To the Graduate Council:

I am submitting herewith a thesis written by Adam David Fulton entitled "Economic Impacts of Production, Storage, Transport, and Conversion of Switchgrass for a Cellulosic Ethanol Facility in Tennessee." I have examined the final electronic copy of the thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Economics.

Kimberly L. Jensen, Major Professor

We have read this thesis and recommend its acceptance:

Burton C. English

James A. Larson

Dan L. McLemore

Accepted for the Council:

Carolyn R. Hodges
Vice Provost and Dean of the Graduate School

(Original Signatures are on file with official student records)

Economic Impacts of Production, Storage, Transport, and Conversion of Switchgrass for a Cellulosic Ethanol Facility in Tennessee

A Thesis Presented for the

Master of Science Degree at

The University of Tennessee, Knoxville

Adam David Fulton

May 2010

ACKNOWLEDGMENTS

I would first like to thank the Department of Agricultural Economics for the leadership and direction bestowed upon me during my undergraduate and graduate education. Also, I would like to thank my community in Knoxville for their support. Most significantly, I must thank my family for their kindness and love during my education.

I would like to thank committee chair, Dr. Kimberly Jensen for her patience, instruction, and encouragement in producing this manuscript. I express my sincere gratitude to Dr. Burton English, Dr. James Larson, and Dr. Dan McLemore for their involvement, advice, and aid as committee members. A special recognition also needs to be conveyed to Jamey Menard for continual guidance and support throughout this process. Also, I would like to extend my gratitude to all faculty, staff, and students that have shared their lives with me over the past six years.

In Knoxville, many individuals and families have supported my education. I thank Matt and April Grimsley for their love and acceptance. Also, Cade and Marissa Benedict for their encouragement and charity of their home. Sincere thankfulness is sent to Will Hamblen and Michael Phillips for opening up their home. Lastly, I appreciate all members of Redeemer Church of Knoxville for their hospitality and prayers over the past three years.

Finally, I would like to dedicate this manuscript to my family. Their love and inspiration, has inspired me to grow education and seek knowledge. I thank my father and mother, who have taught me to love others unconditionally. I earnestly thank my brother, who has always been a voice of reason. For the past 25 years, my family has encouraged and shaped me into the person I am today, which I will be forever grateful for.

ABSTRACT

The goal of this study is to evaluate the introduction of cellulosic ethanol conversion plants using switchgrass as the feedstock and how it impacts the economies of two Tennessee regions. Switchgrass feedstock production, storage, and transportation costs are estimated for one plant in West Tennessee and one plant in East Tennessee. In each region, the location for a cellulosic ethanol conversion plant and the acreage required to meet a 61.8 million-gallon/year capacity are specified. The costs associated with switchgrass production and cellulosic ethanol conversion are then entered into IMPLAN to estimate the economic impacts of one cellulosic ethanol plant in each region.

The key findings of the study for West Tennessee are as follows. The investment impacts of switchgrass farming are \$100.4 million more in total industry output, an increase of 914 jobs, and \$46.9 million more in total valued added. Investment impacts of a cellulosic ethanol conversion plant include \$121.3 million increase in total industry output, an additional 653 jobs, and a \$47.7 million increase in total valued added. Year-to-year operations of switchgrass farming and cellulosic ethanol conversion increase the region's total industry output by \$57.1 million, increase jobs by 297, and increase total value added by \$26.0 million.

In East Tennessee the investment impacts of switchgrass farming are \$118.3 million increase in total industry output, 949 jobs created, and a \$66.4 million increase in total valued added. Investment impacts of a cellulosic ethanol conversion plant include a \$116.9 million increase in total industry output, an additional 765 jobs, and a \$48.3 million increase in total valued added. Year-to-year operations of switchgrass farming and cellulosic ethanol conversion increase the region's total industry output by \$80.4 million, jobs by 393, and the total value added by \$39.4 million.

TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION

1.1 Background

The dramatic increases in the price of crude oil in 2008 highlighted the issue of America's reliance on foreign oil and heightened consumers' concerns about the source nation's energy in the future. The increased cost of energy makes it more expensive for consumers to heat homes, provide fuel for their vehicles, and makes consumer goods more expensive to distribute. In addition to concerns about energy security, consumers are concerned for the environment and how their demand for energy impacts it. Bioenergy could be a solution for providing a greater share of energy production from domestic resources. Bioenergy could also decrease the amount of carbon dioxide emitted into the atmosphere (Morrow 2006). Furthermore, feedstock production and conversion to energy could assist struggling rural communities by providing new economic opportunities.

In response to national concerns about energy independence and the desire to expand more environmentally friendly alternative energy production, interest in policies to promote bioenergy production has increased. In late 2007, the '25x'25 Action Plan was presented to the United States Congress to show how farms, ranches, and forests could provide 25 percent of America's energy by the year 2025, while still providing safe, abundant and affordable food, feed and fiber. The '25x'25 plan has the goal to increase net farm income, develop new economic activity, and create new jobs (Smith 2007). In December of 2007, the Energy Independence and Security Act of 2007 (H.R. 6) was signed into law. This law requires 36 billion gallons of biofuels by the year 2022. Of this 36 billion, 16 billion must come from cellulosic sources (U.S. Congress 2007). Other legislative proposals have been made that would potentially expand the use of alternative energy, in particular bioenergy. An example of this is legislation H.R.2454 - American Clean Energy And Security Act of 2009, a bill passed in the House in 2009 (U.S. House of Representatives 2009).

Bioenergy is renewable energy produced from agricultural feedstock, such as corn grain, dedicated energy crops such as switchgrass, or forest products wastes. Starch from corn grain is used to produce ethanol and is currently the primary biofuel produced in the United States. Potential second generation biofuels may come from switchgrass and forest product wastes that are converted into ethanol by using enzymes that break down the cellulose to produce starch necessary for fermentation.

Increased concern for the environment and the use of food or feed crops for biofuel production has also spurred interest in developing dedicated energy crops such as switchgrass. Furthermore, demand for ethanol over the next few decades is projected to exceed the availability of corn ethanol (De La Torre Ugarte et al. 2007). Over the past few decades, consumers are demanding energy products that cause less harm to the environment. Also, increases in carbon emissions have demanded changes to the energy market (McDonald et al. 2006). Production and use of cellulosic ethanol may significantly reduce greenhouse gas emissions per BTU of energy, compared with both gasoline and corn grain ethanol (Wang 2008). Switchgrass, a grass native to the United States, can often be grown with lower levels of production inputs than corn because it is a deep-rooted perennial. Furthermore, it generates less erosion than corn (Brown et al.1999). It can be grown in marginal soil conditions and low rainfall, which is suitable for land in the United States where row crop farming is not manageable and geographically difficult (Epplin 1996). When ethanol is produced from switchgrass, CO_2 emissions are reduced to zero net emissions (Morrow 2006). Hence, switchgrass contributes to the offsetting carbon emissions by replacing a percentage of petroleum with cellulosic ethanol.

In addition, cellulosic ethanol can come from a wide variety of other sources, including dedicated energy crops (i.e. wheat straw, or sugar cane), wastes from the forest products industry, and agricultural wastes, such as crop residues. Because cellulosic ethanol's feedstock may not come from non-feed, non-food sources, it creates less direct competition for farmland in the production of food and animal feed.

Tennessee is an ideal region for cellulosic ethanol production because its land is well suited for switchgrass production and the state has a significant forest products industry. If cellulosic ethanol is produced in the state, switchgrass may provide an alternative to current farm enterprises and create additional economic activity in rural communities. Economic activity not only includes the production of switchgrass, but also storage, transportation, and conversion activities. Interest in producing and using renewable fuels in the state has led to a state program developing a biofuels corridor network and construction of a research-scale cellulosic ethanol conversion facility.

In 2006, Tennessee Governor Bredesen allocated $1.5 million to the Tennessee Department of Transportation to develop a Biofuel Green Island Corridor network along Tennessee's interstate system and major highways. The goal of the Green Island program is to assist in establishing refueling stations for B20 biodiesel and E85 ethanol no more than 100 miles apart along the corridors (TDOT 2006). A map of these Green Island Corridors is provided in Figure B.1. As of November 2009, Tennessee had 29 E85 stations open across the state (Alternative Fuels Data Center 2009).

A research-scale cellulosic ethanol facility is under construction in Vonore in East Tennessee. The University of Tennessee in a partnership with Dupont Danisco Cellulosic Ethanol develops the research facility (University of Tennessee 2009a). The facility has a capacity of only 250,000 gallons annually, but there is interest in developing commercial scale cellulosic ethanol facilities in the state. Commercial scale facilities may have an initial production capacity of between 10 and 25 million gallons per year (U.S. Department of Energy 2007a), but could have a capacity of more than 60 million gallons per year (Phillips, et al. 2007).

Because Tennessee has there distinct East, Middle, and West regions, where the topography differs as does the economic base, the economic impacts of placing cellulosic ethanol conversion facilities in these regions could be quite different. However, research to evaluate the economic impacts of placing commercial scale cellulosic ethanol facilities in these different regions is lacking.

1.2 Objectives

The primary objective of this research is to evaluate the economic impacts associated with a switchgrass to cellulosic ethanol production refinery in two regions of Tennessee. One of these refineries is located at the current East Tennessee site of the research-scale cellulosic ethanol facility. The other facility is located in West Tennessee. To achieve this objective, several steps must be pursued including:

a) Determine the conversion facility plant sizes and locations to serve as study regions,

b) Determine potential for feedstock production in these study regions,

c) Determine production costs of switchgrass for feedstock,

d) Determine switchgrass storage costs,

e) Determine transportation and logistics costs,

f) Determine conversion costs into ethanol,

g) Project land use changes from other crops, hay production, or pastureland into switchgrass, and

h) Use the costs of switchgrass production, storage, transportation, and conversion to ethanol to project the economic impacts of a commercially scaled cellulosic ethanol facility and associated feedstock production on the economies of the study regions.

CHAPTER 2: RELATED LITERATURE

This chapter provides an overview of previous research from which input-output modeling can estimate how an industry can impact an economy in a region. First, input-output literature is discussed. This is followed by a discussion of literature on economic impact models of ethanol industry development, including cellulosic ethanol industry development.

2.1 Input-Output Models

Input-output models estimate how an investment may be dispersed through out the economy and estimate its impacts. Economic impacts determine an industry's economic and political significance. Results from input-output models can help in ascertaining an industry's economic significance. Estimating an investment's impact on the economy is important to its citizens, elected officials, journalists, planning commissioners, neighborhood organizers, local businesses, and other stockholders (Kay 2002). These stockholders can use the results from the model to understand the positive or negative impact of an investment on its economy. Policy makers can use the information to plan and make decisions about the new potential industry.

The input-output model provides estimates of multipliers that determine how a dollar invested in an industry impacts output, employment, and income in a region. To understand the value of a multiplier, the final demand of an industry is projected. Final demand or the output of an industry is the sales of a good or service produced from the initial investment. The initial investment is either added to an existing industry or invested to create a new industry. Industries supplying the initially invested industry will also increase their final demand. The initial investment continues to cause a chain of spending over multiple industries impacting their final demand. The effects of the final demand of the industries impacted diminish as the supply chain gets further from the initial investment.

Input-output models that determine economic impacts of an industry have increased significance and are popular in today's economic environment, because time and financial resources are limited. Increased uses of economic impact models determine how resources can best be distributed amongst industries that demand it. However, economic impact models are not only used to estimate a facility being built. Parks and recreation industry may estimate a one-time event or programs expenditures to understand its impacts as well. One-time events have an indirect or induced impact as well. Indirect effects are industries that support the direct industries with goods or services. Induced effects are the response by local industries from the increase in household incomes and transfers generated by the direct and indirect industry changes in final demand (Graefe 2001). Industries that express induced impacts vary from income towards grocery stores to taxes that improved highways.

While economic impact models may provide important information to policy makers, input-output models have limitations that must be considered when using such models. Economic impact models can overstate how monies and employment are distributed. The three most prominent limitations of economic impacts models are: 1) the model expresses impacts using sales rather than income, 2) the model ignores the "with or without" principle, 3) the model fails to account for general equilibrium effects. Sales figures may be larger than income figures, making their impacts greater. The "with or without" principle considers how an event withdraws income from other industries. The model typically includes the event being modeled and the continuance of other industries. Lastly, a general equilibrium of how industries interact must be accounted for to estimate an industry's true measure of impact. An event in the model may not be isolated, since most regions have limited resources, causing the event to be overstated if industries do not interact (EMSI 2008).

In addition, leakage occurs because not all values are transferred from industry to industry. This is because trade exists from outside the region (Kay 2002). For example, most goods purchased from a retailer in the area are not manufactured in the region. Therefore, only a portion of the revenue is retained in the region, while the other portion leaks outside of the economy.

Many types of input-output models are available for governments, universities, or research institutes. Determining what model to use depends on price and the complexity of the model. Three examples of an input-output program that are commercially available are RIMS, REMI, and IMPLAN. RIMS is affordable and simple. IMPLAN is more complex and moderate in price. REMI has the highest cost and complexity (Lynch 2000).

IMPLAN is used in this study because of its ability to distribute a state's total gross output by county, based on county employment earnings. In addition to county level data, IMPLAN is a non-survey based model and its structure is found from regional science literature. Plus, IMPLAN accounts for inflation and deflation that exists within each industry, so costs entered into the IMPLAN model are translated into 2006 dollars as the base year (Lynch 2000).

2.2 Studies of Economic Impact Models in a Cellulosic Industry

The studies of the economic, or an ethanol industry differ by region and agricultural commodity used for ethanol production. A study by Leistritz projected that a biorefinery using wheat straw to produce ethanol, fiberglass, and plastic could have an impact of $183 million and employ 2,474 people in North Dakota (Leistritz 2007). Wheat straw not only has an output of ethanol, but produces a byproduct of fiberglass and plastics as well. However, ethanol production is the primary economic reason to grow wheat straw, because fiberglass and plastics manufacturing from wheat straw alone is not economical. Given that wheat straw produces ethanol, fiberglass, and plastics, the direct impacts of construction and operating a refinery are estimated to be $53.78 million. The primary sectors receiving the increase are households, financial institutions, insurance carriers, real estate, communications, utilities, and retail trade. The secondary impact values (indirect and induced) were estimated with the North Dakota Input-Output Model. This model predicted the secondary impact to be $130 million.

Leistritz's results were also used to compare the impact of a corn-based ethanol facility with a cellulosic ethanol facility. The study found that a corn-based ethanol facility has a small impact on the community. Removing corn that would have been sold in another market causes the difference between the impacts. Corn is now being sold to production ethanol instead. A facility that produces ethanol from cellulosic sources has a larger impact. Using the North Dakota Input-Output Model construction costs for a corn-based facility is estimated at $83.3 million, a cellulosic facility cost $176.5 million, a difference of $93.3 million for its initial investment the would increase its impact to the state. Also a corn-based facility creates 40 direct jobs and 500 secondary (indirect and induced) jobs (Hodur 2009). Since the demand of ethanol is expected to increase and corn's ability to meet that demand is limited, the high cost cellulosic facilities are likely to be built, increasing their impact on communities.

Since American consumers have become more and more aware that energy is primarily from foreign fossil fuels, elected officials are looking to produce energy from renewable and domestic resources. However, corn-based ethanol has the best opportunity of production within the corn-belt. Introducing another type of feedstock from ethanol production gives states and rural communities not in the corn-belt a relative advantage to the production of cellulosic ethanol. This feedstock potentially gives other regions not in the corn-belt the ability to establish a long-term ethanol plant that will produce additional jobs, increase valued added to agricultural production, make a good corporate citizen, and be an anchor to rural communities (Low 2008). Nonetheless, the location of an ethanol facility must have the infrastructure to support the ethanol plant, because it will require large amounts of energy, water, and will burden a region's road system.

2.3 Other Bioenergy Production Impacts

A case study in Kansas researched how bioenergy development could impact crop production, livestock, and water resources (O'Brien et al. 2008). The study found development of a grain based ethanol production negatively impacts feedgrain and livestock industries. Also, ethanol production compromises the region's water supply. In addition to those industries, the grain trucking industry is dramatically affected by the increase in demand from ethanol production. This increased demand for ethanol lowers profitability in livestock feeding enterprises. Also, the low supply of feedgrain brings uncertainty to the industry. The increase demand ethanol production must transfer to a feedstock what would lower the negative impacts of livestock, crop production, and water resources.

Furthermore, communities surrounding the cellulosic ethanol facility may question its environmental impacts. In 2007, the Department of Energy evaluated how a plant proposed in Treutlen County, Georgia, may impact the environment according to the Environmental Policy Act (U.S. Department of Energy 2007b). The proposed plant could produce a maximum of 100 million gallons of ethanol annually. The factors evaluated included: land use, geologic impact, hydrology, water quality, disturbance of wetland, biological resources, safety and occupational health, noise, meteorology, air quality, waste management, cultural resources, transportation, utility infrastructure, aesthetics, and socioeconomic factor. The proposed plant needs to drill a vertical well to a depth of between 124.5 and 135.0 feet to withdraw 316,800 gallons daily. Considering the depth of the pump and the amount needed by the plant, the test concluded that the water level in the aquifer would not affect surrounding areas within 1,000 feet. After testing the aforementioned factors, the study concluded that the plant would not significantly affect the quality of the environment.

A reference point on how an ethanol production plant can impact an economic region, Swenson analyzed how the corn-based ethanol industry impacts the region. A corn ethanol plant would have similar impacts to a cellulosic ethanol plant. However, the impact would be greater because cellulosic ethanol uses new feedstocks, since corn as a feedstock is currently being removed from existing industries. According to Swenson, an ethanol plant has an output multiplier of 1.13, value-added multiplier of 1.38 and a job multiplier of 3.79 (Swenson 2006). Theses multipliers assume that the plant produces 50 million gallons of ethanol a year from corn as the primary feedstock.

Lazarus and Tiffany (2009) used IMPLAN to estimate how the establishment of short rotation woody crops assists energy production within the state of Minnesota. Their study considers how short rotation wood crops may be better utilized for energy production rather than wood products. IMPLAN modeling estimates that short rotation woody crops are utilized more efficiently when used to produce energy rather than wood products. Furthermore, the reductions of cow-calf operations do not have a negative net impact in the state.

CHAPTER 3: METHODS

With the production, storage, and transport of switchgrass to the cellulosic ethanol conversion facility, many resources are required from a region's economy. In analyzing the economic impacts from creating a cellulosic ethanol conversion facility and associated expenditures to provide its feedstock, both fixed costs and variable costs, are investigated. The fixed costs include the initial investment, for example, of constructing an ethanol conversion facility. These costs produce one-time economic impacts. The variable costs, the year-to-year costs, to operate a cellulosic ethanol facility includes labor, utilities, and feedstock costs. Investigating the cost of each phase of producing switchgrass and converting it to ethanol will allow models to estimate how a region would be impacted (De La Torre Ugarte, et al. 2006).

