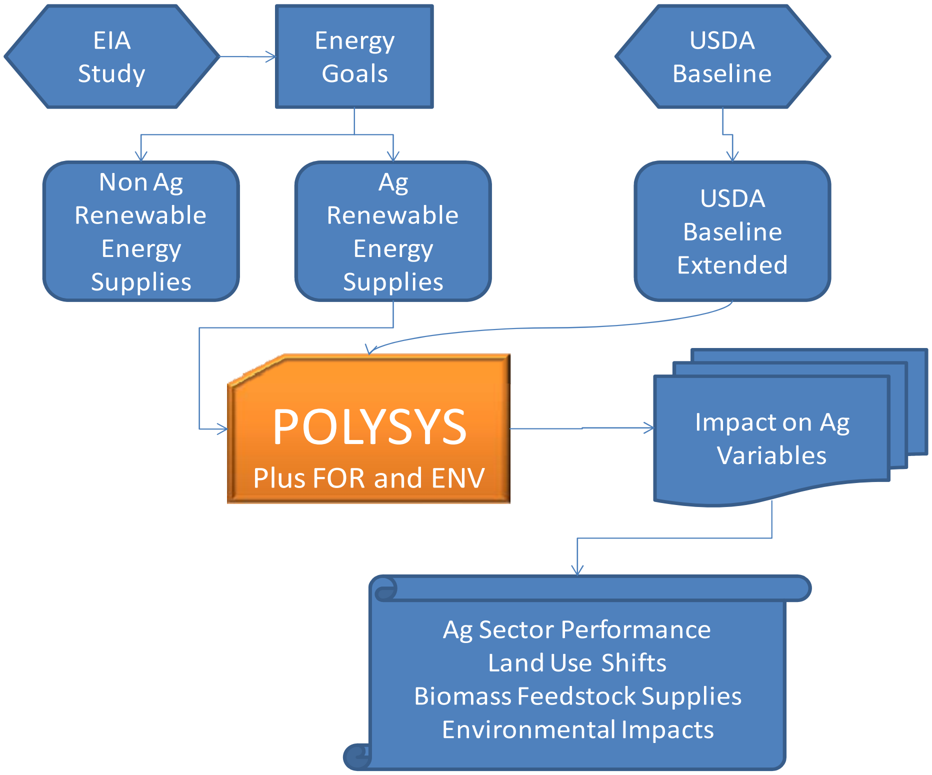

Figure A. 1. Flow of Information Schematic, Part 1

The second diagram, Figure A.2, reflects the process to estimate state and national level economic impacts of producing renewable energy from agricultural feedstock, along with targeted non-agricultural feedstock from solar and wind sources. The process provides not only the impacts of producing the feedstock, but also the impacts of the conversion processes on the overall economy.