Several steps are entailed in the analysis. The first step is the selection of the cellulosic facility site and size of the hypothetical facility. Second is the compilation of cost information for production, transportation, and conversion of switchgrass to ethanol. Third, these costs are assigned to the appropriate IMPLAN (Impact Analysis for Planning) sectors. Finally, the economic impacts of the production, transportation, and conversion of switchgrass is projected using the IMPLAN model. In this chapter, a brief description of the IMPLAN model is provided. This description will be followed by the methods and data used in selecting site locations, size of facility, compilation of feedstock production, transportation, and conversion costs, and assignment to IMPLAN sectors.

The IMPLAN model employs a regional social accounting system and can be used to generate a set of balanced economic/social accounts and multipliers (Lindall). The model describes the transfer of money between industries and institutions, as well as containing both market-based and non-market financial flows, such as inter-institutional transfers. Output from the model includes descriptive measures of the economy including total industry output, employment, and value-added for over 500 industries in the Tennessee economy. Because no industry for switchgrass exists, and hence it is not one of the industries in the model, an industry must be constructed based upon projected costs.

Total industry output is the value of production by industry per year. Employment represents total wage and salary employees, as well as self-employed jobs in a region, for both full-time and part-time workers. Total value added is defined as all income to workers paid by employers; self-employed income; interests, rents, royalties, dividends, and profit payments; and excise and sales taxes paid by individuals to businesses. The model also provides estimates of multipliers. Direct effects measure the response for a given industry given a change in final demand for that same industry. Indirect effects represent the response by all local industries from a change in final demand for a specific industry, for example the effects on agricultural input industries from switchgrass production. Induced effects represent the response by all local industries caused by increased (decreased) expenditures of new household income and inter-institutional transfers generated (lost) from the direct and indirect effects of the change in final demand for a specific industry. This effect would include, for example, expenditures by employees of a cellulosic ethanol plant in the local communities from the wages earned at that plant. Total effects are the sum of direct, indirect, and induced effects (MIG 2004).

3.1 Conversion Facility Site Selection and Facility Size

To illustrate the potential economic impacts of development of a cellulosic ethanol industry in two regions of the state, this study will consider the impacts of two cellulosic ethanol plants that convert switchgrass to ethanol. The location of each site, as well as the study region for each site, is shown in the map in Figure B.2. Each plant will have the capacity to convert 771,536 tons of switchgrass into 61.8 million gallons of ethanol each year. This size of facility has been studied as a commercially viable size of facility for cellulosic ethanol conversion (Phillips et al. 2007). To meet annual capacity of 771,536 tons, approximately 123,446 acres are needed within an average 25-mile distance of the plant. Because switchgrass is a bulky feedstock and relatively expensive to transport per ton, the average distance is limited to 25 miles, or a 50-mile maximum increasing the distance would impair the facility of providing an affordable feedstock (Turhollow 1998).

One of the sites is in West Tennessee with its acreage from selected counties in the north section of Agricultural Supply District (ASD) 63. The southern section of ASD 63 has little acreage in pasture and hay production. Also, the majority of the section's acreage consists of high value crops with which switchgrass could not currently compete. Thus, making the northern section of ASD 63 better suited for the facility. North Carroll County is a centralized location to the counties included in the acreage assessment. The counties selected in the model have the majority of its acreage within of 25 miles of the proposed plant location. The counties include Benton, Carroll, Gibson, Henderson, Henry, Madison, and Weakley (Figure B.2). Including counties beyond a distance of 25 miles would cause some of its acreage to be beyond the maximum travel distance of 50 miles.

The rational for the proposed West Tennessee plant location are as follows. First, switchgrass crops are currently being grown at the University of Tennessee Milan Research and Education Center in Milan, TN (University of Tennessee 2009b). Second, North Carroll County has access to highways for truck transportation and rail lines that extend to each county in the model. Third, using local railroads as a method of transportation may have potential to decrease the average costs of transporting switchgrass per ton. However, this study uses semi-tractor trailers as its transportation method. Fourth, the region has the ability to supply the acres required by switchgrass farming to meet the annual demand of the conversion facility. Lastly, the selected region contains Interstate 40, which could be a key route for transporting the output from an ethanol conversion facility to end-users. Moreover, the plant has the potential to supply motorists on Interstate 40, in Madison County, assessed as a priority county in Tennessee's Biofuel Corridor Network (Alternative Fuel Data Center 2009).

The second model is in East Tennessee with its acreage centralized in ASD 67. Again, counties selected in this model have the majority of its acreage within of 25 miles of the proposed plant location. The counties include Anderson, Blount, Knox, Loudon, McMinn, Meigs, Monroe, and Roane (Figure B.2). Again, including counties beyond an average distance of 25 miles would cause some of its acreage to be beyond the maximum travel distance of 50 miles. The rational for the location of the proposed East Tennessee plant are as follows. First, this region currently has the site for the research scale cellulosic ethanol plant scheduled to be operational in 2010. In October 2008, the DuPont Danisco Cellulosic Ethanol LLC, and the University of Tennessee Research Foundation, through Genera Energy LLC started construction of a pilot-scale cellulosic ethanol bio-refinery in Vonore. Vonore is located between Blount County and Monroe County. This pilot scale plant is expected to produce 250,000 gallons annually (University of Tennessee 2009a). A pre-existing research scale plant provides infrastructure that will be utilized by a commercial-scale conversion facility. Secondly, the region has access to major highways for feedstock transportation between counties. Thirdly, the acreage of the selected counties included has the ability to supply the proposed plant with feedstock. Lastly, the selected region contains Interstates 75, 40, 640 and 140. Theses interstates are in the priority counties (Anderson, Knox, Loudon, and McMinn) in Tennessee's Biofuel Corridor Network (Alternative Fuel Data Center 2009).

The majority of the cropland that could potentially be converted in each region includes corn, hay, soybean, cotton, wheat, and cropland in pasture or grazed. In West Tennessee, the aforementioned cropland accounts for 88 percent of total cropland in its counties. In the East Tennessee acreage assessment, the potential cropland crops account for 79 percent of its counties total cropland. For this analysis, cropland acreage is assumed to be the potential area available for switchgrass production (Table A.1). However, acreage with the lowest opportunity cost for switchgrass production is obtained either by converting hay production into switchgrass or by cropland used for pasture and grazed. Removing high input cropland acreage, such as corn, cotton, or soybeans, could severely decrease total output from its industries in each region. Since many rural communities base their economies on high-input farming, such as corn, cotton, or soybeans, low input farming, such as switchgrass farming, could not compete for acreage on the basis of net returns per acre. Therefore, the majority of acreage allocated to switchgrass production is assumed to come from cropland used for hay production or cropland in pasture. This acre type will be used over typical cropland because of the two-year lag time switchgrass has between planting and harvesting (De La Torre Ugarte et al. 2006). Most cropland acreage rotates annually; switchgrass production will need to be produced for a 10-year period, including the 2-year lag period. The two-year lag discourages farmers to produce switchgrass. No income would be made during these two years. Therefore, farms that contain low value cropland would more likely to produce switchgrass.

Given that switchgrass production requires acreage and each region has limited cropland, a portion of cropland will be reallocated for switchgrass. In order for the cellulosic ethanol facility to produce at full capacity, 123,446 acres of cropland must be converted into switchgrass farming. For modeling purposes, all hay production acreage will first be converted into switchgrass production. The remainder is obtained from cropland in pasture or grazed. Since, cropland in pasture or grazed has high value per acre than land used from hay production, because beef cattle use this type of land. Both regions contain enough acreage in hay production and pastureland to meet the 123,446 acre requirement. Therefore, no acreage would be withdrawn from food or fiber cropland acres. The East Tennessee model can obtain all the required acreage from hay production alone. Furthermore, 20 percent of hay will remain in production. However, the West Tennessee model converts all of the regions hay acreage to switchgrass production. The remaining acreage required is derived from cropland in pasture or grazed.

The West Tennessee ASD 63 region has 563,491 acres or 74 percent of land in crops and 199,058 acres or 26 percent of land in hay and pasture. At the 10-year average yield of 6.25 tons per acre, this acreage could provide a potential of 4,765,931 tons of switchgrass (Garland 2008). Hay and pasture land acreage alone could provide 1,244,114 tons of switchgrass, more than the estimated annual capacity of 771,536 tons need to produce the 61.8 million gallons each year.

The East Tennessee ASD 67 region has 20,094 acres, or 8 percent of land in crops and 203,492 acres or 92 percent of land in hay and pasture. Switchgrass is expected to yield an average of 5.5 tons in the first 5 years, achieving full yielding average of 7 tons by its third year. With full yielding at an average of 7 tons from year 5 through 10, switchgrass will average 6.25 tons per acre over its 10-year life expectancy. At this yield the region could potentially provide

1,357,938 tons of switchgrass annually (Garland 2008). However, to meet the plant's annual capacity of 61.8 million gallons, only 771,536 tons is demanded from the region.

3.2 Feedstock Production Costs

University of Tennessee Extension budgets are used to estimate switchgrass production cost, calculated by acre over a 10-year production period, and is in 2008 dollars (Gerloff 2008). In the first two years of switchgrass production, expenses are identical at $248.75 per acre of production. In these two production periods the use of P205, K20 fertilizers, and rental spreader is included in the cost, however if the soil test are medium or high theses fertilizers are not needed. Also, pure live seeds are used at a rate of 6 lbs per acre in the first year and seed prices will vary in different regions. Since the costs in years 1 and 2 are responsible for establishing switchgrass and are one-time expenses, they are switchgrass's investment expenditures. In years 3 through 10, the year-to-year cost of producing switchgrass increases to $356.19 per acre. This increase is from introducing the harvesting process and its costs in year 3. The year-to-year operating costs of switchgrass with the costs associated in years 1 and 2 prorated at 8 percent, is estimated at $401.22 (Gerloff 2008). As mentioned in the previous section, switchgrass should yield an average of 5.5 tons in the first 5-years, achieving full yielding average of 7 tons by its third year. With full yielding at an average of 7 tons from year 5 through 10, switchgrass will average 6.25 tons per acre over its 10-year life expectancy (Garland 2008). At this yield, switchgrass operating costs from year-to-year, not including first two years for establishing, are $50.88 per ton. The feedstock production costs are displayed in Tables A.2, A.3, and A.4.

Since switchgrass farming is a new industry to the region and acreage is finite, the area converted to switchgrass production is either removed from hay production or cropland in pasture. In both regions, the proposed plant size requires 123,446 acres to be in switchgrass production annually. As stated above, acreage is first removed from hay production, since hay is a comparable crop to hay and many equipment costs are similar. The remaining acreage will be acquired from cropland in pasture. This acreage is used as an input from cattle production. Therefore a reduction of pasture is equivalent to a reduction in cattle.

In West Tennessee, hay area totals 100,537 acres, and 100 percent of hay acreage would need to be converted into switchgrass production. The remaining 22,909 acres required to produce enough switchgrass is obtained from cropland in pasture. Cropland in pasture in the region totals 98,521 acres (USDA 2007). This would constitute a 23.3 percent removal of acres of cropland in pasture. The reduction in output from hay production not only decreases hay output by $10.7 million, but it is projected to also reduce cattle industry output by $8.6 million. See Table A.5 for other industry's loss in output by converting acreage into switchgrass production.

In East Tennessee, hay area totals 152,778 acres. Thus, a total of 80.8 percent of hay acreage is converted into switchgrass production and 80.8 percent of hay production output is withdrawn from with in the region. About 19.2 percent or 29,332 acres remain in hay production. The reduction in output from hay production totals $10.7 million (USDA 2007). Cropland in pasture in the region totals 64,385 acres, however no pastureland is needed to be converted in this region, consequently, no reduction in cattle industry output is assumed for this region. See Table A.5 for other industry's loss in output by converting acreage into switchgrass production.

3.3 Feedstock Storage Costs

For round bale storage for switchgrass, there were 5 different methods that were studied at the University of Tennessee Experiment Station in Milan, TN (Table A.6). Based on that research harvested switchgrass can be baled, stacked on gravel or pallets in stacks of 72 bales and possibly covered with plastic tarps. Use of gravel to store round bales incurred the highest storage costs. Switchgrass placed on the ground is the lowest cost, however dry matter and quality are potentially reduced because of exposure to weather. The lowest cost for storage, while maintains a high quality is placing bales on pallets in a 3-2-1 design, and then covering the bales with a plastic tarp. This type of storage is used in this study because of its low cost and ability to retain a high quality. The total annual cost per acre is $102.56 and $14.65 per ton in 2008 dollars (Wang 2009). Acreage cost is multiplied by the yield of 6.25 tons per acre (Garland 2008). Farmers were assumed to bear the cost of storage and storage costs were added to the costs of production to create switchgrass farming as a new IMPLAN sector. All storage costs excluding labor were treated as an investment expense in this analysis. Because tarps and pallets used in the process have a 5-year life expectancy with no salvage value, the annual depreciation expense for storage is assumed to be 20 percent of the initial investment. Storage calculations are reflected as an IMPLAN expenditure in Table A.10.

3.4 Feedstock Transport Costs

Switchgrass bales are assumed to be loaded on a 48-foot flatbed semi-tractor-trailer for transport to the biorefinery. Average loading time is one half hour and unloading time at the refinery is one-third of an hour. Equipment costs associated with transporting switchgrass is rated at 48 cents per ton (Wang 2009). The cost of labor for loading and unloading is $12.00 per hour. If the driver does the loading and unloading, the cost will increase. Loading and unloading costs totals $16.20 per truckload. The average transport distance for switchgrass is 25 miles or a 50-mile round trip. Including loading and unloading times, the total time is 2 hours. Fuel cost is calculated by dividing the truck gas mileage by the average round trip and then multiplied by the cost of fuel by the gallon. At 2 hours for each round trip, trucks would be able to make 4 round trips per day in an 8-hour workday. A semi-tractor trailer cannot exceed a gross vehicle weight of 80,000 pounds (TDOT 2003). Therefore a single truck can carry 26 bales or 13 tons. A single truck in on an average workday can transport 52 tons of switchgrass to the refinery. The total cost per ton is $7.25 at that capacity or a total cost per day of $377.20 in 2009 dollars. Adjusting the cost to 2006 dollars, transporting switchgrass is $7.04 per ton. At that rate, the cost to transport the annual required amount of 771,536 tons is $5,434,697. For the purpose of the study in IMPLAN, the conversion plant will purchase truck transportation industry within the region. The transportation costs are presented in Table A.7 and reflected in Table A.11 as an IMPLAN expenditure.

3.5 Conversion

The facility costs are those based upon the study by the National Renewable Energy Laboratory in April 2007. The expenditures for converting switchgrass biomass into 61.8 million gallons of cellulosic ethanol per year include 24 different IMPLAN industry sectors. Each plant has the ability to convert one dry ton of switchgrass into 80.1 gallons of ethanol (Phillips et al. 2007). Each expense is broken down into an investment expense, operating expense, or a depreciation expense. Investment costs take into account what the capital expenditures are initially for the industry to operate. Operating costs are the expenditures necessary to operate a facility day to day. The plant's life expectancy is 20 years. Therefore the annual depreciation for the conversion plant in this study, assuming no salvage value, will be 5 percent of the all investment expenditures. In addition to the plant's expenses, a byproduct will be produced as a power supply, crediting the conversion plant's expenses. The expenses are totaled and then divided by the total gallons produced a year to estimate the cost per gallon to convert switchgrass into ethanol. Investment expenditures are estimated and adjusted to be $144,075,132 in the base year of 2006. Annual operating expenditures total $60,496,343. Operating costs without the feedstock expenditure total $16,640,415. Annual depreciation is $7,203,757. All expenditures are in 2006 dollars.

In addition to producing 61.8 millions gallons of ethanol annually, the plant produces 70.062 million kWh per year of electricity creating a byproduct. Tennessee's industry average price per kWh in August 2009 is $0.0652 (Energy Information Administration 2009). Adjusting for inflation, the plants byproduct is $4,250,126. However, the plant needs 70.027 million kWh per year of electricity to operate the facility, costing the plant at the same kWh rate is estimated at $4,248,126. The net impact gives the plant a credit of $2,000. Individual equipment or investment costs and operating expenditures details are in Tables A.8 and A.9. It is also reflected as an IMPLAN expenditure in Table A.11.

3.6 IMPLAN Input

Tables A.2 through A.9 contain the totals by category for each type of expenditure used to create a Switchgrass Farming sector (IMPLAN sector 9) and Cellulosic Ethanol Conversion sector (IMPLAN sector 50). In those tables, each expenditure type is either deflated or inflated to 2006 (base year) dollars. Also included in these tables is the assignment of each type of expenditure to the appropriate IMPLAN codes. These IMPLAN codes represent the industries in the IMPLAN model for which the expenditures occur. These codes are then used, along with the expenditure information to project the economic impacts from the expenditures to produce, transport, and convert switchgrass to cellulosic ethanol. Depreciation for production investments is used over a 10-year period, and is 10 percent of the initial expense. Storage depreciation is 20 percent, because of its 5-year life expectancy. Depreciation on storage is reflected in switchgrass farming sector 9. Truck transportation will be considered an operating expense given to the plant. The investment and operating costs are translated into IMPLAN for both ASD regions 63 (West Tennessee) and 67 (East Tennessee). All values stated in the section are in 2006 dollars, for this is the base year used in IMPLAN.

Data used for IMPLAN are combined and developed into two different sectors (Switchgrass Farming and Cellulosic Ethanol Conversion). These sectors represent the needed feedstock production and conversion for one plant to produce 61.8 million gallons per year.

The sector, Switchgrass Farming, includes the production and storage of switchgrass. Investment includes all necessary costs needed to establish switchgrass crops and store switchgrass. The total industry output (TIO) is estimated by multiplying the price switchgrass is sold to the plant by the quantity produced in order to supply the conversion plant at capacity. The cost to produce and store switchgrass is in 2006 dollars is estimated to be $52.72 per ton. Since switchgrass bales is not sold currently, price of switchgrass in this study is cost plus a 5 percent profit. Adding a 5 percent profit to the cost, $55.36 per ton is the estimated price of switchgrass. The quantity sold in the region is 771,536 tons. Therefore, switchgrass farming's total industry output in the base year is estimated to be $42,713,139.

Values for each new sector in the study area were calculated to create a new industry. The values calculated include the industry's employee compensation, proprietor's income, other property income, indirect business taxes, and number of employees. Employee compensation is the total payroll costs including benefits that are paid by the local industries, and the proprietary income is the income from self-employment. Other property income includes corporate income, rental income, interest and corporate transfer payments from the industry. Lastly, indirect business taxes including sales, excise, licenses and other paid taxes during normal operation of the industry were calculated using the IMPLAN model. This data also includes payments to the government, but do not include taxes based on income. The number of employees includes full time and part-time positions needed by the industry (MIG 2004).

Switchgrass farming is currently not an industry sector in IMPLAN. Therefore, information about an industry comparable to switchgrass farming is needed to calculate employee compensation, proprietary income, indirect business taxes, and employment for the study area values. IMPLAN sector 10 (all other crop farming) which includes hay production were used in is analysis. Existing study area values for sector 10's calculated an absorption ratio of the industry, by dividing each value by its own TIO. Then, the absorption ratio of the corresponding study area value is multiplied by the calculated TIO of switchgrass farming, creating the new study area values. Using switchgrass farming's TIO at $42,713,139 and the absorption ratio in sector 10, the study area data is estimated to be the following: Employee Compensation is estimated to be $2,844,781, Proprietary Income is estimated to be $3,784,418, Other Property Income is estimated to be $15,375,212, Indirect Business Taxes is estimated to be $776,323, and the industry is estimate to employ 3,051 people. The created switchgrass farming industry is assigned to IMPLAN sector 9. For details, see Table A.10.

The sector, Cellulosic Ethanol Conversion, includes the costs of conversion and transportation of switchgrass as a feedstock. The total industry output (TIO) is estimated by multiplying the annual production of the conversion plant at 61.8 million gallons by the market price of ethanol. In October 2009, commodity price of ethanol is priced at $1.87 per gallon (CME Group 2009). At that price the base year total industry output would be $104,870,756. Once the total industry output is calculated, it is then compared to organic chemical manufacturing to estimate the study area data. For that industry's study area, an absorption ratio of the industry is calculated by dividing each production function by its TIO. The absorption ratio is calculated by dividing each study area value by the compared industries TIO. The absorption ratio is multiplied by the calculated TIO of cellulosic ethanol conversion, creating the new study area data assigned to IMPLAN code 50. Using the cellulosic ethanol conversion TIO of $104,871,756 multiplied by the absorption ratio, the study area data is estimated to be the following: Employee Compensation of $6,517,882, Proprietary Income of $636,738, Other Property Income of $3,595,833, Indirect Business Taxes of $428,930, and employment of 97 people. In addition, the cellulosic ethanol conversion industry will include the byproduct in power generation of $4,250,126 in the base year. See Table A.11.

In both West and East Tennessee, some goods and services purchased for switchgrass production or cellulosic ethanol conversion will originate from the corresponding region. In IMPLAN, the regional purchase coefficient (RPC) represents local trade flows and is the percent of local demand met by its local producers. Another factor necessary to consider is the foreign imports ratio (FIR). This ratio represents good and services demanded by the industry, but not provided by the region do not meet its demand (MIG 2004). In this study, for both switchgrass farming and cellulosic ethanol conversion the RPC is assumed to be 1.0. The FIR for both industries assumed to be 0.0. Thus, the assumption for these two ratios implies that the supply and demand of both industries will be met or absorbed within each local economy. In other words, all switchgrass produced by the plant is used by the plant and all ethanol produced is consumed in the study region.

CHAPTER 4: RESULTS

The input data in Tables A.10 and A.11 are entered into the impact section of the IMPLAN model for both the West and East Tennessee study regions to obtain the economic impacts. When interpreting the results it is important to remember that investment expenditures for switchgrass farming and cellulosic ethanol conversion are treated as separate impacts. Operating expenditures consist of both annual operating expenditures and depreciation associated with the investments. Once both expenditure types are combined, the defined operating figures for switchgrass farming and cellulosic ethanol conversion are entered separately. The four impacts are reported for each study region, the West Tennessee model (ASD region 63) and the East Tennessee model (ASD region 67). Each impact made in the IMPLAN model is reported as the following: Investment-Production (IP), Operating-Production (OP), Investment-Conversion (IC), and Operating-Conversion (OC). West or East at the end of each term defines for the region the values are being reported. All IMPLAN results can be seen as tables in Appendix C. Tables C.1-C.10 report the West Tennessee impacts, while Tables C.11-C.20 report the East Tennessee.

The IP impact for each study region represents investments associated with switchgrass production. An investment impact represents the one-time impact of the industry being established. The OP impact for each study region represents the impacts from year-to-year expenses associated with switchgrass production and what effect they have on each region's economy. The IC impact is the investment impact associated with the establishment expenses of a cellulosic ethanol conversion facility. Again, this is an investment impact, and as such, is a one-time impact. The OC impacts represent the recurring impacts that project year-to-year expenditures from a cellulosic ethanol conversion facility.

Output reflects the value of each industry's total outgoing product. Employment data explains how many full-time and part-time employees are created. The total value added is the sum of these four components: employee compensation, proprietor income, other property income, and indirect business taxes. This study will evaluate total value added as the sum of the mentioned components, or the total calculated earnings in each industry. All dollar values in the results section, except for employment, are in 2006 dollars.

Three types of effects explaining impact of the industry are represented. These effects are defined as direct, indirect, and induced. Direct effects measure the response for a given industry given a change in final demand for that same industry. Indirect effects represent the response by all local industries from a change in final demand for a specific industry, for example the effects on agricultural input industries from switchgrass production. Induced effects represent the response by all local industries caused by increased (decreased) expenditures of new household income and inter-institutional transfers generated (lost) from the direct and indirect effects of the change in final demand for a specific industry.

4.1 Results for Switchgrass Farming in West Tennessee

Investment Impact

Impact analysis for the switchgrass farming industry established in West Tennessee (ASD region 63) is separated into investment and operating impacts, with investment impacts presented first. The investment impacts are the one-time investment effects that result from producers investing in establishing switchgrass production. The costs used to make the investment expenditure impacts projections for switchgrass production in the West Tennessee region are those found in Table A.10. These costs include seed purchase, agricultural chemicals, machinery/equipment, fuel, credit, and other costs associated with establishing the switchgrass crop in the first year.

Industry output impacts from IP-West are $64.4 million in direct effects, $15.1 million in indirect effects, and $20.8 million in induced effects. Total industry output impact from investment, including the direct, indirect, and induced effects are projected at $100.4 million. Employment projections are 540 direct employees, 123 indirect employees, and 251 induced employees. Thus, a total of 914 individuals are employed in the region due to the introduction of switchgrass production. IP-West expenditure impacts on value added are $26.4 million in direct effects, $7.3 million in indirect effects, and $13.2 million in induced effects. Total valued added impact from investment is $46.9 million. (Table C.1.)

Based upon total impacts, including direct, indirect, and induced impacts, the top 10 industries impacted in terms of valued added, employment, and output for IP of West Tennessee can be seen in Table C.2. For total industry output, the largest impacts are to farm supply retailers, fertilizer and pesticide manufacturing, sawmill and woodworking machinery, and credit intermediation. Farm supply retailers is where farmers will purchase switchgrass seed. Switchgrass in the first year of establishment require fertilizer and pesticides. Sawmill and woodworking impact come from pallets needed for switchgrass storage. Lastly, credit intermediation reflects farmers obtaining capital for farm purchases.

Operating Impacts

As switchgrass is introduced into the study region, other farming industries convert acreage to switchgrass production. The decreases in economic activity associated with these declines in production of other commodities must be accounted for in the analysis. In West Tennessee, all acreage from hay production was converted to switchgrass with a projected 23.3 percent decline in cattle production. The results in Table C.3 encompass the projected declines in hay and cattle production along with increases in switchgrass production; hence capturing how the introduction of switchgrass could reduce output, employment, and value added from the hay and cattle industries for that region.

The OP-West economic impacts from switchgrass production, without taking into account the decrease in hay and pasture used for cattle (in millions), are $39.8 in direct effects, $8.7 in indirect effects, and $5.9 in induced effects. Total output impact is $54.4 million. Employment is estimated at 294 direct, 66 indirect, and 63 induced jobs, totaling 423 jobs added to employment in the region. Impact values on value added (in millions) are $14.6 in direct effects, $39.5 in indirect effects, and $3.6 in induced effects. Total valued added impact is $57.7 million.

The impact of decreasing hay and cattle production output is the withdrawal of $19.2 million in direct effects, $6.8 million in indirect effects, and $1.8 million in induced effects. Total output declines by $27.8 million. The decrease in employment is 268 direct, 85 indirect, and 20 induced jobs, totaling 373 jobs removed from the region. Value added decreases by (in millions) $6.3 in direct effects, $38.3 in indirect effects, and $1.1 in induced effects. The decline in total valued added impact is $45.7 million.

The net effect on switchgrass farming's TIO is found by taking the difference between the economic activity from switchgrass production and declines in hay and cattle production. The Net OP-West impact for industry output is $20.6 million in direct effects, $1.9 million in indirect effects, and $4.0 million in induced effects. Thus, impact on total output is $26.5

million. Employment is estimated to be 26 direct, -19 indirect, and 43 induced, totaling 50 jobs created in the region. Impact values on value added (in millions) are $8.3 in direct effects, $1.1 in indirect effects, and $2.5 in induced effects. Total valued added impact is $11.9 million net. Hence, even though there are negative impacts associated with hay and cattle industry declines, the overall impact of the additional switchgrass production is still projected to be positive.

The top ten industries impacted in terms of total output, total employment, and total value added can be seen in Table C.4. For total industry output, these industries include fertilizer mixing, gasoline stations, farm machinery, machinery repair and maintenance, and farm supply retailers. Fertilizer, machinery repair, and farm supply retailers are year-to-year costs for switchgrass production. Gasoline stations will be impacted because of the needed fuel for light truck and farm machinery. Some farms will likely purchase new machinery for switchgrass production.

The top five industries negatively impacted in output, employment, and value added can be seen in Table C.5. For total industry output hay production, cattle ranching and farming, agricultural support activities, veterinary services and grain farming are projected to have the largest decreases in industry output.

4.2 Results for Cellulosic Ethanol Conversion in West Tennessee

Investment Impacts

Impact analysis for the Cellulosic Ethanol Conversion established in West Tennessee (ASD region 63), is separated into investment and operating impacts, with investment impacts presented first. The IC impacts are the up-front one-time investment impacts that result from producers investing to establish a Cellulosic Ethanol Conversion industry. The costs used to make the investment expenditure impacts projections for IC in the West Tennessee region are those found in Table A.11. These costs include the purchase of switchgrass as its feedstock, industrial machinery, heating and cooling equipment, various metal products, air purification equipment, and other costs needed to establish a cellulosic ethanol conversion plant.

Industry output impacts from IC-West are $85.6 million in projected direct effects, $16.3 million in projected indirect effects, and $19.5 million in projected induced effects. Total industry output impact from investment, including the direct, indirect, and induced effects are projected at $121.3 million. Employment projections are 317 direct employees, 120 indirect employees, and 217 induced employees, totaling 653 employees. IC expenditure impacts on value added are $28.0 million in direct effects, $7.9 million in indirect effects, and $11.8 million in induced effects. Total valued added impact from investment is therefore $47.7 million (Table C.6.)

Based upon total impacts, including direct, indirect, and induced impacts, the top 10 industries impacted in terms of valued added, employment, and output for IC of West Tennessee can be seen in Table C.7. For total industry output, the largest impacts are power boiler and heat exchanger manufacturing, air and gas compression manufacturing, wholesale trade, and miscellaneous metal product manufacturing.

Operating Impacts

As shown in Table C.8, the OC-West impacts for industry output (in millions) are $60.8 in direct effects, $4.7 in indirect effects, and $7.8 in induced effects. Total output impact is $73.3 million. Employment is estimated at 415 direct, 42 indirect, and 84 induced, totaling 541 jobs in the region. Impact values on value added (in millions) are $21.5 in direct effects, $2.5 in indirect effects, and $4.8 in induced effects. Total valued added impact is $28.8 million.

The top ten industries projected to be impacted in terms of total valued added, total employment, and total output can be seen in Table C.9. For total industry output, these industries include the direct costs of feedstock, truck transportation, air and gas compression manufacturing, power boiler and heat exchanger manufacturing, and power generation and supply. Sector 507 represents direct feedstock costs. Truck transportation is required to obtain all necessary inputs for the plant. Air and gas compression manufacturing and heat exchanger account for depreciation expenses of the investment costs. Maintenance and repair expenses are needed year-to-year to ensure plant is operational.

Year-to-Year Operating Impacts of both industries in West Tennessee

As shown in Table C.10, the operating expenditure impacts for both switchgrass farming and cellulosic ethanol conversion industry (excluding feedstock expenditures for the conversion process). The combined impacts have an output of $38.7 million in direct effects, $6.6 million in indirect effects, and $11.9 million in induced effects. Total output impact is $57.1 million. Employment is estimated at 148 direct, 22 indirect, and 127 induced jobs, totaling 297 jobs in the region. Impacts on value added are $15.2 million in direct effects, $3.6 million in indirect effects, and $7.3 million in induced effects. Total valued added impact is $26.0 million.

4.3 Results for Switchgrass Farming in East Tennessee

Investment Impact

Impact analysis for the switchgrass farming industry established in East Tennessee (ASD region 67), is separated into investment and operating impacts, with investment impacts presented first. The costs used to make the investment expenditure impacts projections for switchgrass production in the East Tennessee region are those found in Table A.10. These costs include seed purchase, agricultural chemicals, machinery/equipment, fuel, credit, and other costs associated with establishing the switchgrass crop in the first year.

Industry output impacts from IP-East are \$62.7 million in direct effects, \$16.9 million in indirect effects, and \$38.7 million in induced effects. Total industry output impact from investment, including the direct, indirect, and induced effects are projected at \$118.3 million. Employment projections are 436 direct, 121 indirect, and 392 induced jobs, totaling 949 employees that will be employed in the region due to the increased demand for switchgrass. The IP-East expenditure impacts for value added are \$33.6 million in direct effects, \$9.0 million in indirect effects, and \$23.8 million in induced effects. Total valued added impact from investment is therefore \$66.4 million. (Table C.11.)

Based upon total impacts, including direct, indirect, and induced impacts, the top 10 industries impacted in terms of valued added, employment, and output for IP in East Tennessee are shown in Table C.12. For total industry output, the largest impacts are to farm supply retailers, fertilizer and pesticide manufacturing, credit intermediation, and plastic packaging materials. Farm supply retailers is where farmers will purchase switchgrass seed. Switchgrass in the first year of establishment requires fertilizer and pesticides. Credit intermediation reflects farmers obtaining capital for farm purchases. Lastly, plastic packaging materials are needed to cover switchgrass bales while they are in storage.

Operating Impacts

As in West Tennessee, acreage conversion to switchgrass and out of other uses occurs in the East Tennessee region. In East Tennessee, the model has 80.8 percent removed acreage from hay production, or 80.8 percent of the hay production total output. The declines in hay production are taken into account along with increases in switchgrass production. Table C.13

presents estimates of how conversion to switchgrass could reduce output, employment, and value added from the hay industry.

In OP-East expenditure without taking into account the decrease in hay production (in millions) is \$40.6 in direct effects, \$9.8 in indirect effects, and \$12.5 in induced effects. Total output impact is \$62.9 million. Employment is estimated at 257 direct, 70 indirect, and 112 induced jobs, totaling 438 jobs in the region. Impact values on value added (in millions) is \$20.0 in direct effects, \$5.2 in indirect effects, and \$7.5 in induced effects. Total valued added impact is \$32.7 million.

The impact of decreasing hay production output, withdraws \$14.6 million in direct effects, \$3.2 million in indirect effects, and \$2.5 million in induced effects. Total output impact decline is \$20.2 million. The decreases in employment are projected at 265 direct, 23 indirect, and 22 induced jobs, totaling 311 employees removed from the region. Value added is projected to decrease by \$7.2 million in direct effects, \$1.6 million in indirect effects, and \$1.5 million in induced effects. Total valued added impact declines by \$10.4 million.

The Net OP-East impact for industry output (in millions) is \$26.1 in direct effects, \$6.7 in indirect effects, and \$10.0 in induced effects. Total output impact is \$42.8 million. Employment is estimated to experience a loss of 8 direct, and a gain of 46 indirect and 89 induced employees. The net jobs created are 127 in the region. Impact values on value added (in millions) are \$12.8 in direct effects, \$3.6 in indirect effects, and \$6.0 in induced effects. Total valued added impact is \$22.4 million. Therefore, while there would be negative effects associated with hay acreage declines, the overall impact of switchgrass production would still be positive.

The top ten industries impacted in valued added, employment, and output can be seen in Table C.14. For total industry output, these industries include fertilizer mixing, gasoline stations, farm machinery, machinery repair and maintenance, and farm supply retailers. Fertilizer, machinery repair and farm supply retailers are used year-to-year for switchgrass to maintained and grow switchgrass. Gasoline stations will be impacted because of light truck and farm machinery use during the production process. Farm machinery manufacturing is a deprecation expense from switchgrass production. The region will demand new equipment from year-to-year as well.

The top five industries negatively impacted in output, employment, and value added is shown in Table C.15. For total industry output hay production, agricultural support activities, industrial truck and trailer manufacturing, spring and wire manufacturing used in hay production and tobacco farming have the largest decrease in its industry output.

4.4 Results for Cellulosic Ethanol Conversion in East Tennessee

Investment Impacts

Impact analysis for the Cellulosic Ethanol Conversion established in East Tennessee (ASD region 67) is separated into investment and operating impacts, with investment impacts presented first. The investment impacts are the one-time investment impacts that result from producers investing to establish a Cellulosic Ethanol Conversion industry. The costs were used to make the investment expenditure impacts projections for switchgrass production in the East Tennessee region are those found in Table A.11. These costs include feedstock purchase, industrial machinery, heating and cooling equipment, various metal products, air purification equipment, and other costs needed to establish a cellulosic ethanol conversion plant.

Industry output impacts from IC-East expenditures are $70.1 million in direct effects, $19.4 million in indirect effects, and $27.4 million in induced effects. Total industry output impact from investment, including the direct, indirect, and induced effects are projected at $116.9 million. Employment projections are 373 direct, 129 indirect, and 263 induced jobs; totaling 765 jobs create in the region. The IC-East expenditure impacts on value added (in millions) are $21.4 in direct effects, $10.4 in indirect effects, and $16.4 in induced effects. Total valued added impact from investment is therefore $48.3 million. (Table C.16.)

Based upon total impacts, including direct, indirect, and induced impacts, the top 10 industries impacted in terms of valued added, employment, and output for IC of West Tennessee can be seen in Table C.17. For total industry output, the largest impacts are power boiler and heat exchanger manufacturing, air purification equipment manufacturing, wholesale trade, metal tank manufacturing, and miscellaneous fabricated metal products. Each industry is required during the first year a cellulosic ethanol plant is established.