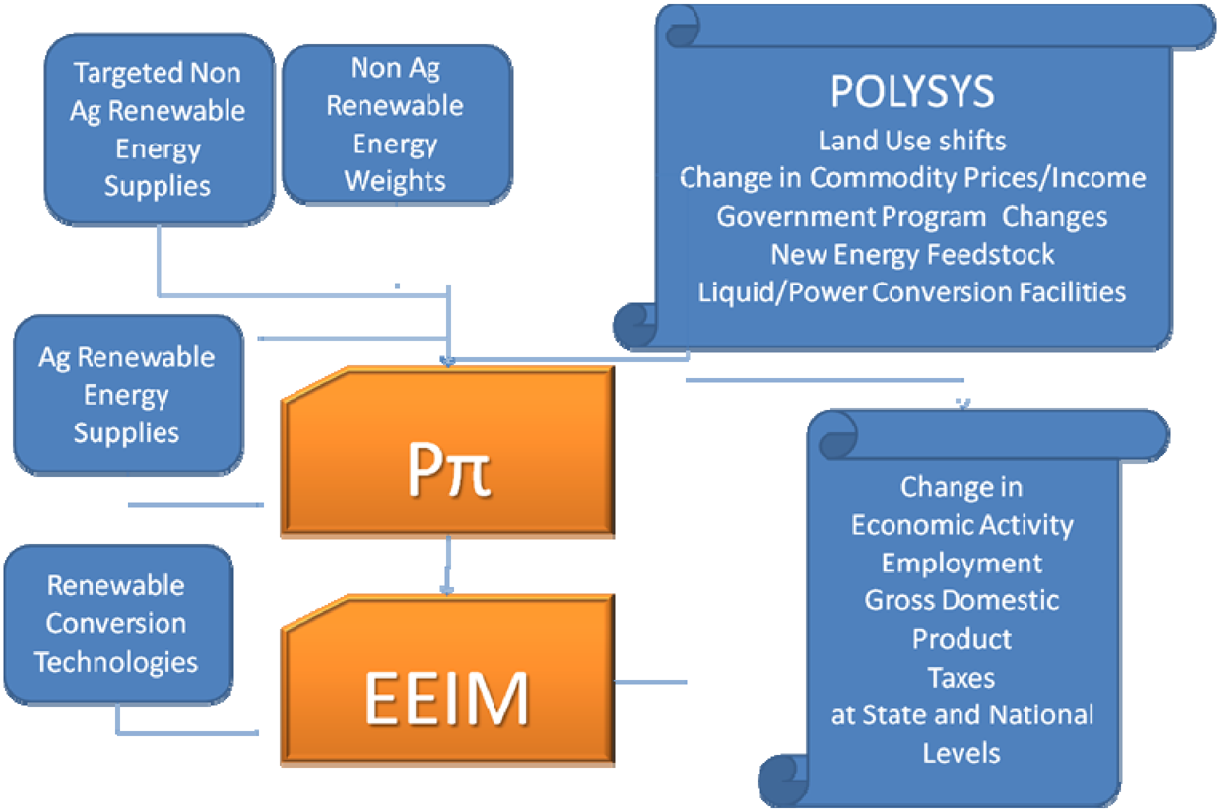

Figure A. 2. Flow of Information Schematic, Part 2

From the diagrams, it can be noted 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, modifies IMPLAN input files, and IMPLAN, an input-output model.

Several key methodological steps are involved in arriving at the projections, these are:

1. **Scenario Development –** Both energy and carbon scenarios are included,
2. **Renewable Energy Goals –** Definition of renewable energy goals, including bioenergy,
3. **Carbon Policy Tools –** Develop potential carbon policy instruments that reflect potential policy,
4. **Conversion Technologies –** Collection of the data on the conversion technologies available,
5. **POLYSYS –** Analysis of agricultural sector impacts given the policy scenarios defined, and
6. **PII + IMPLAN-**Analysis of economic impacts given the policy scenarios defined.

CONVERSION TECHNOLOGIES ASSUMPTIONS

The conversion technologies used in the analysis are summarized in Table A.1. This table also provides sources of information about costs of each technology. More detailed illustrations of the renewable technologies used in this analysis are presented in Appendix B. Appendix B is available from the authors upon request. The projections of electricity generation for the representative facilities contained in Appendix B are not adjusted with capacity factors. However, these adjustments were made in the model. 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.

Table A.1. 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	17,328,520 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 Food Residues	69.3 MM Gal/year	NA	Aden, A., M. Ruth, K. Ibsen, J. Jechura, K. Neeves, J. Sheehan, B. Wallace, 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	448,443 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	8.666,667 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	1,298,701 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	**140,160,000 kWh/year**	**NA**	Renewable Energy Technical Assessment Guide – TAG-RE: 2006, EPRI, Palo Alto, CA. 2007. 1012722

Table A.1. Continued

Conversion Technology	Facility Size—Output	Facility Size—Feedstock Use	Cost Information Source
Solar Thermal Technology (Parabolic Trough Gas Hybrid)	**876,000,000 kWh/year**	**NA**	Renewable Energy Technical Assessment Guide – TAG-RE: 2006, EPRI, Palo Alto, CA. 2007. 1012722
Utility Scale Solar Photovoltaic Power Plant (One-Axis Tracking)	**438,000,000 kWh/year**	**NA**	Renewable Energy Technical Assessment Guide – TAG-RE: 2006, EPRI, Palo Alto, CA. 2007. 1012722
Large Residential/Small Commercial Photovoltaics	**87,600 kWh/year**	**NA**	Renewable Energy Technical Assessment Guide – TAG-RE: 2006, EPRI, Palo Alto, CA. 2007. 1012722; Borenstein, S. 2008. "The Market Value and Cost of Solar Photovoltaics Electricity
Wood Fired Power Plant	**219,000,000 kWh/year**	**110,811 dry tons**	Renewable Energy Technical Assessment Guide – TAG-RE: 2006, EPRI, Palo Alto, CA. 2007. 1012722
Dedicated Crop Fired Power Plant	**219,000,000 kWh/year**	**116,173 dry tons**	Renewable Energy Technical Assessment Guide – TAG-RE: 2006, EPRI, Palo Alto, CA. 2007. 1012722
Citrus Fired Power Plant	**219,000,000 kWh/year**	**125,043 dry tons**	Renewable Energy Technical Assessment Guide – TAG-RE: 2006, EPRI, Palo Alto, CA. 2007. 1012722
Poultry Litter Fired Power Plant	**481,000,000 kWh/year**	**700,000 dry tons**	Frazier, Barnes & Associates, LLC. "Feasibility Study for Use of Poultry Litter to Create Biomass Energy Final Report". Prepared for Michigan Biomass Energy Program. 2004; Renewable Energy Technical Assessment Guide -- TAG-RE: 2006, EPRI, Palo Alto, CA: 2007. 1012722; La Capra Associates, Inc., GDS Associates, Inc., and Sustainable Energy Advantage, LLC. 2006. “Analysis of a Renewable Portfolio Standard for the State of North Carolina, Technical Report.” Prepared for the North Carolina Utilities Commission.

Table A.1. Continued

Conversion Technology	**Facility Size—Output**	**Facility Size—Feedstock Use**	Cost Information Source
Gasification	**876,000,000 kWh/year**	**NA**	"Renewable Energy Technology Characterization." 1997. Prepared by DOE's Office of Utility Technologies, Energy Efficiency and Renewable Energy and EPRI. TR-109496; Niessen, W., C. Markes, and R. Sommerlad. 1996. "Evaluation of Gasification and Novel Thermal Processes for the Treatment of Municipal Solid Waste". NREL/TP-430-21612
Co-fire (15%) of Cellulosic Residues (Corn, Wheat, Rice, Switchgrass, Forest, Poplar, Mill, and Urban) with Coal	**137,313,000 kWh/year**	**Corn Residues 74,450 dry tons** **Wheat Residues 78,287 dry tons** **Rice Residues 78,287 dry tons** **Forest Residues 87,128 dry tons** **Switchgrass 72,840 dry tons** **Poplar 69,478 dry tons** **Mill Residues 87,128 dry tons** **Urban Residues 87,128 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)	91,542,000 kWh/year	45,334 dry tons	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. 2004b. "Economic Impacts of Using Alternative Feedstocks in Coal-Fired Plants in the Southeastern United States".

Table A.1. Continued

Conversion Technology	**Facility Size—Output**	**Facility Size—Feedstock Use**	Cost Information Source
Landfill Gas	**40,243,440 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.

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, Ray, and Tiller, 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 C which is available from the authors. A more detailed discussion of POLYSYS follows.

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. Of the 434 million acres of total cropland, POLYSYS includes 307 million acres available for the eight major crops and for hay. Pastureland can convert to perennial bioenergy crops in regions where there is adequate moisture for the intensification of remaining pasture to make up for the lost forage. This condition lowers the total pastureland available for conversion to 68 million acres. For this pastureland to convert, net returns of perennial bioenergy crops must be greater than the regional pastureland rental value plus additional costs for intensifying remaining regional pasture to make up for the lost forage. We assume that the forage yields on this land can double through intensified management. Therefore, an equal amount of regional pastureland must be converted to intensive management to offset the loss of forage from pasture conversion to bioenergy crops.

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 dedicated biomass crops are determined to be profitable, some pasture can be converted to bioenergy production. For pastureland to come into production, any loss of regional forage production must be replaced through intensification of an equal amount of regional pastureland. We assume that forage production can double through management intensive grazing, therefore total forage production is held constant at the county level.

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.