Operating Impacts

As shown in Table C.18, the OC-East for industry output is $62.3 million in direct effects, $7.3 million in indirect effects, and $10.8 million in induced effects. Total output impact is $80.3 million. Employment is estimated at 375 direct, 51 indirect, and 97 induced jobs, totaling 523 jobs created in the region. Impact effects on value added (in millions) are $27.5 in direct effects, $3.8 in indirect effects, and $6.5 in induced effects. Total valued added impact is $37.9 million.

The top ten industries impacted in valued added, employment, and output are listed in Table C.19. For total industry output, these industries include its feedstock cost truck transportation, maintenance of nonresidential buildings, and power boiler, heat exchanger manufacturing, and pumping equipment. Feedstock costs are valued in sector 507. Truck transportation is required to obtain all necessary inputs for the plant, such as switchgrass. Yearly maintenance and repair expenses are needed year-to-year to ensure the plant remains operational. Power boiler, heat exchanger and pumping equipment manufacturing are depreciation expenses of the conversion facility.

Year-to-Year Operating Impacts of Both Industries in East Tennessee

As shown in Table C.20, the operating expenditure impacts for both switchgrass farming and cellulosic ethanol conversion industry (excluding feedstock expenditures for the conversion process). The combined impacts have an output of $45.6 million in direct effects, $13.9 million in indirect effects, and $20.8 million in induced effects. Total output impact is $80.4 million. Employment is projected at 110 direct, 97 indirect, and 186 induced jobs to be created. Totaling 393 jobs to be employed in the region. Impacts on value added are $19.5 million in direct effects, $7.4 million in indirect effects, and $12.5 million in induced effects. Total valued added impact is $39.4 million.

CHAPTER 5: SUMMARY

5.1 Summary

Commercial scale ethanol conversion from switchgrass, a dedicated energy crop that is from a non-feed, non-food agricultural source, could boost the economy of the region in which it is located. Because such a conversion facility is not currently located in Tennessee, little is known about how such a facility might impact the region's economy. Therefore, the objective of this study was to evaluate how locating a cellulosic ethanol industry in two selected regions in Tennessee might impact those regions' economies. All components of the cellulosic ethanol industry from feedstock production and storage to transportation and conversion to ethanol have been examined to better estimate how introducing a renewable energy industry could impact the economies in two Tennessee locations, one in East Tennessee and one in West Tennessee. After collecting cost and production data from the various components of a cellulosic ethanol industry, the expenditures on inputs were used with IMPLAN to determine how these expenditures could impact over 500 industries defined in the IMPLAN model, in terms of valued added, employment, and industry output.

Two regions were selected, West Tennessee and East Tennessee, to evaluate how an industry could impact each region. Counties within an average transportation distance of 25-miles of the proposed plant location in the respected region were included as counties in the study region in the IMPLAN model. The plants in both locations were assumed to produce 61.8 million gallons of cellulosic ethanol annually.

In West Tennessee, the impacts of switchgrass farming investment are estimated at an additional $100.4 million in total industry output, 914 added jobs, and $46.9 million in total valued in the year of investment. The year-to-year operating expenses are estimated at a net impact of $26.5 million in total industry output, 50 additional jobs, and $11.9 million in total value added. The investment impact of a cellulosic ethanol conversion industry is estimated $121.3 million in total industry output, 653 added jobs, and $47.7 million in total valued added in the year of investment. The year-to-year operating impacts are estimated at $73.3 million in total industry output, 541 added jobs, and $28.8 million in total value added. Combined West Tennessee's year-to-year impact of switchgrass farming and cellulosic ethanol conversion is estimated at $57.1 million in total industry output, an additional 297 jobs, and $26.0 million in total valued added. In this region, year-to-year impacts switchgrass farming and cellulosic ethanol conversion are projected to increase the region's output by 0.29 percent, increase employment by 0.19 percent, and increase total value added by 0.29 percent.

In East Tennessee, the impacts of switchgrass farming investment are estimated at $118.3 million in additional total industry output, 949 added jobs, and $66.4 million in additional total valued in the year of investment. The year-to-year operating impacts are estimated at $42.7 million in total industry output, 127 jobs created, and $22.4 million in total value added. The investment impacts of a cellulosic ethanol conversion are estimated at $116.9 million in total industry output, 765 jobs created, and $48.3 million in total valued added in the first year. The year-to-year operating impacts are projected to be $80.3 million in total industry output, 523 jobs, and $37.9 million in total value added. Combined East Tennessee's year-to-year impact of switchgrass farming and cellulosic ethanol conversion are estimated at $80.4 million in total industry output, 393 jobs created, and $39.4 million in total valued added. In this region, year-to-year impacts switchgrass farming and cellulosic ethanol conversion are projected to increase the region's output by 0.13 percent, increase employment by 0.08 percent, and increase total value added by 0.12 percent.

5.2 Limitations of IMPLAN

Using the IMPLAN software requires the user and data to acknowledge limitations that exist within its programming. It is important to note that IMPLAN is a linear model. Industry production functions and returns to scale for each firm remain constant. Thus, increasing returns to scale that might be expected with an increase in plant size are not captured. Also, IMPLAN represents a snapshot in time. Thus, any changes in economic conditions over time in the selected region are not accounted for. Furthermore, IMPLAN assumes any commodity being purchase or sold within the region is unlimited. For instance, the region is assumed to be capable of supplying switchgrass seeds for switchgrass production, even if seed is of limited availability in the region. Also, the model cannot calculate changes in the region's environment. For example, one might expect environmental benefits from switchgrass production relative to row crop production, since switchgrass uses fewer inputs. However, these environmental benefits are not captured directly by the model, only changes in input expenditures. In addition, with smaller study regions, there can be significant leakages. For example, a worker in the ethanol facility might commute to work in that facility from outside the study region. The model does not capture this. Finally, the results are specific to the region modeled. This study cannot be multiplied to estimate an impact outside of the defined study region, for example to the state level.

The results from this study suggest that adding a commercially scaled cellulosic ethanol industry to either the regions of East or West Tennessee could add significantly to either region's economy. While the economic impacts are larger in the East Tennessee region, as a share of overall economic activity, the percentage impact is larger in the West Tennessee region. Further research determining an ethanol facilities site, should consider not only potential economic impacts, but also infrastructural networks, environmental impacts, attitudes toward ethanol facility citing in communities, and other site location issues. These issues are beyond the scope of this study.

REFERENCES

Alternative Fuels Data Center, Energy Efficiency and Renewable Energy, U.S. Department of Energy. Alternative Fueling Station Total Counts by State and Fuel Type. Internet Site: http://www.afdc.energy.gov/afdc/fuels/stations_counts.html (Accessed November 18, 2009).

Brown, R., N. Rosenberg, C. Hays, W. Easterling, and L. Mearns, Potential production and environmental effects of switchgrass and traditional crops under current and greenhouse-altered climate in the Central United States: a simulation study, *Agriculture, Ecosystems & Environment* 78, 1 (March 2000), pp. 31-47.

CME Group – Ethanol Futures. Internet Site: http://www.cmegroup.com/trading/energy/ethanol/cbot-ethanol.html. (Accessed October 9, 2009)

De la Torre Ugarte, D., B. English, and K. Jensen. "Sixty Billion Gallons by 2030: Economic and Agricultural Impacts of Ethanol and Biodiesel Expansion." *American Journal of Agricultural Economics* 89(Number 5, 2007):1290-1295.

De la Torre Ugarte, D., B. English, K. Jensen, C. Hellwinckel, J. Menard, and B. Wilson. "Economic and Agricultural Impacts of Ethanol and Biodiesel Expansion." Department of Agricultural Economics, The University of Tennessee, December 2006

Economic Modeling Specialist Inc, (EMSI). "Economic Impact Analysis: Common Pitfalls." Resource Library, 2008. Internet Site: http://www.economicmodeling.com/resources/wp-content/uploads/ 2008/02/bp_economic_impact_pitfalls.pdf. (Assessed on December. 2, 2009)

Energy Information Administration – Office of Energy Statistics from the U.S. Government, "Average Retail Price of Electricity to Ultimate Customers by End-Use Sector, by State."

Internet Site: http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_a.html (Accessed November 4, 2009)

Epplin, F. "Cost to produce and deliver switchgrass biomass to an ethanol-conversion facility in the southern plain of the United States." *Biomass and Bioenergy* 11 (Number 6, 1996) 459-467.

Garland, K. "Growing and Harvesting Switchgrass for Ethanol Production in Tennessee." *UT* Biofuels Initiative, University of Tennessee Agricultural Extension. SP701-A. 2008.

Gerloff D. "Switchgrass Working Budgets." The University of Tennessee. Agriculture Extension. AE 07-43. 2008.

Graefe, A. "Economic Impact Analysis: A Look at Useful Methods." *Parks and Recreation*. March 1, 2001. Internet Site: http://www.thefreelibrary.com/Economic+Impact+Analysis:+A+Look+at+ Useful+Methods-a072868383. (Assessed on December 2, 2009).

Hodur, N., and L. Leistriz. "Economic Impacts of Biofuel Development." Agricultural Marketing Resource Center (AgMRC). Renewable Energy Newsletter: February 2009. Internet Site: http://www.agmrc.org/renewable_energy/biofuelsbiorefining_general/economic_impacts_of_bio fuel_development.cfm. (Assessed December 2, 2009)

Kay, D. "Economic Multipliers and Local Economics Impact Analysis." Cornell Local Government Program: December 2002. Internet Site: http://www.cdtoolbox.net/economic_development/000149.html (Assessed on December 2, 2009).

Lazarus, W., and D. Tiffany. "Economic Impacts of Establishing Short Rotation Woody Crops to Support Energy Production in Minnesota." Staff Paper (P09-2): Department of Applied Economics, University of Minnesota. January 2009.

Leistritz, F., N. Hodur, D. Senechal, M. Stowers, D. McCalla, and C. Saffron. "Biorefineries Using Agricultural Residue Feedstock in the Great Plains." *Agribusiness and Applied Economics* 07001 (January 2007).

Lindall, S., D. Olson, "The IMPLAN Input-Output System." MIG, Inc., Stillwater, MN.

Low, S. and A. Isserman. "Ethanol: Implications for Rural Communities" Paper presented at the conference of American Agricultural Economics Association Annual Meeting, Orlando, FL, July 27-29 2008.

Lynch, T., "Analyzing the Economic Impact of Transportation projects using RIMS II, IMPLAN, and REMI." Washington DC: Office of Research and Special Programs: U.S. Department of Transportation. October 2000.

McDonald, S., S. Robinson, and Karen Thierfelder. "Impact of switching production to bioenergy crops: The switchgrass example." *Energy Economics* 28 (2006) 243-265.

Morrow, W., W. Griffin, and H. Matthews. "Modeling Switchgrass Derived Cellulosic Ethanol Distribution in the United States." *Environmental Science and Technology* 40 (Number 9, 2006): 2877-2886.

Minnesota IMPLAN Group, Inc. (MIG). *User Guide, Analysis Guide, and Data Guide*. IMPLAN Professional. Version 2.0. Social Accounting and Impact Analysis Software. 3rd edition. Stillwater, Minnesota. February 2004

O'Brien, D., M. Woolverton, L. Maddy, V. Pozo, J. Roe, J. Tajchman, and E. Yeager. "A Case Study of the Impact of Bioenergy Development Upon Crop Production, Livestock Feeding, and Water Resource Usage in Kansas." Paper presented at the conference of American Agricultural Economics Association Annual Meeting, Orlando, FL, July 27-29 2008.

Phillips, S., A. Aden, J. Jechura, D. Dayton, and T. Eggeman, *Thermochemical Ethanol via Indirect Gasification and Mixed Alcohol Synthesis of Lignocellulosic Biomass.* Technical Report: NREL/TP-510-41168, April 2007.

Swenson, Dave. "Input-Outrageous: The Economic Impacts of Modern Biofuels Production." *Iowa State University, Department of Economics*, June 2006.

Smith, J., W. Richards, and E. Shea. *25 x '25 Action Plan – Charting America's Energy Future*. 25x'25 National Steering Committee. February 2007.

Tennessee Department of Transportation (TDOT). *Biofuel Green Island Corridor Grant Project*. Internet Site: http://www.tdot.state.tn.us/biofuel/application.htm. (Assessed on November 19, 2009).

Tennessee Department of Transportation (TDOT), "Rules of Tennessee Department of Transportation Central Services Division" *T.C.A. 55-7-205*. Revised on February 1, 2003.

Turhollow, A., M. Downing, and J. Butler. "Forage Harvest and Transportation Costs." *Oak Ridge National Lab, prepared for the U.S. Department of Energy* ORNL/TM13724, December 1998.

U.S. Congress. ENERGY INDEPENDENCE AND SECURITY ACT OF 2007. PUBLIC LAW 110–140—DEC. 19, 2007, 110th Congress. Internet site: http://frwebgate.access.gpo.gov/cgibin/getdoc.cgi?dbname=110_cong_public_laws&docid=f:publ140.110.pdf. (Accessed November 17, 2009).

U.S. House of Representatives. American Clean Energy and Security Act of 2009 HR2454, Passed House of Representatives, June 26, 2009, 111th Congress.

U.S. Department of Energy. DOE Selects Six Cellulosic Ethanol Plants for Up to $385 Million in Federal Funding. February 28, 2007 (a). Internet Site: http://www.energy.gov/news/4827.htm. (Accessed November 17, 2009).

U.S. Department of Energy. *Construction and Operation of a Cellulosic Ethanol Plant - Range Fuels, Inc. Treutlen County, Georgia*. Final Environmental Assessment. DOE/EA 1597. October 2007 (b).

University of Tennessee, Institute of Agriculture – Office of Bioenergy Programs (a). Internet site: http://www.utbioenergy.org/TNBiofuelsInitiative/Biorefinery+Groundbreaking.htm (Accessed November 17, 2009)

University of Tennessee, Institute of Agriculture (b) – Research and Education Center at Milan "Researchers Look at Storage and Transportation Efficiency in Ongoing Switchgrass Study." Internet Site: http://milan.tennessee.edu/research/switchgrass%20study.asp (Accessed November 16, 2009)

USDA, National Agricultural Statistics Service – 2007 Census of Agriculture, Tennessee. Internet site: http://www.nass.usda.gov/Statistics_by_State/Tennessee/index.asp (Accessed September 24, 2009)

Wang, Chenguang. "Economic Analysis of Delivering Switchgrass to a Bio-refinery from both Farmers' and Processor's Perspectives," Masters Thesis, University of Tennessee, May 2009.

Wang, M. "Well-to-wheels Energy and Greenhouse Gas Emission Results and Issues of Fuel Ethanol," *The Lifecycle Carbon Footprint of Biofuels Proceedings of a Conference* in Miami Beach, FL (January 29, 2008).

APPENDICES

APPENDIX A: ACREAGE AND COSTS TABLES

Table A.1. Total Cropland for Major Crops, by Crop Type, in Counties Located in the West Tennessee and East Tennessee Study Regions

West TN *(ASD-63)*	*Corn*	*All Hay*	*Soybeans*	*Cotton*	*Wheat*	*Pasture*	*Total*
Benton	4,207	8,623	3,881	0	200	11,337	28,248
Carroll	39,764	13,493	16,551	21,682	3,712	12,413	107,615
Gibson	64,177	13,538	76,471	51,634	31,799	16,245	253,864
Henderson	12,499	21,873	18,215	1,765	1,298	13,425	69,075
Henry	7,738	17,379	11,161	11,370	2,990	15,768	66,406
Madison	5,104	9,253	5,365	2,457	1,190	14,832	38,201
Weakley	73,669	16,378	73,544	575	20,473	14,501	199,140
Total	207,158	100,537	205,188	89,483	61,662	98,521	762,549

East TN *(ASD-67)*	*Corn*	*All Hay*	*Soybeans*	*Cotton*	*Wheat*	*Pasture*	*Total*
Anderson	25	9,222	0	0	0	6,703	15,950
Blount	1,761	27,069	2,802	0	919	14,705	47,256
Knox	469	21,619	0	0	64	9,226	31,378
Loudon	1,395	20,684	3,210	0	1,391	9,414	36,094
McMinn	871	30,420	2,358	0	469	13,216	47,334
Meigs	0	10,884	0	0	0	6,626	17,510
Monroe	584	21,459	2,704	0	1,056	12,898	38,701
Roane	41	11,421	0	0	0	4,926	16,388
Total	5,121	152,778	11,074	0	3,899	77,714	250,611

a) 2007 Census of Agriculture. USDA. National Agricultural Statistics Service, Volume 1, Chapter 2, County level for Tennessee

Table A.2. Establishment Cost for Switchgrass in Year 1

						2008 Dollars		2	tons/acre**
Variable Expenses		Price	$/Unit	Quantity	Unit	$/ton	$/acre	IMPLAN Sector (2001)	
Seed (Pure Live Seed)		20.00	$/pound	6.00	pounds	$60.00	$120.00	*404*	*Farm Supply Retail*
Fertilizer									
P205		0.39	$/pound	40.00	pounds	$7.80	$15.60	*158*	*Fertilizer Mixing Manufacturing*
K20		0.35	$/pound	80.00	pounds	$14.00	$28.00	*158*	*Fertilizer Mixing Manufacturing*
Weed Control									
Fall burn-down	*Roundup original max*	5.92	$/pt	1.60	pt	$4.74	$9.47	*159*	*Pesticides and other Ag chemicals*
Spring burn-down	*Roundup original max*	5.92	$/pt	1.60	pt	$4.74	$9.47	*159*	*Pesticides and other Ag chemicals*
Post-Emerge	*Cimarron*	19.00	$/oz	0.10	oz	$0.95	$1.90	*159*	*Pesticides and other Ag chemicals*
Post-Emerge	*Grass Herbicide*	7.00	$/acre	1.00	acre	$3.50	$7.00	*159*	*Pesticides and other Ag chemicals*
Post-Emerge	*Grass Herbicide*	7.00	$/acre	1.00	acre	$3.50	$7.00	*159*	*Pesticides and other Ag chemicals*
Post-Emerge	*Grass Herbicide*	7.00	$/acre	1.00	acre	$3.50	$7.00	*159*	*Pesticides and other Ag chemicals*
Machinery Repair		6.80	$/acre	1.00	acre	$3.40	$6.80	*485*	*Commercial Machinery Repair & Main.*
Machinery Fuel		3.05	$/gallon	4.17	gal/acre	$6.36	$12.72	*407*	*Gasoline Stations*
Operating Capital (6 months)		224.96		8.0%	0.007	$4.50	$9.00	*425*	*Non-depository Credit*
Machinery Expenses									
Machinery Depreciation		7.92		1.00	acre	$3.96	$7.92	*257*	*Farm machinery equipment manufacturing*
Interest Expense		5.17		1.00	acre	$2.59	$5.17	*425*	*Non-depository Credit*
Labor Expenses									
Labor		8.50	$/hour	0.20	hr	$0.85	$1.70	*5001*	*Employee Compensation*
Total ($/unit)						**$124.38**	**$248.75**		
Annual Cost (Prorated over 10 yrs at 8%)						**$18.54**	**$37.07**		

Footnotes:

i. Switchgrass established using spring seeding with a no-till drill.
ii. There is a wide range of seed prices. The recommended seeding rate is 6 lbs of pure live seed per acre
iii. Assumes a soil test low in P and K. If soil test values are medium or high in P and K, No P205 or K20 is recommended. Costs of renting a spreader are included in the fertilizer price.
iv. Lime is not recommended if soil pH is 5.0 or above.
v. Appropriate weed control measures vary greatly according to previous cropping history and specific weed varieties. Carefully evaluate fields and adjust the budget accordingly.