LIVESTOCK MODULE

The livestock module is an integrated version of the Economic Research Service (ERS) econometric livestock model (Weimar and Stillman, 1990) 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.

FOREST MODULE

The forest module minimizes the cost of meeting today’s and future demands for traditional forest products and restricts the harvesting of trees for energy production by the remaining net growth.

Minimize Cost

$$\sum_{i=1}^{305}\sum_{j=1}^{3}\sum_{k=1}^{2}\sum_{m=1}^{5}\sum_{n=1}^{5} X_{i,j,k,m,n}(HarvCost_{i,j,k,m,n} + StumpCost_{i,j,k,m,n}\upsilon_m + ChipCost_{i,j,k,m,5})$$

The costs incorporated in the model include harvesting and chipping costs obtained from the Fuel Reduction Cost Simulator (FRCS) harvest cost model (Skog, 2010) and estimated stumpage costs (Perlack *et al.*, 2010)(Table A.2).

The demand level for traditional forest products are divided into hardwood and softwood and are estimated using the United States Forest Products Model (USFPM) which is extracted from the Global Forest Products Model (GFPM) (Zhu *et al.*, 2010). These demands increase over time and are expressed at three regional levels north, south, and west (Table A.3).

Table A.2. Stumpage Costs by Timber Types and Regions

	Stumpage Costs		
Timberland Type	South	North	West
Lowland and Upland hardwoods	13.34	15.42	23.48
Natural Pine and Planted Pine	15.68	20.70	27.60
Mixed woods	14.80	18.72	26.06

Source: (Perlack *et al*., 2010; Skog, 2010).

Table A.3. Demand for Timber Products from 2010 to 2030

Timber Products and Regions	**Units**	**2010**	**2015**	**2020**	**2025**	**2030**
Hardwood Log:						
South	*million cubic feet*	3,011	3,141	3,278	3,435	3,594
North	*million cubic feet*	1,847	1,919	1,983	2,053	2,128
West	*million cubic feet*	110	113	115	117	120
Softwood Log:						
South	*million cubic feet*	7,467	8,110	9,737	11,337	12,520
North	*million cubic feet*	724	763	833	904	972
West	*million cubic feet*	2,231	2,250	2,322	2,433	2,554
Residue:						
South	*million green ton*	23	25	30	34	37
North	*million green ton*	14	15	15	16	16
West	*million green ton*	8	8	8	9	9

Several major assumptions define the supply of trees harvested from our nation's forests for use in meeting the RES and RFS. Regarding cost, two issues surfaced. The first is whether to incorporate stumpage fees, and it was decided that these fees represent the value of the standing inventory of trees and cover the costs of growing and maintaining that inventory. The second issue focuses whether a premium should be placed on that value to cover the intrinsic utility of a standing forest and the non-market services it provides. It is understood that not all trees become available to harvest at the current stumpage price as landowner's utility for a standing forest is greater than its market value. Using solely stumpage value would result in overestimation of supply. It is assumed that all trees, except for planted pine, should have a value equal to two times the stumpage price. Harvest is restricted by growth. In the model the amount one can harvest from timber land is restricted to the total growth within the region of that timberland. In addition, it is assumed that only timberland with a slope <= 30 percent is available to meet wood demands placed on the model. In these results, no logs are assumed to come from private land with slopes greater than 30 percent. Finally, it is assumed that all wood products either for traditional demands or new energy demands are met from the nation's privately owned industrial and nonindustrial timberland. When solved, the output from this module interacts with POLYSYS to provide wood supply curves for each year of the analysis.

ENVIRONMENTAL MODULE

Fertilizer and chemical expenditures are the proxy for changes in the quantities of fertilizers and chemicals applied on crops. Prices of chemicals and fertilizers in each year of the simulation are set at levels in the 2009 USDA agricultural baseline. Thus, changes in fertilizer and chemical expenditures are due to changes in quantities given that input prices are kept at the baseline levels for each ethanol production scenario evaluated in the analysis. Fertilizer and chemical expenditures (expressed in 2010 dollars) are estimated using crop supply module budgets and by multiplying either the fertilizer (N, P, and K) or chemical expenditures by the land area for a given crop and region. The expenditures used in the analysis are a weighted average of the tillage system employed in the analysis for a specific CRD.