---

a) Gerloff D. "Switchgrass Working Budgets." The University of Tennessee. Agriculture Extension. AE 07-43. 2008.
*b) **Yield – Garland, K. "Growing Harvest Switchgrass for Ethanol Production in Tennessee." UT Biofuels Initiative, University of Tennessee, Agricultural Extension. Sp701-A, 2008.*

Table A.3. Establishment Cost for Switchgrass in Year 2 (Reseeding)

						2008 Dollars		3.5	tons/acre**
Variable Expenses	**Description**	**Price**	**$/Unit**	**Quantity**	**Unit**	**$/ton**	**$/acre**	**IMPLAN Sector (2001)**	
Seed (Pure Live Seed)		20.00	$/pound	6.00	pounds	$34.29	$120.00	*404*	*Farm Supply Retail*
Fertilizer									
P205		0.39	$/pound	40.00	pounds	$4.46	$15.60	*158*	*Fertilizer Mixing Manufacturing*
K20		0.35	$/pound	80.00	pounds	$8.00	$28.00	*158*	*Fertilizer Mixing Manufacturing*
Weed Control									
Fall burn-down	*Roundup original max*	5.92	$/pt	1.60	pt	$2.71	$9.47	*159*	*Pesticides and other Ag chemicals*
Spring burn-down	*Roundup original max*	5.92	$/pt	1.60	pt	$2.71	$9.47	*159*	*Pesticides and other Ag chemicals*
Post-Emerge	*Cimarron*	19.00	$/oz	0.10	oz	$0.54	$1.90	*159*	*Pesticides and other Ag chemicals*
Post-Emerge	*Grass Herbicide*	7.00	$/acre	1.00	acre	$2.00	$7.00	*159*	*Pesticides and other Ag chemicals*
Post-Emerge	*Grass Herbicide*	7.00	$/acre	1.00	acre	$2.00	$7.00	*159*	*Pesticides and other Ag chemicals*
Post-Emerge	*Grass Herbicide*	7.00	$/acre	1.00	acre	$2.00	$7.00	*159*	*Pesticides and other Ag chemicals*
Machinery Repair		6.80	$/acre	1.00	acre	$1.94	$6.80	*485*	*Commercial Machinery Repair & Maintenance*
Machinery Fuel		3.05	$/gallon	*4.17*	gal/acre	$3.63	$12.72	*407*	*Gasoline Stations*
Operating Capital (6 months)		224.96		8.00%	0.67%	$2.57	$9.00	*425*	*Non-depository Credit*
Machinery Expenses									
Machinery Depreciation		7.92		1.00	acre	$2.26	$7.92	*257*	*Farm machinery equipment manufacturing*
Interest Expense		5.17		1.00	acre	$1.48	$5.17	*425*	*Non-depository Credit*
Labor Expenses									
Labor		8.50	$/hour	0.20	hr	$0.49	$1.70	*5001*	*Employee Compensation*
Total ($/unit)						**$71.07**	**$248.75**		
Annual Cost (Prorated over 10 yrs at 8%)						**$2.28**	**$7.96**		

Footnotes:

i. Switchgrass established using spring seeding with a no-till drill. The probability of reseeding spring seeded switchgrass is estimated to be 20%

ii. There is a wide range of seed prices. The recommended seeding rate is 6 lbs of pure live seed per acre

iii. Assumes a soil test low in P and K. If soil test values are medium or high in P and K, No P205 or K20 is recommended. Costs of renting a spreader are included in the fertilizer price. Reseeding assumes no harvest of switchgrass and no loss of soil nutrients. Therefore no P305 or K30 applications are necessary.

iv. Lime is not recommended if soil pH is 5.0 or above.

---

a) Gerloff D. "Switchgrass Working Budgets." The University of Tennessee. Agriculture Extension. AE 07-43. 2008.

*b) **Yield – Garland, K. "Growing Harvest Switchgrass for Ethanol Production in Tennessee." UT Biofuels Initiative, University of Tennessee, Agricultural Extension. Sp701-A, 2008.*

Table A.4. Annual Production Costs of Switchgrass in Years 3-10

Variable Expenses		Price	$/Unit	Quantity	Unit	$/ton	$/acre	IMPLAN Sector (2001)	
						2008 Dollars		7	tons/acre**
Fertilizer									
Nitrogen		0.65	$/pound	60.00		$5.57	$39.00	*158*	*Fertilizer Mixing Manufacturing*
P205		0.39	$/pound	40.00	pounds	$2.23	$15.60	*157*	*Phosphate Fertilizer Manufacturing*
K20		0.35	$/pound	80.00	pounds	$4.00	$28.00	*158*	*Fertilizer Mixing Manufacturing*
Triple Tie	*Twine, 1500 lb. bale*	1.19		9.33	bales	$1.59	$11.11		
Weed Control									
Post-Emerge	*Cimarron*	19.00	$/oz	0.10	oz	$0.27	$1.90	*159*	*Pesticides and other Ag chemicals*
Post-Emerge	*Grass Herbicide*	7.00	$/acre	1.00	acre	$1.00	$7.00	*159*	*Pesticides and other Ag chemicals*
Machinery Repair		48.41	$/acre	1.00	acre	$6.92	$48.41	*485*	*Commercial Machinery Repair & Maintenance*
Machinery Fuel		3.05	$/gallon			$11.47	$80.32	*407*	*Gasoline Stations*
Operating Capital (6 months)		231.34		8.00%	0.67%	$1.32	$9.25	*425*	*Non-depository Credit*
Machinery Expenses									
Machinery Depreciation		53.89		1.00	acre	$7.70	$53.89	*257*	*Farm machinery equipment manufacturing*
Interest Expense		28.30		1.00	acre	$4.04	$28.30	*425*	*Non-depository Credit*
Labor Expenses									
Labor		8.50	$/hour	3.93	hr	$4.77	$33.41	*5001*	*Employee Compensation*
Prorated Establishment Cost						**$5.30**	***$37.07***		
Prorated Reseeding Cost						**$1.14**	***$7.96***		
Total ($/unit)						**$57.32**	**$401.22**		

Footnotes:

i. Assumes a soil test low in P and K. If soil test values are medium or high in P and K, No P205 or K20 is recommended. Costs of renting a spreader are included in the fertilizer price.

ii. Lime is not recommended if soil pH is 5.0 or above.

iii. See Table 1 and 2.

---

a) Gerloff D. "Switchgrass Working Budgets." The University of Tennessee. Agriculture Extension. AE 07-43. 2008.

*b) **Yield – Garland, K. "Growing Harvest Switchgrass for Ethanol Production in Tennessee." UT Biofuels Initiative, University of Tennessee, Agricultural Extension. Sp701-A, 2008.*

Table A.5. Other Crop Output losses from Acreage converted to Switchgrass Production*

West Tennessee *(ASD 63)*	Acres in Region	Acres Converted	Percent Removed	Industry Output	Decrease in Total Industry Output
Hay Production	100,537	100,537	100.0%	$10,681,000	$10,681,000
Pasture grazed by Cattle	98,521	22,909	23.3%	$36,817,000	$8,561,057
Total	**199,058**	**123,446**	**-**	**$47,498,000**	**$19,242,057**

East Tennessee *(ASD 67)*	Acres in Region	Acres Converted	Percent Removed	Industry Output	Decrease in Total Industry Output
Hay Production	152,778	123,446	80.8%	$16,597,000	$13,410,525
Pasture grazed by Cattle	64,385	0	0.0%	$78,037,000	$0
Total	**217,163**	**123,446**	**-**	**$94,634,000**	**$13,410,525**

*Values are expressed in 2006 dollars

a) *USDA, National Agricultural Statistics Service – Tennessee 2008 Crop Data. Internet site: http://www.nass.usda.gov/QuickStats/Create_Federal_Indv.jsp*

Table A.6. Switchgrass Storage Costs for 200 days (Years 3-10)

	2008 Dollars			
Round Bale on Pallets (no tarp)	***Cost per Ton***	***Cost per Acre***	***IMPLAN Codes and Descriptions***	
36 Pallets	$7.85	$54.96	262	*Sawmill and woodworking machinery*
Labor to place pallets	$0.30	$2.07	5001	*Employee Compensation*
Pickup truck cost	$0.47	$3.29	344	*Automobile and Light Truck Manufacturing*
Total	**$8.62**	**$60.32**		
Round Bale on Gravel Pad (no tarp)				
Gravel pad for stack	$24.76	$173.29	25	*Sand, gravel, clay, and refractory mining*
Total	**$24.76**	**$173.29**		
Round Bale on Ground (with tarp)				
25' by 54' tarp	$5.74	$40.17	172	*Plastics packaging materials, film, and sheet*
Labor to place cover	$0.30	$2.07	5001	*Employee Compensation*
Pickup truck cost	$0.31	$2.17	344	*Automobile and Light Truck Manufacturing*
Total	**$6.34**	**$44.41**		
Round Bale on Pallets (with tarp)				
25' by 54' tarp	$5.74	$40.17	172	*Plastics packaging materials, film, and sheet*
36 Pallets	$7.85	$54.96	262	*Sawmill and woodworking machinery*
Labor to place cover	$0.30	$2.07	5000	*Employee Compensation*
Labor to place pallets	$0.30	$2.07	5001	*Employee Compensation*
Pickup truck cost	$0.47	$3.29	344	*Automobile and Light Truck Manufacturing*
Total	**$14.65**	**$102.56**		
Round Bale on Gravel Pad (with tarp)				
One 25' by 54' tarp	$5.74	$40.17	172	*Plastics packaging materials, film, and sheet*
Gravel pad for stack	$24.76	$173.29	25	*Sand, gravel, clay, and refractory mining*
Labor to place cover	$0.30	$2.07	5001	*Employee Compensation*
Pickup truck cost	$0.47	$3.29	344	*Automobile and Light Truck Manufacturing*
Total	**$31.26**	**$218.81**		
Round Bale on Gravel Pad (with tarp)				
One 25' by 54' tarp	$5.74	$40.17	172	*Plastics packaging materials, film, and sheet*
Gravel pad for stack	$24.76	$173.29	25	*Sand, gravel, clay, and refractory mining*
Labor to place cover	$0.30	$2.07	5001	*Labor*
Pickup truck cost	$0.47	$3.29	344	*Automobile and Light Truck Manufacturing*
Total	**$31.26**	**$218.81**		

a) Yield (tons/acre) is assumed to be 7.0 - Garland, K. "Growing Harvest Switchgrass for Ethanol Production in Tennessee." UT Biofuels Initiative, University of Tennessee, Agricultural Extension. Sp701-A, 2008.

b) Wang, Chenguang. "Economic Analysis of Delivering Switchgrass to a Bio-refinery from both Farmers' and Processor's Perspectives," Masters Thesis, University of Tennessee, May 2009

Table A.7. Switchgrass Transportation Costs per Truckload*

			$ / Unit	Unit	$ / Load	IMPLAN Codes and Descriptions	
Load Time / hours (b)		0.5 hours	$12.00	$/hour	$6.00	*5001*	*Employee Compensation*
Unload Time/hours (b)		0.33 hours	$12.00	$/hour	$3.96	*5001*	*Employee Compensation*
Equipment cost (f)		13 tons	$0.48	$/ton	$6.24	*257*	*Farm machinery and equipment manufacturing*
	Loading and Unloading Cost				**$16.20**		
Hauling	Fuel Cost/Gal. (c)		$3.05	$/gal			
	Truck gas mileage (d)		6.0	miles/gal			
	Avg. round trip (a)		50.0	miles			
	Fuel Cost				**$25.42**	*407*	*Fuel Stations*
Round Trip	Speed		50	mph			
	Travel Time		2.00	hours			
	Driver Labor Wages (f)		$17.33	$/hour	**34.66**	*5001*	*Employee Compensation*
	Overhead		30%		**18.02**	*425*	*Non-depository Credit*
	Total Costs				**94.30**	*394*	*Truck Transportation*
Truck Capacity							
	Number of Bales (a)				26.00		
	Load in tons				13.00		
	Load in lbs				26000		
Per Unit Costs							
	Tons per Truck				13.00		
	Total Costs per Ton				7.25		
	Total Costs per Ton/Mile				0.145		
	Total Costs per Mile				1.886		

*All Values are expressed in 2009 dollars

a) *Popp, M. and R. Hogan, Jr., Assessment of two Alternative Switchgrass Harvest and Transportation. Farm Foundation Conference Paper, St. Louis MI, April 12-13 2008*
b) *Duffy, M. "Estimated Costs for Production, Storage and Transportation of Switchgrass" Iowa State University-University Extension. PM 2042 October 2007.*
c) *AAA Average Fuel Cost in TN (http://www.fuelgaugereport.com/TNavg.asp). October 2008.*
d) *Turhollow, A., M. Downing, and J. Butler. "Forage Harvest and Transportation Costs" Oak Ridge National Lab, prepared for the U.S. Department of Energy ORNL/TM13724, December 1998.*
e) *Tennessee Department of Transportation, "Rules of Tennessee Department of Transportation Central Services Division" T.C.A. 55-7-205. Revised on February 1, 2003.*
f) *Wang, Chenguang. "Economic Analysis of Delivering Switchgrass to a Bio-refinery from both Farmers' and Processor's Perspectives," Masters Thesis, University of Tennessee, May 2009.*

Table A.8. Cellulosic Ethanol Conversion Investment Costs

Investment Description		Cost ($2005)	IMPLAN Sector
Hopper Feeder		$0	292
Screener Feeder Conveyor		$0	292
Radial Stacker Conveyor		$0	292
Dryer Feed Screw Conveyor		$0	292
Gasifier Feed Screw Conveyor		$0	292
Flue Gass Cooler/Steam Generator #1		$750,965	277
Flue Gas Cooler /Boiler Water Preheater #1		$7,708	277
Flue Gas Cooler / Steam Generator #3		$157,959	277
Flue Gas Blower		$0	276
Hydraulic Truck Dump with Scale		$0	301
Hammermill		$0	257
Front End Loaders		$0	257
Rotary Biomass Dryer		$22,297,257	276
Magnetic Head Pulley		$0	269
Screener		$0	269
Dryer Air Cyclone		$0	276
Dryer Air Baghouse Filter		$0	275
Dump Hopper		$0	240
Hammermill Surge Bin		$0	240
Dryer Feed Bin		$0	240
Dried Biomass Hopper		$0	240
	Subtotal	**$23,213,889**	
Sand/ash Conditioner/Conveyor		$0	292
Combustion Air Blower		$0	276
Sand/ash Cooler		$0	255
Indirectly-heated Biomass Gasifier		$12,916,238	238
Char Combustor		$0	238
Primary Gasifier Cyclone		$0	269
Secondary Gasifier Cyclone		$0	269
Primary Combustor Cyclone		$0	269
Secondary Combustor Cyclone		$0	269
Electrostatic Precipitator		$0	269
Sand/ash Bin		$0	240
	Subtotal	**$12,916,238**	
Quench Water Recirculation Cooler		$0	278
Post-tar Reformer Cooler / Steam Generator #2		$280,793	278
Reformer Flue Gas Cooler/Steam superheater		$573,129	277
Reformed Syngas cooler / Synthesis Reactor Preheat #1		$254,966	277
Syngas Compressor Intercoolers		$0	289
Water-cooled Aftercooler		$79,254	278
LO-CAT Preheater		$4,498	277
LO-CAT Absorbent Solution Cooler		$0	278
Recycle Syngas Cooler / Steam Generator #4		$180,778	238
Recycle Syngas cooler #2 / Air preheat #1		$32,214	278
Syngas Compressor		$17,647,662	289
LO-CAT Feed Air Blower		$0	276
Regenerator Combustion Air Blower		$98,824	276
Syngas Quench Chamber		$0	269
Syngas Venturi Scrubber		$0	275

Table A.8. Cellulosic Ethanol Conversion Investment Costs (cont.)

Investment Description		Cost ($2005)	IMPLAN Sector
LO-CAT Venturi Precontactor		$0	269
LO-CAT Liquid-filled Absorber		$0	269
Sludge Pump		$9,795	288
Quench Water Recirculation Pump		$0	288
LO-CAT Absorbent Solution Circulating Pump		$0	288
Tar Reformer Catalyst Regenerator		$9,719,926	238
Tar Reformer		$8,670,224	238
LO-CAT Oxidizer Vessel		$2,378,057	238
Pre-compressor Knock-out		$638,432	269
Syngas Compressor Interstage Knock-outs		$0	269
Post-compressor Knock-out		$170,781	269
Tar Reformer Cyclone		$0	269
Catalyst Regenerator Cyclone		$0	269
L.P. Amine System		$12,147,805	275
Sludge Settling Tank		$759	239
Quench Water Recirculation Tank		$0	239
	Subtotal	**$52,887,897**	
Flue Gas Cool / syngas rxn preheat		$43,705	278
Air preheat #3 / post Reactor Syngas cooling #1		$24,862	278
Post synthesis cooler #2/Deaerator Water Preheater #1		$52,558	277
Post Synthesis cooler #3/Makeup Water heater		$31,445	277
Post Synthesis cooler #4 / syngas recycle heat #1		$37,295	277
Post Synthesis Cooler #5/Mol Sieve preheater #2		$8,745	277
Post Mixed Alcohol Cooler		$214,230	278
Mixed Alcohol first Condenser (air cooled)		$136,649	238
Mixed Alcohol Condenser		$281,814	238
Recycle Syngas Heat #2 / Flue gas Cool		$344,070	278
Mixed Alcohol Gas Compressor		$2,262,251	289
Purge Gas Expander		$13,710,103	289
Mixed Alcohol Reactor		$3,218,633	238
Mixed Alcohols Condensation Knock-out		$246,225	269
	Subtotal	**$20,612,585**	
Ethanol/Propanol Splitter		$478,460	238
Methanol/Ethanol Splitter		$531,228	238
Syngas Cooler #4 / Mol Sieve preheater #1		$64,211	278
Mol Sieve Superheater / reformed syngas cool #5		$10,842	278
D-504 condenser (air cooled)		$127,442	278
Ethanol/Propanol Splitter Reboiler		$126,830	238
D-505 condenser (air cooled)		$203,538	238
Methanol/Ethanol Splitter Reboiler		$162,330	238
Mol Sieve Flush Condenser (air cooled)		$68,499	238
MA Product Cooler / Mol Sieve preheater #3		$4,649	273
Ethanol Product Pump		$3,992	288
Ethanol Product Cooler / Mol Sieve preheater #4		$11,408	278
Ethanol Product Pump		$196,596	288
Ethanol/Propanol Splitter Bottoms Pump		$24,151	288
Ethanol/Propanol Splitter Reflux Pump		$4,172	288
Methanol/Ethanol Splitter Bottoms Pump		$38,475	288

Table A.8. Cellulosic Ethanol Conversion Investment Costs (cont.)