Changes in water induced soil erosion (sheet and rill) incorporate computed levels of erosion for cropland and CRP land using the Universal Soil Loss Equation (USLE) (Wischmeier and Smith 1965; Wischmeier and Smith 1978). The 1997 and 2003 National Resource Inventory (NRI) data sets (USDA/NRCS 2007a) and the county-level tillage data base from the CTIC (2007) were used to develop the USLE estimates for POLYSYS. Sheet and rill erosion for a Crop Reporting District[4] (CRD) are estimated using the following equation:

$$USLE_i = R_{i,j} \times K_{i,j} \times L_{i,j} \times S_{i,j} \times P_{i,j} \times M_{i,j,l} \times A_{i,j,k,l}, \qquad (1)$$

where *i* is CRD, *j* is land type (1= cropland, 2= pastureland, and 3 = CRP land), *k* is crop grown, l is tillage method (1 = conventional tillage, 2 = reduced tillage, and 3 = no-tillage), *R* is a rainfall and runoff factor, *K* is a soil erodibility factor, *L* is a slope length factor, *S* is a slope steepness factor, *M* is a land cover and management factor, *P* is a crop support practice factor, and A is total available land area.[1] The advantage of the USLE (Wischmeier and Smith 1965; Wischmeier and Smith 1978) over the RUSLE (Yoder *et al.*, 1997) and MUSLE (Williams and Berndt, 1977) models for this application is the simplicity of the USLE and the availability of data to implement the model for all regions of the continental United States.

Estimated average *R*, *K*, *L*, *S,* and *P* factors for each CRD based on the 2003 NRI data were from the USDA National Resource Conservation Service (According to J. Goebel, USDA National Resource Conservation Service, April and June, 2007). The *M* factor was from the 1997 NRI reflecting cropland tillage practice by location. Estimated planted area crop for each CRD region from the POLYSYS crop supply solutions were multiplied by the tillage proportions for that region to determine the land area planted using conventional, reduced, and no- tillage practices. These estimates were then multiplied times *R*, *K*, *L*, *S*, *P*, and *M* factors to estimate gross sheet and rill erosion levels.

The changes in sheet and rill erosion estimated for each CRD using Equation (1) were then weighted to the 105 US Geological Survey 4-digit sub-regional hydrological units (USDA/NRCS 2007b), adjusted to county boundaries, using USDA National Agricultural Statistics Service crop production data as weights (USDA/NASS, 2010). The weighted soil erosion data were used in the Micro Oriented Sediment Simulator (MOSS) to estimate aggregate sediment impacts nationally and in for each 4-digit watershed (Alexander and English 1988). Offsite erosion costs were initially developed by Clark, Haverkamp and Chapman (1985) and later disaggregated to the ten USDA production region level by Ribaudo (1986). These data were updated to 2007 dollars and provide a range of aggregate US offsite sedimentation and deposition costs.

POLYSYS was used to estimate direct and indirect C emissions and SOC sequestered in agricultural soils from changes in cropping activities associated with each ethanol production

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[4] Note: CRD is used instead of county because the NRI is not statistically valid at the county level rather, aggregates of counties must be used for appropriate use of NRI data.

scenario. Direct C emissions include fuel use on farms and the C equivalent emissions for field decomposition of ammonia and lime. Indirect (embodied) C emissions encompass the inputs used in the processing, manufacturing, and transportation of seed, fertilizer, and chemicals applied to crops. C emissions for each ethanol scenario were calculated using methods and estimated coefficients from the C lifecycle literature (West and Marland 2002, Marland *et al*., 2003; Nelson *et al*., 2009). The estimated coefficients and the quantities of fuel and inputs in the budgets in POLYSYS were used to calculate total C emissions for each crop in each CRD. The estimates do not incorporate C emissions from fossil fuels that are being displaced by corn ethanol, nor do they include C emissions associated with transportation of the feedstock, or the transportation of ethanol following its production.

In addition, the SOC sequestered in agricultural soils for each crop and tillage practice was estimated using methods outlined by West *et al* (2008). SOC sequestered was calculated using:

$$CS_{i,k,m} = C_{i,k} \times \Delta_{k,m}, \qquad (2)$$

where *CS* is SOC sequestered (Mg ha^{-1}) in CRD *i* for crop *k* and tillage practice *l*, *C* is the base C level in CRD *i*, for crop *k* (Mg ha^{-1}), and Δ is the annual change in SOC for crop *k* and tillage practice *m*. This analysis was completed using National Land Coverage Data (NLCD) (Vogelmann *et al*., 2001) and STATSGO soils data (USDA/NRCS, 1994). The NLCD is available for the conterminous United States and represents 21 land cover/use classes. For this analysis, all model crops are represented as subclasses defined as row crops, small grains and pasture. Estimates of SOC change at 30 m by 30 m resolution, commensurate with the NLCD land cover, were weighted for each CRD by the relative area of each crop category. This methodology provided crop-specific estimates of SOC change.

Estimates for the annual change in SOC (Δ) were from West and Post (2002). In their study, Carbon Management Response (CMR) curves (West *et al*., 2004) were estimated for every major crop within the United States. The rate of SOC sequestration varies annually until a new steady state is reached. In POLYSYS, linear approximations of CMR curves were applied to the crops modeled in POLYSYS. The resulting annual estimates of SOC sequestered were multiplied by crop area for each tillage practice to arrive at an estimate of total SOC sequestered by CRD.

BIOENERGY MODULE

BIOMASS FEEDSTOCK SOURCES

DEDICATED HERBACEOUS ENERGY CROPS

To evaluate the potential of dedicated herbaceous energy crops, switchgrass is used as a model crop to provide feedstocks to the bioenergy market. Its potential geographic range, yields, and enterprise budgets are incorporated within POLYSYS. While herbaceous dedicated energy crops can grow in all regions of the United States, 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, Allison, and Becker, 1996) and augmented using updated biomass yield projections (Jager *et al.*, 2010). The production of dedicated herbaceous energy crops in this analysis is assumed suitable on 368 million of the total 424 million acres included in POLYSYS with yields varying from 2 to 6.75 dry tons per acre per year(dt/ac/yr) depending on location (Figure A.3).

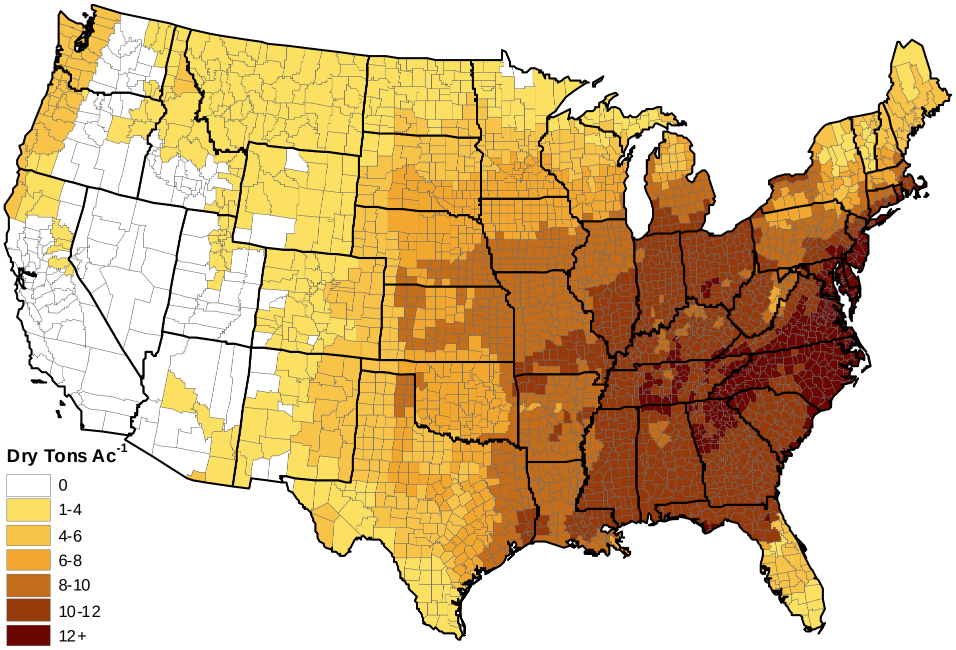

Figure A.3. County Level Switchgrass Yields in 2025

In this application, herbaceous energy crops are not available in the first two years of simulation. Currently, in the United States, dedicated energy feedstock is extremely limited. The lack of large-scale commercial production and the lack of seed necessitates a lag time before dedicated herbaceous crops can become a feedstock for ethanol or other bioproduct production. A minimum of two years to begin large scale switchgrass production is assumed.