Investment Description		Cost ($2005)	IMPLAN Sector
Methanol/Ethanol Splitter Reflux Pump		$4,172	288
Mixed Alcohol Product Pump		$6,661	288
Ethanol Product Pump		$25,773	288
LP Syngas Separator		$106,130	238
Molecular Sieve (9 pieces)		$3,445,594	255
Ethanol/Propanol Splitter Reflux Drum		$12,034	240
Methanol/Ethanol Splitter Reflux Drum		$12,034	240
Mixed Alcohol Product Storage Tank		$452,976	239
Ethanol Product Storage Tank		$1,084,940	239
	Subtotal	**$7,207,137**	
Steam Turbine Condenser		$0	238
Blowdown Cooler / Deaerator Water Preheater		$0	238
Blowdown Water-cooled Cooler		$94,962	278
Hot Process Water Softener System		$3,044,885	273
Extraction Steam Turbine/Generator		$11,801,498	285
Startup Boiler		$579,837	277
Collection Pump		$21,122	288
Condensate Pump		$30,304	288
Deaerator Feed Pump		$50,691	288
Boiler Feed Water Pump		$558,718	288
Blowdown Flash Drum		$43,703	240
Condensate Collection Tank		$71,468	239
Condensate Surge Drum		$83,371	240
Deaerator		$381,292	239
Steam Drum		$27,467	239
	Subtotal	**$16,789,318**	
Plant Air Compressor		$283,936	289
Cooling Tower System		$564,218	278
Hydraulic Truck Dump with Scale		$237,526	301
Flue Gas Stack		$46,530	276
Cooling Water Pump		$807,601	288
Firewater Pump		$110,110	288
Diesel Pump		$36,504	288
Ammonia Pump		$29,921	288
Hydrazine Pump		$16,457	288
Instrument Air Dryer		$48,813	276
Plant Air Receiver		$20,472	275
Firewater Storage Tank		$496,991	239
Diesel Storage Tank		$43,086	239
Ammonia Storage Tank		$859,635	239
Olivine Lock Hopper		$0	240
MgO Lock Hopper		$0	240
Hydrazine Storage Tank		$37,102	239
	Subtotal	**$3,638,902**	
	Total	**$137,265,966**	

a) *Phillips, S., A. Aden, J. Jechura, D. Dayton, and T. Eggeman, Thermochemical Ethanol via Indirect Gasification and Mixed Alcohol Synthesis of Lignocellulosic Biomass. Technical Report: NREL/TP-510-41168, April 2007.*

Table A.9. Annual Cellulosic Ethanol Conversion Operating Cost

Operating Cost Description	2006$	IMPLAN Sector	IMPLAN Description
Feedstock (Switchgrass)	$43,170,329.54	9	Switchgrass Farming
Natural Gas	$0.00	31	Natural Gas Distribution
Catalysts	$215,625.29	151	Other Basic Organic Chemical Manufacturing
Olivine	$408,186.17	24	Stone mining and quarrying
Other Raw Materials	$318,699.71	150	Other Basic Inorganic Chemical Manufacturing
Waste Disposal	$315,192.93	460	Waste Management and Remediation Services
Waste Water	$24,302.56	32	Water, Sewage, and other Systems
Electricity	$4,248,000.00	30	Power Generation and Supply
Building Maintenance	$4,071,392.84	43	Maintenance and Repair of nonresidential buildings
Byproduct Credit (Electricity)	$4,250,126.00	30	Power Generation and Supply
Insurance	$868,199.98	427	Insurance Carriers (Insurance)
Avg. Income Taxes	$736,046.62	438	Accounting Bookkeeping Services (Taxes, etc.)
Employee Compensation	$2,319,720.90	5001	Employee Compensation
Total Annual Operating Costs	**$60,945,822.53**		

a) *Phillips, S., A. Aden, J. Jechura, D. Dayton, and T. Eggeman, Thermochemical Ethanol via Indirect Gasification and Mixed Alcohol Synthesis of Lignocellulosic Biomass. Technical Report: NREL/TP-510-41168, April 2007.*
b) *Energy Information Administration, Average Tennessee Industrial price for electricity (http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_a.html), July 2009.*

Table A.10. IMPLAN Expenditures for Switchgrass Production and Storage Cost

Production: Switchgrass Farming
Capacity: 123,445.69 acres or (771,535.58 tons*) needed to produce 61.8 MM gal/year of ethanol

Employee Compensation: $2,844,781
Proprietary Income: $3,502,431
Other Property Income: $14,659,137
Indirect Business Taxes: $824,694
Employees: 937
Total Industry Output: $42,713,139

** At yield rate of 6.25 tons/acre*

Type	IMPLAN Sector	IMPLAN Description	Expenditures
Investment	404	Seed Purchase / Farm Supplier	$28,920,807
Investment	158	Fertilizer Mixing Manufacturing	$10,120,868
Investment	159	Pesticides and other Ag chemicals	$9,713,248
Investment	485	Commercial Machinery Repair & Maintenance	$1,516,673
Investment	407	Gasoline Stations	$2,963,731
Investment	425	Non-depository Credit	$3,378,559
Investment	257	Farm machinery equipment manufacturing	$1,857,751
Investment	172	Plastics packaging materials, film, and sheet	$4,222,411
Investment	262	Sawmill and woodworking machinery	$5,755,571
Investment	344	Automobile and Light Truck Manufacturing	$213,353
Operating	156	Nitrogenous Fertilizer Manufacturing	$4,526,535
Operating	158	Fertilizer Mixing Manufacturing	$6,072,521
Operating	159	Pesticides and other Ag chemicals	$2,004,303
Operating	485	Commercial Machinery Repair & Maintenance	$5,550,354
Operating	407	Gasoline Stations	$9,653,562
Operating	425	Non-depository Credit	$1,435,447
Operating	257	Farm machinery equipment manufacturing	$6,506,117
Depreciation	172	Plastics packaging materials, film, and sheet	$844,482
Depreciation	262	Sawmill and woodworking machinery	$1,151,114
Depreciation	344	Automobile and Light Truck Manufacturing	$42,671
Depreciation	404	Seed Purchase / Farm Supplier	$2,892,081
Depreciation	158	Fertilizer Mixing Manufacturing	$649,964
Depreciation	159	Pesticides and other Ag chemicals	$971,325
Depreciation	485	Commercial Machinery Repair & Maintenance	$151,667
Depreciation	407	Gasoline Stations	$296,373
Depreciation	425	Non-depository Credit	$337,856
Depreciation	257	Farm machinery equipment manufacturing	$185,775

Expenditure Type	Total $	$ / Acre
Investment	$68,662,971	$556.22
Operating	$35,748,839	$289.59
Depreciation	$7,523,308	$60.94

a) *Gerloff D. "Switchgrass Working Budgets" The University of Tennessee. Agriculture Extension. AE 07-43. 2008.*
b) *Garland, K. "Growing Harvest Switchgrass for Ethanol Production in Tennessee." UT Biofuels Initiative, University of Tennessee, Agricultural Extension. Sp701-A, 2008.*
c) *Wang, Chenguang. "Economic Analysis of Delivering Switchgrass to a Bio-refinery from both Farmers' and Processor's Perspectives," Masters Thesis, University of Tennessee, May 2009*

Table A.11. IMPLAN Expenditures for Ethanol Conversion from Switchgrass

Conversion: Cellulosic Ethanol Conversion from Switchgrass
Facility Size: 61.8 MM Gal/year

Employee Compensation: $6,517,882
Proprietary Income: $636,738
Other Property Income: $3,595,833
Indirect Business Taxes: $428,930
Employees: 97
Total Industry Output: $104,870,756

Type	IMPLAN Sector	IMPLAN Description	Expenditures
Investment	238	Power Boiler and Heat Exchanger Manufacturing	$42,308,514
Investment	239	Metal Tank, Heavy Gauge Manufacturing	$3,742,747
Investment	240	Metal Can, Box and Other Container Manufacturing	$160,213
Investment	255	Miscellaneous Fabricated Metal Product Manufacturing	$3,531,749
Investment	269	Other Industrial Machinery Manufacturing	$1,096,542
Investment	273	Other Commercial and Service Industry Machinery Manufacturing	$3,132,695
Investment	275	Air Purification Equipment Manufacturing	$12,606,752
Investment	276	Industrial and Commercial Fan Blower Manufacturing	$23,467,116
Investment	277	Heating Equipment except Warm Air Furnaces	$2,548,229
Investment	278	AC Refrigeration and Forced Air Heating	$1,944,688
Investment	285	Turbine and Turbine Generator Set Units Manufacturing	$11,917,479
Investment	288	Pump and Pumping Equipment Manufacturing	$2,051,745
Investment	289	Air and Gas Compressor Manufacturing	$35,324,123
Investment	301	Scales, Balances, and Miscellaneous General Purpose Machinery	$242,539
Operating	9	Switchgrass farming (Feedstock)	$43,856,072
Operating	24	Stone mining and quarrying	$408,186
Operating	32	Water, Sewage, and other Systems	$24,303
Operating	43	Maintenance and Repair of nonresidential buildings	$4,071,393
Operating	150	Other Basic Inorganic Chemical Manufacturing	$318,700
Operating	151	Other Basic Organic Chemical Manufacturing	$215,625
Operating	394	Truck Transportation	$5,434,697
Operating	427	Insurance Carriers (Insurance)	$868,200
Operating	438	Accounting Bookkeeping Services (Taxes)	$736,047
Operating	460	Waste Management and Remediation Services	$315,193
Operating	30	Power Generation and Supply	$4,248,000
Depreciation	238	Power Boiler and Heat Exchanger Manufacturing	$2,115,426
Depreciation	239	Metal Tank, Heavy Gauge Manufacturing	$187,137
Depreciation	240	Metal Can, Box and Other Container Manufacturing	$8,011
Depreciation	255	Miscellaneous Fabricated Metal Product Manufacturing	$176,587
Depreciation	269	Other Industrial Machinery Manufacturing	$54,827
Depreciation	273	Other Commercial and Service Industry Machinery Manufacturing	$156,635
Depreciation	275	Air Purification Equipment Manufacturing	$630,338
Depreciation	276	Industrial and Commercial Fan Blower Manufacturing	$1,173,356
Depreciation	277	Heating Equipment except Warm Air Furnaces	$127,411
Depreciation	278	AC Refrigeration and Forced Air Heating	$97,234
Depreciation	285	Turbine and Turbine Generator Set Units Manufacturing	$595,874

Table A.11. IMPLAN Expenditures for Ethanol Conversion from Switchgrass (cont.)

Type	IMPLAN Sector	IMPLAN Description	Expenditures
Depreciation	288	Pump and Pumping Equipment Manufacturing	$102,587
Depreciation	289	Air and Gas Compressor Manufacturing	$1,766,206
Depreciation	301	Scales, Balances, and Miscellaneous General Purpose Machinery	$12,127
Byproduct	30	Power Generation and Supply (Electricity Credit)	$4,250,126

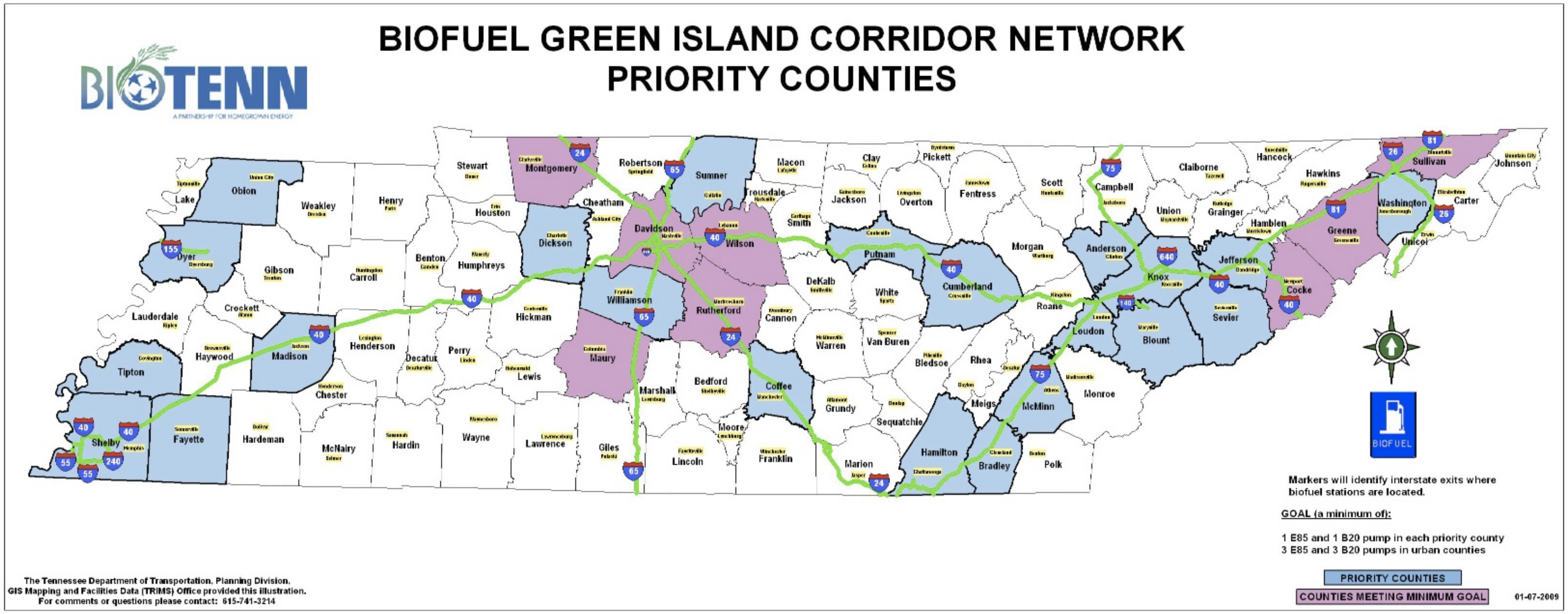
Expenditure Type	Total $	$ / Gallon
Investment	$144,075,132	$2.33
Operating	$51,367,906	$0.83
Operating w/o feedstock	$18,960,064	$0.31
Depreciation	$7,203,757	$0.12
Byproduct	$4,250,126	$0.07

a) *Phillips, S., A. Aden, J. Jechura, D. Dayton, and T. Eggeman, Thermochemical Ethanol via Indirect Gasification and Mixed Alcohol Synthesis of Lignocellulosic Biomass. Technical Report: NREL/TP-510-41168, April 2007.*

b) *Energy Information Administration, Average Tennessee Industrial price for electricity (http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_a.html), July 2009.*

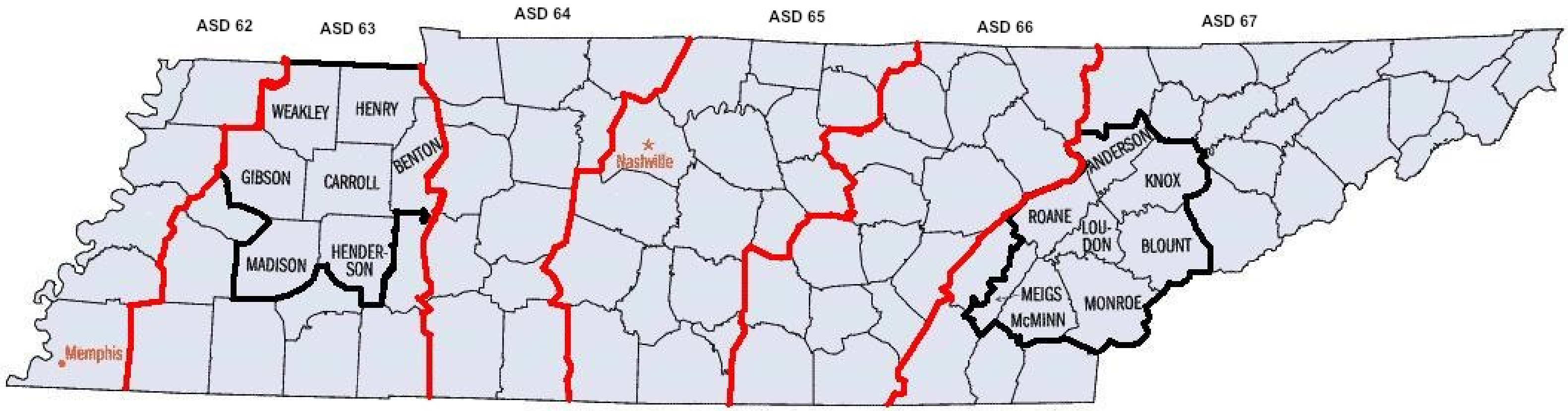
APPENDIX B: MAPS AND CHARTS

Figure B.1. Tennessee's Biofuel Green Island Corridor Network



a) Tennessee Department of Transportation (TDOT). *Biofuel Green Island Corridor Grant Project*. Internet Site: http://www.tdot.state.tn.us/biofuel/application.htm. (Assessed on November 19, 2009).

Figure B.2. ASD Regions and the Counties Included in West and East Tennessee Model



**ASD 63 is West Tennessee Model and ASD 67 is East Tennessee Model*

a) U.S. Census Bureau. Internet Site: http://quickfacts.census.gov/qfd/maps/tennessee_map.html (Assessed Oct 16, 2009)

APPENDIX C: IMPLAN DATA TABLES

WEST TENNESSEE IMPACTS – (ASD REGION 63)

Table C.1. Projected Economic Impacts from Investment in Switchgrass Farming for the West Tennessee Study Region (ASD Region - 63)*

Impact Type	Direct	Indirect	Induced	Total
Output	$64,440,562	$15,109,148	$20,836,292	$100,386,002
Employment	540	123	251	914
Value Added	$26,381,365	$7,273,055	$13,234,387	$46,888,807

*While Output and Value-added are expressed in $2006, Employment is expressed in terms of jobs.

Table C.2. Top Ten Industries Impacted by Investment Expenditures of Switchgrass Farming in the West Tennessee Study Region (ASD Region - 63)

Industry Output Impact

Sector	IMPLAN Description	Direct	Indirect	Induced	Total
404	Building material and garden supply stores	28,920,808	51,724	261,917	29,234,450
158	Fertilizer- mixing only- manufacturing	10,120,868	675,375	2,208	10,798,451
159	Pesticide and other agricultural chemical manuf.	9,713,248	12,834	303	9,726,385
262	Sawmill and woodworking machinery	5,755,571	21,149	42	5,776,762
425	Nondepository credit intermediation	3,378,559	287,394	84,898	3,750,851
407	Gasoline stations	2,963,731	31,429	159,382	3,154,542
509	Owner-occupied dwellings	0	0	2,324,695	2,324,695
431	Real estate	0	1,447,930	787,151	2,235,080
390	Wholesale trade	0	1,236,748	728,062	1,964,810
257	Farm machinery and equipment manufacturing	1,857,751	16,729	22,376	1,896,857
	Total	**64,440,562**	**15,109,148**	**20,836,292**	**100,386,002**

Employment Impact

Sector	IMPLAN Description	Direct	Indirect	Induced	Total
404	Building material and garden supply stores	348.9	0.6	3.2	352.7
262	Sawmill and woodworking machinery	68.1	0.3	0.0	68.4
407	Gasoline stations	41.7	0.4	2.2	44.4
503	State & Local Education	0.0	0.0	38.9	38.9
425	Nondepository credit intermediation	30.6	2.6	0.8	34.0
481	Food services and drinking places	0.0	5.1	21.2	26.4
504	State & Local Non-Education	0.0	0.0	24.4	24.4
158	Fertilizer- mixing only- manufacturing	22.3	1.5	0.0	23.8
485	Commercial machinery repair and maintenance	15.2	0.8	0.2	16.2
390	Wholesale trade	0.0	9.5	5.6	15.1
	Total	**540.3**	**122.7**	**250.6**	**913.7**

Value Added Impact

Sector	IMPLAN Description	Direct	Indirect	Induced	Total
404	Building material and garden supply stores	$17,721,912	$31,695	$160,496	$17,914,104
425	Nondepository credit intermediation	$1,950,859	$165,948	$49,022	$2,165,829
407	Gasoline stations	$2,028,023	$21,506	$109,062	$2,158,591
509	Owner-occupied dwellings	$0	$0	$2,075,748	$2,075,748
431	Real estate	$0	$1,016,140	$552,413	$1,568,554
159	Pesticide and other agricultural chemical manuf.	$1,552,158	$2,051	$48	$1,554,258
503	State & Local Education	$0	$0	$1,531,282	$1,531,282
390	Wholesale trade	$0	$833,168	$490,478	$1,323,646
504	State & Local Non-Education	$0	$0	$1,271,860	$1,271,860
262	Sawmill and woodworking machinery	$1,120,929	$4,119	$8	$1,125,056
	Total	**$26,381,365**	**$7,273,055**	**$13,234,387**	**$46,888,807**

*Total of all Industries in the Region, not the top 10 impacted.

a) Impact results produced by IMPLAN Software (Minnesota IMPLAN Group, Inc. *Social Accounting and Impact Analysis Software*. Version 2.0. Stillwater, Minnesota. February 2004)

Table C.3. Projected Economic Impacts from Year-to-Year Operations of Switchgrass Farming for the West Tennessee Study Region (ASD Region - 63)*

Switchgrass Production (only)	Direct	Indirect	Induced	Total
Output	$39,834,705	$8,660,001	$5,857,518	$54,352,224
Employment	294	66	63	423
Value Added	$14,614,608	$39,451,976	$3,585,050	$57,651,634

Loss in Hay and Cattle Production	Direct	Indirect	Induced	Total
Output	-$19,242,057	-$6,752,320	-$1,845,112	-$27,839,489
Employment	-268	-85	-20	-373
Value Added	-$6,323,149	-$38,302,204	-$1,129,227	-$45,754,580

Net Impact*	**Direct**	**Indirect**	**Induced**	**Total**
Output	**$20,592,648**	**$1,907,681**	**$4,012,406**	**$26,512,735**
Employment	**26**	**-19**	**43**	**50**
Value Added	**$8,291,459**	**$1,149,772**	**$2,455,823**	**$11,897,054**

*While Output and Value-added are expressed in $2006, Employment is expressed in terms of jobs.

Table C.4. Top Ten Industries Impacted from Year-to-Year Operating Expenditures of Switchgrass Farming in the West Tennessee Study Region (ASD Region - 63)

Industry Output Impact

Sector	IMPLAN Description	Direct	Indirect	Induced	Total
158	Fertilizer- mixing only- manufacturing	$10,599,060	$647,318	$253	$11,246,631
407	Gasoline stations	$9,653,562	$10,206	$41,972	$9,705,740
257	Farm machinery and equipment manufacturing	$6,506,117	-$72,038	$430	$6,434,509
485	Commercial machinery repair and maintenance	$5,550,354	-$10,757	$2,539	$5,542,136
404	Farm Supply/Co-op	$2,892,081	$17,105	$69,949	$2,979,135
159	Pesticide and other agricultural chemical manuf	$2,004,303	-$21,004	$59	$1,983,358
425	Nondepository credit intermediation	$1,435,447	$111,905	$20,102	$1,567,454
262	Sawmill and woodworking machinery	$1,151,114	$6,155	$8	$1,157,277
390	Wholesale trade	$0	$499,538	$164,949	$664,487
509	Owner-occupied dwellings	$0	$0	$658,161	$658,161
	Total	**$20,592,648**	**$1,907,681**	**$4,012,406**	**$26,512,735**

Employment Impact

Sector	IMPLAN Description	Direct	Indirect	Induced	Total
407	Gasoline stations	136.0	0.1	0.6	136.7
485	Commercial machinery repair and maintenance	55.6	-0.1	0.0	55.5
404	Farm Supply/Co-op	34.9	0.2	0.8	35.9
158	Fertilizer- mixing only- manufacturing	23.3	1.4	0.0	24.7
257	Farm machinery and equipment manufacturing	15.8	-0.2	0.0	15.6
425	Nondepository credit intermediation	13.0	1.0	0.2	14.2
262	Sawmill and woodworking machinery	13.6	0.1	0.0	13.7
481	Food services and drinking places	0.0	2.6	5.6	8.2
454	Employment Services	0.0	5.1	0.6	5.7
390	Wholesale trade	0.0	3.8	1.3	5.1
	Total	**26.4**	**-19.2**	**42.9**	**50.1**

Value Added Impact

Sector	IMPLAN Description	Direct	Indirect	Induced	Total
407	Gasoline stations	$6,605,743	$6,984	$28,720	$6,641,447
485	Commercial machinery repair and maintenance	$2,467,801	-$4,783	$1,129	$2,464,147
404	Farm Supply/Co-op	$1,772,191	$10,481	$42,679	$1,825,351
257	Farm machinery and equipment manufacturing	$1,450,004	-$16,055	$96	$1,434,045
158	Fertilizer- mixing only- manufacturing	$941,527	$57,502	$23	$999,052
425	Nondepository credit intermediation	$828,861	$64,617	$11,608	$905,086
509	Owner-occupied dwellings	$0	$0	$587,680	$587,680
390	Wholesale trade	$0	$336,527	$111,122	$447,649
159	Pesticides and other agricultural chemicals	$320,284	-$3,356	$9	$316,937
394	Truck Transportation	$0	$206,823	$27,219	$234,042
	Total	**$8,291,459**	**$1,149,772**	**$2,455,823**	**$11,897,054**

*Total of all Industries in the Region, not the top 10 impacted.

a) Impact results produced by IMPLAN Software (Minnesota IMPLAN Group, Inc. *Social Accounting and Impact Analysis Software*. Version 2.0. Stillwater, Minnesota. February 2004)

Table C.5. Top Five Industries Negatively Impacted by Year-to-Year Operating Expenditures of Switchgrass Farming in the West Tennessee Study Region (ASD Region - 63)

	Industry Output Impact				
Sector	IMPLAN Description	Direct	Indirect	Induced	Total
10	All other crop farming	-$10,681,000	-$1,089,267	$2,000	-$11,768,267
11	Cattle ranching and farming	-$8,561,057	-$1,889,001	$14,302	-$10,435,756
18	Agriculture and forestry support activities	$0	-$235,768	$818	-$234,950
449	Veterinary Services	$0	-$241,108	$16,160	-$224,948
2	Grain Farming	$0	-$86,874	$1,114	-$85,760
	Total*	**$20,592,648**	**$1,907,681**	**$4,012,406**	**$26,512,735**

	Employment Impact				
Sector	IMPLAN Description	Direct	Indirect	Induced	Total
11	Cattle ranching and farming	-142.9	-31.5	0.2	-174.2
10	All other crop farming	-124.7	-12.7	0.0	-137.4
18	Agriculture and forestry support activities	0.0	-8.2	0.0	-8.2
2	Grain farming	0.0	-4.6	0.1	-4.5
449	Veterinary Services	0.0	-3.5	0.2	-3.3
	Total*	**26.4**	**-19.2**	**42.9**	**50.1**

	Value Added Impact				
Sector	IMPLAN Description	Direct	Indirect	Induced	Total
10	All other crop farming	-$5,460,021	-$556,822	$1,022	-$6,015,821
11	Cattle ranching and farming	-$863,128	-$190,450	$1,442	-$1,052,136
18	Agriculture and forestry support activities	$0	-$165,062	$573	-$164,489
449	Veterinary Services	$0	-$96,899	$6,495	-$90,404
431	Real Estate	$0	-$179,721	$131,098	-$48,623
	Total*	**$8,291,459**	**$1,149,772**	**$2,455,823**	**$11,897,054**

*Net Impact of Switchgrass Farming

b) Impact results produced by IMPLAN Software (Minnesota IMPLAN Group, Inc. *Social Accounting and Impact Analysis Software*. Version 2.0. Stillwater, Minnesota. February 2004)

Table C.6. Projected Economic Impacts from Investment in Cellulosic Ethanol Conversion for the West Tennessee Study Region (ASD Region - 63)*

Impact Type	Direct	Indirect	Induced	Total
Output	$85,627,161	$16,258,951	$19,453,731	$121,339,844
Employment	317	120	217	653
Value Added	$28,024,059	$7,855,682	$11,805,248	$47,684,990

*While Output and Value-added are expressed in $2006, Employment is expressed in terms of jobs.

Table C.7. Top Ten Industries Impacted by Investment Expenditures of Cellulosic Ethanol Conversion in the West Tennessee Study Region (ASD Region - 63)

Industry Output Impact

Sector	IMPLAN Description	Direct	Indirect	Induced	Total
238	Power boiler and heat exchanger manufacturing	$42,308,512	$153,504	$11,886	$42,473,904
289	Air and gas compressor manufacturing	$35,324,124	$34,040	$5,776	$35,363,940
390	Wholesale trade	$0	$3,130,254	$739,353	$3,869,607
255	Miscellaneous fabricated metal product manuf	$3,531,749	$410	$3	$3,532,162
273	Commercial and service industry machinery Maint.	$3,123,695	$5,443	$393	$3,129,531
509	Owner-occupied dwellings	$0	$0	$2,414,786	$2,414,786
394	Truck transportation	$0	$1,082,994	$306,071	$1,389,064
481	Food services and drinking places	$0	$295,825	$923,808	$1,219,633
431	Real estate	$0	$424,699	$782,205	$1,206,904
465	Offices of physicians- dentists- and other health	$0	$0	$1,144,314	$1,144,314
	Total	**$85,627,161**	**$16,258,951**	**$19,453,731**	**$121,339,844**

Employment Impact

Sector	IMPLAN Description	Direct	Indirect	Induced	Total
238	Power boiler and heat exchanger manufacturing	183.3	0.7	0.1	184.1
289	Air and gas compressor manufacturing	95.1	0.1	0.0	95.3
390	Wholesale trade	0.0	24.1	5.7	29.8
481	Food services and drinking places	0.0	6.8	21.4	28.2
255	Miscellaneous fabricated metal product manuf.	19.1	0.0	0.0	19.1
503	State & Local Education	0.0	0.0	18.5	18.5
273	Commercial and service industry machinery Maint.	12.9	0.0	0.0	12.9
504	State & Local Non-Education	0.0	0.0	11.6	11.6
394	Truck transportation	0.0	8.8	2.5	11.2
465	Offices of physicians- dentists- and other health	0.0	0.0	9.4	9.4
	Total	**317.0**	**119.7**	**216.6**	**653.3**

Value Added Impact

Sector	IMPLAN Description	Direct	Indirect	Induced	Total
238	Power boiler and heat exchanger manufacturing	$17,068,010	$61,926	$4,795	$17,134,732
289	Air and gas compressor manufacturing	$8,756,552	$8,438	$1,432	$8,766,422
390	Wholesale trade	$0	$2,108,779	$498,085	$2,606,863
509	Owner-occupied dwellings	$0	$0	$2,156,191	$2,156,191
255	Miscellaneous fabricated metal product manuf.	$1,235,306	$143	$1	$1,235,451
431	Real estate	$0	$298,049	$548,942	$846,992
465	Offices of physicians- dentists- and other health	$0	$0	$824,139	$824,139
430	Monetary authorities and depository credit	$0	$394,370	$391,368	$785,738
503	State & Local Education	$0	$0	$728,687	$728,687
394	Truck transportation	$0	$484,246	$136,855	$621,102
	Total	**$28,024,059**	**$7,855,682**	**$11,805,248**	**$47,684,990**

*Total of all Industries in the Region, not the top 10 impacted.

a) Impact results produced by IMPLAN Software (Minnesota IMPLAN Group, Inc. *Social Accounting and Impact Analysis Software*. Version 2.0. Stillwater, Minnesota. February 2004)

Table C.8. Projected Economic Impacts from Year-to-Year Operations of Cellulosic Ethanol Conversion for the West Tennessee Study Region (ASD Region - 63)*

Impact Type	Direct	Indirect	Induced	Total
Output	$60,819,892	$4,689,473	$7,839,661	$73,349,025
Employment	415	42	84	541
Value Added	$21,503,965	$2,461,534	$4,798,022	$28,763,521

*While Output and Value-added are expressed in $2006, Employment is expressed in terms of jobs.

Table C.9. Top Ten Industries Impacted from Year-to-Year Operations Expenditures of Cellulosic Ethanol Conversion in the West Tennessee Study Region (ASD Region - 63)

Industry Output Impact

Sector	IMPLAN Description	Direct	Indirect	Induced	Total
507	ROW (feedstock expense)	$42,713,140	$0	$0	$42,713,140
394	Truck transportation	$5,434,697	$800,064	$118,940	$6,353,701
43	Maintenance and repair of nonresidental buildings	$4,071,393	$33,496	$23,101	$4,127,990
289	Air and gas compressor manufacturing	$3,156,056	$1,257	$590	$3,157,903
238	Power boiler and heat exchanger manufacturing	$2,167,897	$9,851	$141	$2,177,889
509	Owner-occupied dwellings	$0	$0	$1,284,534	$1,284,534
427	Insurance carriers	$868,200	$95,478	$108,424	$1,072,102
438	Accounting and bookkeeping services	$736,047	$41,772	$20,129	$797,948
390	Wholesale trade	$0	$452,095	$322,448	$774,543
334	Motor and generator manufacturing	$579,211	$39,045	$423	$618,679
	Total	**$60,819,892**	**$4,689,473**	**$7,839,661**	**$73,349,025**

Employment Impact

Sector	IMPLAN Description	Direct	Indirect	Induced	Total
507	ROW (feedstock expense)	294.0	0.0	0.0	294.0
394	Truck transportation	43.9	6.5	1.0	51.4
43	Maintenance and repair of nonresidental buildings	36.4	0.3	0.2	36.9
481	Food Serivices and drink places	0.0	1.1	11.0	12.1
438	Accounting and Bookkeeping Services	10.2	0.6	0.3	11.1
238	Power boiler and heat exchanger manufacturing	9.4	0.0	0.0	9.4
289	Air and gas compressor manufacturing	8.5	0.0	0.0	8.5
390	Wholesale trade	0.0	3.5	2.5	6.0
465	Offices of Physicians	0.0	0.0	4.9	4.9
427	Insurance Carriers	3.9	0.4	0.5	4.8
	Total	**415.2**	**41.5**	**83.8**	**540.5**

Value Added Impact

Sector	IMPLAN Description	Direct	Indirect	Induced	Total
507	ROW (feedstock expense)	$14,614,608	$0	$0	$14,614,608
394	Truck transportation	$2,430,052	$357,738	$53,182	$2,840,972
43	Maintenance and repair of nonresidental buildings	$1,475,825	$12,142	$8,374	$1,496,341
509	Owner-occupied dwellings	$0	$0	$1,146,976	$1,146,976
238	Power boiler and heat exchanger manufacturing	$874,568	$3,974	$57	$878,599
289	Air and gas compressor manufacturing	$782,360	$312	$146	$782,818
390	Wholesale trade	$0	$304,566	$217,226	$521,792
465	Offices of Physicians	$0	$0	$432,921	$432,921
431	Real Estate	$0	$123,895	$256,582	$380,477
427	Insurance Carriers	$307,394	$33,805	$38,389	$379,588
	Total	**$21,503,965**	**$2,461,534**	**$4,798,022**	**$28,763,521**

*Total of all Industries in the Region, not the top 10 impacted.

a) Impact results produced by IMPLAN Software (Minnesota IMPLAN Group, Inc. *Social Accounting and Impact Analysis Software*. Version 2.0. Stillwater, Minnesota. February 2004)

Table C.10. Projected Economic Impacts from Year-to-Year Operations of Cellulosic Ethanol Conversion and Switchgrass Farming for the West Tennessee Study Region (ASD Region - 63)*

Impact Type	Direct	Indirect	Induced	Total
Output	$38,699,400	$6,597,154	$11,852,067	$57,148,621
Employment	148	22	127	297
Value Added	$15,180,816	$3,611,306	$7,253,845	$26,045,967

*While Output and Value-added are expressed in $2006, Employment is expressed in terms of jobs.

EAST TENNESSEE IMPACTS – (ASD REGION 67)

Table C.11. Projected Economic Impacts from Investment in Switchgrass Farming for the East Tennessee Study Region (ASD Region - 67)*

Impact Type	Direct	Indirect	Induced	Total
Output	$62,694,049	$16,882,763	$38,687,926	$118,264,739
Employment	436	121	392	949
Value Added	$33,641,476	$8,990,022	$23,814,795	$66,446,292

*While Output and Value-added are expressed in $2006, Employment is expressed in terms of jobs.