Expected prices for dedicated energy crops are a function of one year lagged market prices. Once planted, the expected yields remain fixed for the life of the production rotation. Also, once acres are planted, they remain in the dedicated crop through the end of the simulation.

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; Gupta, Onstad, and Larson, 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 (CTIC, 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.

WOOD CONTRIBUTIONS

Forest residues, mill wastes, fuel treatments and forestland thinnings are included in the model as wood residues for conversion to bioenergy. We assume a maximum of 20 million dry tons (mil dt) of logging residues, 20 mil dt of forestland thinnings, 6 mil dt of fuel treatments. In addition, after solving the Forest module, a 160 mil dt of standing forest are available at prices that cover the harvesting costs, stumpage costs plus transportation costs in 2010; however, this decreases over time as traditional forest product demand increases between 2015 and 2025. Prices for these biomass sources range from $20 to $200 per dry ton.

DEDICATED WOODY CROPS

Woody crops, as in the case of herbaceous cellulosic feedstock, can be produced on cropland, cropland in pasture and permanent pasture. To come into production on pastureland, net returns of dedicated biomass crops must be greater than the regional pastureland rental value plus additional costs for intensifying additional regional pasture to make up for the lost forage. If pastureland is converted to biomass crops, then an equal amount of additional regional pastureland must be intensified to make up for the lost forage. This assumes that the forage yields on this land can double through intensified management.

ANIMAL MANURE

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

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.

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.