Table C.12. Top Ten Industries Impacted by Investment Expenditures of Switchgrass Farming in East Tennessee (ASD Region – 67)

Industry Output Impact

Sector	IMPLAN Description	Direct	Indirect	Induced	Total
404	Building material and garden supply stores	$28,920,808	$48,094	$405,525	$29,374,428
158	Fertilizer- mixing only- manufacturing	$10,120,868	$3,866	$34	$10,124,768
159	Pesticide and other agricultural chemical manuf	$9,713,248	$40,833	$1,825	$9,755,906
425	Nondepository credit intermediation	$3,378,559	$586,433	$362,759	$4,327,751
172	Plastics packaging materials - film and sheet	$4,222,411	$2,236	$553	$4,225,200
390	Wholesale trade	$0	$1,519,085	$2,351,910	$3,870,995
431	Real estate	$0	$1,987,700	$1,804,637	$3,792,337
509	Owner-occupied dwellings	$0	$0	$3,485,018	$3,485,018
407	Gasoline stations	$2,963,731	$28,806	$245,326	$3,237,862
503	State & Local Education	$0	$0	$2,570,917	$2,570,917
	Total	**$62,694,049**	**$16,882,763**	**$38,687,926**	**$118,264,739**

Employment Impact

Sector	IMPLAN Description	Direct	Indirect	Induced	Total
404	Building material and garden supply stores	317.5	0.5	4.5	322.5
503	State & Local Education	0.0	0.0	61.9	61.9
407	Gasoline stations	39.2	0.4	3.2	42.9
481	Food services and drinking places	0.0	4.4	28.8	33.2
425	Nondepository credit intermediation	24.2	4.2	2.6	31.1
390	Wholesale trade	0.0	9.4	14.6	24.0
431	Real estate	0.0	11.8	10.7	22.5
504	State & Local Non-Education	0.0	0.0	21.9	21.9
158	Fertilizer- mixing only- manufacturing	20.7	0.0	0.0	20.7
467	Hospitals	0.0	0.0	14.7	14.7
	Total	**435.9**	**121.1**	**391.6**	**948.6**

Value Added Impact

Sector	IMPLAN Description	Direct	Indirect	Induced	Total
404	Building material and garden supply stores	$18,037,826	$29,996	$252,925	$18,320,746
158	Fertilizer- mixing only- manufacturing	$4,840,417	$1,849	$16	$4,842,283
159	Pesticide and other agricultural chemical manuf.	$4,443,073	$18,678	$835	$4,462,586
509	Owner-occupied dwellings	$0	$0	$3,111,815	$3,111,815
431	Real estate	$0	$1,394,945	$1,266,473	$2,661,419
425	Nondepository credit intermediation	$2,073,945	$359,985	$222,681	$2,656,611
390	Wholesale trade	$0	$1,024,579	$1,586,295	$2,610,874
503	State & Local Education	$0	$0	$2,570,917	$2,570,917
407	Gasoline stations	$2,028,023	$19,711	$167,872	$2,215,606
465	Offices of physicians- dentists- and other health	$0	$0	$1,161,055	$1,161,055
	Total	**$33,641,476**	**$8,990,022**	**$23,814,795**	**$66,446,292**

*Total of all Industries in the Region, not the top 10 impacted.

a) Impact results produced by IMPLAN Software (Minnesota IMPLAN Group, Inc. *Social Accounting and Impact Analysis Software*. Version 2.0. Stillwater, Minnesota. February 2004)

Table C.13. Projected Economic Impacts from Year-to-Year Operations of Switchgrass Farming for the East Tennessee Study Region (ASD Region - 67)*

Switchgrass Production (only)	Direct	Indirect	Induced	Total
Output	$40,636,516	$9,827,354	$12,494,070	$62,957,940
Employment	257	70	112	438
Value Added	$20,043,603	$5,199,549	$7,501,866	$32,745,018
Loss in Hay and Cattle Production	**Direct**	**Indirect**	**Induced**	**Total**
Output	-$14,561,494	-$3,150,796	-$2,492,338	-$20,204,628
Employment	-265	-23	-22	-311
Value Added	-$7,240,028	-$1,616,710	-$1,496,456	-$10,353,194
Net Impact*	**Direct**	**Indirect**	**Induced**	**Total**
Output	**$26,075,022**	**$6,676,558**	**$10,001,732**	**$42,753,312**
Employment	**-8**	**46**	**89**	**127**
Value Added	**$12,803,575**	**$3,582,839**	**$6,005,410**	**$22,391,824**

*While Output and Value-added are expressed in $2006, Employment is expressed in terms of jobs

Table C.14. Top Ten Industries Impacted by Operating Expenditures of Switchgrass Farming in East Tennessee (ASD Region – 67)

Industry Output Impact

Sector	IMPLAN Description	Direct	Indirect	Induced	Total
158	Fertilizer- mixing only- manufacturing	$10,599,060	$3,427	$3	$10,602,490
407	Gasoline stations	$9,653,562	$10,908	$80,990	$9,745,460
257	Farm machinery and equipment manufacturing	$6,506,117	$1,834	$680	$6,508,631
485	Commercial machinery repair and maintenance	$5,550,354	$20,302	$6,892	$5,577,548
404	Farming Supply/Co-op	$2,892,081	$18,320	$134,679	$3,045,080
159	Pesticide and other agricultural chemical manuf	$2,004,303	-$99,252	$483	$1,905,534
425	Nondepository credit intermediation	$1,435,447	$254,194	$114,320	$1,803,961
390	Wholesale trade	$0	$987,721	$649,443	$1,637,164
509	Owner-occupied dwellings	$0	$0	$1,305,471	$1,305,471
172	Plastic Materials	$844,482	$589	$157	$845,228
	Total	**$26,075,022**	**$6,676,558**	**$100,001,732**	**$42,753,312**

Employment Impact

Sector	IMPLAN Description	Direct	Indirect	Induced	Total
407	Gasoline stations	127.8	0.1	1.1	129.0
485	Commercial machinery repair and maintenance	41.4	0.2	0.1	41.7
404	Farm Supply/Co-op	31.8	0.2	1.5	33.5
158	Fertilizer- mixing only- manufacturing	21.6	0.0	0.0	21.6
257	Farm machinery and equipment manufacturing	16.3	0.0	0.0	16.3
425	Nondepository credit intermediation	10.3	1.8	0.8	12.9
481	Food services and drinking places	0.0	2.3	10.2	12.5
390	Wholesale trade	0.0	6.1	4.0	10.1
467	Hospitals	0.0	0.0	5.3	5.3
454	Employment Services	0.0	3.9	1.2	5.1
	Total	**-8.4**	**46.4**	**89.4**	**127.4**

Value Added Impact

Sector	IMPLAN Description	Direct	Indirect	Induced	Total
407	Gasoline stations	$6,605,744	$7,464	$55,420	$6,668,628
158	Fertilizer- mixing only- manufacturing	$5,069,116	$1,639	$1	$5,070,756
485	Commercial machinery repair and maintenance	$2,867,666	$10,489	$3,561	$2,881,716
404	Farm Supply/Co-op	$1,803,783	$11,426	$83,999	$1,899,208
257	Farm machinery and equipment manufacturing	$1,300,650	$367	$136	$1,301,153
509	Owner-occupied dwellings	$0	$0	$1,165,671	$1,165,671
425	Nondepository credit intermediation	$881,156	$156,038	$70,176	$1,107,370
390	Wholesale trade	$0	$666,189	$438,031	$1,104,220
159	Pesticide and other agricultural chemical manufact	$916,816	-$45,400	$221	$871,637
431	Real estate	$0	$151,263	$375,427	$526,690
	Total	**$12,803,575**	**$3,582,839**	**$6,005,410**	**$22,391,825**

*Total of all Industries in the Region, not the top 10 impacted.

a) Impact results produced by IMPLAN Software (Minnesota IMPLAN Group, Inc. *Social Accounting and Impact Analysis Software*. Version 2.0. Stillwater, Minnesota. February 2004)

Table C.15. Top Five Industries Negatively Impacted by Operating Expenditures of Switchgrass Farming in East Tennessee (ASD Region – 67)

	Industry Output Impact				
Sector	IMPLAN Description	Direct	Indirect	Induced	Total
10	Hay Production	-$13,410,380	-$133,687	$3,258	-$13,540,809
18	Agricultural Support activities	$0	-$115,523	$982	-$114,541
294	Industrial truck-trailer-stacker manufacturing	$0	-$1,981	$69	-$1,912
242	Spring and wire product manufacturing	$0	-$2,275	$438	-$1,837
7	Tobacco farming	$0	-$371	$3	-$368
	Total*	**$26,075,022**	**$6,676,558**	**$10,001,732**	**$42,753,312**

	Employment Impact				
Sector	IMPLAN Description	Direct	Indirect	Induced	Total
10	Hay Production	-261.3	-2.6	0.1	-263.8
18	Agricultural Support activities	0.0	-4.0	0.0	-4.0
68	Meat Processing	0.0	0.0	0.0	0.1
244	Turned Product and screw-nut-bold manuf.	0.0	0.1	0.0	0.1
334	Motor and generator manufacturing	0.0	0.1	0.0	0.1
	Total*	**-8.4**	**46.4**	**89.4**	**127.4**

	Value Added Impact				
Sector	IMPLAN Description	Direct	Indirect	Induced	Total
10	Hay Production	-$6,853,994	-$68,327	$1,665	-$6,920,656
18	Agricultural Support activities	$0	$80,712	$686	$81,398
242	Spring and wire product manufacturing	$0	-$865	$167	-$698
7	Tobacco farming	$0	-$336	$3	-$333
294	Industrial truck-trailer-stacker manufacturing	$0	-$279	$10	-$269
	Total*	**$12,803,575**	**$3,582,839**	**$6,005,410**	**$22,391,825**

*Net Impact of Switchgrass Farming

b) Impact results produced by IMPLAN Software (Minnesota IMPLAN Group, Inc. *Social Accounting and Impact Analysis Software*. Version 2.0. Stillwater, Minnesota. February 2004)

Table C.16. Projected Economic Impacts from Investment in Cellulosic Ethanol Conversion for the East Tennessee Study Region (ASD Region - 67)*

Impact Type	Direct	Indirect	Induced	Total
Output	$70,073,503	$19,439,249	$27,405,755	$116,918,506
Employment	373	129	263	765
Value Added	$21,449,810	$10,377,377	$16,444,605	$48,271,791

*While Output and Value-added are expressed in $2006, Employment is expressed in terms of jobs.

Table C.17. Top Ten Industries Impacted by Investment Expenditures of Cellulosic Ethanol Conversion in East Tennessee (ASD Region – 67)

Industry Output Impact

Sector	IMPLAN Description	Direct	Indirect	Induced	Total
238	Power boiler and heat exchanger manufacturing	$42,308,512	$604	$1	$42,309,116
275	Air purification equipment manufacturing	$12,606,752	$41	$12	$12,606,805
390	Wholesale trade	$0	$4,770,528	$1,753,990	$6,524,518
239	Metal tank- heavy gauge- manufacturing	$3,742,747	$4,847	$1,484	$3,749,078
255	Miscellaneous fabricated metal product manuf.	$3,531,749	$2,397	$83	$3,534,229
509	Owner-occupied dwellings	$0	$0	$2,633,635	$2,633,635
277	Heating equipment- except warm air furnaces	$2,548,229	$0	$0	$2,548,229
431	Real estate	$0	$730,605	$1,337,450	$2,068,055
288	Pump and pumping equipment manufacturing	$2,051,745	$1,439	$16	$2,053,200
278	AC- refrigeration- and forced air heating	$1,944,688	$1	$0	$1,944,689
	Total	**$70,073,503**	**$19,439,249**	**$27,405,755**	**$116,918,506**

Employment Impact

Sector	IMPLAN Description	Direct	Indirect	Induced	Total
238	Power boiler and heat exchanger manufacturing	231.9	0.0	0.0	231.9
275	Air purification equipment manufacturing	74.4	0.0	0.0	74.4
390	Wholesale trade	0.0	29.6	10.9	40.5
481	Food services and drinking places	0.0	5.5	21.4	26.9
503	State & Local Education	0.0	0.0	26.1	26.1
239	Metal tank- heavy gauge- manufacturing	19.0	0.0	0.0	19.0
255	Miscellaneous fabricated metal product manuf.	18.8	0.0	0.0	18.8
431	Real estate	0.0	4.3	7.9	12.3
467	Hospitals	0.0	0.0	11.1	11.1
394	Truck transportation	0.0	7.2	2.6	9.8
	Total	**372.8**	**129.2**	**262.5**	**764.5**

Value Added Impact

Sector	IMPLAN Description	Direct	Indirect	Induced	Total
238	Power boiler and heat exchanger manufacturing	$12,053,475	$172	$0	$12,053,647
390	Wholesale trade	$0	$3,217,583	$1,183,015	$4,400,598
275	Air purification equipment manufacturing	$4,316,243	$14	$4	$4,316,261
509	Owner-occupied dwellings	$0	$0	$2,351,605	$2,351,605
239	Metal tank- heavy gauge- manufacturing	$1,488,610	$1,928	$590	$1,491,128
431	Real estate	$0	$512,730	$938,607	$1,451,337
255	Miscellaneous fabricated metal product manuf.	$1,271,693	$863	$30	$1,272,585
503	State & Local Education	$0	$0	$1,085,206	$1,085,206
277	Heating equipment- except warm air furnaces	$1,024,282	$0	$0	$1,024,282
465	Offices of physicians- dentists- and other health	$0	$0	$877,473	$877,473
	Total	**$21,449,810**	**$10,377,377**	**$16,444,605**	**$48,271,791**

*Total of all Industries in the Region, not the top 10 impacted.

a) Impact results produced by IMPLAN Software (Minnesota IMPLAN Group, Inc. *Social Accounting and Impact Analysis Software*. Version 2.0. Stillwater, Minnesota. February 2004)

Table C.18. Projected Economic Impacts from Year-to-Year Operations of Cellulosic Ethanol Conversion for the East Tennessee Study Region (ASD Region - 67)*

Impact Type	Direct	Indirect	Induced	Total
Output	$62,252,281	$7,269,572	$10,822,116	$80,343,970
Employment	375	51	97	523
Value Added	$27,530,504	$3,836,388	$6,497,896	$37,864,788

*While Output and Value-added are expressed in $2006, Employment is expressed in terms of jobs

Table C.19. Top Ten Industries Impacted from Year-to-Year Operations of Cellulosic Ethanol Conversion the East Tennessee Study Region (ASD Region - 67)

Industry Output Impact

Sector	IMPLAN Description	Direct	Indirect	Induced	Total
507	ROW (feedstock expense)	$42,713,140	$0	$0	$42,713,140
394	Truck transportation	$5,434,697	$776,361	$130,808	$6,341,866
43	Maintenance and repair of nonresidental buildings	$4,071,393	$67,234	$44,368	$4,182,995
238	Power boiler and heat exchanger manufacturing	$2,115,445	$37	$0	$2,115,482
288	Pumping equipment manufacturing	$1,857,905	$180	$2	$1,858,087
390	Wholesale trade	$0	$964,892	$702,819	$1,667,711
509	Owner-occupied dwellings	$0	$0	$1,412,110	$1,412,110
427	Insurance Carriers	$868,200	$222,381	$285,340	$1,375,921
334	Motor and generator manufacturing	$1,143,690	$26,925	$245	$1,170,860
431	Real Estate	$0	$290,753	$579,083	$869,836
	Total	**$62,252,281**	**$7,269,572**	**$10,822,116**	**$80,343,970**

Employment Impact

Sector	IMPLAN Description	Direct	Indirect	Induced	Total
507	ROW (feedstock expense)	257.0	0.0	0.0	939.6
394	Truck transportation	41.0	5.8	1.0	47.8
43	Maintenance and repair of nonresidental buildings	34.7	0.6	0.4	35.7
481	Food services and drink places	0.0	1.2	11.1	12.3
238	Power boiler and heat exchanger manufacturing	11.6	0.0	0.0	11.6
390	Wholesale trade	0.0	6.0	4.4	10.4
438	Accounting and bookkeeping services	7.9	0.9	0.5	9.3
427	Insurance Carriers	3.9	1.0	1.3	6.2
288	Pumping equipment manufacturing	6.1	0.0	0.0	6.1
467	Hospitals	0.0	0.0	5.7	5.7
	Total	**375.3**	**50.5**	**96.8**	**522.6**

Value Added Impact

Sector	IMPLAN Description	Direct	Indirect	Induced	Total
507	ROW (feedstock expense)	$20,831,040	$0	$0	$20,831,040
394	Truck transportation	$2,578,873	$368,399	$62,071	$3,009,343
43	Maintenance and repair of nonresidental buildings	$1,573,569	$25,986	$17,148	$1,616,703
509	Owner-occupied dwellings	$0	$0	$1,260,891	$1,260,891
390	Wholesale trade	$0	$650,792	$474,031	$1,124,823
431	Real Estate	$0	$204	$406,394	$406,598
238	Power boiler and heat exchanger manufacturing	$602,679	$11	$0	$602,690
427	Insurance Carriers	$304,672	$78,039	$100,133	$482,844
465	Offices of Physicians	$0	$0	$459,870	$459,870
438	Accounting and bookkeeping services	$385,393	$42,021	$22,316	$449,730
	Total	**$27,530,504**	**$3,836,388**	**$6,497,896**	**$37,864,788**

*Total of all Industries in the Region, not the top 10 impacted.

b) Impact results produced by IMPLAN Software (Minnesota IMPLAN Group, Inc. *Social Accounting and Impact Analysis Software*. Version 2.0. Stillwater, Minnesota. February 2004)

Table C.20. Projected Economic Impacts from Year-to-Year Operations of Cellulosic Ethanol Conversion and Switchgrass Farming for the East Tennessee Study Region (ASD Region - 67)*

Impact Type	Direct	Indirect	Induced	Total
Output	$45,614,163	$13,946,130	$20,823,848	$80,384,141
Employment	110	97	186	393
Value Added	$19,503,039	$7,419,227	$12,503,306	$39,425,572

*While Output and Value-added are expressed in $2006, Employment is expressed in terms of jobs

VITA

Adam Fulton is a graduate student in the Department of Agricultural Economics at the University of Tennessee, Knoxville. He came to the university in 2003 as an undergraduate seeking a degree in Agricultural Economics and Business, graduating in May 2007. Adam will obtain his Master of Science degree in Agricultural Economics, with a minor in Statistics, in May 2010.