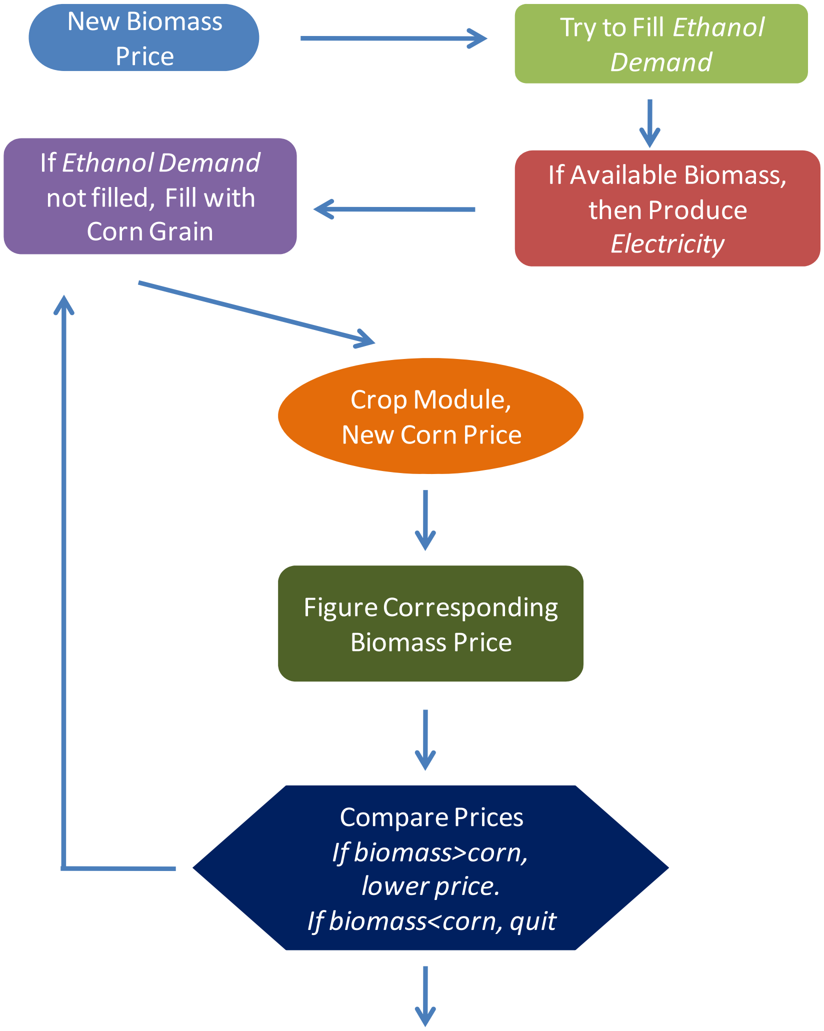

Figure A.4. Schematic of Methods Employed to Determine Feedstock Price Required to Meet Energy Demand

Figure A.4 shows the process of balancing the feedstock quantities so as to arrive at an equivalent price of ethanol from either corn grain or biomass. In the first iteration, ethanol demand is filled with corn grain. The crop module then responds with a high corn price resulting from the increased level of corn demand. At this point, the price of ethanol made from corn grain is used to figure a corresponding price for biomass that would produce ethanol at the equivalent price. The corresponding price of biomass is derived by the following equation:

$$\text{CORPRC}_{\text{biomass}} = (\text{Pcorn} / \text{TECH}_{\text{corn}} + \text{CONV}_{\text{corn}} - \text{CONV}_{\text{biomass}}) * \text{TECH}_{\text{biomass}}$$

Where:

$\text{CORPRC}_{\text{biomass}}$	is the corresponding price of biomass,
P_{corn}	is the price of corn grain,
$\text{TECH}_{\text{corn}}$	is gallons of ethanol per bushel of corn grain,
$\text{CONV}_{\text{corn}}$	is the conversion cost of corn grain to ethanol per gallon,
$\text{CONV}_{\text{biomass}}$	is the conversion cost of biomass to ethanol per gallon, and
$\text{TECH}_{\text{biomass}}$	is the gallons of ethanol per dry ton of biomass

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.

The added 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 (Dager (2005) and USDA/AMS (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 dominant bioproduct that can use biomass or corn grain, its feedstock allocation determines market prices. In instances where 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.

Table A.4. 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 A.4 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)	0.651	0.651	0.651	0.651	0.651	0.651	0.651	0.651	0.651	0.651
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)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Swine Manure to Elect ($/kwh)	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080
Dairy Manure to Elect ($/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)	1632	1632	1632	1632	1632	1632	1632	1632	1632	1632
Wood(KWH/DT)	1676	1676	1676	1676	1676	1676	1676	1676	1676	1676
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)	48.8	48.8	48.8	48.8	48.8	48.8	48.8	48.8	48.8	48.8

CONVERSION COSTS AND COEFFICIENTS

The conversion costs and technical coefficients used in the model are listed in Table A.4. 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., 2007).

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.

IMPLAN

IMPLAN employs a regional social accounting system and can be used to generate a set of balanced economic/social accounts and multipliers (Olson and Lindall, 1999). The social accounting system is an extension of input-output analysis[5]. 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 states' economies. Total industry output is defined as the value of production by industry per year. Total industry output and Gross Domestic Product are expressed in 2010 dollars. A more detailed explanation of IMPLAN and its use in this study is found in the Appendix at the end of the document.

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[5] Input-output (I-O) analysis, also known 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.

In addition to providing measures of economic activity and employment, the IMPLAN 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.

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 cannot 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.

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.

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:

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

$i = 1$ 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 total industry output equaling the gross returns determined from the POLYSYS solution for each ASD aggregated to the state.

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. An interface program called the POLYSIS/IMPLAN Integrator (PII), developed at The University of Tennessee, takes POLYSYS acreage, price, change in government programs, and cost output, and alters the IMPLAN databases to link agricultural sector changes to economic impacts (English *et al.*, 2004a).

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 cannot 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.

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, hybrid poplar, willow, 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, Gross Domestic Product (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; 5) labor costs and the number of employees; and 6) the income generated from wind leases, forest operations, methane production, and net carbon revenues resulting from payments less the increased cost of operation occurring as a result of carbon policy are estimated (English *et al.*, 2004a).

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.

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.